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Teleconference

MEETING MINUTES

8/24/15

B. Scott Gaudi, Chair

for 9/8/15

Hashima Hasan, Executive Secretary

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Tuesday, July 21, 2015

Introduction and Announcements

Dr. B. Scott Gaudi, Chair of the Astrophysics Subcommittee (APS) of the NASA Advisory Committee (NAC) Science Committee, opened the teleconference. He noted that the meeting followed Federal Advisory Committee Act (FACA) rules. These include that the meeting is open to the public; Subcommittee members should not reveal proprietary information; only public sessions can form the basis of recommendations to NASA; members should declare conflicts of interest; only members are to speak unless requested to do so; and the agenda included a public comment session for both days.

Dr. Paul Hertz, Director of NASA's Astrophysics Division (APD), read the list of APS members who were on the call. He noted that Dr. Paul Scowen of Arizona State University had joined the Subcommittee. In addition, this was the last meeting for Drs. Chryssa Kouveliotou and Fiona Harrison.

Astrophysics Division Update

Dr. Hertz began the APD update with a review of science results. The Kepler/K2 Campaign 3 recently captured the movements of Neptune and its moons, Triton and Nereid. The Spitzer mission identified a gaseous planet deep in our galaxy. The Hubble Space Telescope (HST) captured a stellar exodus in action, including two populations of white dwarfs, one was at the expected location. However, the other was still close to the center and therefore much younger. HST enables the aging of such populations.

The Chandra mission found x-ray echoes pinpointing a neutron star. There is now more information on the Kepler-138 planets' mass and radius, with evidence of a number of rocky, small planets. However, some appear to be mini-Neptunes, having a rocky core surrounded by a large, gaseous atmosphere.

APD continues to use the 2010 Decadal Survey (DS) to guide implementation and priority decisions. The Division also issued an update to an implementation plan in 2014. APD's budget appropriation for Fiscal Year 2015 (FY15) came through at around $1.3 billion. The President's FY16 budget request is for about the same amount. APD has been told to plan to that level for the future. The budgets continue to fully fund the James Webb Space Telescope (JWST) plan leading toward an October 2018 launch. Both the appropriation and the request fund preformulation activities for the Wide-Field InfraRed Survey Telescope (WFIRST) and restore funding for the Stratospheric Observatory for Infrared Astronomy (SOFIA) mission. The FY16 request includes funding for the Science Mission Directorate (SMD) Education Program, though at less than the FY15 appropriated level.

Missions

All of APD's operating missions are going well. The Division plans to announce selections from the Small Explorer (SMEX) Announcement of Opportunity (AO) before the end of summer, with a down-select in early CY 2017. NASA is working with the European Space Agency (ESA) on Athena preformulation activities, along with other ESA projects.

Missions in development include ESA's Laser Interferometer Space Antenna (LISA) Pathfinder, which launches later this year. The Japanese Aerospace Exploration Agency (JAXA) is making great progress with ASTRO-H and just completed the thermal vac test. The Neutron-star Interior Composition Explorer (NICER) is scheduled to launch late next summer. However, the recent SpaceX Falcon9 launch issues have potential to affect that schedule. The Transiting Exoplanet Survey Satellite (TESS) will launch in late summer of 2017. JWST is on schedule to launch in the fall of 2018, and ESA's Euclid mission is planned to launch in 2020.

JWST completed some rework in the instruments that was needed after last year's thermal vac test, and the team is now preparing for the third instrument module thermal vac test, to take place later this year. The telescope tower assembly has been connected to the backplane and is being packed to ship to Goddard Space Flight Center (GSFC) soon. The mirrors are being prepared for installation onto the backplane when it arrives at GSFC. The spacecraft subsystems are on track, the sunshield layers are progressing, and the cryocooler will be shipped to the Jet Propulsion Lab (JPL) soon. The Johnson Space Center (JSC) is preparing for the complete observatory test. The schedule shows 9 months of funded slack on the critical path. The sunshield fabrication and the Integrated Science Instrument Module (ISIM) are not far off the critical path. 9 months is well in excess of the plan for reserves at this point in development. The sunshade issues have been addressed.

NASA and ESA are discussing potential NASA contributions for Athena. The Agency put out a Request for Information (RFI) earlier this year and is using this input in these discussions. The next MIDEX AO is on schedule.

Dr. Hertz reviewed the WFIRST milestones. APD issued an RFI for industry input; responses are due later in the month. APD will then issue an RFP on selected studies. Another call is soliciting teams to constitute the science working group for the early phases. Senate language has directed APD to start some WFIRST work earlier than planned, and APD is prepared to comply if that language becomes law. APD has also begun selecting and funding preparatory science in the community, and it has disbanded the science definition team (SDT) that has been in place for the last 2-and-a-half years. The technology development plan to be at technology readiness level 5 (TRL5) by the end of FY16 is progressing.

Archives
APD recently conducted a Senior Review of the Division archives in order to have an independent assessment of their performance and how well they serve the community. The archives have not suffered from budget cuts, but the investments needed for growth and improvement have not been available, either. The review panel advised considering this as an area of investment. The recommendations are on http://science.nasa.gov/astrophysics/documents.

Budget
APD is always working with several budgets. At a moment, these include the FY15 budget that is being implemented, the FY16 budget being developed by the President and the various Congressional committees, and the preliminary work on the FY17 President's budget request. The full House of Representatives has voted on a bill that includes the NASA appropriations, but the Senate has not yet voted and has a logjam that does not relate to NASA. If NASA enters the new fiscal year without a budget, there will be either a Continuing Resolution (CR) or a shutdown.

For FY15, APD had to shift some funding internally despite receiving more than the request, as some of the additional amounts were directed to specific areas. Fortunately, TESS had budgeted additional reserves that were not needed in FY15, and these could be used to offset the shortfall in appropriations. The budget situation for FY16 is shaping up to be similar, and the Division has been told to plan as if future budgets will be flat.

Both chambers of Congress have proposed additional spending for WFIRST and other Division projects and programs; they have both proposed increasing the overall Divsion budget above the President's request, but not enough to fully fund the directed spending increases for WFIRST etc. APD houses the SMD education budget, which must be taken into account when determining the actual Division budget. With this subtraction, the House FY16 budget would result in $21.3 million of general reductions compared to the President's request, while the Senate has a $35.7 million general reduction relative to the request. The final appropriation is likely to fall between those two numbers. Dr. Hertz will not address

how the potential shortfall will be handled until the final figure is available, but he expects to make some hard choices and reductions. He will first look at projects under development that do not seem to need their reserves in the current FY, then programs with carryover funds. Next is the research and analysis (R&A) area, which can be phased more slowly, followed by delays of missions and AOs.

Dr. Joel Bregman was concerned about external influences. He asked if those in Congress who are pushing WFIRST understand that they are hurting other strong science programs, and if there might be a way to discuss this with them. Dr. Hertz replied that everyone is welcome to discuss their opinions with their members of Congress. As for priorities, WFIRST is his highest priority, so he is very happy about the additional funds. The DS is clear in laying out priorities, and those are the priorities that APD will use if there is a need to tighten up.

The House and Senate bills tell APD to follow the DS and not run over on JWST. On WFIRST, the House says specifically to include the coronagraph and accelerate the exoplanet program, while the Senate directs APD to accelerate the formulation start, with a goal of achieving Key Decision Point A (KDP-A) by January 15, 2016. NASA has not yet discussed this and will seek clarification if it is in the final language. The Senate also praised HST. The House said to not put SOFIA in the FY16 Senior Review, while the Senate says to may be included it but the mission may not be terminated. Senior Reviews cover missions that have completed their prime phases, so this is unusual. Including SOFIA would result in a thorough review of the program, however, and he would anticipate many actionable recommendations that could improve its science productivity. Dr. Kenneth Sembach said that, given the potential language, this would be a learning opportunity for SOFIA. Missions tend to improve after going through Senior Reviews.

Dr. Jason Kalirai said that the overall science would be stronger if WFIRST and JWST overlap; this could be enabled by moving up WFIRST. Dr. Hertz noted that the current plans would have the WFIRST launch during the JWST extended mission.

The Senate language directs APD to increase the AO frequency to at least every 3 years, with a goal of every 2 years. That would require the Division to spend more on Explorers, but it is not clear where that money will come from. The Senate also had nice words about Kepler. The House said that SMD education should be split among the divisions, while the Senate said that APD should administer SMD education activities. Both houses accept the change in SMD education, where STEM education projects are no longer housed within missions.

Upcoming Reviews

The National Research Council (NRC) has been authorized to conduct a mid-decade review of APD and its implementation of the 2010 DS. The first meeting was anticipated to take place in August, subsequent meetings were planned for October and December, and the final report is set for May 2016.

The large observatories do the transformative science. Beyond WFIRST, there will be funding for future strategic missions at an expected rate of $500 million per year, assuming a flat budget. The next DS can address this. The HST orbit will eventually decay, and NASA must safely handle that as well. The Agency will have to fly up and put a propulsion unit on it in order to either move it up into a “parking orbit” or bring it back to land in an ocean. In 2009, astronauts installed a grappling fixture on HST, and the other part of that is in storage. However, the current orbit will last at least another 10 years.

Dr. Hertz had previously asked the program analysis groups (PAGs) to study several large mission concepts as candidates for the next DS. Each of those mission concept studies will report out a science case to the DS panel, as well as the technology development needs and approximate cost. The DS can then set mission priorities. The suggested mission concepts included the following:

- Far InfraRed (IR) Surveyor;
- Habitable Exoplanet Imaging Mission;
- UV/optical/IR Surveyor; and,
- X-Ray Surveyor.

Dr. Hertz pointed out that the PAGs are meant to do analysis, not advocacy, and their reports were not a competition. Nor were the reports meant to do the work of the science and technology definition teams (STDTs). Previous DS panels have put out calls for input, so he expects the community to propose more missions beyond these four. There is a limited budget, however, for conducting mission concept studies.

In regard to probes, it would be possible to do something similar to what NASA did 10 years ago, when the Agency funded 19 strategic concepts prior to the DS convening. However, it is not clear how these might be selected. APD could fund some work or wait for the community to submit probe concepts to the DS panel. The DS might recommend that APD do a probe AO similar to the Planetary Sciences Division's (PSD's) New Frontiers AO. However, any Probe missions would come at the cost of slowing the cadence of large missions.

Government Performance and Results Act Modernization Act (GPRAMA) Guidelines

Ms. Jennifer Kearns of SMD presented background on GPRAMA, which requires each Federal entity to provide a strategic plan, an annual performance plan, and an annual performance report.

The over-arching strategic objective for APD is **1.6**: *Discover how the universe works, explore how it began and evolved, and search for life on planets around other stars.* The three underlying science objectives correspond to those in the 2014 Science Plan, with a metric, or Annual Performance Indicator (API), for each. It was against these metrics that APS was being asked to provide a high-level assessment of APD's science progress over the previous 12 months, with examples of accomplishments and/or disappointments. NASA has a strong preference for accomplishments reported in peer-reviewed journals, and the reported activities must have had at least part of their funding from NASA.

The primary requirement was an official recorded vote on the color rating for each of the three areas. NASA needed specific explanatory text for any rating less than green. In addition, NASA cannot publish all of the supporting text in the Annual Performance Report, so Ms. Kearns asked APS to note any particularly compelling items. The color ratings are 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.

Ms. Kearns explained that the dates under consideration covered the time since the August 2014 APS meeting. The preparatory material sent to the members did not overlap that time period. Dr. Gaudi added that the goal was to evaluate the progress in each of the three areas, and therefore APS should focus on results that exemplified the ratings. It was not necessary to highlight specific missions, as GPRAMA is not a platform for advocacy. He advised presenting three highlights per area. Dr. Kouveliotou said that while APS did not want to advocate for missions, it was important to present results from the high performing missions like Fermi. Dr. Hertz explained that, as a rule, SMD does not issue a press release until after a paper is accepted for a peer-review publication. However, the press releases may appear between acceptance and publication.

Dr. Gaudi discussed the process for APS. He advised identifying which press releases the members wanted to include, working on drafts overnight, and completing the task on the second day of the meeting. It was most important to exemplify the goals, rather than present a cross-section of missions.

GPRAMA Discussion

Ms. Kearns presented the first performance goal that APS was to evaluate, **1.6.2:** *Demonstrate progress in probing the origin and destiny of the universe, including the nature of black holes, dark energy, dark matter, and gravity.*

After some discussion of the press releases, the APS members agreed to work on the following examples:

- "Planck Mission Explores the History of Our Universe," to be edited;
- A discussion of black hole discoveries, including the black hole winds; and

Dr. James Bock would also write the introduction for this performance goal. Ms. Kearns noted that the press releases were written at the level needed for the document, so that the general population can understand them.

Dr. Gaudi asked for an official vote on the color rating for this performance goal. It was unanimous in favor of a green rating.

The next performance goal was **1.6.3:** *Demonstrate progress in exploring the origin and evolution of the galaxies, stars, and planets that make up the universe*.

Dr. Gaudi advised having a paragraph each for galaxies, stars, and planets. The APS members agreed to draft pieces on the following accomplishments:

- Galaxies: a combination of an HST example and a press release on youthful compact galaxies;
- "NASA Rocket Experiment Finds the Universe Brighter Than We Thought," to stand as written; and,
- A SOFIA example based on "NASA'S SOFIA Finds Missing Link between Supernovae and Planet Formation."

Dr. Kalirai agreed to write the introduction for this section.

Dr. Gaudi asked for an official vote on the color rating for this performance goal. It was unanimous in favor of a green rating. He added that it would be helpful to include graphics with the examples.

The final performance goal was **1.6.4:** *Demonstrate progress in discovering and studying planets around other stars and exploring whether they could harbor life.*

For this performance goal, APS decided to write initial drafts of the following topics:

- "Kepler Marks 1,000th Exoplanet Discovery, Uncovers More Small Worlds in Habitable Zones, and Discovers a Mars-size Planet Orbits Distant Star;"
- HST characterizing extreme worlds;
- The parallax measurement by Spitzer, combined with Great Observatory (GO) characterization of exoplanets; and
- Spitzer witnesses white dwarf debris/collision and the rejuvenation of a planet.

Dr. Natalie Batalha was to write the introduction.

Dr. Gaudi asked for an official vote on the color rating for this performance goal. It was unanimous in favor of a green rating.

Dr. Gaudi committed to writing the overall introduction. He reminded those with writing assignments to find citations and graphics. Ms. Kearns noted that images are very helpful. She thanked the APS members for their time.

Public Comment Period
Dr. Gaudi opened the meeting to public comment. However, no members of the public asked to speak.

TESS Update
Dr. George Ricker presented an update on the TESS mission. TESS has the goal of discovering potentially habitable transiting earths and super earths orbiting bright, nearby stars. TESS will conduct a large area survey of bright stars, especially M dwarfs, and do "all sky" observations at two cadences. The goal is to launch in 2017. Dr. Ricker presented an animation with transiting planets projected in relation to distance in order to demonstrate what would be transmitted. There are four cameras associated with TESS. These are pointed away from the sun, from the ecliptic plane to the ecliptic pole.

Next, Dr. Ricker reviewed the TESS instruments, including the cameras and their hoods, and the charge-coupled devices (CCDs), which are being fabricated by the MIT Lincoln Laboratory. Graphics showed the quantum efficiency of the instruments and the wavelength versus spectral response. The launch vehicle will be the SpaceX Falcon 9, assuming that its issues have been worked through.

Dr. Ricker discussed the sensitivity of photometric noise and the systematic noise plotted at different image levels. A map indicated the cadence of pre-selected stars, and the yield as a function of planet size was shown. The team will probably select about 6 percent of the small planet candidates for more precise examination. That means that 94 percent of those planets will be available for the community to study.

The critical design review (CDR) was scheduled for August. A bar timeline indicated that there will be a 2-month commissioning phase. The first hemisphere investigation will take place in the first year, with the second hemisphere to be studied the following year. The team has talked about an extended year in 2020, contingent on residual funds from TESS mission reserves. TESS and its orbit should be operable for more than a decade, and possibly as long as 40 years.

Next steps for science planning include coordinating with other initiatives and missions; providing for astroseismology, which uncovers information on rocky versus watery planets; and planning for an extended year. The team is also looking at a guest investigator program. The team expects that TESS will find many planets smaller than Neptune transiting nearby stars. At the same time, TESS will provide a map to the easiest-to-observe exoplanet atmospheres and identify several habitable-zone planets orbiting stars that are bright enough for JWST and future missions to study.

The first science results will be available in 2018, as it will be 4 months for the steady state result, largely determined by the requirements of going through the pipeline developed for TESS use, and another portion of the start-up will take 6 months. It does not now seem possible to accelerate those timeframes.

The team has committed to the 6 percent target for small planets for further study. That would be about 50, which is the minimum they could assure. However, the community could add to that. As for the recent Falcon 9 launch issue, there will be 20-30 Falcon 9 launches before TESS is to go up. Dr. Ricker expects the technology issues to be worked out well before then. The mission still has the specified reserves for funds and schedule. There are always challenges, but there has been nothing daunting with this mission.

Gravitational Observatory Advisory Team (GOAT) Update

Dr. Robin Stebbins discussed the status of the GOAT. The DS has noted the need to study gravitational waves, and ESA plans to select such a mission for a 2034 launch. That seems like a long time from now, but there are reasons to begin now. The team is to look at possible scientific and technical approaches for a gravitational wave observatory, and the current focus is on promising technologies. NASA has examined the milestones that the Agency expects will be important to ESA and is talking with European gravitational wave researchers. ESA scheduled five meetings this year. In mid-2016, the team will produce a report on the LISA Pathfinder, which launches this year.

The GOAT's intermediate report addresses the potential gravitational wave sources and how effectively these sources, which number over 30,000, might be separated. The team is also looking at a broad system aspect and the best way to build gravitational wave detectors. One goal is to identify the technologies that require further investment. The LISA mission is a technology demonstration, but it will not test everything needed for the 2034 mission. The most sensitive issue is the schedule.

Dr. Stebbins noted the reported activities. In the area of science objectives, the GOAT compiled an expanded statement of target science. In looking at detection technologies, the team compiled a long list from the literature, determining that only two address the science recommended by the Senior Selection Committee. Laser interferometry responds to the science goals set out in the 2013 report of the Senior Science Committee, and is sufficiently well advanced to offer a realistic prospect of implementation according to the 2034 launch schedule. The committee is still seeking a full mission proposal based on atom interferometry.

The GOAT is also assessing the architectures with which the science that can be performed. There are no fundamental or conceptual issues with the data analysis. In the area of technology development, the GOAT has identified all required technology developments and is recommending four high-priority technology development activities for immediate start. Not much has been done on cost at this point.

GOAT has made significant progress on several topics. The technology recommendations will allow ESA and its partners to begin investing. There will be an AO for mission concepts and a competitive selection. The NASA contribution is likely to come from among four technology areas: laser subsystems, telescopes, phase meters, and/or micro-neutron thrusters.

Wrap Up for Day 1
Dr. Gaudi ended the meeting at 4:03 p.m.

Wednesday, July 22, 2015

Opening Remarks
Dr. Gaudi opened the second day of the meeting with a review of the FACA rules and the day's agenda.

ExoPAG/PhysPAG/COPAG Updates
Dr. Gaudi summarized the joint activities of the three PAGs in regard to the charge from Dr. Hertz to look at large mission concepts in order to identify missions that might follow JWST and WFIRST. The white paper summarizing these efforts will be available to APS in early October. The PAGs asked that their members react to the list across the disciplines rather than strictly within their own areas.

The effort was to assume the following additional constraints:

- NASA's plans for realizing a space-based gravitational wave observatory is focused on partnering with ESA's L3 (LISA);

- The Cosmic Microwave Background (CMB) Polarization Surveyor is a probe-class
- Mission; and
- The 2010 DS priorities remain.

The initial list of missions included a FIR Surveyor, a habitable exoplanet imaging mission, a UV/optical/IR surveyor, and an x-ray surveyor. As Dr. Hertz emphasized, these missions are not competing with each other, and the PAGs were to analyze, not advocate or set priorities. Over the next 3 years, the STDTs will conduct studies in order to provide input to the DS panel. To that end, the PAGs held many meetings at which this charge was discussed.

The Exoplanet PAG (ExoPAG) had many talks and brainstorming sessions and received input from dozens of exoplanet scientists. Reference material from the Cosmic Origins PAG (COPAG), ExoPAG, and the Physics of the Cosmos PAG (PhysPAG) can be found at the following websites:

- http://cor.gsfc.nasa.gov/copag/rfi/
- https://exep.jpl.nasa.gov/exopag/decadal/
- http://pcos.gsfc.nasa.gov/physpag/

The three PAG chairs have determined how to coordinate reports and have decided to write a joint executive summary, with a joint table of nominal mission parameters. It is likely that they will select the four missions suggested by Dr. Hertz.

PhysPAG Update
Dr. Bock explained that PhysPAG supports investigations that seek to understand the nature of the universe, primarily in the areas of dark energy, inflation, black holes and general relativity, and the behavior of matter in extreme environments. The PAG has six Science Interest Groups (SIGs), which are long-standing groups gathered around a particular science.

The primary activity this last year has been responding to the large mission charge. To that end, PhysPAG gathered input from the community, and the SIGs have discussed the charge as well. PhysPAG members are interested in articulating physics of the cosmos (PCOS) science themes, such as mapping large-scale structure, the formation of supermassive black holes, and follow-up of gravitational wave events.

The PhysPAG report is predicated on two assumptions:

1) The L3 Collaboration Constitutes the Gravitational-Wave Mission
   - PAGs assume U.S. participation
   - The U.S. role will be fully developed for presentation to the 2020 DS review
2) The Inflation Probe Is a Probe-Class Mission
   - The Inflation Probe SIG (IPSIG) feels the mission fits this category
   - PAGs assume the 2010 DS recommendations will be fulfilled

If these assumptions change, the report will need to be reevaluated.

Dr. Bock emphasized that the PAG has a strong interest in probe missions, specifically the following:

- Developing point mission concepts (particularly strong X-ray, gamma-ray, cosmic-ray interest);
- Developing a probe mission category like Discovery or New Frontiers;
- Assisting in a future process defined by NASA.

The sections of the PhysPAG report that were in draft form at the time of the APS meeting addressed PhysPAG science in each of the four large missions; L3 gravitational wave science and development with ESA; and inflation probe science and probe missions.

Other PhysPAG activities included the annual process of reviewing the PCOS Program gap technologies. The community submitted 37 gap technologies, 15 of which were carried over from 2014, along with 11 new x-ray technologies, 7 for general relativity and gravitational waves, and 4 for cosmic rays. A revised and consolidated list was sent to APD for prioritization. This included 14 technologies from 2014, along with 4 new x-ray technologies, 2 new general relativity and gravitational wave technologies, and 3 new cosmic ray technologies.

Future activities include the International Astronomical Union (IAU) meeting in Hawaii, which will roll out the PAG report structure for preliminary feedback. The PAGs will report to APS in October, then prepare for the mid-decade review and the annual PhysPAG meeting at the American Astronomical Society (AAS) conference in January.

COPAG
Dr. Sembach presented the COPAG update, noting that the PAG is seeking additional members for the Executive Committee, one of which must come from academia. The PAG provided input to the Cosmic Origins Program on technology gaps, reducing the number from 33 to 24.

Among the active study analysis groups (SAGs) was SAG 8: Cosmic Origins Science Enabled by the WFIRST- Astrophysics-Focused Telescope Assets (AFTA) Data Archive. The final has been sent to the APS, and Dr. Sembach said that he would be asking the Subcommittee members to review the report so that COPAG can close the SAG. That could occur before or at the next APS meeting. The report will provide great input to WFIRST science investigation teams.

The report from SAG 9: Science Enabled by Spitzer Observations Prior to JWST, was sent to APS in June. Dr. Sembach asked for approval from APS so that COPAG can formally close the activity. In addition, SAG 5: Science Objectives and Technology Requirements for a Series of Cosmic Origins Probes, is inactive and has been for several years, as the topic is redundant with that of another group. Dr. Sembach asked APS approval to close it.

SIG 1: Far IR Cosmic Origins Science and Technology Development held a workshop on the far-IR surveyor concept at Caltech in June, with more than 100 attendees and another 30 or so participating virtually. SIG 2: UV/Visible Cosmic Origins Science and Technology Development, held a workshop at GSFC in June to discuss future mission science drivers, with 80-100 participants. The third SIG, on cosmic dawn science, was approved at the last APS meeting and is organizing.

In responding to Dr. Hertz's charge, COPAG held biweekly teleconferences, with a great deal of crossing over with the other PAGs' meetings. Getting the communities to work together may be one of the biggest successes of this effort. There have been many inputs across a range of topics for the COPAG response, but there have also been common science themes or mission considerations applicable to multiple flagship missions.

ExoPAG
Dr. Alan Boss presented the ExoPAG update. There have been changes in the Executive Committee. The PAG held a meeting in Chicago at which it closed out SAG 9: Exoplanet Probe to Medium Scale Direct-Imaging Mission Requirements and Characteristics and chartered SAG 13: Exoplanet Occurrence Rates and Distributions. ExoPAG sought APS approval of these actions.

Dr. Boss presented the SAG 9 conclusions on the directing imaging requirements and characteristics. He explained that SAG 13 relates to the large mission charge, and will ideally develop a calculation as a standard in order to have consistent measurements that the community can use across data sources. ExoPAG is also working on the SIG 1 response.

Action Items
It was decided that APS would close out the COPAG SAG 8 report at the next meeting, which would allow members the opportunity to provide comments. Dr. Gaudi asked for a summary of the main points of the SAG 9 report. Dr. Sembach said that the SAG was to identify compelling science to be done with JWST that is enabled by or benefits from large blocks of Spitzer observing time prior to JWST launch. The SAG organized itself along science themes, solicited community input, and developed findings and recommendation. The first was that the zodiacal dust contribution to the cosmic background is still unknown, which Spitzer could help reduce for JWST. In addition, Spitzer is still unique in finding extrasolar planets and small bodies for JWST follow-up. Finally, an ad hoc committee should determine if programs requiring multiple years of Spitzer time are necessary for JWST.

APS voted to accept the COPAG SAG 9 report as input to the Subcommittee and close the SAG. The motion to terminate SAG 5 also passed. The motion to accept the ExoPAG SAG 9 report as input passed as well. Finally, APS approved the creation of ExoPAG SAG 13.

Discussion
It was determined that ExoPAG could also have discussions about gap technologies like the other two PAGs did. Dr. Boss agreed to coordinate with the APD Exoplanet Program Office. Regarding overlap in technologies, Dr. Hertz explained that it is fine if two programs list the same technology as having a gap.

Dr. Hertz explained that, in regard to probes, the DS recommends priorities. The upcoming DS might recommend more medium-sized missions like probes, and fewer large missions. If that is the case, APD will have no problem in implementing it. However, it will not happen this decade in advance of the next DS. Dr. Hertz planned on discussing probes with APS in October.

Dr. Bregman was concerned that the DS panel might not be able to sufficiently address issues about the funding boxes, which is an area of NASA experience. This is a central question and a balance issue. APD could have a single strategic mission that tries to do it all, or a smaller strategic mission set with more targeted missions. Dr. Hertz agreed. The current DS did not recommend any medium-sized missions, but the next DS can, and it would be possible to estimate what APD could accomplish during a decade. The community should discuss this in order to provide this input to the DS panel.

Dr. Harrison said that the community needs to consider the different strategies. Also, it is not clear that the DS cannot look at the projected funding wedge and think about the size of the boxes based on the remaining funding. This would be within the DS purview. Dr. Gaudi said that the community needed to have this discussion and make choices as to what to advocate.

Dr. Bock thought that it was a matter of cost and efficiency. There is a possible disconnect if NASA does not weigh in on the size of the boxes and the costs. The last DS had some misconceptions about costs. Some of this is inevitable, but the community alone cannot address it. Dr. Hertz said that there was about to be an NRC report that might address this, though he was not certain (*The Space Science Decadal Surveys: Lessons Learned and Best Practices*; NRC 2015). The costing process has been improving and has matured, so some of the problems have been solved.

Dr. Sembach agreed with Dr. Harrison that the community needed to communicate to the DS panel the importance and need for a probe line. It might make sense to have a community-coordinated response that indicates that the probes can do high-quality, compelling science. The community is wrestling with how it wants to go about this. He wondered if they should consider if there is some kind of structure they could bring to the DS panel to make the case.

Dr. Gaudi pointed out that the community will want to maximize the amount of science possible, given the constraints that arise in the future. That calls for presenting the widest range of options available, exploring the possibility of a probe-class line, and imagining what would happen under various scenarios. He frequently heard the idea of a white paper advocating for probe class missions in general, so that might be something they should do. He asked the PAG chairs to raise the issue among their members and suggested that APS continue the probe conversation at the October APS meeting, after the PAG reports have been presented. It could be a major topic at that time. Dr. Hertz added that APD would be thinking about probes in order to have this discussion in October.

Inclusive Astronomy Meeting Report

Dr. Keivan Stassun discussed the recent meeting on diversity and workforce in astrophysics, held at Vanderbilt University with about 170 attendees, including Dr. Hertz of APD (by videocon). Representatives from the National Science Foundation (NSF) and Department of Energy (DOE) attended as well.

One of the key issues was the steadily decreasing percentages of under-represented minorities (URMs) in the science, technology, engineering, and math (STEM) education pipeline. URMs account for about one third of the U.S. population but have only 6.6 percent of the PhD's in STEM fields. Physics and astronomy have the lowest representation in STEM fields at only 2 percent. NASA has active programs to address URM educational development from grades K-16. However, these efforts do not reach into the higher levels. For example, on average only three African American women earn PhDs in physics each year.

Workshop participants heard of the importance of taking advantage of the Historically Black Colleges and Universities (HBCUs), and their Hispanic and Tribal equivalents. The top 10 producers of black physics baccalaureate degrees are HBCUs. Transitions are important. When URMs in STEM fields go beyond a B.S. degree, they are 50 percent more likely than Whites and Asians to earn a master's degree en route to a PhD. This means they experience more institutional transition with less guidance.

The 2010 DS captured URM issues but did not issue a formal recommendation. However, the DS noted that expanded funding should be provided for programs that can ease the transition of individuals across critical academic junctures, such as high school to college, undergraduate to graduate, etc. Dr. Stassun has been running a bridge program of this sort at Vanderbilt, coordinating with Fisk University. An example of the program's impact can be found in Dr. Fabienne Bastien, who went through the program and became the first African American woman to be the first author of an astronomy article in Nature. She is now a Hubble Fellow at Penn State. The NSF program that supported her education was inspired by a former NASA program, the Minority University College Education and Research Partnership (MUCERPI). MUCERPI was defunded 12 years ago.

URMs are more likely to transition into a M.S. program at a minority serving institution (MSI), and those institutions do not all offer PhDs, which accounts for some of the movement among URM graduate students, who are less likely to be admitted straight to PhD programs. GRE scores are often lower for URMs, which is a primary driver.

Dr. Kouveliotou mentioned NASA's Minority University Research and Education Program (MUREP), the status of which was unclear. Dr. Hertz noted that some of this has been affected by various reorganizations within NASA. He added that if APS wanted to make a recommendation, it might go to the NAC Science Committee for discussion. Dr. Gaudi said that APS needed more information, especially about MUCERP, its termination, and any successor program, in order to make a recommendation, and asked if NASA could provide it. Dr. Hertz suggested that APS ask for that in the letter. SMD has solicited for education programs through the $42 million education CAN, and serving URMs is a theme. It would

be a good idea to see what is selected. He cautioned APS not to go too fast, since there might be changes coming up. They could have a briefing on the CAN selections at the next meeting.

Public Comment Period
Dr. Gaudi opened the meeting to public comment. However, no members of the public asked to speak.

GPRAMA Discussion
Dr. Gaudi gave the status of the drafts. It was agreed to move the extreme physics piece to the 1.6.3 introduction and make some other shifts. Dr. Gaudi was more concerned with the structure than the content at that point, though he also wanted to know about major issues. The goal was to assess whether NASA was meeting its performance goals; it was not as important to emphasize how the Agency got there. It was agreed to work and review further.

Recommendations, Actions
Dr. Gaudi explained that Dr. Kouveliotou was going to be on the Space Science Board and therefore was leaving APS. This meant that APS needed to appoint a new representative to the AAAC task force. Dr. Kouveliotou described the work and the level of effort involved. She and Dr. Boyd agreed to discuss it offline.

Brief to Hertz
Dr. Gaudi next mentioned the travel restriction issues, which had generated some recommendations to NAC. The response to those recommendations to ease restrictions was a non-concurrence. This is something the Science Committee planned to discuss further. The recommendation was to not include contractors with the civil servants for the foreign travel restrictions. NASA replied that the travel is not limited. Dr. Hertz explained that there are currently no constraints on domestic travel if it is within budget and approved by the employee's supervisor. Estimated spending on each conference must still be approved in advance, per the Office of Management and Budget (OMB), to ensure that Agency management is aware of conference spending. There are dollar limits requiring escalating approvals as the amount of estimated spending for a particular conference rises. In addition, Congress asks for quarterly reports on conference spending. A statute restricts NASA travel to foreign conferences, capping it at 50. There are no waivers possible for a statute. The statute does not distinguish between civil servants and contractors; it covers all attendees for whom NASA pays.

Dr. Sembach said that this puts a significant additional burden on contractors, and the tracking system is clumsy, working maybe half the time. Some of the deadlines have been unreasonable, if not impossible. It has been inflexible and burdensome. Dr. Hertz replied that NASA has solved some of these problems. APD has been proactive at trying to figure out how to do this. If Dr. Sembach's issues persist, he would be glad to help. NASA is highly motivated to see that its scientists go to the conferences they need to attend. The system initially put in place had problems. Dr. Kalirai said that Dr. Hertz has pushed through some of the changes, and thanked him. Dr. Gaudi said that APS would seek clarification and assurance that NASA is not misinterpreting the statute.

Because the letter from the previous meeting was never sent to the Science Committee, there was the pending action item of approval of the JWST Space Telescope Advisory Committee (JSTAC) proprietary period for JWST. He asked Drs. Kalirai, Sembach, and Kouveliotou to write something asking for clarification of the 50-person limit on foreign travel. APS would ask for an update at the next meeting.

Dr. Gaudi said that he would write an item on GPRAMA and thank Dr. Ricker for the TESS presentation, acknowledging the mission's progress.

Regarding the GOAT presentation, Dr. Hertz said that NASA is investing in technologies that would be applicable to a laser interferometer for a gravitational wave investigation. LISA is not a formal ESA activity. He expects the next DS to consider ESA's L3 gravitational wave mission. The community will need to make a case for the priority of gravitational wave astronomy. He believes that the path to the earliest gravitational wave observatory is to partner with ESA on L3. NASA is also fully engaged on LISA Pathfinder, which will launch later this year for critical technology demonstration purposes. Dr. Gaudi concluded that APS should simply thank Dr. Stebbins for the GOAT presentation.

Dr. Gaudi asked the PAG chairs to summarize their presentations and the motions they agreed upon. He would summarize the PAG responses to Dr. Hertz's charge. Finally, there was Dr. Stassun's presentation. APS planned to seek additional information about previous programs, MUREP and the programs funded through the education proposals. Dr. Boyd agreed to write that.

Dr. Gaudi said that he would make sure that probes were on the agenda for the October meeting. He asked for other agenda items. Dr. Bregman said that, as Chandra and HST have matured, more and more articles are based on archival data. Therefore, APS might want an agenda item on archival funding. NASA should direct resources in ways that are very productive, which could involve the archives. He learned during the Senior Review that this area has not kept up. It was not obvious to him that the balance was correct. Others expressed interest but asked to wait until the AAAC Proposal Pressures final report was issued. Dr. Gaudi said that APS would wait.

Dr. Hertz welcomed Dr. Scowen to APS. He thanked Drs. Kouveliotou and Harrison for their work on the Subcommittee. As noted, Dr. Kouveliotou was joining the Space Studies Board, and Dr. Harrison had taken on a leadership position at CalTech that she saw as inconsistent with being on APS.

Dr. Gaudi said that he would summarize the meeting at the upcoming Science Committee meeting, so he needed the inputs to the letter soon. The next APS meeting was scheduled for October 22 and 23.

Adjourn

The meeting was adjourned at 3:25 p.m.

Appendix A
Attendees

Subcommittee members (via WebEx)
B. Scott Gaudi, Ohio State University, *Chair, Astrophysics Subcommittee*
Nathalie Batalha, NASA Ames
Marshall (Mark) Bautz, Massachusetts Institute of Technology
James J. Bock, NASA JPL
Alan Boss, Carnegie Institution for Science
Patricia Boyd, NASA GSFC
Joel Bregman, University of Michigan
Giovanni Fazio, Harvard Smithsonian Center for Astrophysics
Fiona Harrison, CalTech
Jason Kalirai, Space Telescope Science Institute
Chryssa Kouveliotou, Marshall Space Flight Center
Paul Scowen, Arizona State University
Kenneth Sembach, Space Telescope Science Institute
Rachel Somerville, Rutgers University
Yun Wang, California Institute of Technology

NASA attendees
Paul Hertz, NASA HQ, *Director, Astrophysics Division*
Dominic Benford, NASA HQ
Jeanne Davis, NASA HQ
Dan Evans, NASA HQ
Shahid Habib, NASA HQ
Stefan Immler, NASA HQ
W. Vernon Jones, NASA HQ
Louis Kaluzienski, NASA HQ
Jennifer Kearns, NASA HQ
Janet Larson, NASA HQ
Andrea Razzaghi, NASA HQ
Rita Sambruna, NASA HQ
Wilton Sanders, NASA HQ
Kartik Sheth, NASA HQ

Non-NASA Attendees
Elizabeth Sheley, Zantech

Webex
Louis Barbier, NASA Goddard
Dominic Benford, NASA
Gary Blackwood, NASA JPL
Joan Centrella, NASA GSFC
Felicia Chou, NASA
Stephen Clark, Spaceflightnow
John Conklin, University of Florida
Anne Connor, Excelis Inc.

Dom Conte, Millennium Space
Alberto Conti
John Dyster, Orbital
Jonathan Gardner, NASA
Hashima Hasan, NASA HQ
Ingolf Heinrichsen, NASA JPL
Mary Beth Kaiser, Johns Hopkins University
Dan Leone, Space News
Mark McConnell, UNH
Gavriil Michas Deborah Padgett, NASA
Elise Miller
Susan Neff, NASA
Alina Rhodes, NASA
George Ricker, MIT
Pete Roming, SWRI
Wilton Sanders, NASA HQ
Nick Siegler, NASA JPL
Eric Smith, NASA
W.S. Smith, Scienceworks
Robin Stebbins, NASA HQ
Eric Tollestrup, NASA
Stephen Unwin, NASA JPL
Azita Valinia, NASA
Roeland Van Der Marel, STSCI

Appendix B
NAC Astrophysics Subcommittee Members

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

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

Natalie Batalha
NASA-AMES

Marshall (Mark) Bautz
Massachusetts Institute of Technology

James J. Bock
Jet Propulsion Laboratory

Alan Boss
Carnegie Institution for Science

Patricia Boyd
Goddard Space Flight Center

Joel Bregman
Department of Astronomy
University of Michigan

Neil John Cornish
Department of Physics
Montana State University

Giovanni Fazio
Harvard Smithsonian Center for Astrophysics

Fiona Harrison
Professor, Physics and Astronomy
CalTech

Jasonjot (Jason) Singh Kalirai
Space Telescope Science Institute

Chryssa Kouveliotou
George Washington University

Paul Scowen
Arizona State University

Kenneth Sembach
Space Telescope Science Institute

Rachel Somerville
Department of Physics and Astronomy
Rutgers University

Yun Wang
Infrared Processing and Analysis Center
California Institute of Technology

Appendix C
Presentations

1. *Astrophysics Division Update*, Paul Hertz
2. *FY 2015 GPRAMA Annual Performance Plan*, Jennifer Kearns
3. *TESS Update*, George Ricker
4. *ESA's Gravitational Observatory Advisory Team (GOAT)*, Robin Stebbins
5. *PAG Activities in Response to the Charge: Input into the 2020 Decadal Survey and Large Mission Studies*, Scott Gaudi
6. *Physics of the Cosmos Report for the Astrophysics Subcommittee*, James Bock
7. *Cosmic Origins Program Analysis Group*, Kenneth Sembach
8. *Exoplanet Program Analysis Group Report*, Alan Boss
9. *Inclusive Astronomy 2015 Meeting*, Keivan Guadalupe Stassun

Appendix D
Agenda

Astrophysics Subcommittee Teleconference
July 21-22, 2015

Tuesday, July 21, 2015

11:00 a.m.	Introduction and Announcements	Scott Gaudi
11:10 a.m.	Astrophysics Division Update	Paul Hertz
12:30 p.m.	Break	
12:45 p.m.	GPRAMA Guidelines	Jennifer Kearns
12:55 p.m.	GPRAMA Discussion	APS members
2:55 p.m.	Public Comment Period	
3:00 p.m.	TESS Update	George Ricker
3:30 p.m.	Gravitational Observatory Advisory Team Update	Robin (Tuck) Stebbins
4:00 p.m.	Wrap up for Day 1	Scott Gaudi

Wednesday, July 22, 2015

11:00 a.m.	Opening Remarks	Scott Gaudi
11:10 a.m.	ExoPAG/PhysPAG/COPAG Updates	Gaudi,Boss/Bock/Sembach
12:40 p.m.	Discussion	APS members
1:20 p.m.	Break	
1:30 p.m.	Inclusive Astronomy Meeting Report	Keivan Stassun
2:00 p.m.	Public Comment Period	
2:05 p.m.	GPRAMA Discussion	APS members
3:30 p.m.	Recommendations, Actions	Scott Gaudi
3:45 p.m.	Brief to Hertz	Scott Gaudi
4:00 p.m.	Adjourn	