NASA ADVISORY COUNCIL

ASTROPHYSICS ADVISORY COUNCIL

October 18-19, 2017
Teleconference

MEETING MINUTES

1/14/2018

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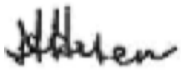
B. Scott Gaudi, Chair



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Hashima Hasan, Executive Secretary

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Ingenicomm

Wednesday, October 18, 2017

Introduction and Announcements

Dr. Hashima Hasan, Executive Secretary of the Astrophysics Advisory Committee (APAC), opened the meeting by welcoming the Committee members. Dr. Hasan then reviewed the Federal Advisory Committee Act (FACA) rules. She noted that a few APAC members had conflicts of interest with specific topics on the agenda. Known conflicts of interest included Dr. Jason Kalirai (STScI) on the James Webb Space Telescope and Hubble Space Telescope; Drs. Mark Bautz (MIT) and Patricia Boyd (NASA GSFC) for the Transiting Exoplanet Survey Satellite (TESS); Dr. Bautz for the Chandra X-ray Observatory; Drs. Boyd and Natalie Batlha for civil service workforce; and Dr. Yun Wang Caltech/IPAC) for the Spitzer Space Telescope. During those presentations, the conflicted members would be allowed to listen to the presentation, but they could not participate in discussion.

In addition, Dr. William Jones of Princeton University had joined APAC as a new member. After taking roll, Dr. Hasan determined that there was a quorum. She then turned the meeting over to Dr. Scott Gaudi, the Chair of APAC.

Dr. Gaudi welcomed the meeting participants and reminded them that only APAC members were free to speak unless he called upon them. FACA discussions had to occur in public if they were to become part of the recommendation to Dr. Paul Hertz, Director of NASA's Astrophysics Division (APD). Dr. Gaudi would take any issues that needed to go to the Science Mission Directorate (SMD) to the NASA Advisory Council (NAC) Science Committee. There were two public comment periods scheduled for the meeting.

Astrophysics Division Update

Dr. Hertz said that NASA had completed executing its budget for Fiscal Year 2017 (FY17) and was currently operating under a Continuing Resolution (CR) through December 8 for FY18. Total funding remained near the planned $1.35 billion for both years. The FY17 appropriation was less than requested, necessitating cuts. Both the House and the Senate have marked up the President's Budget Request (PBR) for FY18, but neither chamber has passed the budget and they have not yet conferred. The markups direct spending for specific projects in a way that puts the program balance at risk. Mr. James Bridenstine, a representative from Oklahoma with an interest in space and a background that includes service as an Air Force pilot, business, and museum administration, has been nominated as the next NASA administrator. Confirmation hearings have not yet been scheduled.

Dr. Hertz next reviewed the APD response to APAC's letter from the July meeting. This meeting was to have presentations addressing requests for information on the new internal science funding model and the Human Exploration and Operations Mission Directorate (HEOMD) timeline for future work that might enable science. In addition, the science program chief technologists were to give a joint presentation. APD had sent the APAC members information on the TESS focus issue, which they could discuss. The meeting would touch on Research and Analysis (R&A) diversity and the small spacecraft virtual institute, with more complete presentations to

occur at the spring 2018 meeting. Finally, APD concurred with the recommendation to ensure that any future directed work is truly best done at the centers.

APD is actively taking steps to advance diversity within its workforce and among grantee institutions, setting an expectation of diversity in all teams. The Division is working with the Office of the Chief Scientist (OCS) to produce a short video on unconscious bias in peer reviews for future distribution to panelists, and is discussing best practices in peer reviews with other agencies, while also observing the demographics of proposers and awardees. Finally, APD is actively seeking diversity on NASA-selected groups like APAC, the Program Analysis Group (PAG) Executive Committees, and others.

APD released a Request for Information (RFI) in order to inform decisions regarding the use of small satellites (smallsats) for astrophysics. Topic 1 of the RFI, Science Mission Concepts, asks the astrophysics community to envision missions advancing compelling astrophysics using smallsats in a cost range between that of the Astrophysics Research and Analysis (APRA) program's cubesats and the Astrophysics Explorers Missions of Opportunity (MOs). Topic 2 seeks information about potential enabling technologies for astrophysics smallsats.

Science Highlights
APD continues to address Decadal Survey (DS) priorities within a balanced program, as laid out in the Astrophysics Implementation Plan. The Division is also planning for the 2020 DS. The balanced program includes operating missions, which produce exciting science results. A great example is the joint Fermi Gamma-ray Space Telescope/Laser Interferometer Gravitational-Wave Observatory (LIGO) kilonova result that was just announced. This was an exciting multi-agency, multi-messenger international discovery.

Hubble has produced a number of major findings recently, such as a view of star-forming regions in the early universe that are much smaller than predicted by a factor of 10. Hubble also observed a pitch-black exoplanet, a "hot Jupiter" that does not reflect light very well. Chandra offered a look at the intense gravitational forces from a white dwarf pulling the outer layers of a red dwarf onto the smaller star's surface, triggering explosions. The Neutron-star Interior Composition Explorer (NICER) is collecting pulsar data that will provide information on the mass of a neutron star. A citizen science project led to the discovery of a brown dwarf through use of Wide-field Infrared Survey Explorer (WISE) data.

Missions and Explorers
Another part of APD's balanced program includes the large strategic missions under development. These reflect DS priorities that go significantly beyond what has been flown already, and they can only be done by NASA. Dr. Hertz compared the upcoming great observatories – Webb and the Wide Field InfraRed Survey Telescope (WFIRST) – with Hubble, noting that they have very different architectures, wavelength coverage, and fields of view, while also exploring different timelines in the age of the universe.

WFIRST is in Phase A and has a mission design responsive to requirements. Work was paused in order to have an independent assessment, the WFIRST Independent External Technical/Cost/Management Review (WIETR), which was recommended by two National Academy of Sciences (NAS) studies. WIETR looked at the scope, cost, schedule, technology requirements, management processes, and the benefits of the coronagraph in relation to the costs and cost risks. The final report was pending.

The DS recommended a higher cadence of Explorers, which APD has implemented. The next Announcement of Opportunity (AO) will be in 2019, for a small Explorer (SMEX). The recent mid-sized Explorer (MIDEX) AO resulted in three candidates that are now in Phase A, with studies due next year: Arcus, Fast INfrared Exoplanet Spectroscopy Survey Explorer (FINESSE), and Spectro-Photometer for the History of the Universe, Epoch of Reionization, and Ices Explorer (SPHEREx). There are also three candidate Missions of Opportunity (MoOs): Contribution to ARIEL Spectroscopy of Exoplanets (CASE), a contribution to the European Space Agency's (ESA's) ARIEL mission's fine guidance sensor assembly; the Compton Spectrometer and Imager Explorer (COSI-X), a small complete super-pressure balloon mission; and the Transient Astrophysics Observer on the International Space Station (ISS-TAO), which is an all-sky X-ray survey to study transients and gravitational wave sources. There will be one MIDEX selection, and at least one MoO selection, with a second being possible but unlikely.

R&A, Mission Concepts, and Technology Development
As part of NASA's investment in the science community, APD continues to grow the R&A program, as advised in the 2010 DS. Starting in FY19, APRA will have an extra $5 million to support the selection of one or two cubesats per year, depending on costs and assuming the proposals are meritorious. This is part of an SMD-wide smallsat and cubesat initiative, though the division implementations vary according to their needs.

A chart illustrated the planned areas of APD community support from FY17-22, based on the FY18 PBR and its notional runout. These include R&A, cubesats, postdoctoral fellowships, and Guest Observer (GO) programs. Levels of support will shift as various missions begin and end. Dr. Hertz noted that there were sources of community support that were not included, such as the Strategic Astrophysics Technology (SAT) program and science teams embedded within flight projects.

In order to get as much technology development done as possible for the large strategic mission concepts and to advance key technologies ahead of the next DS, APD over-selected in the recent SAT competition. Therefore, APD did not plan on making any SAT selections during the next year. Following an assessment of the needs, the Division will let the community know the likely future of SAT in 2019 and beyond.

A sand chart illustrated APD spending from FY04 through FY30, including Webb, WFIRST, and an open wedge for the next DS-prioritized future strategic mission(s). If the budget stays flat or grows with inflation, the mid-2020s open up the wedge for the next strategic mission. With that in mind, NASA is conducting four large

mission concept studies at NASA centers, directed by community science and technology definition teams (STDTs). There are also 10 probe concept studies being led by principal investigators (PIs). All of these studies will be discussed with the community at the January 2018 American Astronomical Society (AAS) meeting. Each large mission concept study team will provide NASA with an interim report in March. After NASA conducts programmatic reviews and provides feedback, the study teams will write their final reports, which will be due in 2019. Following submission of the final reports, the next step will be independent cost assessments. NASA will then deliver the reports and assessments to the upcoming DS committee. The probe studies are not being done by NASA, but the PI-led teams have NASA grants and will have a 1-week run at a NASA mission design lab. NASA will also do a high-level cost assessment at the back end, to be shared with the DS committee.

Technology gaps constitute a major issue for any future mission. The APD program offices have identified and prioritized these technologies. More than 75 percent of the technology gaps identified for the four large mission concepts are being addressed in the current technology program, which is important for putting implementable concepts before the DS. For ESA's Large Interferometer Space Antenna (LISA) and Athena missions, NASA is doing technology development related to Agency participation in those missions. Dr. Paul Scowen asked about smallsats and whether it was redundant with the recent the RFI from the Space Technology Mission Directorate (STMD). Dr. Hertz replied that redundancy is fine, but APD wanted to reach out to the astrophysics community about technologies specifically enabling of astrophysics smallsats and cubesats. The responses will go to STMD as input for their technology maturation programs. SMD focuses on payloads and STMD does enabling platform technology. All SMD divisions want to ensure that there are opportunities for smallsats in addressing science priorities. However, astrophysics traditionally requires larger missions, so Hertz feels like he needs to gather input on smaller payloads and what they can contribute to astrophysics. All SMD divisions are looking at smallsats and cubesats.

Dr. Gaudi asked if the Webb delay was included in the sand chart. Dr. Hertz replied that Dr. Eric Smith could provide a more complete answer, but the delay in the launch date is fully funded by the existing budget and has no impact on the APD budget. It is funded by Webb reserves built into the profile at replanning in 2011 and has no impact on the rest of astrophysics. Dr. Gaudi pointed out that at the last APAC meeting, Dr. Smith only showed 3.5 months of reserve. Dr. Hertz explained that was from the project-held reserves, not the Headquarters-held reserves.

Budget

Regarding the budget, the plan supported by the FY18 PBR supports the APD responses to the DS and the midterm assessment. Most of the planned growth in "the rest of astrophysics" is in the Explorer program. At the moment, NASA is operating under a CR for FY18 through December 8. In order to come up with the FY18 budget, each chamber of Congress must pass an appropriation, then consolidate the two appropriations through conference before voting on them again. NASA is also formulating the FY19 budget. The FY19 request has been submitted to the Office of Management and Budget (OMB).

The final FY17 budget, which was finalized in September through approval of an operating plan for NASA astrophysics, allowed cost-sharing of the Science, Technology, Engineering, and Math (STEM) activation project. Directed increases for the Stratospheric Observatory for Infrared Astronomy (SOFIA) mission and WFIRST required APD to find $27 million in savings. Fifteen million dollars came from TESS, which no longer has any Headquarters-held reserves. The project is currently on plan and has tight schedule reserves to make it to a March 2018 launch. If that does not happen, APD will have to either cancel the mission or reallocate funds other from other projects. The Balloon Program faced a $3 million reduction, which was taken from upgrades designated for facilities in Antarctica. Another $9 million came from various projects through rephasing, reducing carryover, etc. Hubble, SOFIA, WFIRST, Webb, and STEM activation were all set as line items and are thus untouchable, necessitating cuts out of the remainder of the program.

The combined House and Senate markups for the FY18 budget could keep the $1.35 billion total but result in a 13 percent reduction in the rest of astrophysics not specified by line item appropriations. Specific line items include Webb, WFIRST, Hubble, SOFIA, R&A, and STEM activation. The House also has language on high energy observatories, probes, starshade technology, and finding targets for an interstellar probe, while the Senate wants APD directs spending on life detection in exoplanets technology. If this is in the final language, NASA will ask Congress for clarification. The final budget could include some significant differences from the DS recommendations. If all of the line items stay from both markups, APD will have to cut $43.7 million from the rest of astrophysics, which would be very difficult in the absence of additional funding to go along with the additional requirements.

Selected Missions

Dr. Hertz next provided updates on selected missions. NASA is seeking information from parties interested in operating Spitzer once NASA funding ceases in March of 2019. This would cost about $14 million per year, not including the cost of Deep Space Network (DSN) downlinks. In 2012, Caltech took over funding operations of NASA's Galaxy Evolution Explorer (GALEX), so there is precedent for such an arrangement. The ISS Cosmic Ray Energetics and Mass (ISS-CREAM) mission launched and has been going through calibration and data checks on ISS. TESS is in integration and testing (I&T), with the Ka-band transmitter to be delivered soon and a launch planned for March 2018. The detector systems for Euclid have been failing in characterization testing, with a weakness in cold temperatures that requires a redesign. This will cause a delay of at least 12 months. The FY18 budget for the Imaging X-ray Polarimetry Explorer (IXPE) mission has been reduced, with an accompanying 6-month delay. The X-ray Astronomy Recovery Mission (XARM) continues to move forward. It is currently in Phase A, and will soon conduct its combined preliminary design review (PDR) / critical design review (CDR), as well as a combined key decision point (KDP) B and C in January 2018. APD has put out a call for members of the XARM science team. ESA is moving forward with LISA and will start Phase A in January, with NASA partnering every step of the way. NASA

has formed a U.S. LISA study team to participate in the consortium, and ESA is appointing three U.S. scientists to the ESA LISA Study Science Team.

Discussion
Dr. Hertz asked APAC to let him know if NASA should lead any other studies prior to the DS, for possible priorities that have not yet been identified. Dr. Kalirai asked for more detail about Spitzer, specifically the FY18 cost of the GO program. Dr. Hertz explained that this would be provided during the Spitzer discussion later in the meeting, but NASA does not require any consortia to include the GO program in their plan for Spitzer. First, however, a potential operator needs to come forward in order to proceed. He also welcomed APAC advice on priorities in the rest of astrophysics, assuming the worst-case scenario with the proposed line items. He has to make hard budget decisions every year, and while he did not expect APAC to find $43 million in reductions, any advice would be helpful.

Dr. Bautz noted that there had been a mid-term assessment recommendation about the SAT program. Dr. Hertz explained that APD is investing in mid-Technology Readiness Level (mid-TRL) technologies at high levels, and SAT is the competed area. APD must determine if there are critical technology needs that should be advanced at this time and that warrant setting aside additional mid-TRL funds at the expense of something else in the budget. In preparing for the next DS, the Division wants to invest in technologies that would fill the gaps for DS priorities. The STDTs have already presented their technology gaps. The issue is how to set priorities in the face of a limited budget.

<u>Summary of Hubble/Chandra Senior Reviews</u>
Dr. R. Milkey discussed the 2016 Senior Review (SR) for Hubble. This was an incremental review, following a full SR in 2014. The incremental review looked at any changes since 2014 that would impact the science program, and changes in operations at Goddard Space Flight Center (GSFC) and the Space Technology Science Institute (STScI). The panel found no reason to question the 2014 review findings and determined that the observatory should put forth a serious scientific program well into the next decade. The project team is exercising good stewardship and Hubble has extremely high science value. The panel did identify two concerns, however. First was the data reduction software. The panel also looked at the purchasing power in the GO/Archival Resource grants, as costs to universities are going up. The panel recommended a review of the latter to match costs with desired outcomes, as university costs are rising faster than inflation.

Dr. Donald Kniffen discussed the 2016 SR of Chandra. As with Hubble, there have been no changes since the 2014 SR, so this was an incremental review. The review was overwhelmingly positive, and the panel praised the Chandra staff and management, also making note of the pending release of the second Chandra Source Catalog. Chandra has been operating since 1999, and several subsystem deficiencies have developed over time. The review panel found that these have been mitigated well to minimize scientific impact. There was concern that funding decreases have resulted in stress on the staff, however. The panel praised the efforts to increase diversity in the pool of investigators.

The greatest concern was outside the charge, on the topic of the time given to Guaranteed Time Observers (GTOs). This issue was noted in the 2010, 2012, and 2014 SRs as well. The total number of hours given to GTO programs has been high due to the mission far exceeding its 5-year prime lifetime. Releasing some of the GTO time might enable some high-risk, high-reward programs, even if the same investigators were to win back that time. The project scientists argued that the GTO time vests instrument scientists in mission success. However, most of the time awarded to the High-Resolution Camera (HRC) scientists was used for Advanced CCD Imaging Spectrometer (ACIS) observations, not HRC observations.

Dr. Gaudi asked for more information on what will set the lifetime of these missions and how much longer they can operate effectively. Dr. Milkey said that although redundancy was built in, issues crop up, like with gyro failures. The current approach will likely enable Hubble to go well into the next decade. He would expect a slow degradation, and he was not certain about the battery lifetimes. Eventually, there may need to be a creative scheduling approach to observing. Observing efficiency is quite high at the moment. Another potential issue is budget pressure. Dr. Kniffen said that there are similar issues with Chandra. There is no hard cut-off or expectation of a particular failure. However, slow degradation of solar panels will lead to adjustments of viewing profiles, times, and lengths. The sense is that the mission could last quite a few more years, but there is no way to quantify that. There are concerns that the budget could be reduced, and the power cannot be pushed much further. The GO budget has not been reduced to increase funding for operations, and that strategy might be difficult to maintain. Dr. Hertz noted that Chandra's annual operating budget is $57 million.

Dr. Kalirai said that he agreed with the idea of rebalancing the GTO hours. The argument in favor of keeping GTO hours is more relevant early in a mission, not this far out. Dr. Kniffen explained that the assumption had been that there would be another x-ray mission launched within 7.5 years, but that did not happen. No one was expecting Chandra to last 20 years. Dr. Gaudi agreed, adding that these are aging missions, and new missions are coming up to compete for resources. He recalls that Spitzer rebalanced by going to larger survey studies and fewer individual awards. He wondered if that might address some of the issues raised regarding costs, GTOs, etc.

Dr. Gaudi also asked if the two missions had close-out plans. He understood that Hubble will be de-orbited at some point. Dr. Hertz explained that close-out plans are typically developed at the beginning of a mission and only are revised in response to mission changes. There is no plan to stop these missions. NASA will operate both as long as they are scientifically productive and the instruments are fully functional. There is no reason to believe that their value is questionable. Their SRs were not about continuation, but rather about getting the most science value at lowest possible cost. When he makes sand charts going out 30 years, he assumes the two missions will terminate at some point due to random hardware failures. Dr. Gaudi suggested that there might be a way of making these missions as scientifically productive as possible with lower budgets or different strategies. He

thought something like this happened with Spitzer. Dr. Hertz replied that Spitzer decreased its operating costs in response to SR critiques. There is a loss of science when such reductions are done.

Dr. Gaudi identified three issues: GTO time for Chandra; GO allotments for Hubble not keeping pace with costs; and newer missions taking up more of the budget wedge. Dr. James Bock noted that other SRs address budget issues. It was confirmed that the Hubble and Chandra SRs consider budgets. Dr. Milkey explained that the SR was not tasked with making changes based on lower budgets. They determined that if there were operational restrictions on the spacecraft, there could be a need to restructure the resources. He added that the middle age of a mission is the easiest. The first phase involves getting a sense of how the mission works, and the later phases involve addressing engineering challenges of failing missions. Both the 2014 and 2016 SR panels felt it was important for Hubble to go well into an overlap period with Webb.

Dr. Feryal Ozel noted that the budget numbers were developed years ago, so a blanket request of both in terms of efficiencies does not seem right. Dr. Kniffen explained that with Chandra, there was a change in operations staff on weekends, which increased risks. They were concerned about further cuts stressing staff and creating problems. It is hard to imagine any major way of reducing the budget without a major impact. Dr. Ozel agreed, noting that Chandra is very lean. Dr. Milkey said that Hubble also made major staffing cuts. He was not sure that it could be squeezed any more.

Dr. Gaudi said that GO funding is a concern, and GTO funding for Chandra seems to lack parity with other missions. Dr. Hertz explained that NASA reviews the Chandra GTO funding every 5 years. He advised APAC to consider the charges given to the SRs in order to make well-informed recommendations.

Webb Telescope Update

Dr. Smith explained that the main issue with Webb is the schedule change, as the launch has been moved to late spring of 2019. There is some testing that remains for early 2018. With the change in the launch date, the Optical Telescope element/Integrated Science (OTIS) payload and the ground observatory move well off the critical path and present no schedule concerns. The only hardware issue involves thruster repairs. Resolution of that will dictate where Webb falls in the launch window. Dr. Smith noted the Integration and Test (I&T) completion dates for the Science and Operations Center (S&OC) subsystems. Cryotesting of OTIS at the test chamber at Johnson Space Center was complete and the chamber door was to open in a few days. The cryotesting went a week longer than planned, in part due to Hurricane Harvey. There was a NIRCam side B shortwavelength channel boresight issue however, it falls within the requirements. The team is also looking at Mid-InfraRed Instrument (MIRI) communications issues, which are mostly in the ground support equipment and not an instrument problem. The big issue is the thermal coupling in the Integrated Science Instrument Module (ISIM) electronics compartment with the primary mirror backplane. Otherwise, the testing went extremely well. A test of alignment focused on a concern about acoustic testing and

micro-shutters, and that went well. The spacecraft element is now stowed in launch configuration in order to conduct deployment testing, a major milestone. Dr. Smith listed the deployment testing steps and remaining activities.

The Northrup Grumman workforce remains high. The change in the launch date will likely consume much of the Headquarters reserves. Much of the earlier (3.5 months) schedule reserve was consumed by the integration of the sunshield and spacecraft. The propulsion subsystem is the last issue of concern, and the team is addressing small leaks by replacing or reworking them.

Dr. Gaudi noted that Dr. Smith had previously said there were 3.5 months of schedule reserve, and he was now saying that while most of the reserve was eaten up, the schedule slip will not cause problems. Dr. Smith said that there was additional reserve added at Headquarters, in the 2011 replan as contingency for situations like this. Headquarters holds budget reserve that can be used to "buy more time" without impacting other programs. He was not aware of any project that would publicly show these reserves.

Dr. Gaudi asked if the delay was related to a conflict with an ESA mission needing the same time period at the launch facility. Dr. Smith said that it ended up being completely unrelated. ESA had asked NASA to analyze Webb needs, and it became apparent that the pace of Webb I&T required that NASA move the launch date. Therefore, NASA made the move for its own reasons. The Agency was still revising the launch readiness date with Northrup Grumman, taking into consideration the thruster issue. At the moment, Webb had a launch window, not a launch date. The latter should be available at the next APAC meeting. Regarding ISIM electronics compartment instabilities, the threatened requirement is encircled energy stability in 24 hours. Testing showed more than the allowance of 2.3 percent, so the team is looking at the ISIM electronics compartment to see what might be causing this and how to possibly reduce this if it is due to flight hardware and not ground support hardware.

S&OC

Dr. Nikole Lewis discussed the S&OC highlights. The S&OC Release 2 has been verified and delivered. Cycle 1 science program specifications and proposals for GTO and the Director's Discretionary Early Release Science (DD-ERS) have been solicited and received. There has also been continued support of astronomical and public engagement, and growth of the Webb user support infrastructure. Dr. Lewis presented a diagram of the S&OC Release 2, which pulls together five subsystems and includes more than 100 verified requirements. S&OC received 106 DD-ERS proposals that span the full range of science topical areas. There is also a range of user tools to support DD-ERS. Dr. Lewis described the Astronomer's Proposal Tool (APT) and the exposure time calculator, which is totally open source. The testing went extremely well, and the help desk took in and addressed over 100 help tickets.

There are many online resources. The Webb Observer news and events now go out via email, not just on the website, Facebook, and Twitter. There were more than

two dozen webinars in 2017, which have been archived online. The first meeting of the James Webb Space Telescope User Committee (JSTUC) took place, and JSTUC charter, membership and meeting agenda are available online. In answer to a question, Dr. Smith explained that there are two types of data. Early release observations will be available immediately. Dr. Lewis added that early release science will be executed in the first 4 months of Cycle 1 science, in mid-2020. Dr. Gaudi said that it would have been good to have a look at Webb data for the DS, but it sounded like that was unlikely. Dr. Smith said that the DS panels would have nominal information that the mission was working, but not science information.

Dr. Boyd asked whether JSTUC was evaluating the science impact of the launch delay. Dr. Lewis said that the Committee was involved and looking for ways to mitigate the impact, while also soliciting input from the community. Dr. Smith added that the plan was to keep Cycle 1 for GOs as planned, with avenues for insertion of timely new data. There are logistical issues that make these mechanisms preferable to delaying the entire call.

Spitzer Update

Dr. Lisa Storrie-Lombardi discussed the Spitzer capabilities. This is the first year for which there is no GO budget. After the last SR, NASA designated Spitzer for funding through March 2019, at which point the mission is to close out. The observatory and InfraRed Array Camera (IRAC) are in excellent health. The orbital geometry is the primary operating challenge, as Spitzer moves further from the Earth every year. There has been no degradation in sensitivity.

Spitzer is currently focused primarily on the early universe, exoplanets, and near-Earth objects and comets. The mission selected 2 years of science in 2016, then also had two reviews for Director's Discretionary Time (DDT). Exoplanets account for 85 percent of the proposed time. Spitzer has sufficient time remaining in its final 5 months to have a full proposal call, which will be issued in April.

Dr. Storrie-Lombardi next discussed Spitzer's Earth-trailing solar orbit. The benefits from this orbit include very long observations with limited interruptions; a thermally stable environment; one-third of the sky always visible; and visibility windows of at least 40 days. Constraints require that the pitch be beyond 30 degrees in order to communicate with the ground station. That degrades the solar panel effectiveness and, by extension, the batteries. There is a low pitch angle used to recharge the batteries, and parts of the observatory are exposed to more sunlight than the design anticipated.

The science impact is more time spent in the lowest data volume modes due to the lack of available Deep Space Network (DSN) passes. Spitzer supports a few long, higher-data volume observations with custom-built sequences. Assuming comparable DSN, Spitzer should be able to support extragalactic surveys, exoplanet studies, and microlensing. The DSN requirements become increasingly restrictive, however.

Dr. Michael Werner reported on the science possible beyond 2019, which has been the subject of a series of papers. The first theme has to do with exoplanets. Spitzer supports exoplanet science, and some of its observations complement Hubble and Webb, as well as Kepler/K2 and TESS. For example, Spitzer has long time baseline observations and complements Webb's far-IR wavelengths and Hubble's optical wavelengths. Spitzer also enables microlensing observations. In this capacity, it will frame the science questions for WFIRST and collect the first data for comparisons, while also validating microlensing techniques that will be used to characterize WFIRST microlensing planets. Another paper discusses brown dwarfs, which are prime Webb targets for biosignature detection on habitable exoplanets. Spitzer can detect strong targets with about 95 percent confidence, and can observe a great number of brown dwarfs. Finally, Spitzer has a unique ability to measure thermal flux of near-Earth objects, which Webb cannot do. These operations are feasible through November 2020.

Dr. Kalirai said that it is undeniable that Spitzer does unique science. However, in looking at where the field is going, it appears that other missions will overtake it. In addition, Webb will greatly exceed Spitzer's viewing survey capabilities. Dr. Werner agreed that this was true regarding near-Earth objects and the Large Synoptic Survey Telescope (LSST). However, the two missions are complementary. Similarly, Spitzer can do important preparatory work for Webb, Euclid, and WFIRST.

ExoPAG/PhysPAG/COPAG Updates

Exoplanet Program Analysis Group (ExoPAG)

Dr. Alan Boss began the ExoPAG update by noting that the Executive Committee (EC) membership is basically unchanged, though some affiliations have changed. He gave a list of the completed Study Analysis Groups (SAGs) and said that he would be asking to close out SAG 14, on targets for TESS. SAG 16, on exoplanet biosignatures, and SAG 17, on resources for K2 and TESS planetary candidates, were about to close out, while SAG 19, on exoplanet imaging signal detection, is ongoing. Recent ExoPAG activities include a meeting prior to KepSciCon in June, suggestions on expanding communications, teleconferences, and work on the technology gap list. Future activities include additional teleconferences, finishing SAG work, gap list reviews, and various ExoPAG meetings at the January AAS conference.

The action item was to close out SAG 14, as Dr. Boss indicated that it was concluded that there was no longer any need for the final report from this SAG.. Dr. Gaudi motioned to close out SAG 14. With no members opposed, the motion passed unanimously.

Physics of the Cosmos PAG (PhysPAG)

Dr. Bautz explained that because PhysPAG covers a lot of different science areas, it is organized around six Science Interest Groups (SIGs). The PAG convened a teleconference to review NASA SMD R&A methods to foster high-impact/high-risk research (HIRR). There were two questions to the charge, and PhysPAG focused on the first: does the R&A program have effective processes in place to solicit HIRR projects? PhysPAG determined that if APD wants to solicit HIRR, there would need

to be dedicated solicitations because the proposals would have to be evaluated separately from moderate impact (conventional) research. There was uniform support for HIRR as long as the allocation is fixed as a percentage or a funding total. One thought was to structure the solicitation like the NASA Innovative Advanced Concepts (NIAC) program in STMD, which seeks visionary, revolutionary concepts. The research should be early TRL but associated with a mission, architecture, or system concept, and PhysPAG recommends a two-step process.

Other, non-consensus, points came up. Few PhysPAG members have ever submitted a HIRR proposal, noting that there does not seem to be an appetite for such proposals at NASA. A web survey for the broader community might be warranted. Some members felt that NASA's risk aversion may have had large and unrecognized opportunity costs. PhysPAG members are also accustomed to funding across the range and assume there is a sensitivity to risk at all budget levels. The balance of risk among programs was not discussed, either, but there may be correlations between risk tolerance and project objectives.

Highlights include the ISS-CREAM launch, a productive AAS HEAD meeting in Sun Valley, a call for XARM participating scientists, the LISA study team appointments, the Physics of the Cosmos (PCOS) annual technology report, a call for PhysPAG EC members, and the recent gravitational wave breakthrough results. PhysPAG also acknowledged the work of PCOS Chief Scientist, Dr. Ann Hornschemeier. She has stepped down from that position and is moving on to a role in LISA

Cosmic Origins PAG (COPAG)
Dr. Scowen noted EC membership changes. COPAG members continue to be active in the STDT exercises. The Technology Interest Group (TIG) gave input to the Cosmic Origins (COR) program's final version of the technology gap list. The EC hosted a teleconference among the three PAG ECs and Dr. Hertz to revisit the question about the Great Observatories vision during the 2020s in the face of fiscal realities. No Earth-shattering conclusions resulted, but a lot of good information was shared and misconceptions were dispelled. This will not be input to the DS, but it was a good conversation to have in order to reclaim the vision. One concern that arose is access to multiple wavelengths.

COPAG members continue being involved in the STDTs. There are no open SAGs, though the PAG might create a new one. The three open SIGs and one TIG will all meet at the January AAS. The STDTs will be meeting with all three PAGs, but COPAG wants to hear the specific elements related to cosmic origins. Regarding the HIRR charge, COPAG discussions led to the conclusion that NASA has become more risk averse, though that may reflect limited resources. Rather than have a separate activity like PhysPAG advised, COPAG would cordon off part of the APRA funding. There needs to be more community input on the level of risk that is acceptable. COPAG also discussed the capabilities that HEOMD might have in order to build observatories and missions in a space-based environment, and what astrophysics might gain or lose as a result.

SIG 1, on Far InfraRed (FIR) astronomy, is still meeting but has submitted a paper for publication and has plans for a webinar series. SIG2, on UV-visible astronomy from space, is considering the capabilities on DS large mission concepts, specifically the Large UV/Optical/IR Surveyor (LUVOIR) and Habitable Exoplanet Imaging (HabEX). The cosmic dawn SIG is assembling a steering committee and has engaged with the FIR Surveyor and Origins Space Telescope (OST) STDTs. The TIG has been dormant since the review was released in July, but there is talk of starting a matrix of the available technologies. Finally, COPAG will continue its teleconferences and meetings.

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

Discussion
Dr. Gaudi identified several topics for APAC discussion: the Webb delay; Spitzer; HIRR research; and the SAT program. Dr. Bock was concerned about the proposal to cancel the SAT call in ROSES-2017, noting that this proposal opportunity affects much of the community. He understood the pressures on the program and the need to move funds, but he remained concerned about the future. Dr. Scowen agreed, noting that the community was concerned, especially those planning to propose as part of their path of research. Although part of the rationale for the change had to do with technology development going into the DS, the original thrust of the STDTs was to use the studies to identify technologies for additional investments, and shifting funds does not constitute additional investment.

Dr. Gaudi said that this was not in line with the philosophy of developing low TRL technologies, and it was dangerous to project the technologies. He was hearing that the basic idea had merit but the impact could have negative consequences. It also seemed to be leading to more directed research. It seemed antithetical to HIRR funding as well. Dr. Hertz explained that he would not characterize the move as reducing competition. The proposals were selected through competition. There was not a budget line for funding the large mission research. If the DS were years off, this would not be happening. In addition, the absence of resubmission of high-ranking proposals that are not selected the first time keeps the impact from being a factor of two.

Dr. Gaudi observed that this mirrored the discussion about the staggering of the Theory program. It would have been preferable to be able to make the decision earlier in order to make the announcement. There are many fewer SAT proposals than Theory proposals, and the consistency of the proposals is very high. Investigators can still propose to APRA. He wondered if this called for a recommendation in the letter. There seemed to be concern that this was done without consultation, though Dr. Hertz pointed out that the current discussion was a result of his consulting APAC, as the call had not yet been changed.

Dr. Gaudi next raised the issue of whether to allocate funds by amount or percentage for HIRR. Dr. Hertz said that that was an SMD issue, and nothing had

been decided yet. Dr. Gaudi noted a general concern toward labeling funds in finer and finer bins, which would reduce competition. Dr. Hertz agreed that that was a valid concern. Regarding mid-TRL technology, the budgets in that area have been fairly constant with funds allocated to specific missions, like LISA. The priorities have been evolving through the decade, and the ratio of competed and directed work has changed. The STDTs were a factor, as was the mid-term assessment. It is not always possible for APAC to weigh in, but it would be ideal. As for renewing SAT for the next year, he still had time to do that. He thought APAC should recommend that he discuss a 2019 SAT call with them.

Dr. Gaudi advised waiting until any responses came in to the RFI before having additional discussions about Spitzer. Other members agreed, so he said they would request time for discussion of this at the next meeting. Dr. Kalirai suggested that they also seek a summary of current science productivity, along with metrics such as publication and citation rates. He was concerned about APAC supplanting the SR process. Dr. Gaudi said that the Spitzer team did not actually propose to extend the mission lifetime in the previous SR, so if APAC recommended that APD try to fund it longer, that would not go against the SR. Dr. Hertz noted that they were asking for SR metrics. Dr. Gaudi thought that the metrics might have changed, and the revised Webb launch date could be a factor. Dr. Ozel said that they should note that NASA was seeking private funding and that APAC wanted to compare it to GALEX. Dr. Hertz explained that GALEX was recommended for termination, an additional year of non-NASA funding became available through a Caltech-led consortium, and the mission then went to Caltech. If a private entity were to take over Spitzer, they would decide how to use it and why. The Wide-Field Infrared Survey Explorer (WISE) was turned off when a SR did not approve it for APD, but the Planetary Science Division (PSD) took it over as the Near-Earth Object WISE (NEOWISE) mission. The SR is for NASA missions operating beyond their prime mission phase, and only those missions are invited to participate in the SR.

Dr. Bock thought the shutoff date for Spitzer was triggered by the Webb launch date, which had changed. Dr. Hertz said that that was part of the rationale, as the science value of Spitzer goes down once Webb begins operations. The question was, if he had a pot of money, should he spend it on Spitzer or something else? Regardless, he did not have the funds, and Spitzer received an extra 6 months beyond their SR request. Dr. Gaudi agreed that APAC should not go around the SR, but it was not obvious that that was happening here. He wondered if they should get more information on community perception and discuss it at the next meeting. Dr. Ozel added that they should not ask for metrics because that overlapped the SR. Others agreed. Dr. Gaudi concluded that APAC would have no recommendation coming from this meeting. They would thank the presenters and reopen discussion in the spring.

Dr. Kalirai raised the issue of the potential budget shortfall, asking if it would make sense for APAC to have a quick teleconference. Dr. Hertz explained that the timing might not work, as he may need to react in a single day. They were talking about the appropriation for the entire Federal government, which needed to be addressed

and passed by December 8. Congress could also pass another CR or shut down the government. Dr. Gaudi said that there were other topics to discuss.

Wrap up for Day 1
The meeting adjourned for the day at 4:56 p.m.

Thursday, October 19

Opening Remarks
Dr. Hasan opened the meeting, then turned it over to Dr. Gaudi, who reminded participants of the FACA rules. Dr. Hasan then took roll of the APAC members and determined that there was a quorum.

R&A Update
Dr. Daniel Evans, APD R&A Lead, presented an update on R&A activities. A recent APRA selection was the Star-Planet Activity Research CubeSat (SPARCS), which will provide time-dependent slope and other measures that will help determine planetary atmospheres around low-mass stars. Dr. Evans then reviewed the proposal status list. A highlight is the TESS Cycle 1 call, which received 143 proposals. R&A sets a goal to release notifications within 180 days, which has become the norm.

The Balloon Program for 2017 ended up terminating or rescheduling a number of flights due to a combination of equipment failures and weather. Four sounding rocket launches were on the schedule for the fall and winter.

The 2017 R&A program falls into four broad areas: supporting research and technology (R&T), data analysis, data science and instrumentation, and separate calls for programs such as XARM and TESS. The Astrophysics Theory Program (ATP) was shifted to every other year. This was publicized broadly due to Astrophysics Subcommittee (APS, APAC's predecessor) advice. The call received few additional proposals. Since it has the same total funding and is now running less often, R&A projects a success rate of 25-30 percent, which will allow APD to fund some proposals it could not have supported otherwise.

Theoretical and Computational Astrophysics Networks (TCAN) supports fundamental theory and computational techniques. Its value is in collaborative networks that cross institutions. NASA previously ran this program with the National Science Foundation (NSF) but now supports it alone. First-year awards are up to $1.5 million annually for ~3 networks, and awards can last for 2 or 3 years. Another change in the Research Opportunities for Space and Earth Sciences (ROSES) program was the Roman Technology Fellowships (RTFs). Now early career applicants can submit a one-page proposal along with an APRA proposal. Previous RTFs can submit for up to $300,000 in Fellowship funds. Upcoming proposal opportunities include a call for XARM participating scientists.

Dr. Evans showed how the R&A budget is divided by discipline and research area. He pointed out that Astrophysics Data Analysis Program (ADAP) supports use of data from multiple missions. Of increasing importance is High-End Computing (HEC). There is a lot of pressure for computing time here, and R&A is happy to receive any advice that APAC can give. Dr. Hertz has made R&A a priority, so funding is increasing. In addition, the program is not receiving quite as many proposals as it once did. The success rate percentage is rising gradually and is now in the low 20s. However, proposals are becoming more expensive and more ambitious in scope. Dr. Evans reviewed the budget history of the R&A programs.

Plans for 2018 include a new ROSES element for LISA science and data analysis, and a new element for the NICER GO program, pending review of mission success. He was to address directed work in a separate presentation. APD values best practices, and to that end is working closely with the Office of the Chief Scientist (OCS) to better integrate training for program officers and reviewers on unconscious bias. R&A also plans to integrate APAC findings on HIRR into its programs. Finally, R&A hopes to further strengthen relationships with the community to foster the next generation of talent.

Dr. Kalirai pointed out that missions support a broad range of proposals that the R&A program data do not seem to capture. Dr. Evans replied that he would try to include those data going forward. Dr. Boyd asked for more details about the unconscious bias training, and whether R&A will collect data comparing the demographics of winning Principal Investigators (PIs) to data on everyone who submitted proposals. Dr. Evans replied that a training video video on unconscious bias was being reviewed and was likely to come out soon. It will not be ready for the ATP review, but the program officers are already aware of it. The data on gender and under-represented groups in selections are not available unless the proposers volunteer it. Dr. Hertz added that, officially, those are the only data APD can discuss.

<u>Internal Scientist Funding Model</u>

Dr. Evans next discussed the Internal Scientist Funding Model (ISFM), thanking APAC for providing useful recommendations at the last meeting:

1. "The APAC would like to understand how the reduction in proposal numbers will be implemented and the metrics and standards that are going to be used to judge whether the new civil servant funding model was a success or not in the three-year review."
2. "The APAC also requests more information on how setting limits on the number of proposals submitted by NASA Center scientists will be implemented."
3. "The APAC recommends that the APD continues to ensure that any future directed work is truly best done at the centers."

Dr. Evans then listed eight success criteria, including having more research directed to centers than competed, less NASA scientist time spent on proposals and more time spent on research, feedback, increased ability of NASA scientists to participate in review panels without conflicts-of-interest, maintenance of the balance of funding

to the external community, and others. Some of this is still being discussed. Dr. Evans also presented the OCS ISFM success metrics.

NASA has identified four key qualities of directed work; it must be strategic, science-enabling, forward-leaning, and distinctive. APD has identified seven principles for directed work and is taking a cautious approach to ISFM. The Division intends to direct very little new work, and expects only modest reductions in the number of proposals submitted. Dr. Hertz added that larger work packages will involve fewer proposals and more people. APD does not plan to roll up smaller R&A projects into larger packages. Dr. Evans said that the intent is not to meet a given metric, but rather to do what makes the most sense. Dr. Hertz noted that APAC made it clear that APD should be conservative in what the Division directs. The Agency might not see that as successful, however.

Dr. Gaudi observed that APAC is more inclined to favor a conservative approach to direction, with less concern about the reduction in the number of proposals from civil servants. He asked if there were a weighting plan for the metrics. Dr. Evans said that SMD has a 33% percent goal across the Directorate. If APD is under that, other divisions might be over it. Dr. Hertz confirmed that some divisions are indeed over it, so APD can be conservative and the Agency-level metric will still be met. When asked about the other divisions, Dr. Hertz reminded APAC that they are to advise the Director of APD, not other SMD divisions. Several APAC members expressed their support for the APD approach.

Dr. Evans said that all but one of the current directed work packages are one-to-one conversions of existing awards. The exception came from Ames Research Center (ARC) as an SAT proposal and seemed clearly appropriate for directed work. Another issue is how to manage the proposal numbers, which will involve coordination between APD and the centers, a requirement that all work packages describe all of the proposals encompassed, strong Headquarters program team monitoring, and internal controls at the centers. He showed responses from several centers and highlighted key points from the GSFC response. That center now requires an additional page for GSFC proposers to describe how the proposal is not in conflict with GSFC work packages. Marshall Space Flight Center (MSFC) has a gated process at the branch and division levels, and ARC is proposing something similar.

Dr. Bautz asked if there were any effort to coordinate the two packages concerning x-ray optics. Dr. Evans confirmed that there was discussion about linkages. Some of the directed work will reduce the competed amounts available, but it withdraws proposals from civil servant scientists. The amounts will be tracked, and he will present the data in a year.

Discussion

Dr. Gaudi reopened the Spitzer conversation by noting that the $14 million required of another entity taking over Spitzer is much more than the $1 million for GALEX. He added that the Planck mission came to APS after its SR and asked for additional funding. Dr. Hertz said that he had asked APS for advice on Planck after the SR.

The funding was for analysis and archiving of data, and the mission had stopped collecting it.

Dr. Gaudi then asked if APAC wanted to make any recommendations about the FY18 budget markups worst-case scenario and how Dr. Hertz might make up any shortfall. Dr. Wang was concerned about creating an additional burden on Dr. Hertz, and thought any recommendations should reflect community input. Dr. Gaudi said that it was clear that they would not have enough information to make a very well-informed recommendation because they did not know what might be enacted or to what extent, or how long Dr. Hertz would have to make a decision or when. That precluded having another meeting or going to the community. He saw three ways to respond: 1. Tell Dr. Hertz to do his best; 2. Cut a mission; 3. Tell Dr. Hertz to make cuts that will maximize the amount of science per dollar..

Dr. Ozel opposed the second suggestion, because it is not right to cut something just because the numbers match up. She preferred something more productive, possibly looking at what might fill the same niche as the markups in order to eliminate duplication. Dr. Kalirai said that it is not obvious that there is a process to minimize the science lost, and recommended stating that explicitly. Dr. Boyd was concerned that Explorers are the only area that can be squeezed. She would encourage Dr. Hertz to protect the Explorers. Dr. Gaudi said that he thought Dr. Hertz maintains programs with the least amount of pain in the face of shortfalls, and he trusts Dr. Hertz to do this well and effectively. He preferred to encourage him to maximize the science per dollar and maintain DS priorities.

SMD Cubesats Program Update

Dr. Larry Kepko, a GSFC program executive on detail for the SMD suborbital program, defined cubesats as being a subset of smallsats. Cubesats began as education and demonstration tools, but they are now used for science throughout SMD, especially in the Earth Science Division (ESD) and Heliophysics Division (HPD). SMD has a directorate-wide approach with five objectives, which Dr. Kepko listed. Cubesats are relatively inexpensive, entailing some risk.

The NAS recommendations address programmatic concerns, education and training, constellations and capabilities, technology investments, and policy. Most of these topics have readily available actions. In response to the need for PI interaction, NASA established the Small Spacecraft Coordination group (SSCG) and the SMD Smallsat Working Group (SSWG). Dr. Kepko listed SSWG's highest priority tasks. The four SMD divisions manage smallsats quite differently, and it is important that they learn from each other in order to address weaknesses and standardize processes and language. There is also the issue of access, which includes rideshares. Finally, SSWG plans to identify and fill technology gaps that smallsats can address. There is a NASA-wide SSCG task list emphasizing communications, secondary payloads, awareness, and coordination. The Small Spacecraft Systems Virtual Institute (SSSVI) is based at ARC, funded by SMD and STMD. The Institute produces a yearly small spacecraft state-of-the-art report and has a new database of smallsat parts now on orbit, encompassing other government agencies in addition to NASA.

For astrophysics, the primary mission need is to capture photons, and this effort does not seek to change that. Dr. Kepko listed current opportunities for cubesats and smallsats. There is also an RFI out that seeks more information about how smallsats might be used in astrophysics. The PSD RFI yielded many responses and a great deal of useful information.

Dr. Gaudi observed that much of the risk discussion has been focused on technology but not necessarily science, and yet there is also HIRR science. Dr. Scowen said that the cubesat initiative constitutes a paradigm shift in risk management. Dr. Gaudi suggested including a paragraph about risk in the context of the suborbital and balloon program for the letter. He asked if there should be designated funding or portions of programs for HIRR work. Dr. Bautz cautioned that it will be hard to identify and fund such work without a separate evaluation, regardless of how it is done. He agreed that HIRR work is underfunded. The community is convinced that the current process would not allow it even though there is an appetite for it. Dr. Gaudi said that if the HIRR proposals are included with other proposals, they will likely lose. Dr. Jones said that he had yet to see a balloon or rocket proposal come in that did not claim to be HIRR. Dr. Gaudi suggested that he might tell the Science Committee that there are areas in which the HIRR reticence is not so strong, but it is otherwise an issue and there might be a need for a specific call for HIRR and transformative research.

HEO Future Exploration Plans

Mr. Jason Crusan, Director of Advanced Exploration Systems (AES) for HEOMD, presented an overview of future exploration plans. HEOMD hopes to expand human presence into the solar system in a phased approach, with Phase 0 being a continuation of current work on the International Space Station (ISS). Phase 1 will take place in cis-lunar space, where assembly of the Deep Space Gateway (DSG) will occur, as well as beginning assembly of the Deep Space Transport (DST). There will also be some work on the lunar surface during this phase. Phase 2 will include the DST completion and a Mars simulation mission, with further phases leading to human exploration of Mars.

HEOMD has identified eight principles for sustainable exploration, including science exploration. Dr. Kalirai said that astrophysicists would want to emphasize deep space exploration with telescopes. APD developed a 30-year roadmap with large flagship missions and telescopes. Science exploration goes beyond the solar system. Mr. Crusan replied that the DSG and DST can help lead to a host of science objectives. HEOMD is conducting workshops on how the infrastructure can help enable science, including astrophysics.

Mr. Crusan noted that science instruments on ISS have opened up many science endeavors. NASA's Space Launch System (SLS) and Orion spacecraft will enable large payloads in addition to carrying crew. A range of ground-based facilities will support the planned missions, and both SLS and Orion are in testing, with some hardware in production. EM-1, the first mission, will involve an uncrewed test of SLS and Orion in a distant retrograde orbit of 25 to 40 days. The idea is that the

lunar gravity assist will push performance. HEOMD will deploy cubesats at different points along the way.

The DSG Phase 1 concept involves a lunar orbit that will enable both activities in cis-lunar space and a gateway to further travel. Solar Electric Propulsion (SEP) engines will be used to move around cis-lunar space. These can be refueled as needed, but HEOMD anticipates 10 to 15 years of operations before refueling. A notional manifest for the gateway build-up assumes crews of four. For the DST, the current baseline is 800 to 1,200 days of a crewed mission. The propulsion will be a combined SEP/chemical system that can be used for Mars exploration or other long-duration missions.

The DST can go up in a single launch and is expected to have a lifetime of at least three Mars missions. HEOMD hopes to do a shakedown cruise by 2029. The Directorate is working on interoperability standards, exploration objectives and requirements, the design concept for operations, and a utilization plan. Some of the utilization work could be scientific. HEOMD seeks to capture the breadth of use cases and have a utilization plan that includes them. The Directorate is now entering into study contracts for the DSG power propulsion element, which it hopes to launch on EM-2, the first crewed mission.

Dr. Scowen sought more details about assembling astrophysics missions in space. Mr. Crusan said that assembly attached to the DSG could be feasible, possibly involving human and robotic assistance. He did not envision anything beyond the science airlock, and large scale I&T would be unlikely. Dr. Gaudi said that at least three of the four flagship studies for the upcoming DS assume SLS as the launch vehicle. Mr. Crusan noted that HEOMD is developing payload interfaces, which he could share. Dr. Kalirai said that it would be great to start including astrophysics missions as part of the science, adding that Elon Musk is talking about the next-generation rocket for SpaceX, which could launch large payloads into space. Mr. Crusan said that HEOMD envisions a mixed launcher suite, and there are other heavy lift options in development.

Technology Gap Update

Dr. Brendan Crill of the Exoplanet Exploration Program (ExEP) said that the program focus is on discovering planets around other stars, characterizing them, and identifying those that might harbor life. To invest in technologies, ExEP annually seeks recommendations from the community starting at the summer ExoPAG meeting. At the moment, most of the recommendations came from the large mission STDTs: HabEx, LUVOIR, and Origins Space Telescope. Some technologies on the technology list are carried over from previous year, as well. The selection criteria are reviewed annually for relevance by an APD peer review and by the Exoplanet Technology Assessment Committee (Exo-TAC). Outcomes include: not accepted; watch list for technologies that could eventually benefit exoplanet science; or "accepted," which are then prioritized and scored by impact, urgency, and trend. This information goes into the ExEP technology list, which is reviewed by the Exo-TAC. The final list is published in the Technology Plan Appendix and serves to inform APD and the community of the Program's prioritized needs. The three APD

program technologists coordinate and share their work, sometimes determining which Program is best to advance a particular technology and to ensure that no important technologies are missed.

Dr. Crill used the starshade and coronagraph to illustrate the technology gap process. Investments in technologies from the 2017 list come from a number of sources. Competed SAT or APRA awards address many of the technology gaps. Directed funding from APD is another option. Some gaps are advanced through missions or mission concepts, with WFIRST being an example. The large mission STDTs are looking at these technologies to further refine their requirements. Most of the technologies on the list have funding, but there is the question of how far the individual technologies are being advanced with current funding levels, as only 5 of the 17 are funded through TRL 5. The next DS could affect funding priorities for these technologies.

Dr. Gaudi was concerned about items not on the list and the criteria for inclusion, giving interferometry as an example of a complex technology that will be important in the future and should be addressed now. Dr. Crill said that the selection criteria are broad. The program technologists normally consider those gaps that are submitted, however. He also noted that the list he presented was from January, and the next list will have additional technologies. The list shows priorities, not the funding. If the community submits interferometry, it can go on the list.

This list helps to inform SAT solicitations asking for specific technologies. The chief technologists do not have input into APRA calls, but people use the technology list to help propose in ways that help address APD's technology priorities. The portion of exoplanet funding from existing missions or mission concepts has not been broken out, but technologies do not have to be tied to missions or mission concepts. Some of the starshade technologies may reach TRL 5 by 2019; remainder early in the next decade. Additional funding to mature the starshade past TRL 5 may become available if recommended by the 2020 Decadal Survey.

Dr. Thai Pham, the Technology Development Manager for PCOS and Cosmic Origins (COR), explained that the PCOS technology focus covers x-ray, gravitational waves, and Cosmic Microwave Background (CMB) polarization measurement, while COR emphasizes next generation detectors, optical devices and coatings, and precision large mirrors. The programs identify technology gaps to rank them, inform solicitations, and leverage investments. The process begins with DS priorities as outlined in the APD implementation plan. The community provides input on technology gaps, as do STDTs and study teams. The integrated list is prioritized then used to inform calls, and the program office monitors the progress, resulting in an annual report that identifies a final list prioritized gaps and the status of currently funded developments. Prioritization reflects program science rather than missions, so each gap is evaluated in terms of alignment with program science and programmatic priorities, benefits and impacts, scope of applicability, and urgency.

The PCOS gap list has four tiers: highest interest, highly desirable, supportive of program but lower priority, and not currently aligned with strategic objectives. The

current COR gap list has three tiers, as no submitted gaps fall into the fourth tier's definition, and some of the listed technology gaps are receiving funds from the ExEP. Pham showed charts of the current investments. Impediments include limited funding, limited time before the 2020 DS, and limited technology solutions. The programs can always use new ideas. Some high-ranking gaps do not receive any proposals that would close them, and some solutions are incremental. While PCOS and COR are separate, they use the same process, and there are shared personnel.

NASA Airborne Astronomy Ambassadors Program

Dr. Dana Backman described the Airborne Astronomy Ambassadors (AAA) program, which aims to enhance student STEM engagement and achievement. The project includes immersion experience, participation in SOFIA research flights, involvement with NASA subject matter experts, and measurement of the program's impact on STEM learning. The audiences are teacher participants, typically high school physics and physical science teachers. SOFIA Cycle 5 roughly tracks to the current school year. AAA has school districts supply the teachers based on NASA criteria, and the current iteration involves seven school districts in California. The evaluation measures the impact on students rather than on teachers.

Teachers are in either Group A, the "treatment" group, or Group B, the "control" group. Dr. Backman explained that Group B teachers will have an opportunity to fly on SOFIA in the next cycle but will not use the same curriculum, and they will receive professional development sessions later than Group A teachers. The program will evaluate how the teacher experience affects students. The Group A teachers were starting to teach the SOFIA curriculum that week. The WestEd evaluation plan involves design, measurement, and evaluation. At the end of 2018, WestEd will assess the two groups, with 2,000 students in Group A and about 1,200 in Group B. The assessment will also gauge the interest and engagement of students in STEM, teacher views of student engagement and learning, and documentation of teaching implementation. WestEd has determined that the sample size is sufficient to be statistically significant. The content is entirely science-based, using six SOFIA science case studies addressing the electromagnetic spectrum, wavelengths, etc. There are also hands-on activities for students.

Public Comment Period

The meeting was opened for public comment period.

Dr. Remi Soummer from STScI spoke in order to object to the SAT funding change. The need is to accelerate technology development. This cancellation comes at a time when his group was planning to progress toward proposing in the next cycle. He appreciates that NASA has to deal with budget shortfalls, but he urged NASA to find another way to do this. Dr. Gaudi thanked him and said that APAC would consider this in discussion.

Discussion, Recommendations, Actions

Dr. Gaudi suggested discussing the cancellation of SAT for the next year, R&A, the Webb delay, the TESS response to concerns about the focus issue, the HIRR charge, and funding cuts.

APAC considered were a separate and explicitly advertised program to fund HIRR proposals, or to charter each panel to select one or two HIRR proposals they would not select otherwise.

The next topic was funding for FY18 under the worst-case scenario that both House and Senate appropriations were approved, resulting in a $43.7M shortfall in non-appropriated items. The options were: 1. Do nothing and trust Dr. Hertz; 2. Recommend explicit cuts or methodology; 3. Endorse a general structure for maximizing the science per dollar retained.

Dr. Bautz asked Dr. Hertz what would be most helpful to him. Dr. Hertz replied that it would help to know if APAC had anything to say about priorities in the part of the budget not subject to line items. For example, would they say that R&A is more important than the Explorers, or that he should turn off a mission, or determine kinds of priorities. The vulnerable areas included operating missions, R&A, Explorers under development, archives, the balloon program, and other ways of saving money in the face of a difficult budget situation. He noted that delaying mission calls does not save money in the current fiscal year.

Dr. Gaudi asked if there were a realistic option to delay XARM funding. Dr. Hertz replied that everything under consideration had negative consequences. Cutting XARM would be bad, but was that worse than cutting a competed mission? He wanted APAC's priorities. Dr. Ozel said it would be a mistake to turn off missions. Her priorities would be existing missions first, and R&A second. She would postpone new programs if necessary, and would prefer delay to cancellation.

Dr. Kalirai asked if it would be helpful to advise minimizing the science per dollar lost. Dr. Hertz replied that that would be useful, though it would be helpful to know whether they were thinking about science at the moment or over the long run. Dr. Gaudi thought that, given the uncertainties and timing, and the fact that it is difficult to prioritize different topics, a general guideline is the best approach. However, he would add the caveat that R&A probably should not be touched. APAC always feels that it is not sufficiently supported. After further discussion, he suggested explicitly calling out R&A, as it is the lifeblood of the field. It would also be better to delay missions than cancel them. Dr. Hertz said that it was important to set priorities rather than look at individual missions. He added that appropriations have the force of law, so looking for areas of overlap in order to make cuts would not work, and NASA discusses areas of ambiguity with Congress.

Dr. Bautz preferred the third option, of minimizing the science per dollar lost, but thought that Dr. Hertz did that already and believed that Dr. Hertz was the best person to make these decisions. Dr. Gaudi agreed. Given the uncertainties of the timing of the FY18 budget, the ambiguity of any shortfall amount, and the short time for any APD response, he thought APAC should advise Dr. Hertz to minimize science per dollar lost in the long term while following DS priorities and maintaining R&A to the best extent possible.

Dr. Cornish agreed, observing that this situation has come up before. Some of the markups reflect lobbying. Dr. Gaudi said that there are grey areas. He thought members of Congress had their own special interests. Part of the frustration is that this does come up over and over again. The European model is more stable and longer-term. He did not see a long-term solution to this issue. The DS guidance is their strongest ally. Dr. Boss pointed out that both the House and the Senate call for following DS priorities. He liked Dr. Gaudi's proposed language and trusted Dr. Hertz to do the right thing. He cautioned against getting into a test of wills with Congress and advised doing whatever was possible with the final budget.

Dr. Jones proposed getting a report on the response to the suborbital mishaps, and how these will affect launch rates and the program going forward. He was concerned about the impact on suborbital missions, especially as cubesats come on. Dr. Gaudi agreed and added language to that effect.

Regarding SAT, Dr. Gaudi proposed writing that APAC requests that they weigh in on changes in R&A funding and strategic decisions before they are enacted. They also recommended that Dr. Hertz discuss the criteria for resuming SAT in 2019. Dr. Hertz asked if they would prefer that he take the funding from APRA. He added that he had not officially cancelled the call. Regarding APRA, APD significantly expanded the funding for LISA technology, and it was essentially the same pot of mid-TRL technology money. SAT funding equals roughly 10 percent of APRA funding.

After further discussion, APAC considered recommending that Dr. Hertz restore the SAT call and take the funds from the FY18 APRA budget. Dr. Ozel was not convinced that the Committee had enough data to make a recommendation. She wanted to understand the scope and the possible remedy. Dr. Hertz said that, at worst, this recommendation would result in about 30 percent less for new APRA awards. If APAC were to make this recommendation and if he were to act on it, he would not have to award all of the funds. Instead, he would let the quality of the proposals drive the balance, with the excellence – based on peer review – as the determinant. The only change he would make to ROSES would be to clarify this in both the APRA and SAT calls. He said he was hearing that any highly meritorious SAT proposals should be funded from the APRA budget. He asked that APAC's recommendation address intent, not implementation.

Dr. Gaudi read the final draft recommendation, stating that APAC strongly opposes sudden changes in funding lines and appreciates that Dr. Hertz allowed the Committee to weigh in on the possible SAT call cancellation. APAC recommended that the Committee be able to weigh in on mid- and low-TRL research, and advocated keeping the SAT call. Any highly meritorious SAT proposals should be funded from the APRA budget.

Adjourn

After thanking the members, Dr. Gaudi adjourned the meeting at 4:07 p.m.

Appendix A
Participants

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

NASA attendees
Paul Hertz, NASA HQ, *Director, Astrophysics Division*
Dominic Benford, NASA HQ
Lucien Cox, NASA HQ
Daniel Evans, NASA HQ
Ingrid Farrell, NASA HQ
Thomas Hams, NASA HQ
Hashima Hasan, NASA HQ, *Executive Secretary, APAC*
Jeffrey Hayes, NASA HQ
Vernon Jones, NASA HQ
John Karcz, NASA HQ
Larry Kepko, NASA HQ
Mario Perez, NASA HQ
Andrea Razzaghi, NASA HQ
Rita Sambruna, NASA HQ
Kartik Sheth, NASA HQ
Martin Shill, NASA HQ
Eric Smith, NASA HQ
Linda Sparke, NASA HQ
Harley Thronson, GSFC

Non-NASA attendees
Nikole Lewis, STScI
Elizabeth Sheley, Ingenicomm

Webex/Telecon
Mansoor Ahmed, NASA

Matthew Ashby, Harvard
Dana Backman, SETI
Sara Barber, U.S. House of Representatives
Charles Beichman, JPL
Edward Belte, Orbital ATK
Dominic Benford, NASA
Michael Bicay, NASA Ames
Terri Brandt, NASA
Sean Carey, Caltech
Joan Centrella, NASA Goddard
Steven Clark, Space Flight Now
Dominick Conte, Millennium Space Systems
Daniel Coulter, JPL
Charlie Craig, NASA
Brendan Crill, JPL
Jason Crusan, NASA
Patricia Daws, NASA
Megan Eckart, NASA Goddard
Giovanni Fazio, Harvard
Jeff Foust, Space News
Michael Garcia, NASA
Alison Gardner, NASA Goddard
Jonathan Gardner, NASA Goddard
George Helou, Caltech
Grace Hu, OMB
Bethany Johns, AIP
Ben Kallen, Lewis-Burke
Patricia Knezek, NSF
Donald Kniffen
David Leisawitz, NASA
Amanda Leitz, Ball Aerospace
Charles Lillie, Lillie Consulting
Sara Lipsey, Ball Aerospace
Eric Mamajek, JPL
Egard Maskarenker, Stanford University
Stan Metchez, Western University
Robert Milkey
Mark Mozena, ULA
Susan Neff, NASA
Oscralet Penn, NASA Ames
Joshua Pepper, Lehigh University
Thai Pham, NASA
Aki Roberge, NASA
John Rummel, SETI
Kartik Sheth, NASA HQ
Nick Siegler, JPL
Marcia Smith, Ace Policy Online
Alan Smale, NASA

Remi Soummer, STScI
Karl Stapelfeldt, JPL
Lisa Storrie-Lombardi, Caltech
Amber Straughn, NASA
Micheline Tabash, ESA
Pasquale Tami, NASA Ames
Will Thomas, American Institute of Physics
Ashlee Wilkins, AAS
Stephen Willner, Harvard
Jennifer Yee, SAO
Harold Yorke, SOFIA Science Center
Eddie Zavala, NASA

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 of 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

William Jones
Princeton 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. *Hubble Senior Review – 2016*, R. Milkey
3. *Chandra 2016 Senior Review,* Donald Kniffen
4. *Webb Telescope Update,* Eric Smith, Nikole Lewis
5. *Spitzer Space Telescope Update,* Lisa Storrie-Lombardi, Michael Werner
6. *ExoPAG Report*, Alan Boss
7. *PhysPAG Report*, Mark Bautz
8. *COPAG Report,* Paul Scowen
9. *R&A Update*, Daniel Evans
10. *Internal Scientist Funding Model*, Daniel Evans
11. *SMD CubeSat Program Update*, Larry Kepko
12. *HEO Overview and Update from Advanced Exploration Systems*, Jason Crusan
13. *NASA's Exoplanet Exploration Program (ExEP): Technology Selection, Prioritization, and Investment*, Brendan Crill
14. *PCOS and COR Programs: Technology Gaps, Prioritization, and Development*, Thai Pham
15. *Airborne Astronomy Ambassadors*, Dana Backman

Appendix D
Agenda

Astrophysics Advisory Committee (telecom/webex)
October 18-19, 2017
Time Zone: Eastern

Wednesday 18 October

11:00 a.m.	Introduction and Announcements	Hashima Hasan/Scott Gaudi
11:10 a.m.	Astrophysics Division Update	Paul Hertz
1:00 p.m.	Summary of Hubble/Chandra Senior Reviews	R. Milkey/D. Kniffen
1:30 p.m.	Discussion	APAC members
2:00 p.m.	Break	
2:15 p.m.	Webb Telescope Update	Eric Smith/Nikole Lewis
2:45 p.m.	Spitzer update	Mike Werner/Lisa Storrie-Lombardi
3:15 p.m.	ExoPAG/PhysPAG/COPAG Updates	Alan Boss/Mark Bautz/Paul Scowen
4:00 p.m.	Community Comment Period	
4:05 p.m.	Discussion	APAC members
5:00 p.m.	Wrap up for Day 1	Scott Gaudi

Thursday 19 October

11:00 a.m.	Opening Remarks	Scott Gaudi
11:10 a.m.	R&A Update	Dan Evans
11:40 a.m.	Internal Scientist Funding Model	Dan Evans
12:00 p.m.	Discussion	APAC members
12:30 p.m.	SMD Cubesats Program update	Larry Kepko
1:00 p.m.	HEO Future Exploration Plans	Jason Crusan
1:30 p.m.	Technology Gap update	Thai Pham/Brendan Crill
2:15 p.m.	Break	
2:30 p.m.	NASA Airborne Astronomy Ambassadors Program	Dana Backmam
3:00 p.m.	Public Comment Period	
3:05 p.m.	Discussion, Recommendations, Actions	APAC members/Scott Gaudi

4:00 p.m.	Brief to Division Director	Scott Gaudi
4:15 p.m.	Adjourn	