# ASTROPHYSICS ADVISORY COMMITTEE

July 19-20, 2017
NASA Headquarters
Washington, DC

## MEETING MINUTES

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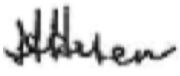
B. Scott Gaudi, Chair



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Hashima Hasan, Executive Secretary

*Table of Contents*



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*Ingenicomm*

Wednesday, July 19, 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 sessions, the conflicted members would be allowed to listen to the presentation, but they could not participate in discussion. Known conflicts of interest included Dr. Jason Kalirai on the James Webb Space Telescope (JWST); Drs. Mark Bautz and Patricia Boyd for both the Transiting Exoplanet Survey Satellite (TESS) and the Neutron-star Interior Composition Explorer (NICER); Dr. Boyd and Dr. Natalie Batalha for civil service workforce; and Dr. Batalha for K2. Dr. Hasan reviewed the Federal Advisory Committee Act (FACA) rules, 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. There were two public comment periods scheduled for the meeting. He then took APAC roll, including members participating via telephone.

Astrophysics Division Update

Dr. Paul Hertz, Director of NASA's Astrophysics Division (APD), reviewed his agenda, which began with science highlights.

The Hubble Space Telescope (HST) found a collapsing star that gave birth to a black hole. Neither HST nor the Spitzer mission can find any residual emissions, so investigators assume the black hole quietly collapsed instead of turning into supernova. This has implications for gamma ray bursts. The K2 mission recently discovered that small planets come in two size categories, relative to Earth: rocky Earth-size and super-Earth-size planets, and mini-Neptunes. The planets with the most massive rocky core tend to be Neptune-like but not as large, and the smaller ones lose their gases. This is the kind of thing Kepler/K2 was built to learn.

A red dwarf star with flares as bright as solar flares is an example of archival research using GALEX that takes data in a different direction from what was designed. A science discovery involving HST and the Chandra mission determined that a super-massive black hole (SMBH) was off-center relative to its host galaxy, based on the Chandra X-ray position of the supermassive black hole relative to the HST-determined location of the galaxy's center. This may be an example of a pair of black holes that merged and were displaced by the resulting gravitational radiation. The redshift was 0.35.

APD operates under a number of governing documents, but a constrained budget does not support all of their priorities. As a result, APD will always be prioritizing, and will draw on the science community for feedback on science priorities. The most recent governing documents are the mid-term assessment and the 2016 implementation plan. APD is currently planning for the 2020 Decadal Survey (DS).

Regarding the budget, both the Fiscal Year 2017 (FY17) appropriation and the FY18 President's Budget Request (PBR) are at about $1.35 billion, which includes JWST and which is essentially flat. The budgets fund JWST for an October 2018 launch, along with formulation of the Wide Field InfraRed Survey Telescope (WFIRST), Explorers, increased Research and Analysis (R&A) funding, new suborbital capabilities, and continued technology development. The FY17 consolidated appropriation is less than the planning budget. NASA has not yet received approval of the operating plan, so Dr. Hertz could not discuss it further. APD continues to follow the DS to set priorities. The suborbital budget includes water recovery, the New Zealand (NZ) launch site, and other areas that will give Principal Investigators (PIs) access to more capabilities.

NICER launched on June 3, and the recent post-launch assessment review (PLAR) showed that it was operating as planned. Medium-size Explorer (MIDEX) proposals were received in December, and the Division was on track for selections in summer 2017.

At the April meeting, APAC submitted some requests and recommendations, which Dr. Hertz now addressed. The current meeting was to have presentations addressing the funding of civil servant scientists and the science of the suborbital program. APAC had also recommended that the Science Mission Directorate (SMD) have a workshop for the community regarding cubesat capabilities, and that response was pending. APD agreed that the Program Analysis Groups (PAGs) should include more early career members on their executive committees.

Regarding cubesats, SMD has had calls and activities in the other divisions, where the application of cubesats was more obvious than in APD. NASA is collecting and sharing lessons learned, and there is a repository of expertise at the Ames Research Center (ARC). The FY18 PBR proposed a $70 million cubesat technology and mission investment for SMD, with $5 million of that being for APD starting in FY19. The APAC insight that the Division needs lessons learned was important. APD does get cubesat proposals, but some of the PIs do not know what is already available or standard, leading them to believe they must invent things that already exist. APD wants proposers to think more about science and less about how to construct a cubesat, so there will be a workshop on this.

Other topics APAC raised included the status of Spitzer's end-of-mission planning; the Jet Propulsion Lab (JPL) is developing a closeout plan for FY19. The Galaxy Evolution Explorer (GALEX) operated past its final year with non-NASA funding, and the Agency is open to a partnership to do something similar for Spitzer. The partners must be U.S. institutions, and NASA would retain ownership and liability while the partner operated the mission. NASA would then take Spitzer back, close it out, and safely dispose of it.

Congress has required the National Academy of Sciences (NAS) to conduct studies on exoplanets and astrobiology, and APD has formally asked NAS to start the work. The reports are due in 2019, timed to serve as input to both the APD and Planetary Science Division (PSD) Decadal Surveys.

APAC will receive reports from the large mission science and technology definition teams (STDTs) and discuss them before making recommendations. The Senior Reviews (SRs) are now at a cadence of every 3 years, and these, too, will report to APAC. The SRs were determined to be the most urgent of the subordinate groups. The PAGs are not subordinate groups and will still answer to APD, not APAC, although they will report at APAC meetings and their Chairs will still be APAC members. Dr. Hertz noted that the latter is his policy rather than a requirement. The STDT members must do some paperwork under this structure, as NASA has decided that members of subordinate groups must be Special Government Employees (SGEs), and for that they must fill out the financial disclosure forms. Their reports will go to APAC, which will decide whether to pass the information to Dr. Hertz with or without advice.

There have been some personnel changes within SMD. Dr. Michael New is now the Acting Deputy Associate Administrator for Research. The Planetary Protection Office, led by Dr. Cassie Conley, is moving out of SMD and into the Office of Safety and Mission Assurance. In the Heliophysics Division (HPD), Mr. Stephen Clarke, HPD Director, will do a 1-year detail at the Office of Science and Technology Policy (OSTP) on space weather, during which time Ms. Margaret Luce will be Acting Director. There has been no nomination for NASA Administrator.

Next, Dr. Hertz provided more detail on the budget situation. The FY18 PBR is with Congress, where the House has done a mark-up and the Senate has not. Dr. Boyd asked what would happen with the FY17

operating plan, since there were only 10 weeks left. She also asked if it would affect FY18. Dr. Hertz explained that the practice is to wait to hear from Congress, executing the contingent plan in the interim. If Congress were to make a change, NASA would have to respond. Most of the appropriation is not under discussion, however. Should late direction make it difficult to respond, that will be something that everyone knows, including Congress. It is getting close to the next fiscal year, and the change in the White House was a factor. This is not different, just late. The FY17 appropriation is $31 million less than requested, and it comes to a de facto $47.4 million reduction after factoring in the Congressionally directed spending.

The FY18 PBR was down from FY17 by 3 percent for NASA as a whole and down by 1 percent for SMD. However, it includes an increase of 1.6 percent for APD. This is still lower than the FY16 budget. It includes a short-term reduction for HST operations, which have been efficient enough to have accumulated a significant carryover. APD hopes to use up the carryover over the next 3 years. The Stratospheric Observatory for Infrared Astronomy (SOFIA) has a small carryover as well. The carryovers will be used to maintain the missions. When faced with tight budgets, APD prefers to use budgets for science rather than build up significant reserves. The HST budget will go back up eventually, and the mission is planning on future efficiencies.

Dr. Gaudi observed that a flat budget means the actual budgets are decreasing in buying power. Dr. Hertz explained that most Federal budgets went down, and NASA fared quite well by comparison. The Office of Management and Budget (OMB) said for APD to plan to $1.35 billion going forward. As JWST moves ahead, it will cost less. Dr. Hertz then explained that the Physics of the Cosmos (PCOS) program line includes operating missions, where mission extension budgets are being held in the Senior Review line. As JWST moves into operations, there will be growth in the rest of the mission lines, including Explorers.

The FY18 House markup will have to be worked out after the Senate does its markup. The House gives NASA 4.1 percent more than does the PBR, with SMD receiving 2.6 percent more. The Earth Science Division (ESD) would receive 2.9 percent less, HPD would be flat, APD was marked to receive an extra 0.1 percent, and PSD would get 9.9 percent more. The House language says that NASA mission priorities will come from the Decadal Surveys, then states that NASA must ensure that the United States is the first nation to launch an interstellar mission to the nearest Earth-like planet with evidence of extant life. The House also directs NASA to provide a draft roadmap for this project, with specifications for propulsion at 0.1 c, to launch by the 100th anniversary of the Apollo 11 moon landing.

Dr. Hertz reviewed additional details of the proposed budget and House markup. For SOFIA, the House specified that APD issue a call for fourth-generation instruments, have at least 100 flights in FY18, and not change the management of operations. The House also reinserted the carryover money that APD had removed. NASA must report on its plans to maintain leadership in x-ray and gamma-ray research, which has not been an explicit goal in the past. The House also directs APD to look at the needs for and benefits of a competitive probe line. Dr. Hertz added that the DS will weigh in on probes. APD has not yet provided a written response, but will mention the DS. Dr. Gaudi expressed concern that the Congressional guidance could be inconsistent with the DS.

Dr. Hertz noted that WFIRST would receive the requested $126.6 million, but there is concern about cost growth, so the House wants a briefing. Dr. Hertz noted that the House directs APD to spend $20 million of this $126.6 million on starshade technology development, resulting in a de facto $20 million cut from WFIRST if entacted. Funding for starshade technology development is currently elsewhere in the budget; there are plans to discuss this with Congressional staff. Dr. Hertz hopes to maintain starshade compatibility in the WFIRST design but not commit to building the hardware yet. Another issue is that the House says that WFIRST should enable NASA to identify the nearest Earth-like planet around the nearest star, which will be hard to do with the planned WFIRST telescope, which has a relatively small

aperture of 2.4-meters. This is not binding yet, as the Senate will weigh in. NASA will receive a final report from the conference committee that will merge and change the two markups. The House markup also tells APD to find targets for starshades. Finally, APD is to do a separate DS for exoplanets.

Dr. Batalha was concerned about the level of Congressional direction and the many erroneous assumptions in their statements. Dr. Hertz explained that he had information to share with Congressional staffers along those lines. He believed that some of these ideas went to the staff or members via individuals or groups advocating for various policies and funding. The House Science Committee is interested in exoplanets and the search for life. Whether that involves a starshade is something to discuss with them while explaining things like the limits of WFIRST detection abilities.

Dr. Hertz next presented R&A allocations over time and the PBR. The $5 million annual new initiative to enable the selection of cubesats starts in FY19. This is in the current call for the Astrophysics Research and Analysis (APRA) Program. The selections will be made based on the quality of the science. There was to be a presentation on the suborbital program's science; Dr. Hertz noted highlights of recent suborbital launches. A recent anomaly was holding up balloon launches from Texas until the cause was determined.

After showing the mission milestone chart and the timeline for Explorer Announcements of Opportunity (AOs), Dr. Hertz explained that SOFIA is in NZ for the annual summer deployment. He described some of the Southern Hemisphere flights, one of which was of MU69 occultation in support of New Horizons. There were also ground-based observations of MU69 occultations. A chart comparing the capabilities of HST, JWST, and WFIRST illustrated their respective fields of view, wavelength coverage, and capacity to study the age of the Universe. WFIRST is still in formulation and making progress. APD was told to have a WFIRST Independent External Technical/ management/cost Review (WIETR), separate from a NASA review.

The X-ray Astronomy Recovery Mission (XARM, pronounced "Charm") is the successor to the Hitomi mission, which is being led by the Japanese Aerospace Exploration Agency (JAXA). It will provide breakthrough advances in our knowledge of winds, outflows, clusters, and dark matter. NASA is doing a rebuild with the same interfaces as for Hitomi, an effort that will take 2 years. There will be changes on the Japanese end. U.S. community involvement should be high, as this is a directed mission. The community can participate as participating scientists, Performance Verification (PV) Phase Target Team members, and Guest Observers (GOs). Dr. Hertz described the timeline for participation of the three types of involvement. This will ensure that the community gets the data. The PV Phase data and GO program are being negotiated. In order to help ensure that there is not another failed mission, NASA has the instrument team, a co-PI, and participation on the high-level teams with JAXA. NASA is on all of the organizational charts as well, which was a condition for participation, and JAXA has been enthusiastic about this involvement. XARM is in the Explorer program space. NASA is spending more on science for XARM than for Hitomi. The timeline is tight and has a minor budget impact on some projects.

The European Space Agency (ESA) selected the Large Interferometer Space Antenna (LISA) as the L-3 observatory of its Cosmic Vision Programme and has begun Phase 0. This will be a gravitational wave mission. Discussions between NASA and ESA are going well. The mid-term assessment advised APD to invest beyond the 10 percent share originally envisioned, and ESA has welcomed this increased investment. NASA is funding U.S.-based technologies with the aim of reaching Technology Readiness Levels (TRLs) 5 and 6 by Adoption, nominally in 2022. The Goddard Space Flight Center (GSFC) will manage the technology investments and strategize optimizing NASA's involvement. APD will evolve its L3 study team into a LISA study team. The next DS will need to reprioritize LISA. The ESA schedule has the respective ESA and NASA responsibilities being determined by end of Phase A. Dr. Hertz described the LISA study team development and role. NASA will also be nominating U.S. members for the ESA

science study team and will ask for self-nominations for both the LISA and ESA science study teams. Investigators can be members of both.

ESA's Adoption Date is when they commit to doing the mission for a cost, and the member states commit to their portions. It is comparable to confirmation at NASA. The expected launches for Athena and LISA are 2028 and 2034, respectively. The LISA team is moving fast in case they can launch sooner. On the other hand, Athena is not progressing as planned and may need to be rescheduled. There is not yet a closed architecture of the science and the cost box, so teams are working on reconciling that. Dr. Hertz was unsure whether this might affect LISA. ESA is in an extended Phase A for Athena.

Dr. Neil Cornish observed that the LISA timeline makes sense from a technology standpoint, and it is practical in that it rolls over staff from LISA Pathfinder. Dr. Hertz said that ESA has asked NASA to work on the following: lasers with ESA; the telescope with ESA; two consortium areas – charge management and phase meter – in collaboration with the European consortium; microthrusters, for which NASA must select an investment area; and, science and data analysis, which will involve funding for the community to build a backup for data challenges. He assumes that the DS panel will be pleased with the plans for LISA, and he expects to be told to continue with LISA and WFIRST. The DS will then set the remaining priorities. No one knows the true costs of LISA at this point, because the technology is still in development.

Report on FY18 Civil Servant Directed Work

Dr. Hertz explained that NASA has about 1,000 civil servant (CS) scientists. Of these, about 350 CS scientists are working on competed projects, accounting for about 150 full-time equivalents (FTEs). NASA wants to have more directed work, while also reducing the number proposals from its center-based scientists by one third. The new directed work will come from the current competed work. There will be no changes in the balance of the research budget allocated between NASA CS scientists and the external community. The allocation will be across all NASA centers, not by division or any other unit. A good directed work package must be: strategic, use unique NASA capabilities and/or facilities, either benefit from or require long-term stability, enable science, and be ambitious rather than incremental. This will not be work that the community can also do outside of NASA, though external collaboration will be allowed as a minor component.

Unlike the other three SMD divisions, APD does not generally roll up Research Opportunities in Space and Earth Sciences (ROSES) awards into larger work packages. If a center wants to continue with something ongoing, that is not likely to succeed. Nor is APD likely to accept projects with substantial cost growth. Under the Internal Scientist Funding Model (ISFM), APD has selected eight packages. Dr. Hertz listed the projects and the justification for each. Six projects are existing work, extrapolations of existing work, or replacements for existing work. Only one replaces a funding stream going to a center. The thinking was that the easiest way for an early win was to take work that had been peer-reviewed and awarded, and have it done via direction rather than requiring future proposals to renew the funding, though there were occasional changes in focus.

Dr. Bautz asked if the directed work will preclude others proposing in the same area. Dr. Hertz replied that it will not, but APD will ensure that proposers know what work has been directed. When his predecessor, Dr. Jon Morse, began the Strategic Astrophysics Technology (SAT) program, APD was less sure where to invest technology dollars. Over time, however, the technology work has been increasingly directed and SAT has evolved. The goal for the centers is to have one-third fewer proposals. Dr. Gaudi was concerned that this could exacerbate existing animosity among the centers. Dr. Hertz explained that the desire and theory of the decision makers is that this will reduce competition among the CS centers and increase collaboration. When the Agency decision makers decided to address the issue of center scientists writing too many proposals and being uncertain about funding, it was the centers themselves that raised

the issue and developed this solution. Those centers did not include JPL, which is different by virtue of being a contract facility.

Dr. Gaudi asked what larger problem the ISFM is meant to solve. Dr. Hertz replied that it is the issue of too much time spent on writing proposals. This is a 3-year experiment, at the end of which the Agency will decide to continue, change, or terminate it. Dr. Gaudi said that while he saw the positive aspects of ISFM, he was concerned that it could reduce opportunities for those outside the Federal government. He asked about the criteria for judging the relative success of the experiment. Dr. Hertz said that the Office of the Chief Scientist (OCS) wrote the standards and metrics for the decision. It is on the agenda for the next Science Committee (SC) meeting, so APAC had the option of directing recommendations to that Committee or to him. He advised making an official request for the metrics.

Dr. James Bock noted that without the rigors of peer review, it may be difficult to assess these programs. Dr. Hertz explained that the plan requires peer review at several junctures, as well as annual status reports. At the 3-year mark, there will be a full peer review, though not a competitive one. The reviewers can include individuals who have been involved with competitive reviews. Dr. Debra Fischer asked how NASA can ensure a reduced number of proposals. She could see a situation in which direction could lead the Agency to pass up compelling science coming from the centers, or to send more funds to the centers. Dr. Hertz agreed that this was a concern for everyone, and NASA will not allow this effort to take community funds. He has charged the center managers with determining how to do this. Dr. Kalirai was also concerned that the program might discourage or inhibit investigators with good ideas from proposing. Dr. Gaudi said that APAC will seek more information on how the center managers plan to implement the program.

Dr. Paul Scowen said that investigators from academia competing with centers that have the same topics will be at a disadvantage. Dr. Hertz agreed that this was true in theory. However, he is directing work in very limited areas where the centers have longstanding programs that have always been part of the context of deciding to propose. APD does not want to direct work where it should be competed. Dr. Gaudi summarized APAC concerns. They included intra-Agency relations, reduced competition, and the need to ensure that the directed work be based on the particular center capabilities. APAC also wanted the metrics and standards for assessment, as well as information from the centers on how they will limit the number of proposals.

<u>High Risk/High Impact R&A Discussion</u>

Dr. Hertz explained that this is an action for all of the SMD advisory committees to deliver a report. Dr. Michael New elaborated, saying that SMD and the NAC SC are asking the Advisory Committees to address certain questions. For APAC, they want to know if APD has effective processes in place to solicit, review, and select high-impact/high-risk projects. They also want APAC to determine if the program has effective processes in place to solicit, review, and select focused, interdisciplinary, and interdivisional projects. Dr. New reviewed a series of sub-questions, then explained that APAC should advise on how to do these things rather than why. The request concerned tactics, not strategy. SMD had a range of materials that could help APAC in this task.

The interdivisional opportunities that already exist are Exoplanets Research Program (XRP) and Habitable Worlds, which are co-funded between APD and PSD. Dr. Kalirai asked if there had been research on how other NASA-funded opportunities have enabled high-risk, high-reward programs. Dr. New replied that there is an option for a recommendation to have separate high-risk, high-reward calls. He was not sure how those have worked out, but he could get the information. He next presented a series of working definitions that APAC can adjust as needed. He noted that “risk” is more about intellectual risk and uncertainty as to the outcome, not failure. It does not mean implementation risk. Dr. Cornish said that a positive high-risk item might be a novel method of analysis. Dr. Bock said that including the word

"novel" would help; NASA is risk-averse so that terminology might not work well. Dr. Yun Wang pointed out that the definition for high-risk opens a loophole for "crackpots" and wanted to know how to prevent that. Dr. New suggested that perhaps they would not prevent it. Dr. Gaudi said that he was called "crazy" for some of his work that was later confirmed. There is a difference between crackpots and people who are going off in different directions that are wide open. Dr. New said that high-risk research would encompass situations in which it is not possible to predict the probability of success or failure.

Dr. Hertz explained that the charge is to determine whether SMD should change its R&A program processes. APAC will only advise on improving NASA processes. This is about how open calls can better achieve NASA goals. Dr. New asked to have the findings and recommendations at the next APAC meeting, both as a letter to Dr. Hertz and as a presentation. SMD also wanted the APAC chair to make the presentation at the November SC meeting. The goal was to complete this task by the end of the year. Dr. Gaudi said that the schedule was unrealistic, as all of the APAC members were working on STDTs and/or WFIRST and were over-extended as a result. Ms. Elaine Denning explained that the initial thinking was to differentiate from NAS endeavors and have a more short-term response. Dr. New added that it was not necessary to poll the community, as APAC members are thought to represent the community. Dr. Gaudi said that while it might be possible to produce something by November, the quality would be questionable. Dr. New explained that the hope was to incorporate the results into ROSES 2018. PAG involvement would be helpful. Dr. Gaudi thought it would be possible to present the APAC report at one of the PAGs' monthly telecons in order to get some informal input.

Discussion

Dr. Batalha thought there were two key questions. The first addressed high-impact science, and the other involved interdisciplinary and intradivisional work. The answers would seem highly subjective. Dr. Gaudi agreed. He proposed having an APAC member synthesize the members' opinions. Dr. Fischer thought they could present the range, and Dr. Alan Boss pointed out that the other SMD advisory committees would have reports as well. Dr. Bock proposed having two sections, consensus and non-consensus. This was agreed to be the best way forward.

Dr. Hertz added that under the advisory committee structure, SMD and the divisions can give the advisory committees tasks directly, which was not an option with the subcommittees. In addition, SMD would like to learn whether the advisory committees can offer quick, tactical advice that comes in faster than what NAS provides. After some discussion, Dr. Gaudi said that he would collect the Committee's thoughts, collate the consensus and non-consensus ideas, and provide the results to the rest of APAC.

Dr. Gaudi asked APAC to discuss Dr. New's presentation. They kept the definition of "high-impact research project" and decided to make it clear that "high-risk" does not include schedule or management risk. Drs. Gaudi and Fischer liked the idea of having a separate call for high-risk research. Dr. Fischer wondered if such proposals need a deadline or can just come in as the proposers write them. Dr. Hertz said that while the National Science Foundation (NSF) is experimenting with that approach, they still need review panels to meet at a specific time.

Webb Telescope Update

Dr. Eric Smith provided an update on JWST, beginning with the schedule. There are two hardware flows remaining, the Optical Telescope element/Integrated Science instrument module (OTIS) and the spacecraft element. The tasks now involve integration and testing (I&T). OTIS is undergoing cryovac testing, for which the pacing element in the cooldown of the chamber is the test equipment. This is the last cryovac test in the program and will be completed in October. Sunshield membrane integration is

complete and the team is testing deployment of the entire structure. The watch list shows budget and schedule, but the reserves are being managed well and there are 3.5 months of funded critical path schedule reserve left. Some of that could be taken by the propulsion system, as there are leaks in the thrusters. The leaks are under review and the thrusters will require replacement. This is a concern, and depending on the solution, it may consume some schedule reserve. Another watch item came to light during vibration testing and involved some dampers on the aft optics assembly and secondary mirror supports. The project is doing schedule risk assessment and looking at all remaining activities. There were also issues with welding and vibration, and four items moved to the next fiscal year from the 2017 milestone list. These deferrals vary by importance and are related to propulsion. The schedule reserve is slightly below the plan but still above the recommendation. The mission is still within the replan budget, as well. However, there is a lot of testing yet to be done, and a number of challenges remain.

Regarding the launch date, ESA has a mission aiming for the same launch window, and the two (ESA's BepiColombo and JWST) spacecraft cannot be in the launch facility at the same time (because they are both large missions). If BepiColombo were to precede JWST, the new launch date for JWST would be in the spring of 2019. There is also a commercial payload on the schedule. JWST will require 85 days for launch pad work. Dr. Batalha said that this was leading her to think that the launch will be in 2019, since the ESA mission needs 6 months on the launch pad. Dr. Gaudi agreed, and asked about the funding impact of a delay. Dr. Smith replied that this is why the program carries reserves. As the actual and recommended reserves converge, which is the normal tendency, the team will stay focused. NASA will need to formally reserve the launch time, which means the team must ensure that the mission is ready. All of the technical requirements are being met. The launch window decision will be in the fall.

TESS Update

Dr. George Ricker, the PI for TESS, explained that TESS is a MIDEX mission that will discover at least 50 small planets orbiting bright, nearby stars. There will be a Guest Investigator (GI) program. The team has delivered the instruments and will launch in early 2018, after which there will be 2.5 months of commissioning. By late May 2018, TESS will be operating and will begin viewing the Southern Ecliptic Hemisphere. Dr. Ricker reviewed the current status of instrument integration. Cameras have been installed, integrated, and tested. The multilayer insulation was scheduled to be added that week, with instrument integration to the observatory to occur soon thereafter.

Mr. Jeff Volosin, the TESS Project Manager (PM), reviewed the spacecraft progress and described the communications baseline plan, which calls for repointing the Ka-band antenna towards earth and downloading data twice a month. The lagging item is the Ka-band transmitter, which needed to be unique and is not off-the-shelf. There was also a camera focus shift anomaly. Dr. Ricker explained that in testing, the camera focus seemed to drift--and then settle-- to a new location at flight temperatures (-75C, faster at -85C). Focus shifts on time scales comparable to transit durations were never observed. It took several months to identify the likely source of the focus shift, which was partial crystallization of the RTV lens bond pads at low temperatures. Extended tests already underway will inform how to address this anomaly. After the Project's discussing this issue with Dr. Hertz, NASA HQ recommended moving forward with the camera as it is. The Level 1 science requirement that TESS establish masses for 50 small planets will certainly be met, although the overall yield of small exoplanets orbiting faint stars could be affected by up to 10-20 percent. The shift slightly reduces the focus sharpness near the outer edge of the field-of-view in the range of temperatures that TESS is expected to experience in

orbit, while further sharpening the camera focus towards the center of the field-of-view. The concern is that the focus might change further. The team has determined a way of addressing the impact of the focus shift on small planet yield. Dr. Ricker presented a graph with the expanded region of yield versus focus and reviewed the Level 1 requirements. In the absence of any shift, the simulations predict about 230 small planets will be detected in the solar neighborhood, which could decrease to about 185-205 small planets if the camera focus shift anomaly is experienced in orbit. Thus, there remains ample margin (>250%) in the number of small planets suitable for mass measurements that TESS will expect to discover orbiting bright, nearby stars.

The GI program is moving ahead well at GSFC. The program will begin about 60 days after science operations begin. There will be two solicitations for new investigations, but there will be no proprietary period for GI data. TESS is not just for exoplanets; Dr. Ricker reviewed several of the proposal categories envisioned. He then presented the GI program timeline and described Cycles 1 and 2.

Mr. Volosin presented the schedule status. TESS is making lots of good progress; there are 22 days of funded schedule reserve remaining, and the mission should launch in March, 2018. As noted, the critical path issue is the Ka-band transmitter, which was being tested by the vendor. The mission team hoped to start observatory testing in August.

Dr. Ricker explained that the focus shift could change with time, but there is not clear evidence that it would do so. Dr. Batalha sought more information about the assumptions that went into planet yield studies regarding the focus shift, and whether there is a specific size of planet that would be lost. Dr. Ricker presented the results from a study on simulated planet yields, and said that any lost planets would be those orbiting stars fainter than 11th or 12th magnitude. There should be no additional losses for planets orbiting brighter stars. Faint stars would be affected more than bright stars. Dr. Batalha said that gave the impression they were adapting the aperture and asked if there would be fewer total targets. Dr. Ricker replied that since TESS is not "pixel starved" for postage stamps to the degree that Kepler was, and there would be no loss in total postage stamp targets for TESS; i.e. adding an additional ring of pixels to collect the light in image wings--if needed-- can be readily accommodated by the TESS data handling and telemetry system, since the TESS spacecraft can telemeter data for >25 times as many pixels than was the case for the Kepler mission.

Public Comment Period

Dr. Niell Reid said that for the HST budget, the more "efficient operations" Dr. Hertz referenced reflect overhead, not a change in operations. It is a term of art for budget people. Dr. Hertz said that it reflects past efficiency; the carryover built up over past efficient operations.

GPRAMA Guidelines

Ms. Jennifer Kearns of SMD provided the background of the Government Performance and Results Act Modernization Act (GPRAMA), which requires each Federal entity to provide a strategic plan, an annual performance plan, and an annual performance report to evaluate progress made in key areas. In SMD, the performance measures address milestones for missions and development.

In determining NASA's success in meeting the performance goals related to astrophysics, APAC was free to evaluate anything that occurred during the last year, though they were only to consider items funded in whole or in part by NASA. That funding did not need to come from APD specifically. Dr. Hasan had sent the members a document with items that they could consider, though they were not bound to using those examples. The only requirement for the APAC material was that it be sufficient material to back the conclusions. Unlike prior years, APAC was free to offer more than four items per Annual Performance Indicator (API) if they wished; use of links was encouraged. If there were critically important items, Ms. Kearns asked that APAC please note them.

The key requirement was for a color rating, as follows:

- A rating of Green meant that the expectations of the research program were fully met in context of the resources invested;
- Yellow meant that there were some notable or significant shortfalls, but some worthy science advancements were achieved; and
- Red meant that there were major disappointments or shortfalls in scientific outcomes in context of resources invested, uncompensated by other unusually positive results.

Finally, it was requested that the document be written at a level appropriate for the intelligent layperson.

GPRAMA Discussion

Dr. Gaudi led the APAC discussion. Each example was to include a title, an image, a caption, and about three paragraphs and references, with a link to a press release or peer reviewed paper. As APAC was to continue the discussion the next day, he suggested the members use this session to identify the topics to include.

The discussion began with:
*API: FY 2017 AS-17-1: Demonstrate planned progress in probing the origin and destiny of the Universe, including the nature of black holes, dark energy, dark matter, and gravity.*

While the gravitational wave discovery was impressive, and while NASA did have some involvement in it via LISA Pathfinder, it did not directly address progress toward NASA science goals. APAC agreed to note it in the introduction but not include it among the examples. Items selected for this API were:

- Chameleon Supernova
- Black Hole Kicked Out of Home Galaxy
- Disappearing Star
- Astronomers Discover Powerful Cosmic Double Whammy

*API AS-17-2: Demonstrate planned progress in exploring the origin and evolution of the galaxies, stars, and planets that make up the universe.*

There was more debate about this API, as some APAC members wanted to include a SOFIA result, but Dr. Gaudi was wary of trying to find a result related to a specific mission, since the GPRAMA is not an advocacy document. The Committee considered the topics of Fermi bubbles, Crab Nebula, incoming galaxy pairs, ultrafaint dwarf stars, an HST result on super-hot balls of gas with masses of twice that of Mars coming from a red giant, and star formation discoveries.

*API AS-17-5: Demonstrate planned progress in discovering and studying planets around other stars and exploring whether they could harbor life.*

For this API, APAC chose TRAPPIST-1, Fulton gap, HAT P-26, and the catalogue for the closeout of Kepler as examples.

The voice vote was unanimous for Green on all three areas. Dr. Gaudi committed to producing a further draft for discussion the next day.

As there was time, APAC returned to the discussion of the ISFM. Dr. Gaudi reviewed what APAC intended to request. First were the metrics and standards SMD would use to judge the new model, and second were the implementation plans for limits on CS proposals at the centers. The letter to Dr. Hertz was to state that APAC has concerns about competitiveness and wants to ensure that the directed work is really judged to be best done at centers. They are also concerned that JPL is treated differently and that the new model will affect intra-center politics. Dr. Bock added that he was concerned about the panel for the evaluation.

Dr. Wang observed that everyone seemed to think this was a bad idea. All scientists write a lot of proposals, not just NASA scientists. She was not convinced that this was good for NASA, especially from the science front. If the directed research is determined by officials and not scientists, will it be the best science? Dr. Gaudi agreed that there was cause for concern, but he saw some positive aspects as well. For example, the centers do bring in good core groups, with a structure for technology development that most academic centers cannot do. Dr. Bautz also had misgivings but agreed that, in some cases, it makes sense to consolidate technology development. He saw possible execution issues, however.

Dr. Bock thought this was a massive effort for fewer proposals. Dr. Brenda Dingus recalled that one purpose was to address longer-term goals, but they had not heard about that at this meeting. Dr. Gaudi reminded APAC that this came from outside of APD, but they could take their issues to the NAC SC and state that it needs to be done right. Dr. Batalha explained that CS scientists who do not have directed work are supposed to make up the remainder of their salaries. In this configuration, the centers will get the same funding and the staff will get some relief. Dr. Bock thought it changed center flexibility, and Dr. Wang advised stating that APAC is concerned that there could be negative consequences. Dr. Dingus thought the projects Dr. Hertz had chosen to fund were appropriate.

Next, Dr. Gaudi reported that Dr. Bradley Peterson, Chair of the NAC SC, had told him that the SC was to meet with the Human Exploration and Operations Committee (HEOC) to discuss areas of common interest and possible collaboration. An example might be infrastructure. New observatories must be serviceable going forward, which could be another topic. On-orbit assembly was another idea. Dr. Batalha observed that APD is sending observatories deeper into space with larger instruments, and the lack of serviceability could be an obstacle. Dr. Gaudi wondered about the Human Exploration and Operations Mission Directorate (HEOMD) timeline for achieving these abilities.

Regarding LISA, Dr. Bautz asked for clarification regarding the study team. Dr. Cornish said that based on discussion with Dr. Hertz, he understood that both LISA and Athena are in pre-adoption but are advancing development. The LISA study team will put together the science case. In discussing TESS, Dr. Gaudi noted that Drs. Batalha and Wang were very worried about the focus drift. Dr. Fischer added that the presentation gave the adjusted yield but not the photometry. Dr. Bautz said that a focus change was observed, but it is not yet known whether the focus will change with time on orbit. The team intends to characterize the long-term stability of the focus in long-term testing before launch. Dr. Gaudi said that APAC would ask for more information on how the focus shift will affect the stability of the photometry coming from TESS. He asked Dr. Batalha to write this piece, as it was in her area. He thought it might be possible to apply lessons learned from K2 to help mitigate the problems. Dr. Batalha said they need to know what can be done with software and how this will affect follow-up. NASA made the decision to go forward, not the team, so the recommendation should be something the team can follow. Dr. Gaudi

suggested recommending that the team come up with more mitigation or compensation plans. He added that this is relatively late, which limits their options.

Wrap up for Day 1
Dr. Gaudi adjourned the meeting for the day at 4:11 p.m.

Thursday, July 20, 2017

Opening Remarks
Dr. Gaudi opened the second day of the meeting by reminding APAC of the FACA rules. He then conducted roll.

Update on Suborbital Science
Dr. Michael Garcia began the presentation on suborbital science by listing the APRA suborbital proposal evaluation factors. Panels consider scientific merit, TRLs, and the extent to which the work advances the readiness of junior researchers to move into leadership roles. The suborbital area includes sounding rockets, balloons, cubesats, and International Space Station (ISS) -attached. The Roman Technology Fellowships (RTFs) are now coupled with APRA. Dr. Garcia gave data on the suborbital APRA 2015 and 2016 proposals, 2015 selections, and possible 2016 selections. He also showed the breakout by specialty. He then profiled a few select missions. These included a UV rocket program involving fabrication and testing of spectrographs; UV development at the Experimental Astrophysics Group at UC Berkeley; a far-UV project for validation and verification of the next generation of FORTIS from Johns Hopkins; the Planetary Imaging Concept Testbed Using a Recoverable Experiment – Coronagraph (PICTURE-C), done at UMass Lowell; and the Faint Intergalactic medium Redshifted Emission Balloon (FIREBall-2), scheduled to fly later this year under the guidance of a project scientist who has an RTF.

The program has selected two cubesat/smallsat proposals from about 40 such proposals over past 4 years. Other SMD divisions have more involvement with cubesats and therefore more proposals, but APD will have dedicated funds for this purpose starting in FY19. The HaloSat is an astrophysics cubesat that will launch in 2018 to study the hot galactic halo. The Colorado Ultraviolet Transit Experiment (CUTE) is a cubesat to study atmospheres and magnetic fields in exoplanets, to launch in 2019. Regarding cost and the success rate, proposals vary by length of time, and sometimes there will be a descoping of work in which APD asks the PI to do part of the proposed work for less funding. If the mission increase beyond a certain size, they get into having to pay launch costs.

Dr. Eric Tollestrop discussed the Far InfraRed (Far IR) and sub-mm balloon science flights. FIR balloon payloads are the ones more closely connected with galactic work, and they have been detectors primarily. He described STO-2, a reflight of the Stratospheric Terahertz Observatory (STO) that has possible applications to SOFIA. The Balloon-borne Large Aperture Submillimeter Telescope – Polarimeter (BLAST-Pol) should launch in the 2018/2019 Antarctic season and will map FIR polarization to understand magnetic fields and turbulence in star formation. The Primordial Inflation Polarization Explorer (PIPER) is a series of eight balloon flights to demonstrate FIR arrays and show where the inflation signal separates from lensing. The Suborbital Polarimeter for Inflation, Dust, and the Epoch of Reionization (SPIDER) had a recent flight and is also studying inflation. Results from these missions could apply to an inflation probe. The Balloon Experimental Twin Telescope for Infrared Interferometry (BETTII) crashed, and the team has to determine what to do about it. Should it launch again, BETTII will study the early states of star formation in clusters. These five balloon missions were selected for their science but also involve a lot of technology development. Dr. Boss noted that the ratings for initial, current, and target TRLs at bottom of the slides were very helpful.

Dr. Stefan Immler discussed the APRA High-Energy (HEA) suborbital portfolio, which currently has eight investments, mostly for technology development. The Water Recovery X-ray Rocket (WRX-R) is a rocket mission for diffuse x-ray spectroscopy. The Diffuse X-rays from the Local Galaxy (DXL) is a sounding rocket mission to study properties of the solar wind charge exchange. The Compton Spectrometer and Imager (COSI) launched last year as a super-pressure balloon flight, orbiting at 110,000 feet and proving very effective in detecting gamma rays. The Advanced Scintillator Compton Telescope (ASCOT) is a balloon experiment studying gamma rays and is also a key miniaturization effort. X-Calibur is a hard-focusing X-ray mission that flew last year. All of these test technology and conduct unique science that is not otherwise being done, while also training new investigators.

Dr. Dingus said that since the suborbital program is meant to train future leaders, she was especially concerned at the lack of female PIs. Dr. Immler said they had tracked these data and found there were quite a few female PIs in APRA, though not as many in the suborbital program. Dr. Gaudi suggested that there is cultural element of males gravitating to instrumentation projects. Dr. Dingus was not convinced, and stated the need to nurture a diverse workforce regardless. Saying that it is necessary to go further back in the pipeline just blames someone else. This program is quite important, as it is the beginning of the pipeline. Dr. Wang agreed, stating that the problem is systemwide. Women who try to take leadership roles on NASA projects or proposals are very aggressively discouraged at all levels. The call should include language about diversity. She has been made uncomfortable in professional situations, and not everyone is tough enough to be the only woman or to sit next to people who ignore them.

Dr. Hasan agreed, adding that while things are better now, advice would be helpful. Dr. Dingus recommended informing PIs that APD tracks diversity, and seek the data, including for students. If the PIs know NASA tracks this, it becomes a factor. Dr. Boyd advised having a workshop focused on a diverse sample of young people who could apply for this. Dr. Thomas Hams said that a recent balloon workshop in Minnesota brought in a large group of young researchers with a good balance of gender and some minority representation. There were also diverse student populations involved in flying payloads from Antarctica. There is movement, and while the pace cannot be forced, it is a trend in the right direction.

Dr. Gaudi hoped that the next DS will address this; the last one did, but without any recommendations. APAC had discussed including younger professionals in the PAGs, and they could ask that the next suborbital presentation include these data. Dr. Hertz explained that gender information has been gathered from ROSES for the last 2 years regarding PIs and co-Is, but otherwise it is not available. Due to privacy issues, he would have to ask for a legal ruling on whether he can provide that information.

Dr. Batalha noted that at an APS meeting, the members asked about bias in proposal selection, and the Space Technology Science Institute (STScI) tested it. However, she did not get the follow-up she wanted and therefore wanted to push to get the data. Dr. Hertz asked if these issues warranted forming an APAC task force. Dr. Gaudi said that this has been a consistent theme that has come up several times and is of concern to the majority of the Committee.

He asked Dr. Immler for the fraction of each experiment that is technology development and the fraction that is science. Dr. Immler replied that they are both part of the evaluation criteria and cannot be separated. The main thrust is technology development. Dr. Fischer pointed out that these are good examples of high-risk, high-reward science.

Dr. Hams described the suborbital particle astrophysics (PA) payloads, which usually go up via balloons. In PA, the payloads are the main platform for conducting cutting-edge research. There are seven currently funded projects, including Cosmic Ray Energetics and Mass (CREAM), which measures cosmic rays and

is to be adapted for ISS. The CALorimeter Electron Telescope (CALET) will also go on ISS to study cosmic rays, dark matter, and other phenomena. The Extreme Universe Space Observatory (EUSO) has different branches; the SPB studies cosmic rays using air fluorescence. This is the starting point for a probe study. The Antarctic Impulsive Transient Antenna (ANITA) payload would be balloon.

Dr. Gaudi asked if it would be possible to map the awards against the technology gaps. This presentation was very responsive, but he would still like additional information. Dr. Hertz explained that addressing technology gaps is not an APRA criterion, as APRA is for low TRL technologies. The SAT program is the one that addresses technology gaps. At the next meeting, APD can give a presentation on what the Division is doing to address future technology needs, which are broader than the gaps. Another option would be to present a table of gaps mapped to funding. After several members asked for a summary, Dr. Gaudi said that APAC could discuss a recommendation. He then thanked the presenters, saying that this information was what APAC wanted.

K2 End of Mission Science Planning

Mr. Charles Sobeck explained that the K2 mission concept followed the failure of two reaction wheels on the Kepler mission. Differences between the two missions include fields of view, number of targets, frequency of downlink, searching, and the fact that Kepler was mission-directed while K2 is community-directed. K2's photometric precision is very close to that of Kepler. Operational challenges include attitude control, communications, data storage, and fuel efficiency.

K2 emphasizes "high-value" exoplanets that are around bright stars and amenable to exploration. The mission explores stellar rotation rates as a proof of evolution. Supernovae are also investigated. Mr. Sobeck presented a graphic showing the science breadth of K2, which enables a diverse array of science investigations. The science community is engaged globally and includes early career investigators, as well as synergies with other missions. There are multiple funding levels for GOs. Examples of community response include a paper on TRAPPIST-1 submitted just 60 hours after the raw data were released.

The mission will end when K2 runs out of fuel, which cannot be predicted, though the best guess is that it will be between Campaigns 17 and 19, which will be in 2018. The GO office is focusing on developing and updating legacy user tools. The mission team is watching the spacecraft systems to facilitate early identification of performance degradation, get the final data down, and inform the community. The spacecraft will be abandoned in place, and the transmitters will be turned off to preserve bandwidth. K2 is funded through FY20, which will help get data into archives and fund GOs. Mr. Sobeck closed by noting that not every mission will be as responsive to retooling.

In answer to a question, Mr. Sobeck gave his initial recollection of the K2 budget as being about $6 million, but Dr. Hertz had a higher figure of $11 million. The latter included all of the Kepler-related costs, so Mr. Sobeck determined that about $1 million went to Kepler closeout, $2 million to the GO program, and about $8 million to K2 operations. Dr. Hertz added that after the project ends in FY20, analysis of the archived data will be supported by the Astrophysics Data Analysis Program (ADAP), which is standard for missions that have closed.

NICER Update

Dr. Keith Gendreau, NICER PI, explained that the baseline program just started, and the GO program will begin in the extended mission. The instrument has twice the effective area of XMM-Newton, and each photon is energy-resolved. An animation of NICER on ISS showed the mission's box with 56 detectors and the pointing system, which must account for adjacent payloads. The mission must also account for ISS vibrations. The success criterion is to discriminate among types of neutron stars via x-ray timing and other mechanisms. The box maintains alignment through the various thermal distortions ISS might experience. This is a non-imaging mission, so it does not do pointing control.

The June 3 launch went very well. Dr. Gendreau showed animations of the installation, which was managed robotically by operators in Canada rather than the astronauts on ISS. A launch lock issue was resolved. Commissioning, which is now complete, included observations and analysis of well-known celestial objects to confirm that the measurements matched those of other observatories. There was a bolt issue that was still in root-cause analysis at the time of the meeting. The pointing system has worked all along. This had been Dr. Gendreau's greatest concern, but there were never any problems.

Dr. Gendreau showed the science target tracking data. The next and most challenging action will be to align the X-ray scanner with the star tracker. NICER scans indicate a good overlap with other missions. There was also good confirmation with known millisecond pulsars. Some of the energy resolution and gain scale calibration data have been released already. Initial results of the background spectrum were as expected. ISS is not the best place for an astrophysics mission, so adjustments will be ongoing. The mission team expects to achieve 50 percent overall observing efficiency. Dr. Gendreau presented the target plan for the first 3 months, along with objects that are targets for early observations. NICER has viewed some targets of opportunity.

The total science team comprises 62 members and 3 students, with 14 affiliated slots remaining. These are divided by working group. The GO program will stand up in the fall. Dr. Hertz added that there will be a non-competitive review to bridge NICER to the SR, and there will be an option for a GO program at that time. Dr. Gendreau explained that institutes that provided an instrument can have "affiliated" positions on the science team. Potential members had to send him a letter explaining what science they brought to mission. In addition, the 25 original members could sponsor up to two other scientists.

ExoPAG/COPAG Updates

Dr. Boss began the PAG updates by showing the membership of the Exoplanet Program Analysis Group (ExoPAG) Executive Committee (EC). He then gave the status of the various Study Analysis Groups (SAGs). Eight are complete. Three were closing out and needed approval from APAC. Of the four active groups, SAG 14 is struggling and on hold due to its members having other priorities. SAGs 16, 17, and 19 are active and moving ahead. Recent ExoPAG activities included including a meeting at KepSciCon in Mountain View, CA. ExoPAG is now working on the current technology gap process. Future activities include a face-to-face meeting prior to the January American Astronomical Society (AAS) meeting. There will be a mini-science symposium on JWST's role in exoplanet transit spectroscopy.

Dr. Boss asked APAC to accept the close-out of SAGs 13, 15, and 18. Dr. Gaudi pointed out that SAG 15's presentation was shorter than the final report, and it was hard to identify the takeaway message. Dr. Boss agreed that it was broad. Regarding a question about the possibility of finding life on an exoplanet, Dr. Gaudi said that SAG 13 addresses it and that the Large UV/Optical/IR Surveyor (LUVOIR) website uses the SAG 13 information to calculate the habitable planets. Dr. Boss added that it will feed into SAG 16 regarding which data can be trusted. Dr. Gaudi observed that SAG 13 reflects a tremendous amount of work, SAG 18 has a lot of good information, and SAG 15 is rather encyclopedic and can be quite useful. He advised voting to approve close-out. Dr. Batalha moved to approve all three. The vote was unanimous in favor of closing them out.

Next, Dr. Scowen discussed the Cosmic Origins PAG (COPAG), starting with a list of EC members and identifying members who were rotating off. This would leave COPAG with no representatives from the NASA centers, which he would like to have. COPAG's greatest effort has been in the STDT exercises. The new Technology Interest Group (TIG) spent a month analyzing the Cosmic Origins (COR) technology gap list. Dr. Scowen presented a summary of the science drivers for all STDT mission concept studies at a meeting in New Mexico. There are no open SAGs, but three open Science Interest Groups (SIGs) will hold meetings at the 2018 AAS meeting. There will also be a joint PAG meeting at AAS. Dr.

Hertz said that NASA is sponsoring a full day of special sessions at that meeting, and Dr. Gaudi said that some of the STDTs planned to apply for splinter sessions.

Dr. Scowen reported that SIG 1, on Far IR astronomy, continues to be active in connecting with the community. Members of SIG 2, on UV visible astronomy from space, are very active in a variety of different workshops. The focus is on UV instruments for the LUVOIR and Habitable Exoplanet Imaging (HabEx) mission concepts. The Cosmic Dawn SIG is still setting up. The inaugural TIG review of technology gaps drew on a core team of 24 members.

There were no action items for APAC, but the EC had three questions. First, they wanted to know what APD thought of the NAS requirement to deliver separate science strategies to NASA on exoplanets and astrobiology. They also wanted to know NASA's reaction to findings of the recent SMEX report. Finally, given a flat budget, how might NASA and the community recapture the spirit of the great observatories working together, rather than seeing them in competition with each other?

Dr. Hertz replied that the NAS reports are in process and the reports will be inputs to the DS. The SMEX report was accepted, and APD plans to have a SMEX AO in the first half of 2019. The third question generates a longer discussion. The reality of the flat budget will require either long flagship missions or probes. One thing to consider with large missions is how to eliminate the life-limiting factors.

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

PhysPAG Update
Dr. Bautz provided the update for the Physics of the Cosmos PAG (PhysPAG), listing the six active SIGs. The main effort in recent months has been the technology gap assessment. PhysPAG helped refine the community input in this area, which Dr. Bautz reviewed, also noting that he thought "needs" was a better term than "gaps." Twelve of the 33 gaps identified were deemed non-strategic, but that is not the same as unimportant, and at least half of the non-strategic gaps had to do with probes.

Discussion about whether the COPAG TIG model would work for PhysPAG led to the conclusion that it would be different. The SIG leaders are generally confident that they understand the technology needs. PhysPAG science highlights included the NICER launch, ISS-CREAM, and the impending LISA study team. An upcoming meeting in Sun Valley, ID, will have a PCOS town hall, X-ray and gamma-ray SIGs, and special sessions on various topics.

Dr. Batalha said that for the gaps not tied to existing missions, the 30-year roadmap would be more relevant. Dr. Bautz explained that the directions came from the program. A concern was expressed that seven people were rotating off the EC all at once. Dr. Bautz said that the dates were flexible, and Dr. Rita Sambruna added that the Program was finalizing the solicitation for new applications.

Dr. Kalirai said that the flat budget dominates the discussion, so it was important to communicate with all stakeholders and aspire to break through the flat budgets. Dr. Gaudi said that he was not optimistic about changing the flat budgets. However, he thought that the less competitive the Decadal STDT mission studies are with each other, the more likely APAC was to paint a picture of flying many great observatories at the same time.

LUVOIR STDT Update
Dr. Fischer explained that the LUVOIR and HabEx STDTs meet together, as they see the two missions as being on a continuum. LUVOIR, which will be parked at L2, is a space telescope that could last for decades, as it will be serviceable and upgradable. The focus is on a telescope of 9-15 meters in the Far IR

to Near IR bandpass with a suite of imagers and spectrographs. There are multiple science cases for this mission. A graphic mapped the telescope size to the detectable stars. The resolution would be 100 parsec.

In addition to cosmic origins, LUVOIR will also monitor solar system moons with subsurface oceans. Dr. Fischer compared what LUVOIR and HST are likely to see in viewing the Europa jets. The essential application will be imaging and spectroscopy, and the wavelength ranges will be 0.4 microns to 2.4 microns. The latter is a break point because anything higher would require cooling. This range will allow detection of water vapor and methane. The team ran some simulations, for which Dr. Fischer provided the data and showed biosignatures over Earth's history as an example.

In confirming biosignatures, access to many molecules will enable understanding of the state of the atmosphere and the abundance of the molecules, ruling out false positives. Longer wavelengths would require larger telescope bandwidths. Dr. Fischer presented the aperture sizes and the exoplanet yields, and the chances of detecting an Earth twin. The aperture sizes make a tremendous difference in terms of quantity. The largest aperture would identify an incredible number of Earth twins out to 30 parsecs. If habitable conditions are present in 10 percent, 30 candidates will guarantee seeing one true exo-Earth at 95 percent confidence. Dr. Fischer then presented the instruments the STDT has considered, noting those that were studied and included in Architecture A based on community feedback as to the highest priorities. The team made technical notes on difficulty and urgency for seven technology areas.

The LUVOIR and HabEx STDTs are often asked about the differences between the two missions, which Dr. Fischer described. Both focus on exoplanet detection and biosignatures, as well as a broad range of general astrophysics. However, LUVOIR puts both goals on equal footing in a more general mission closer to HST. HabEx will be optimized for exoplanet imaging and a more focused mission in the 4- to 8-meter class. She sees these as being on a continuum. Independent costing will be done later in 2017 and again in mid-2019. Until then, costs are unknown. Both teams will look at two mission architectures while presenting a continuum of options. The DS will judge the optimal science/cost ratio. It is not straightforward to scale up costs based on aperture, as the telescope is a small fraction of the mission cost. The challenge is to blend the goals into a single powerful mission. A wide range of capabilities can enable decades of future investigations and unexpected discoveries.

Regarding precision astrometry, obtaining the masses for the planets is important for interpreting the spectra, and the High Definition Imager (HDI) lends itself to that, as would provide full masses and orbits. HDI is the characterization instrument, though it might not get masses. Dr. Batalha observed that it is important to distinguish yield estimates about characterization versus discovery.

HabEx STDT Update

Dr. Gaudi identified the STDT leads and explained that the teams have weekly telecons, as well as joint telecons with other study teams. The goals are to develop an optimal mission concept to characterize the nearest planetary systems, and to detect and characterize a handful of exo-Earths. The HabEx team wants to offer a continuum of options. Dr. Gaudi showed the wavelength range, including that of Earth. The mission would seek to detect water bands and CO2, and to identify the ozone drop-off.

HabEx is in a different trade space from LUVOIR. A starshade is an option for HabEx, but much less so for LUVOIR. For general astrophysics, the team is considering a UV spectrometer and a UVOIR imager. Dr. Gaudi listed the general astrophysics and solar system themes, many of which scale with aperture. The design team used a Kepner-Tregoe (K-T) methodology to settle on an architecture and completed several design trades before settling on four architectures: starshade only, coronagraph only, starshade and coronagraph, and two starshades. The team has finalized the first architecture (a 4m telescope with a starshade and coronagraph) and is still working on the second. While there are no TRL 2 technologies under consideration, there are six TRL 3 enabling technologies. The goal is to get down to only two TRL

3 technologies by the final report. The team found that small working groups were productive, the K-T matrix was useful, and limiting the trade space is necessary. For the telescope, the STDT is studying a 4-meter monolith as its first achitecture and a 6.5-meter instrument that would be segmented in order to manage costs.

The team decided not to jettison general astrophysics, because the cost would make it hard to sell a mission based on exoplanets only. The fractions of time for each purpose are still being determined. LUVOIR is a more even split. HabEx will have a minimum lifetime of 5 years. However, missions are now mandated to be serviceable, so the STDT envisions swapping out old and new instruments that have dedicated purposes. They are talking about characterizing about 10 habitable planets. The spectrum he showed will enable getting almost the entire spectra in one shot, which LUVOIR cannot do. The yields on the coronagraphs might be different. The integration times will be long regardless of aperture. It is harder to get a coronagraph to work with segmented apertures.

Origins Space Telescope STDT Update

Dr. Asantha Cooray described the Origins Space Telescope (OST), which will trace the rise of dust and metals in galaxies and the path of water across cosmic time to Earth and other habitable planets. The STDT has a number of science working groups, and about 250 community members are involved. The work involves white papers and regular telecons. Dr. Cooray listed science cases covering a wide range, and summarized some of the science goals. He then described how the mission could probe the interstellar medium in high redshift galaxies. Another way to think about this is to compare the work done in 1987 and more recently in terms of spectroscopy. By 2030, the field might be able to exceed current limits in a similar level of progress. OST could venture beyond JWST and image gas collapsing to form the first stars. The mission will look at primordial cooling via H2 rotational lines and will study the seeds of supermassive black holes.

OST will look at the biosignatures of exoplanets with transit and secondary eclipse spectroscopy, and will do direct imaging via a mid-IR coronagraph. Dr. Cooray presented a graphic of spectroscopy regarding weather and climate on super- Earths through Jupiters. The noise floor will be due to mid-IR detector stability. By comparison, JWST will not have the capacity to study habitable zone worlds. Dr. Cooray then presented the mission study design implementation and three mission concepts. The first concept is science-driven, with a 9-meter aperture telescope, for which the mass will be a limitation. The second concept is science-per-dollar maximized and still being developed. The third concept is constrained by a maximum cost of $3 billion. JPL is working on this concept. The study center has proposed merging the second and third, but the STDT has not quite worked this out.

Under the first concept, the mission will have a duration of 5 to 10 years. Dr. Cooray showed a graphic of the deployed configuration, presented instrument specifications, and gave comparisons with existing missions on wavelengths and sensitivities. OST will provide a factor of 10,000 improvement in sensitivity, will offer immense discovery potential, and will be revolutionary rather than just building on what is already known. Regarding spatial resolution, that information is available but Dr. Cooray did not have it on the slides. The primary science will be spectroscopy, and characterization of Earths and super-Earths. On the cost-constrained configuration, the team is still working through its ideas on how to meet the science priorities.

Lynx STDT Update

Dr. Alexey Vikhlinin, co-chair of the Lynx STDT, presented on behalf of Dr. Feryal Ozel. The team has eight science working groups, plus an optics working group and an instrument working group. The groups have weekly telecons and other meetings. They have made some major decisions about what kind of observatory Lynx should be, its size, the details of optics, the instrument suite, and requirements. The teams have also been working on a mission design, technology development roadmap, and science case.

All decisions have been science-centered. There are two science pillars: invisible drivers of galaxy formation and evolution, and the dawn of black holes. The team plans to identify a third pillar, but believes the two it has are sufficient for moving forward. Dr. Vikhlinin presented an animation to illustrate how Lynx will observe the state of baryons in galactic haloes, measure the energetics and statistics of all relevant feedback modes, and gain unique insights on the physics of feedback to informal numerical models.

Dr. Vikhlinin presented diagnostics of the Circum-galactic Medium (CGM) and Intergalactic Medium (IGM), with the gases that Lynx will observe. The team hopes Lynx will map the IGM. A cosmic web simulation addressed the x-ray surveyor sensitivity threshold. The dawn of black holes is another major theme, essential to understanding the early universe. Lynx will likely detect supermassive blackholes at their seed state or soon after, and will observe low mass black holes as well. Lynx will be able to cover almost all parameter space for black holes and will have three orders of magnitude more sensitivity than Chandra, plus considerably more than Athena. The team has identified five significant TRL gaps, from TRLs 2 to 4, and is working on raising the TRLs for these technologies. Dr. Gaudi asked whether there are viable paths to grow the TRLs to 5. Dr. Vikhlinin said that the team has involved industry and has plans to move these up before the DS panel meets. Dr. Bautz added that the DS needs to see a demonstration of the capability to make progress, and there has been recent progress in this area, which he believed would continue.

Reaching for the Stars

Dr. Pamela Harman described the Reaching for the Stars program, which is funded by SMD and brings NASA science to Girl Scouts. The focus of the scout activities is to discover, connect, and take action. The processes are to be girl-led and will involve both learning by doing and cooperative learning. There are about 2 million Girl Scouts across the United States. The program is in the second year of a 5-year Cooperative Agreement (CAN). Of the five Committee on Science, Technology, Engineering, and Math Education (CoSTEM) goals, the program addresses four, particularly the goals on engagement of youth and of under-represented populations. The program also supports NASA education goals.

There will be space science badges and a virtual toolkit, train-the-trainer sessions, interactive experiences with NASA experts, and activities related to the August 2017 solar eclipse. The program will have badges for each of the six levels of scouts. Badge development is ongoing and being tested with both urban and non-urban scout troops in Northern California. Badge requirements will be released in 2018/19 and will be disseminates through the online store, a convention preview, and bridging events.

Ms. Harman described the activities related to the eclipse, for which 90 councils received kits. There will be a patch for participation in the eclipse event. The train-the-trainer experiences are held at the University of Arizona twice each year. A hybrid experience held at GSFC is science rich. In 2017, three of four Destination camps, for scouts 11 and older, will relate to the eclipse; the fourth is astronomy focused with telescope observations. There is also amateur astronomer training. All programs are assessed by astronomers and by the Girl Scout Research Institute and Rockman et al.. Once the badges are released, the program could reach any portion of the 2 million Girl Scouts. Dr. Boss asked if the program might be transferrable to under-represented Boy Scouts in the future. Ms. Harman thought that was a great idea.

GPRAMA Discussion (cont'd.)

Dr. Gaudi explained that he took into account almost everything that was suggested, though he did make a few changes. Specifically, he put in a mention of the LISA Pathfinder. The list of major NASA astrophysics milestones included the following:

- NuSTAR Finds New Clues to "Chameleon Supernova"
- Astronomers Pursue Renegade Supermassive Black Hole

- Astronomers Discover Powerful Cosmic Double Whammy
- Collapsing Star Gives Birth to Black Hole
- Hubble Dates Black Hole's Last Big Meal
- Observatories Combine to Crack Open the Crab Nebula
- Hubble Uncovers a Galaxy Pair Coming in from the Wilderness
- "Kitchen Smoke" Molecules in Nebula Offer Clues to the Building Blocks of Life
- NASA Telescope Reveals Largest Batch of Earth-Size, Habitable-Zone Planets Around TRAPPIST-1
- NASA Releases Kepler Survey Catalog with Hundreds of New Planet Candidates
- Small Planets Come in Two Sizes
- NASA Study Finds Unexpectedly Primitive Atmosphere Around "Warm Neptune"

He found pictures for all of these. No one disagreed with this list of milestones.

Discussion

In discussing other topics, Dr. Batalha raised the issue of gender balance. She wants to see data similar to what APS was given for the proposal review, and she wants to know the success rate for proposals. Dr. Hertz said that APD could do that, but would have to break out GO proposals separately, as the Division only has access to larger mission data. Dr. Wang said there are many studies about the bad experiences women have in science, and that it was time for APAC to make recommendations instead of repeatedly hearing about how bad things are. The data will help in that regard.

Dr. Boss said that it would be helpful to see how suborbital programs flow into the technology gap lists developed by the three PAGs, though he was not sure it was necessary. Nonetheless, he wondered if those working on the gap lists felt they were getting the technology development they needed. Dr. Hertz said that the technology gaps were addressed outside of the suborbital program, which he did not want to link with the gap lists. Dr. Boss then asked if APAC could get a presentation on how the lists are merged and move forward, whether they get the resources they need, etc. He also wondered if the SAT program is sufficient. Dr. Hertz replied that the three programs' technologists could give a joint presentation, and suggested that APAC ask for one in order to learn what they can and cannot do with the resources.

Dr. Gaudi then read comments from Dr. Kalirai about the SOFIA mission, in which Dr. Kalirai stated that the presentation at the last meeting showed that SOFIA is not comparable to other missions of similar scale in terms of the number of papers published. SOFIA is very expensive in that regard. Perhaps it should not be compared to the great observatories. He expected a broader report from SOFIA, like the number of users, press releases, postdocs involved, archived science, etc. Dr. Boss pointed out that Congress keeps funding SOFIA and guiding the decisions. APAC is not the decision-maker here. Dr. Gaudi agreed. Dr. Batalha added that it was unfair to compare SOFIA to HST, which has been operating for decades, and Kepler took 4 years to build up. It takes time for a community to respond. Dr. Bock suggested recommending some metrics to the SOFIA team, in addition to asking that they provide Dr. Kalirai's requested information. Dr. Boss considered that reasonable, noting that it would keep pressure on the SOFIA team.

Dr. Hertz asked what APAC would do with these metrics, adding that he does not like to have APD staff do work that goes nowhere. Dr. Gaudi thought the requested metrics correlate with those APAC receives, and Dr. Boss advised not making the request. Dr. Hertz said the SOFIA team is not tracking some of these things, and if HST does, it is because they have a much larger staff. He asked that APAC not generate non-value-added work. This is also more in the purview of the Senior Review, and he prefers to keep that clean. The Senior Review is where missions are compared. Dr. Bock said that he would still ask about the state of the archive. Dr. Gaudi said that the fact that APAC asked about these metrics indicated concern, and he expected that the team understood that.

Dr. Wang thought the definition of high-risk was too open, and asked that it be made more precise and useful. Dr. Gaudi said that he, Dr. Boyd, and Dr. Kalirai would collect information from APAC on the provided questions, solicit answers from the PAC ECs, and sort the replies into consensus and non-consensus. Dr. Boss asked if they wanted to look at the NASA Innovative Advanced Concepts (NIAC) group from the Space Technology Mission Directorate (STMD). Dr. Hertz said that NIAC funds high-risk projects and that that is where the starshade came from. Dr. Gaudi said that APAC would look at NIAC further.

Recommendations, Actions, and Brief to Division Director

Dr. Gaudi explained that APAC, unlike its predecessor subcommittee, no longer needed to summarize its meeting since Dr. Hertz was there. Dr. Gaudi's letter would thank all of the presenters. The letter would make a statement on civil servant funding, that APAC believes there may be positive outcomes from the new model but has some significant concerns about competitiveness and the balance of grants, as well as exacerbating differences among the centers. APAC would like to understand the metrics and standards to be used in judging the model, and wanted more information on how limits will be set on the number of center proposals. Dr. Bock said that he was concerned about the quality of work and previous standards of peer review. Dr. Gaudi replied that APAC can suggest that as a metric if it is not presented as one.

GPRAMA resulted in all green ratings. Regarding work with HEOMD, APAC wanted to know about plans for serviceability and the ability to build modular missions. Dr. Boss asked about robotics. Dr. Hertz said that it was under STMD's Restore-L project. The PBR has some direction to work with the Defense Advanced Research Projects Agency (DARPA) on that. Dr. Gaudi said that for the TESS mission, several APAC members were concerned about the focus issue and sought more information about the photometric stability. The changes to planet yield constituted another concern. There may be software fixes. If not, the community might need to know what to expect.

ExoPAG closed out three SAGs. APAC was requesting that APD provide proposal success rate by gender on core research programs. Dr. Hertz asked that the Committee tell him if they needed additional information. Dr. Dingus asked if there are other things that APD does to encourage diversity, and if they could summarize the efforts, like the proposal language. Dr. Hertz said that the presentation will include everything the Division is doing to encourage diversity.

Dr. Gaudi continued, saying that APAC was requesting a joint presentation by the chief technologists on the topic of strategic technology gaps. Dr. Hertz observed that he was hearing a lot of requests for information. Dr. Gaudi confirmed the observation. He planned to summarize in one sentence each of the presentations APAC heard, thank the presenters, and make special mention of the Suborbital Program's response to the specific request for science information.

Adjourn

The next meeting was planned for October 18 and 19 as a teleconference from 11 a.m. to 5 p.m. Eastern time both days. Dr. Bock asked if they could have a presentation from the Ames smallsat program. Dr. Gaudi said that that would be possible at either the October meeting or the one after that.

The meeting was adjourned at 4:13 p.m.

**Appendix A**
**Attendees/Participants**

Committee members
B. Scott Gaudi, Ohio State University, *Chair, Astrophysics Advisory Committee*
Nathalie Batalha, NASA Ames
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 (via teleconference)
Neil John Cornish, Montana State University (via teleconference)
Brenda Dingus, Los Alamos National Laboratory
Debra Fischer, Yale University
Jason Kalirai, Space Telescope Science Institute (via teleconference)
Paul Scowen, Arizona State University (via teleconference)
Yun Wang, California Institute of Technology
Beth Willman, University of Arizona (via teleconference)

NASA attendees
Paul Hertz, NASA HQ, *Director, Astrophysics Division*
Dominic Benford, NASA HQ
Max Bernstein, NASA HQ
Jeanne Davis, NASA HQ
Elaine Denning, NASA HQ
Keith Gendreau, NASA GSFC
Shahid Habib, NASA HQ
Hashima Hasan, NASA HQ, *Executive Secretary, APAC*
Jeffrey Hayes, NASA HQ
Stefan Immler, NASA HQ
Jennifer Kearns, NASA HQ
Susan Neff, NASA GSFC
Michael New, NASA HQ
Rita Sambruna, NASA HQ
Wilton Sanders, NASA HQ
Eric Smith, NASA HQ
Linda Sparke, NASA HQ
Roy Tabor, NASA HQ
Eric Tollestrup, NASA HQ
Dan Woods, NASA HQ

Non-NASA Attendees
Mary Floyd, Ingenicomm
Todd Gaier, JPL
Eric Hand, Science Magazine
Richard Robers, Stellar solutions
Elizabeth Sheley, Ingenicomm
Alexey Vikhlinin, SAO

Webex/Telecon
Louis Barbier, NASA HQ
Dominic Benford, NASA
Gary Blackwood, JPL
Heather Bloemhard, American Astronomical Society
Joan Centrella, NASA Goddard
Steven Clark, Space Flight Now
Adrian Clausell
Anne Connor, Harris Corporation
Jeanette Domber, Ball Aerospace
Daniel Evans, NASA
Michael Garcia, NASA
Jonathan Gardner, NASA Goddard
Thomas Hams
Pamela Harman
Grace Hu, OMB
Jennifer Kearns, NASA HQ SMD
Patreicia Knezek, NSF
Dara Lipsey, Ball Aerospace
Eric Mamajek, JPL
Joel Parriott, American Astronomical Society
Stephen Reinhart, NASA Goddard
George Ricker, MIT
Erin Rigby, Ball Aerospace
Kartik Sheth, NASA HQ
David Shoemaker, MIT
Kendra Short, JPL
Alan Snale, NASA Goddard
Charlie Sobeck
Jeff Volosin

**Appendix B**
**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

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. *Internal Scientist Funding Model,* Paul Hertz
3. *R&A Charge to SMD Advisory Committees,* Michael New
4. *Webb Telescope Update,* Eric Smith
5. *TESS Current Status,* George Ricker, Jeff Volosin
6. *Guidelines for GPRAMA Annual Science Progress Review,* Jennifer Kearns
7. *Astrophysics Suborbital Science, Technology, and the Next Generation*, Michael Garcia
8. *K2 End of Mission Science Planning*, Charles Sobeck
9. *NICER Update,* Keith Gendreau
10. *ExoPAG Report*, Alan Boss
11. *PhysPAG Report*, Mark Bautz
12. *COPAG Report,* Paul Scowen
13. *LUVOIR Study,* Debra Fischer
14. *The Habitable Exoplanet Imaging Mission (HabEx),* Scott Gaudi
15. *Origins Space Telescope,* Asantha Cooray
16. *Lynx Mission Concept Report to APAC,* Alexey Vikhlinin
17. *Reaching for the Stars: NASA Science for Girl Scouts,* Pamela Harman

**Appendix D**
**Agenda**

**Astrophysics Advisory Committee**
**July 19-20, 2017**

**Wednesday, July 19, 2017**
**NASA Headquarters, Washington, DC, Room 6H41**

| | | |
|---|---|---|
| 8:30 a.m. | Introduction and Announcements | Scott Gaudi/Hashima Hasan |
| 8:40 a.m. | Astrophysics Division Update | Paul Hertz |
| 10:15 a.m. | Report on FY18 Civil Servant directed work | Paul Hertz |
| 10:45 a.m. | Break | |
| 11:00 a.m. | Q&A with SMD Associate Administrator | APAC members |
| 12: 00 noon | Working lunch | |
| 12:30 p.m. | High risk/high impact R&A discussion | Michael New |
| 1:00 p.m. | Discussion | APAC members |
| 1:30 p.m. | Webb Telescope Update | Eric Smith |
| 2:00 p.m. | TESS Update | George Ricker/Jeff Volosin |
| 2:30 p.m. | Public Comment Period | |
| 2:35 p.m. | Break | |
| 2:50 p.m. | GPRAMA Guidelines | Jennifer Kearns |
| 3:00 p.m. | GPRAMA Discussion | APAC members |
| 4:30 p.m. | Wrap up for Day 1 | Scott Gaudi |

**Thursday, July 20, 2017**
**Residence Inn Capitol, 333 E Street SW, Washington, DC**

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|---|---|---|
| 8:30 a.m. | Opening Remarks | Scott Gaudi |
| 8:40 a.m. | Update on Suborbital Science | Michael Garcia |
| 9:40 a.m. | K2 End of Mission Science Planning | Charles Sobeck |
| 10:10 a.m. | NICER Update | Keith Gendreau |
| 10:40 a.m. | Break | |
| 10:55 a.m. | ExoPAG/PhysPAG/COPAG Updates | Alan Boss/<br>Mark Bautz/Paul Scowen |
| 11:45 a.m. | Discussion | APAC members |
| 11:55 a.m. | Public Comment Period | |
| 12:00 p.m. | Lunch | |
| 12:30 p.m. | Science talk: Event Horizon Telescope | Feryal Ozel |
| 1:00 p.m. | LUVOIR STDT Update | Debra Fischer |
| 1:15 p.m. | HabEx STDT Update | Scott Gaudi |
| 1:30 p.m. | Origins Space Telescope STDT Update | Asantha Cooray |
| 1:45 p.m. | Lynx STDT Update | Feryal Ozel |
| 2:00 p.m. | Reaching for the Stars | Pamela Harman |
| 2:30 p.m. | Break | |

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|---|---|---|
| 2:45 p.m. | GPRAMA Discussion (cont'd.) | APS Members |
| 3:30 p.m. | Recommendations, Actions | Scott Gaudi |
| 3:45 p.m. | Brief to Division Director | Scott Gaudi |
| 4:00 p.m. | Adjourn | |