NASA ASTROPHYSICS ADVISORY COMMITTEE

April 11-12, 2018
NASA Headquarters
Washington, DC

MEETING MINUTES

5/21/2018

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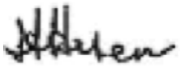
B. Scott Gaudi, Chair



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Hashima Hasan, Executive Secretary

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Zantech

Wednesday, April 11, 2018

Introduction and Announcements

Dr. Hashima Hasan, Executive Secretary of the Astrophysics Advisory Committee (APAC) of the NASA Advisory Council (NAC), opened the meeting by welcoming the Committee members. Dr. Hasan then reviewed the Federal Advisory Committee Act (FACA) rules. She noted that a number of APAC members had disqualifying conflicts of interest (COIs) with specific topics on the agenda. Known COIs were: Wide Field Infrared Survey Telescope (WFIRST) – all members except Drs. Neil Cornish, Brenda Dingus, John Conklin, and Kelly Holley-Bockelmann; James Webb Space Telescope (JWST) – Dr. Jason Kalirai; Transiting Exoplanet Survey Satellite (TESS) – Drs. Mark Bautz and Patricia Boyd; Stratospheric Observatory for Infrared Astronomy (SOFIA) – Dr. Natalie Batalha. Dr. Hasan said that if there were others, they should identify themselves to her right away. Any questions related to ethics should go to her; she would convey them to the NASA attorneys if necessary.

Dr. Scott Gaudi, APAC Chair, welcomed the new members: Drs. Laura Brenneman (not present), John Conklin, Kelly Holley-Bockelmann, Victoria Meadows, and Leonidas Moustakas. Dr. Gaudi then made a brief statement about the COI rules, noting that although the COI rules had not changed during his 6 years on APAC and its predecessor subcommittee, the Astrophysics Subcommittee (APS), he and others had noticed that the COIs were currently being interpreted much more strictly. WFIRST constituted a particular problem as, among other things, there would not be a quorum for the presentation on that mission. These interpretations of the COI rules render the Committee ineffectual and make it difficult for the members to do their job.

Astrophysics Division Update

Dr. Paul Hertz, Director of NASA's Astrophysics Division (APD), welcomed the new members and thanked those who would be leaving. He reviewed APD's purpose and strategy, noting that there would be much discussion of the budget. He was not presenting science highlights at this meeting due to time constraints. Major accomplishments of the last year include the start of development of the Imaging X-ray Polarimetry Explorer (IXPE) as the next Small Explorer (SMEX). JWST was at Northrup Grumman, the X-ray Astronomy Recovery Mission (XARM) was progressing quickly, TESS was launching the next week, and WFIRST was on track for Key Decision Point B (KDP-B). APD was taking steps to address diversity and inclusion issues, which would be the subject of a separate presentation. Dr. Hertz showed data on the demographics of research proposers and awardees, which seem to be proportional to each other regarding gender. However, the demographics of proposers' gender are not proportional to the larger science community.

The Fiscal Year 2018 (FY18) budget appropriation is good for astrophysics. The total goes up $33 million, or 2 percent, from the FY17 funding. Congress directed $43 million more in spending than planned on specific items, however, resulting in an implicit $10 million reduction to the rest of the program's budget. The FY18 appropriation tells APD how much to spend on JWST and repeats language that it shall not go over the cost cap of $8 billion. There is general statutory language for NASA stating a commitment of total lifecycle costs and headquarters reserves, as well as the latest possible launch date NASA will commit to. Such a cost and schedule commitment is made for every project. If a mission overruns the commitment by 6 months or 15 percent, that must be reported to Congress in order to get permission to continue. JWST has different rules, however. The developmental cost cap is written into law. Any overrun has to go to Congress in order to get permission to continue. The FY18 appropriation also included more for WFIRST than was requested. The faster APD can develop WFIRST, the more can

be done in parallel, which will reduce the risk of cost overruns. The FY18 appropriation also requires NASA to provide a report to Congress on the estimated lifecycle cost including the cost to make WFIRST a Class A mission.

The FY18 appropriation gives the Hubble Space Telescope (HST) more money than it can spend. SOFIA also has more funding that it can spend in FY18, and NASA has been directed to not spend any of that money preparing SOFIA for the next Senior Review (SR). Congressional direction states that SOFIA's prime mission is 20 years, not 5 years. APAC had previously recommended that SOFIA go to SR. In addition, the Congressional direction conflicts with other requirements from the past. Therefore, NASA is seeking clarification. Research and Analysis (R&A) funding language stated that APD must put forth a report on plans for high-energy astrophysics. After the markups, this leaves APD addressing a $10 million reduction for the rest of the program. The operating plan to Congress will explain how this reduction is to be addressed, at which point he can share the details with APAC. Dr. Kalirai asked if the SOFIA SR language was law. Dr. Hertz explained that it is in the explanatory statement that accompanied the Appropriations Act. The FY18 appropriations report also states that SOFIA must have 100 flights, which would have been possible were the plane not in Germany for maintenance beyond the planned schedule. APD did budget for 100 flights originally. The prime mission of 20 years would be unprecedented. Even Hubble, Chandra, and Webb had 5-year prime missions.

Dr. Kalirai observed that there is a pattern of differences between what is sought and what is appropriated. He wondered if there might be a way to adjust the request. Dr. Hertz replied that that would require reductions elsewhere in the program. He is handed his topline and directed to propose a balanced program that addresses Decadal Survey (DS) priorities, supports the community, and does everything APD believes to be necessary. There have been continuing discussions about the carryover situation, and Congress understands, but this is the direction APD received. He was not complaining, because he did get an additional $33 million. There was carryover for both HST and SOFIA, and APD had hoped to reduce their budgets to reduce it.

Class A missions include WFIRST, JWST, and HST. Chandra is Class B, and TESS is Class C. The coronagraph on WFIRST is a Class C instrument on a Class A mission. At the time of the WFIRST Independent External Technical/Management/Cost Review (WIETR), WFIRST was proposed as an enhanced Class B mission, but the Review recommended otherwise, so WFIRST is now a Class A mission with some tailoring. Regarding the appropriation, NASA policy is to implement Congressional direction. As a result, the Agency is producing a report on high-energy astrophysics that will explain the process for making choices.

The FY19 President's Budget Request (PBR) moves JWST back into the APD budget. It had been a separate line in the NASA science budget and continues to be managed outside of APD. At the time NASA formulated the FY19 budget, the Agency expected JWST to launch in the middle of FY19; the mission will not report to APD until it completes commissioning. The budget request came out in February, and NASA announced the latest JWST delay at the end of March. Also, due to its significant cost and competing Agency priorities, the PBR proposes that WFIRST be terminated, and that the Astrophysics budget be reduced with any remaining funding redirected to competed astrophysics missions and research. The FY19 NASA PBR request made it clear that the Agency proposes to implement the Space Council priorities and the President's space policy directive, which state that NASA's first priority is to return humans to the moon. Therefore, there are increases elsewhere in the NASA budget to accelerate that priority. For example, the Planetary Science Division (PSD) budget went up as a result with the increase required for lunar science projects. The FY19 notional budget from the

previous year shows that APD planned on spending close to $300 million on WFIRST, but the topline for APD came down by less than that; the difference are the remaining funds to be directed to competed astrophysics missions and research.

WFIRST is going to Phase B in FY18, which is the normal progression. Congress appropriated $150 million for WFIRST in FY18, and APD is required to spend that on WFIRST. Therefore, the Division will continue with its plans to move WFIRST into Phase B and will keep working to the planned launch date while waiting to see if Congress accepts the FY19 PBR or appropriates WFIRST some funds. The appropriation committees will be considering this budget in the spring and summer. Dr. Yun Wang noted that Congressional language on strategic planning is to follow the DS.

Dr. Hertz explained that the Euclid budget increased in order to recover from the failed sensor electronics design in the hardware that NASA was contributing to this European Space Agency (ESA) mission. The best recovery plan was a redesign, and to implement that, there is a need for more funds. NASA's contribution to the X-ray Astronomy Recovery Mission (XARM), a Japanese Space Agency (JAXA) mission, has gone through KDP-C and is in the Explorers Program budget. Spitzer operations are being extended until December 2019. APD put out a Request for Information (RFI) for private operations of Spitzer following the end of NASA's mission, and received at least one credible response.

Dr. Dingus asked what would happen with WFIRST should there be a Continuing Resolution (CR) for FY19. Dr. Hertz replied that there is some discretion on how to divide CR funding, so a lot will depend on the markups, which send some signals. APD would not turn it off if Congress were marking it up to full funding, for example. But it was too soon to know. Under a CR, APD would have to not break anything, and would have to continue programs that are likely to be funded. However, the Division would have to be careful to not spend more than it would get in a passed budget. For APD, the markups between the two Congressional committees were similar in the previous year, which made things pretty straightforward.

The budget sand chart has a flat, 12% lower topline number for FY20-23 than did previous notional runouts of the Astrophysics budget. Dr. Kalirai noted that the National Academy of Sciences (NAS) said that APD should plan for both large strategic missions and smaller ones. He took that to mean that the large missions are an important part of the balance. Dr. Hertz agreed, but the notional budget does not include a large mission beyond JWST. If Congress accepts the PBR and terminates WFIRST, any remaining funding is to go to additional competed missions and research. APD is not putting a lot of energy into planning on those potential competed missions until the Congressional markups are available. The FY18 markups tell him that he should wait. Dr. Feryal Ozel wanted to know how APD would react if WFIRST is terminated and the DS proposes another flagship mission. Dr. Hertz replied that APD's highest science priority is to follow the DS, which means doing WFIRST, but the FY19 proposed budget funds other priorities instead of WFIRST. Hard choices between competing priorities are being made at science agencies across the government. If APD plans to its lowest budget in 30 years, the DS panel will have to think hard about what a balanced program looks like, as well as the mission sizes. Big missions would take up a larger fraction of a smaller total budget.

Dr. Batalha observed that a reduction of this magnitude would affect the Space Act requirement that NASA find life elsewhere in the universe. Dr. Hertz thought that a future observatory capable of finding life on other stars would have to be a flagship mission and would not fit into the notional budget he had been given. With JWST under APD, the Division is likely to pay for any overruns, but he expects the size

of any overruns to be modest. The budget assumed an October 2018 launch date for JWST, which had reserves to slip to June 2019. Whether this covers a slip to 2020 is under review.

Dr. Hertz then presented some photos of JWST activities, including thermal vacuum testing. The sunshield is quite complicated, with complex alignment. During Integration and Testing (I&T), the team needed to find the places where cables snagged during deployment of the sunshield. There were fewer than expected, and they were repaired. The expectation for the second deployment is that there will be no tears. Dr. Gaudi noted that he had believed that the tears were at least one reason for the delay, but Dr. Hertz just said his understanding is some were expected. Dr. Hertz explained that it is not the existence of the tears, rather it is that everything about the sunshield is taking longer than anyone expected when the mission was planned 7 years ago. Some of the delays happen in parallel. NASA had budgeted time for sunshield repairs, but the repairs are taking longer than expected.

The Standing Review Board (SRB) is giving a Launch Readiness Date (LRD) of about May 2020 at the 70 percent confidence level. An Independent Review Board (IRB) will assess whether the project and contract have all done the due diligence expected to make sure the mission will work after it is launched. NASA wants to ensure that they are not cutting corners to force a launch date or cost cap. The IRB report will be completed in May/June of 2018, at which point NASA will reschedule the launch, and then report to Congress by the end of June. There is no hardware still to be made; all of the future funding is for labor. The new launch date and any new funds that will be needed will be determined following the IRB report.

Dr. Hertz showed a graphic of JWST's remaining I&T activities, identifying three that must be done for the first time: observatory system (electrical) test for observatory integration; observatory deployment; and acoustics, vibration, and thermal vacuum tests for the spacecraft element. The spacecraft element is the integrated sunshield and spacecraft. The sunshield and spacecraft have gone through acoustics, vibration, and thermal vacuum tests separately, and now they must go through the tests together. The Science Mission Directorate (SMD) has made some reassignments in the JWST program office, and there have been staffing changes at the Goddard Space Flight Center (GSFC) and Northrup Grumman as well.

He thinks of the JWST budget in three ways:

1. Lifecycle cost, through 5 years of operations;
2. Cost to commissioning, which is development and set by law to be no more than $8 billion;
3. How much more money is needed on a yearly basis – the number that affects the APD budget.

Number 1 will go up when JWST is delayed because of any increase in development and also because it will be operating in years beyond the original 5-year prime mission. Number 2 will go up because NASA will be building in years that had been planned for operations. This will involve conversion of funds by phase and may take no other APD funds. There will be costs after the end of the extended mission, presumably in the 2030s, where the impact from the 18-month delay will occur. The mission has reserves to get to June of 2019. Although it is taking longer, this is mostly budgeted work, so instead of having some number of people working at a time, there will be fewer people working at a time but it will take longer. A lot of the delay will not raise the top line, and the funds will be covered. The project may have adequate funding in the current budget for FY19. The first year that might require additional funding might be FY20, where development continues when operations was budgeted, or FY21 due to commissioning costs. The WFIRST budget for those years was very large. If WFIRST remains in the astrophysics budget, JWST could have an impact on WFIRST without changing the program balance. He

is not worried that the JWST delay will cause huge problems for the portfolio. The highest priority will be to maintain program balance.

If there were a constant budget for flagship missions, APD would be starting one as the previous one was in development. That is what APD was following. If WFIRST is not in the portfolio, it might impact where the funding for JWST would come from, and what impact that would have on the astrophysics portfolio. Dr. James Bock asked if Congress would tell him how to reallocate. Dr. Hertz explained that that typically does not happen. NASA goes to Congress with an operations plan that addresses the situation. While JWST may not go over $8 billion without explicit Congressional permission, the mission has spent $7.3 billion so far and will not hit the $8 billion mark for a while. NASA will submit the new JWST cost and schedule to Congress in June.

Dr. Cornish noted that WFIRST has had direction for some years, so he was not sure the funds from that mission will be available. Dr. Hertz explained that NASA talks to Congress and they will know the impacts. The Agency will build its proposed solutions into the presentation to them. The FY20 budget goes to the Office of Management and Budget (OMB) in the fall, so he has to develop that as well. Breaking the JWST cost cap (i.e. cumulative spending exceeds $8B) is not imminent, and there are people who think it will not be broken at all, while others think NASA will miss it by a small percentage. NASA will take this to Congress in June because the Agency anticipates a breach, and that report will give a new budget and launch date, including the funds needed to get to the launch date.

APD is not working on a plan to reallocate the WFIRST funds until the Congressional markups are available. The worst thing he could do would be to put out an Announcement of Opportunity (AO) based on the proposed redirection of funds, and then have to rescind it. Congress has more for WFIRST than requested for the last 5 years, so it is reasonable to wait and see what they will do. He was not sure about the level of detail the IRB will produce. Some outside reviewers want a revised probabilistic cost assessment annually, but if a mission is going according to plan, NASA does not feel the need. Dr. Beth Willman was concerned that people had already been hired to support JWST operations, and wanted to know what would happen with them. Dr. Hertz answered that those employees at the Space Telescope Science Institute (STScI) are working on I&T. NASA does not need to lay them off or pay them to do nothing. This is not a big driver. He could not discuss Northrup Grumman's award fees because contracts are not public information.

As previously mentioned, the WIETR was conducted to examine WFIRST issues. The resulting direction to the project team was to reduce cost and complexity. The coronagraph is now a technology demonstration instrument. NASA has done three independent cost assessments for WFIRST, and Dr. Hertz has been directed to address dysfunctional program management. Therefore, he created the Strategic Astrophysics Missions Program (SAMP), which will host WFIRST. KDP-B is underway. This is a Category 1 mission, for which the NASA Associate Administrator must make approvals, not SMD Associate Administrator, Thomas Zurbuchen. The coronagraph is a Class C technology demonstration instrument, and the Space Technology Mission Directorate (STMD) is co-funding the technology demonstration. NASA is assuming there will be international partnerships. The mission has improved the budget profile and advanced the launch date by 6 months, which requires adjustments in the APD budget. Work continues on additional risk reduction.

A chart compared JWST and WFIRST development risk at KDP-B. WFIRST is entering with more maturity, higher Technology Readiness Levels (TRLs), and less new technology development overall. WFIRST science reflects the three key science pillars of dark energy, exoplanets, and great observatory

astrophysics laid out in the DS. There are no expectations of specific amounts of observing time for any of these. There had been the perception that time was already locked up, so NASA is now trying to be explicit that the decisions will be based on the most recent science at the time of the mission. The specific surveys in the DS were the right ones in 2010, but no one yet knows what will be best in 2025. It is important to ensure that the science calls reflect the science at the time of the launch, not at the time the 2010 DS was being written. Dr. Hertz is giving the 2020 DS the baseline program and assuming the WFIRST development will go forward. On JWST, the Early Release Science (ERS) program will allow the community to see how the mission is performing before they write the Cycle 2 proposals.

There have been changes in the APD program offices. Previously, all but the R&A Program were set up to manage flight projects. Physics of the Cosmos (PCOS)/Cosmic Origins (COR) and Exoplanet Exploration (EXEP) each managed one project. SMD found that APD stood out for having these anomalies, so now APD has withdrawn the PCOS/COR and EXEP charters to manage flight projects, and they are now supporting research and technology activities. Explorers Program continues to manage flight projects, which includes missions in development. The SAMP at Headquarters will have a new program manager to oversee WFIRST, JWST after commissioning, and SOFIA after the SR. There will be some personnel shifts. Operating missions are generally not managed by program offices, but directly from HQ.

Dr. Hertz added that he cannot discuss whether SOFIA will actually undergo SR because NASA is still seeking clarification from Congress about it. Dr. Ozel pointed out that one of the APAC concerns is that SOFIA does not meet the science standards expected from other missions. The Committee wants a review in order to either change the standards or terminate SOFIA. She asked what APAC could do. Dr. Hertz said that the language in the FY18 appropriation directed NASA to do something else. The Agency is looking to see how to reconcile the differences between the various requirements. APAC can tell him what they think he should do. If SOFIA cannot go to SR, they can consider what else might be appropriate.

Dr. Asantha Cooray asked about competitive Phase A missions, noting that ESA selected the Atmospheric Remote-sensing Exoplanet Large-survey (ARIEL) mission. Dr. Hertz replied that APD has not given direction on this. He cannot select the Contribution to ARIEL Spectroscopy of Exoplanets (CASE) mission yet because it assumed the Euclid detectors were qualified. The CASE team needs a new plan to show they can stay in the cost cap with the changes to Euclid and ARIEL. He has also given no new instructions to the Fast INfrared Exoplanet Spectroscopy Survey Explorer (FINESSE) team.

The RFI on smallsats brought in 55 replies from a broad range of respondents, convincing APD that there are opportunities from small astrophysics missions that do compelling science. There will be two steps. First, the Division will release a new ROSES element for smallsat concept studies that fit into a cubesat or Evolved Expendable Launch Vehicle (EELV) Secondary Payload Adapter (ESPA) ring. APD will the decide whether to add smallsats as a Mission of Opportunity (MO) in next year's SMEX AO. There would be a $35 million cost cap, and NASA would find the ride to space. Step 1 was moving forward, and Step 2 was being considered. The Step 1 solicitation will offer some partnering with NASA engineering. There would be an MO in FY19.

NASA is still working on the Agency contribution to ESA's Large Interferometer Space Antenna (LISA) and Athena missions. SOFIA has a regular cadence of new instruments and remains in a planned maintenance period that identified some problems that have taken a much longer than planned to resolve. There are some long-standing work issues that created no permanent damage but which take

time to address. The current science cycle has lost about 6 months, and the mission is shifting the cycle by 2.5 months.

The missions that will go to the 2019 SR include Chandra, Fermi, HST, Neutron star Interior Composition ExploreR (NICER), Nuclear Spectroscopic Telescope Array (NuSTAR), Neil Gehrels Swift Observatory (Swift), TESS, X-ray Multi-mirror Mission-Newton (XMM-Newton), and possibly SOFIA. The SR will be done differently than in the past, as APAC must approve the Terms of Reference (TOR). All SRs answer to FACA committees now, so the SR will report the results to APAC, and the APAC will pass the results to NASA with comments, findings, and recommendations. There will be four panels, with HST, Chandra, and SOFIA having standalone panels and the others being in a single panel ("rest-of-missions" panel). The SR subcommittee will do the ranking. Despite being about to launch, TESS was on the list because it will end between the 2019 and 2022 SRs. A Spitzer extension will not be a SR decision unless APAC says otherwise, as NASA plans to end its funding in CY 2019, at which point it is hoped that a private operator will pick it up.

APD is integrating technology management and will go to a two year cadence for the program annual technology reports (PATRs), while continuing to do technology gap lists via the Program Analysis Groups (PAGs). The Science and Technology Definition Team (STDT) interim reports have been helpful, and some technology gaps are being closed. APD is sponsoring additional studies for DS input: a balloon program roadmap, evolution of data centers, smallsats, an in-space servicing/assembly study, and a system-level segmented telescope technology program for which two industry-led teams are developing roadmaps.

Discussion

Dr. Willman asked if the new studies would result in white papers. Dr. Hertz answered that that was the intent, though a sizing study for pixel analysis could lead to white papers. Dr. Cornish asked about the impact of the DS being delayed to about 2022, especially regarding the STDTs and other preparatory efforts. Dr. Gaudi clarified that there was a rumor that NASA had asked to switch the PSD and APD DSs. Dr. Hertz explained that this was not so much a switch, but that the APD DS might come after the PSD DS. It is not possible to advance the PSD study, and it was not obvious that the delay would occur. Therefore, APD had not thought through any changes in direction the Division might give. One basis for a hypothetical switch was that, in the context of JWST not having launched and WFIRST being in an indeterminate state, a 2-year delay might resolve some questions regarding astrophysics. NASA was concerned that if the schedule were maintained, the DS would take place during a period of great ambiguity, and the DS astrophysics committee would be conservative and risk-averse, without the innovative thinking that should characterize a DS. NASA is studying in-space assembly to have an idea of when in-space assembly will be more cost-effective, so that the DS committee can build that into their recommendations. In-space assembly is a hot topic and yet it is not clear how far in the future it be before NASA has that capability. Is it a 2020s problem or a 2030s problem? It could involve leveraging other capabilities being developed elsewhere within NASA. The International Space Station (ISS) was created through in-space assembly, but it is not yet clear how NASA would do it now. He wants to know what does and does not matter in the 2020s.

ExoPAG Report

Dr. Meadows, Chair of the Exoplanet Program Analysis Group (ExoPAG), reviewed the PAG's executive committee membership. ExoPAG has completed 11 Study Analysis Groups (SAGs). SAG 14, addressing targeted exoplanets, has been closed and removed, while three SAGs are ongoing and should close out in 2018: SAG 16, on exoplanet biosignatures; SAG 17, on community resources needed for Kepler 2 (K2)

and TESS planetary candidate confirmation; and SAG 19, on exoplanet imaging detection theory and metrics. The ExoPAG17 meeting, held at the January 2018 American Astronomical Society (AAS), had about 100 attendees and included a mini-science symposium. The PAG has adopted a measure to provide some financial support to students who will present their research at ExoPAG meetings. SAG 16 held a workshop in 2016 addressing some key questions on exoplanet biosignatures. Six review papers that grew out of that workshop have been accepted for publication in a special issue of *Astrobiology,* in May 2018.

ExoPAG will also participate in a great observatories SAG with the Cosmic Origins PAG (COPAG) and the Physics of the Cosmos PAG (PhysPAG). The ExoPAG18 meeting is scheduled for July 2018 in Boston, and would include a 2-3 hour mini-science symposium. ExoPAG will provide limited travel support for postdocs and students. There were no APAC actions requested. As the new ExoPAG chair, Dr. Meadows' priorities include expanding expertise, getting more young people involved, and the interplay between ground and space-based observatories. However, she mostly wants to advocate and help the community.

PhysPAG Report

Dr. Conklin, the new PhysPAG chair, briefly reviewed the PAG's objectives, listed the six Science Interest Groups (SIGs), and noted the executive committee membership. Via telecon, PhysPAG members discussed high-impact research at it relates to the SMD R&A charge conveyed to APAC in July, 2017. The focus was on processes to solicit, review, and select high-impact research projects. Answers included dedicated solicitations, a percentage of the budget, and the example of the STMD NASA Institute for Advanced Concepts (NIAC) program. A web survey with 61 respondents showed broad agreement on some items and little agreement on others. PhysPAG will provide all of the data to APAC. Dr. Conklin noted that the survey comments were unprompted and provided freely at the end of the survey.

Dr. Conklin next discussed the proposed Multi-Messenger Astrophysics (MMA) SAG, which PhysPAG considers important because NASA observatories will play an important role in future MMA observations. The purpose is to see what MMA science goals can be achieved using current and planned NASA science observatories, while also considering what mission concepts might be possible without calling out something that could filter into the next DS. The SAG will be multidisciplinary and will include COPAG members. It will not necessarily be specific to gravitational waves. The desired outcome is a series of white papers to be commensurate with the next DS process and to be delivered to APAC. The community will become involved through the normal SIG process of soliciting broader input, as well as sessions at conferences. Dr. Gaudi thought this was a great idea but cautioned Dr. Conklin to keep the scope reasonable and identify one person who is strongly motivated to keep everyone on schedule with deliverables. Dr. Conklin thanked him and said that PhysPAG had pondered the best organizational structure for balancing the various interests. He hopes someone will emerge as the leader.

Other PhysPAG activities include the Lynx STDT and the NASA LISA study team. Dr. Conklin provided updates on the various SIG activities. Dr. Cooray asked why there is a study team for LISA and not Athena. Dr. Bautz explained that Athena is much further along and there are agreements. Dr. Cornish added that Athena is entering competitive Phase A. Dr. Kartik Sheth, sitting in for Dr. Hertz, said that there is significant NASA participation in both. Dr. Cooray remained concerned that LISA is being treated differently.

Dr. Gaudi held a vote to approve the MMA SAG. As there were no votes opposed, it was officially approved as SAG 3.

COPAG Report

Dr. Paul Scowen began the COPAG report by showing the executive committee membership and noting that the PAG's members have been very active. COPAG hosted a number of events at the January 2018 AAS meeting from the various SIGs and the new Technology Interest Group (TIG). The event had representatives from all of the STDTs. He planned to propose a SAG on great observatories. Like PhysPAG, COPAG surveyed the community about high-impact research. The 59 respondents showed no clear evidence of dissatisfaction with the process; the answers neatly fit the bell curve. There were some good suggestions and testimony. There are no open SAGs, though there are three open SIGs.

The purpose of the new SAG on great observatories, mentioned by Dr. Meadows, is to analyze the gaps that are anticipated over the next 10-20 years as the great observatories age or are decommissioned. The SAG will also look at how to replicate or extend these capabilities, and address whether they call for flagship missions, probes, or something else. The idea is to focus on what might be lost and to provide a series of options that the SAG could deliver to NASA in order to address the priorities of the next DS.

Dr. Scowen summarized the various SIG activities, and then said that there were questions for APD. First, COPAG wanted to know the likely impact that the JWST would have on Spitzer. Dr. Sheth said that the Division is discussing this with teams that responded to the RFP. Spitzer will not be as nimble over time, and it will bring back less data, so those are considerations. Dr. Scowen also asked about SOFIA not being in the SR. Dr. Sheth replied that that is being clarified. The Office of the Inspector General (OIG) issued a report in 2014 recommending that there be no unreviewed missions. If that were an APAC concern, the Committee should recommend what else might be done with SOFIA should the SR not be an option.

Dr. Scowen said that COPAG was concerned that a delay in the DS would affect the STDT studies, which might not be current by time the DS panel meets. There was a question as to whether the studies would need updates. Dr. Gaudi agreed, pointing out that a 2-year delay is quite different from the 6-month delay APAC had previously discussed. APAC had discussed the delay of the Guest Observer (GO) call as well. Dr. Moustakas noted that there were rumors. It would help to have more certainty and to know the rationale. Dr. Cornish suggested that APAC provide input on the impacts of a delay. Related to that, while it was not yet known whether SOFIA would go to SR, he preferred to be proactive and therefore wanted to discuss the contingency plan for another kind of review when Dr. Zurbuchen met with APAC the next day. Dr. Wang wanted to know the point of a review with no comparison. Dr. Ozel said that they would get some information on metrics. Dr. Sheth said that his goal is to get the most science possible out of SOFIA, so any review would have that standard.

Dr. Scowen asked APAC to approve the new SAG on great observatories. This SAG will identify gaps and ways to mitigate them. Dr. Bock was concerned that it could tread the line on advocacy, and Dr. Gaudi urged caution. Dr. Moustakas said that he was fine with the focus on the science gap, but the proposal also mentioned mission concepts. Dr. Cooray thought that part sounded like a DS issue. Dr. Bautz explained that the premise is that they want to maintain existing capabilities. Dr. Gaudi said it seemed reasonably considered, but it also had risks of ballooning. He encouraged Dr. Scowen to work to keep it in bounds.

Dr. Gaudi proposed approval of the new SAG on great observatories. As there was no opposition, the SAG was officially approved.

HabEx STDT Report

Dr. Gaudi, co-chair of the HabEx STDT, explained that the full name for "HabEx" had been changed to the "Habitable Exoplanet Observatory." The goals are to characterize nearby planetary systems and exoplanets, maximizing the science yield while maintaining feasibility and working within constraints of cost, technology, and schedule. Dr. Gaudi described the notional architecture and capabilities. The latter include direct imaging, resolution and effective areas that are significant improvements over HST's, and starlight suppression using both a starshade and a coronagraph. Dr. Gaudi provided illustrations of images that were possible from the coronagraph and starshade, and presented the types of data that might indicate habitability. There was also a notional projected yield of characterized planets. HabEx will not be restricted to study of exoplanets; it will also conduct general observatory science, study the lifecycle of baryons, and conduct solar system science and general astrophysics. At the moment, most of the technologies are at TRL3. The 5-year mission will look at spectra and orbits. If precursor missions identify some targets, more time will be spent on the GO program, which is planned for a minimum of 25 percent and could be higher. The mission is considering a dual spacecraft/starshade launch, athough the STDT is focusing on options for just one launch. The biggest science driver for GO is lifecycle baryons, which is likely the most exciting non-exoplanet science.

Lynx STDT Report

Dr. Ozel, a co-chair of the Lynx STDT, said that the key science goals of Lynx are to find the first supermassive black holes, trace their growth, learn how they shape their host galaxies, and study stellar evolution. All of the Lynx science is expected to be GO, which means it will all be community-driven. Dr. Ozel described what LISA and Lynx can access between them, and presented the required capabilities and observations. One of the capabilities will be multi-messenger events. X-ray observatories are best for studying young stars, and there will be further study of the impact that space weather has on the atmospheres of planets and their habitability. Lynx will be much more capable than Chandra and Athena. The STDT is now doing trade studies. A lot of science questions need to be addressed with different capabilities. The mission size means that it would need a medium-to-heavy launch vehicle. The team is looking at different configurations of optics, coatings, and more.

OST STDT Report

Dr. Cooray, a co-chair of the OST STDT, gave the status of the Origins Space Telescope (OST) STDT's work. The Team is looking at two concepts, a 9-meter deployable telescope (Concept 1) and a 5-meter telescope (Concept 2). Both of these would present an enormous improvement in sensitivity, driven primarily by the colder operating temperature rather than aperture size. OST will address three science themes: the frequency of life-bearing planets, the conditions for habitability that develop during planet formation, and how galaxies form stars, make metals, and grow their central supermassive black holes. The mission includes a coronagraph as a secondary driver. Dr. Cooray discussed how OST will study the water trail and use infrared to explore the history of the universe. He also described the mission's sensitivity. The STDT began with a call for two-page white papers, which informed the concepts under study. Dr. Cooray presented some highlights, including instruments, some of which are international. He then reviewed Concept 1 requirements, noting that even Concept 2 will offer gains over JWST. Concept 1 is for a 5-year mission with 10 years of consumables, designed to be serviced at intervals to go to more than 30 years. The Concept 2 design study was going on at the time of the meeting. This mission would be like Spitzer, with no deployments on orbit other than a sunshade and solar array. It would have lower complexity and mass relative to JWST and the Concept 1 mission. It is scaled down from Concept 1. Dr. Cooray described the launch requirements, for which there are multiple options. The goal is to match the JWST collecting area. The technology gaps have been identified. The Concept 1 study is complete and has been delivered to NASA. Dr. Cornish asked about how much JWST science Concept 2 would be

able to recover. Dr. Cooray replied that the 1-2 micron science would not be available. He was unable to define the tradeoff of the cooling at the moment.

LUVOIR STDT Report

Dr. Aki Roberge, the study scientist for the Large UV/Optical/IR Surveyor (LUVOIR) STDT, presented the report. The STDT is looking at two architectures, A and B, with 15-meter and 9-meter telescopes, respectively. Both designs are for a mission that will be serviceable and upgradable, so the community can use it for an extended period. Dr. Roberge discussed the high sensitivity capabilities of LUVOIR A, and the background quasars that would be available at four sizes. The STDT is also looking at solar system sensing. A graphic compared HST and LUVOIR A views of Pluto. A key science driver is discovering and characterizing potentially habitable planets in the solar neighborhood. LUVOIR will use direct spectroscopy. A LUVOIR simulation showed models of the inhabited Earth through time. Organic haze, not oxygen, may be the biosignature for the Archean Earth. LUVOIR will be a warm telescope. Unlike HabEx, LUVOIR will do a statistically significant survey of life in the solar neighborhood. An inverted pyramid showed the questions to ask in identifying habitable exoplanets and life. The LUVOIR instruments can go all the way down the pyramid. Although it might be possible to determine planet masses from the ground, LUVOIR is designed to able to do that as well using on-board astrometry. Dr. Roberge showed the spectra that can be obtained. She then described the hardware. The LUVOIR A telescope will be segmented and deployable and launch in a SLS Block 2 vehicle, while LUVOIR B will go up in a smaller launch vehicle. The instruments will include a coronagraph but not a starshade, which would have to be enormous for this mission. There will also be UV multi-object spectrograph and a high-definition wide-field imager. POLLUX, a fourth instrument under study by a European consortium, is a UV spectropolarimeter to address magnetic fields on solar system objects. The STDT includes community working groups, instrument teams, and more.

APAC Report on High Risk/High Reward R&A Charge

Dr. Gaudi introduced the topic of high-risk, high-reward (HRR) research, which SMD has charged the science Advisory Committees (ACs) to review. The two questions addressed whether SMD R&A has effective processes in place to solicit, review, and select HRR projects, and if the program has effective processes in place to solicit, review, and select interdisciplinary, and interdivisional projects. There were sub-questions as well. APAC generally thought that review panels were risk-averse, but came to no consensus on how to address HRR research. Two PAGs queried their membership, but the results showed a lot of disagreement, broad responses, inconsistency, etc. The only common thread was that there are hurdles to get such proposals funded. Panels are seen as too conservative and risk-averse. Some of this was attributed to over-subscription, and there was a perception of practical limitations, like the proposal page length. One thought is that these proposals are not written because the Principal Investigators (PIs) know they will not be funded. There was some consensus that reviewers tend to be picked from narrowly defined fields, and there are `territorial' barriers to getting these proposals funded.

APD has begun asking panels to identify HRR proposals and will have data in a year or two. There was concern that if there were a separate call, people would submit to both. Dr. Gaudi noted that the SMD R&A Director, Dr. Michael New, suggested definitions, COPAG changed them for its own discussions, and APD gave Dr. New's definitions to the panels. Dr. Ozel observed that there will be variations in the panels, but there are studies showing that simply instructing the panels and providing definitions works. Dr. Sheth explained that APD's process is to allow the panels to review proposals normally, then give them a five-question survey. Dr. Gaudi said that he has only heard anecdotal information, which makes him uncomfortable. Dr. Bautz added that there will be differences in interpretation.

Dr. Gaudi said that Dr. Hertz wanted APAC to conclude this effort. Each AC has been asked to provide a presentation and letter to Dr. Zurbuchen, and to make a presentation to the Science Committee, which will deliberate and produce written answers. He suggested that APAC commend APD and SMD for this effort, and state that the Committee wants to see the results once there are some data. He wanted to note that the community values HRR research but is inconsistent in their definitions and how they want to move forward.

Public Comment Period

The meeting was opened for public comment.

Dr. Roberge said that she is on the Planetary Science Advisory Committee (PAC). She reported that when their SAGs were presenting, there was a running theme of their use of astrophysics assets. However, APAC does not have anything on the solar system, and she thought it would be good to give some solar system people a seat at the table. Dr. Gaudi said it was possible that the great observatory SIG would have solar system representation. Dr. Wang suggested following up on this.

Dr. Ashlee Wilkins of AAS spoke next, stating that the decision on scheduling of the APD DS in part reflected a possible need to have the PSD DS earlier, as that Division has a lot of new funding now. She said that while Dr. Zurbuchen prefers the switch, NSF does not. NAS is ready to start tasking on astrophysics, and prefers to do only one DS at a time. Dr. Scowen asked if PAC was ready for this, and was told they were not. PSD has not even had its mid-decade assessment.

Balloon Program Update

Ms. Debora Fairbrother gave an overview of the Balloon Program and addressed some of the issues from the previous year. The Program provides low-cost opportunities to conduct science investigations, serves as a platform for technology development, and helps train scientists and engineers. There are two types of balloons. The zero pressure balloon (ZP) is standard, but the science is affected by the diurnal cycle. The super pressure balloon (SPB) allows long-duration flights at stable latitudes. SPBs are under development. The science community wants higher altitudes, which requires lighter payloads. The Program is doing test flights in that area with the 60 million cubic foot balloon. NASA's balloon services cover command and control capabilities and other elements so that scientists can focus on the payloads they are launching. Most payloads have a range for height, which the Program can meet. Leaks do occur but are uncommon; there was no detection of leaks on a 55-day Antarctica flight, for example.

Bases are in New Mexico, Texas, Sweden, Antarctica, New Zealand, and Australia. The two or three annual Antarctic missions are flown in collaboration with NSF. NASA has also done some work qualifying parachutes with STMD in Hawaii. Ms. Fairbrother described each site. The Palestine, Texas, facility is the main center of operations, which NASA recently took over from NSF. The change elevates some of the NASA requirements at the facility, and affects security, foreign nationals access, etc. Ft. Sumner, New Mexico, launches short duration flights and has both a NASA building and a WWII hangar that leaks. Missions fly from New Mexico to Arizona and Texas. Esrange, Sweden has a long-duration balloon (LDB) facility, while the Alice Springs, Australia, site launches 1- to 3-day flights. NASA has investments in property at McMurdo, Antarctica. The Wanaka, New Zealand, site will be funded for expansion but thus far has only launched smaller sized payloads due to the facilities. Ms. Fairbrother showed a launch through termination video of a SPB test flight conducted from Sweden.

SPBs have been under development for a while, and there have been some issues in this area since 2015. Ms. Fairbrother described a leak that developed over Australia, resulting in a loss of differential pressure after 32 days aloft. In 2016, differential pressure issues arose after about 2 weeks, resulting in early termination of the flight after 46 days aloft in the southern hemisphere. A 2017 flight out of New Zealand had a problem with the launch collar due to a manufacturing issue, and NASA lost the balloon and payload in the ocean. There are environmental constraints affecting when and where the balloons can be brought down.

In terms of next steps, the Balloon Program began an instrumentation team, continued leak testing, is working on scaled balloons, and is modifying fitting designs. There were several investigations due to issues that appeared in the last year. For example, another collar anomaly resulted in a stand-down of the program to get a handle on electronics workmanship. An interim collar has been developed for the next couple of campaigns. In addition, there were some close calls from a science perspective, resulting in another stand-down and discussions with all of the science teams. Process improvements have involved additional training, added quality assurance, and changed procedures for science teams. The program is adding detail to the gondola design requirements and changing the overall program. Finally, there will be a lot of outreach. None of the recent changes are expected to affect the Balloon Program's ability to operate as a low-cost program. The goals of the improvements include streamlining, specificity, refinement, and prevention of problems. There are also more safety procedures now.

Adjourn Day 1
The meeting was adjourned for the day at 4:58 p.m.

Thursday, April 12

Opening Remarks
Dr. Gaudi opened the meeting. Dr. Patricia Knezek sat in for Dr. Hasan.

Q&A with SMD AA
Dr. Zurbuchen thanked the APAC members for their work. The Division Advisory Committees (ACs) provide valuable advice through their diverse areas of expertise and work, and it is helpful to get viewpoints from outside NASA Headquarters. Astrophysics faces some challenges. NASA does not set priorities, but rather implements DS guidance. The Kepler mission has produced over and above what was expected, so NASA is excited about the new possibilities.

Dr. Ozel asked for his view on the future of flagship missions for NASA. Dr. Zurbuchen replied that a program that wants to lead in astrophysics must have large missions, as many of the field's questions relate to sophisticated spacecraft. It is a dimension in which progress happens more than in any other discipline. There are small mission topics, but big missions are important and necessary. The DS has flagship missions as part of a balanced portfolio. Even the best manager will be over the limits sometimes on the flagship missions, while a small percentage increase on an expensive mission equates to a significant number of R&A grants. The way SMD does big missions depends on what it learns from both past and present. The JWST issues help SMD manage better. There are many variables, like the scope of the mission – how broad or focused should it be, for example. It is a trade. The community needs to help SMD understand how best to do this. WFIRST has scope as a tradable. SMD managers learn as they go along, and the PI missions inform the Directorate on how to make decisions. It is

important to be able to say no. It is also important to always have a big mission going forward as part of the balance. This is something NASA is spending a lot of time on. SMD looks across all of the disciplines for lessons.

Dr. Gaudi said that he was on one of the four large STDTs. To achieve the science they want in the future, they seem to be going out of scope for budget. The ambitions of the four missions do not seem to be within the budgets, meaning that the teams will run into boxes and limitations. He asked about the solution. Dr. Zurbuchen said that he did not know the answer and wanted community input. One thing that is not the solution is to leave ambition at the door. To persuade the public about the importance of astrophysics, NASA must have an ambitious program, not a shadow. Partnerships are part of the answer. It is also worth thinking about whether there are new ways of doing things. If space were easy for astronauts and robots, it would be different, and others at NASA are moving in that direction. He asked how the question might be posed in that context and asked if increasing mirror size, sensitivity, etc. is a solution or a complication. Innovation is not about constraints, though there are known constraints in this case. He believes they will figure it out in the next decade.

Dr. Batalha observed that the 2017 authorization act and the appropriations seem inconsistent. She then asked if Dr. Zurbuchen saw a ripple effect in the return to the moon. He replied that NASA is in the middle of a number of powerful, opinionated stakeholders. There is a trend in science to address some meaningful questions about where life comes from, etc. He did believe that lunar exploration will have a ripple effect. It is evident that the cross-divisional interactions need to be stronger and more enabling. Dr. New is involved in this. SMD has discussed research with other directorates as well. However, the return to cis-lunar space is not the Agency's only priority. Dr. Bock noted that PSD handles mission designation differently and wondered if APD might learn from that. Dr. Zurbuchen said that the PSD approach is very frugal with the New Frontier class, and there are some exciting priorities. This is the kind of guidance he would like to see in the DS.

Dr. Alan Boss asked about the order of the PSD and APD DSs. Dr. Zurbuchen explained that SMD relies on NAS guidance a lot. He was concerned about doing what is right and could argue both sides of the question. He raised the issue of flipping the PSD and APD DSs because of his own experience on the heliophysics DS. If the boundary conditions of the DS make it impossible to have any positive story and the only free energy is 5 years from now, that DS is not going to be ambitious, forward-looking, or helpful to the community. The HPD DS had all of these characteristics. With JWST and WFIRST uncertainties, and the science community being unsettled, he worries about setting the tenor for the next decade. He wanted to consider this. He wants to think about the next generation of leaders and make sure to do what is best for the community. He thinks the DSs need to be valuable. He worries, and he talks to other people who are worried. Early career people and professors will be affected by this, so what are their opinions? He asked NAS to have the discussion and meet again in early July. Neither he nor Dr. Hertz will be going to the community with strong opinions. He just wants to make sure SMD does the right thing; that is all he cares about. He wanted to do that by getting some ambiguity out of the system.

Dr. Jones pointed out that the cost growth issue is not just about flagship missions, as it extends to PI-led efforts. International cooperation is a great way to address cost on flagships, but not for PI-class missions. The top line for the PI class can increase without great impact on flagship missions. Dr. Zurbuchen agreed, stating that SMD needs to fly spacecraft but does not fly enough. He wants the ACs and national groups to have this discussion. He and Dr. Hertz talked about whether the SMEX level is too low. The NAS Committee on Astronomy and Astrophysics (CAA) produced a report saying the SMEX area

is rich. That was not what Dr. Jones asked, but that is the type of discussion APAC should have, discussing opportunity costs and balance. Dr. Jones also described his concerns about maintaining some baseline capabilities, which relates to the capabilities of flagship missions. Dr. Zurbuchen thought that was a DS question, but Dr. Gaudi recast it as a great observatory issue. NASA has been fortunate with these missions, but some of these windows are going to close, and APAC wanted to know how the Agency will address that.

Dr. Holley-Bockelmann observed that there might be incompatibilities with international partners in terms of both flagship missions and timelines. Dr. Zurbuchen said that the world they are exploring is international, and the teams and collaborators reach across many boundaries. So collaboration is natural, and NASA has done well with it. Getting there has constraints, like the lack of alignment of decision processes. The ESA and NASA processes are different, which is also true of JAXA and other space agencies. The answer is not an uber-DS, which has been suggested. The intent of international collaborations is not to make things simpler. The Earth Science Division (ESD) DS just came out and recommended more international collaborations on PI-class missions, but the mechanisms are hard, and there are other constraints. There is a need to fly more often to have capabilities in the whole ecosystem. Dr. Gaudi observed that the level of ambition in the flagship missions seems to put them beyond the capabilities of a single country. Partnerships are necessary to make these things happen. Dr. Holley-Bockelmann asked how Dr. Zurbuchen sees NASA maintaining U.S. leadership. He answered that a lot of the topics APAC addresses are cross-cutting, not just in astrophysics. Dr. Hertz added that it is within the APAC scope to advise him on when international collaborations are needed.

Dr. Batalha asked Dr. Zurbuchen what keeps him up at night. Dr. Zurbuchen said that he is concerned that the astrophysics community is not very well aligned. There is more noise in the system and squabbling than in other communities, and there are people doing advocacy that is detrimental to the community in the long term. That is partly due to human nature. He has put a lot of attention on JWST recently, and NASA cannot get that mission wrong. The Agency is betting the farm on the mission, and that is what leaders do – bet the farm. Every once in a while, NASA needs to try something extremely hard, and that can lead to painful experiences. Compared to the astrophysics community, there are no other communities with issues coming from so many directions. He feels these issues needs to be addressed in the community itself, not by Headquarters. With all the amazing work they are doing, it does not help to have these conflicts instead of moving the community forward and setting up the next generation for success.

Dr. Scowen said that many of the APAC members were in STDTs leading up to the original schedule of the DS, and much of the community is gearing up for that schedule. The community will be greatly affected if there is a delay. He asked how to give the best input without losing the momentum that exists. Dr. Zurbuchen said that APAC should provide input. He wants the discussion to happen in order to make sure that all aspects are considered. Dr. Boss said that the NAS astrobiology and exoplanet groups were meeting soon, and would the ambiguity in the DS schedule affect them. Dr. Hertz advised executing the Statement of Work (SOW) for these studies and not worrying about DS timing.

Dr. Gaudi agreed that the community should be having discussions, but they would not be able to make well-informed decisions until around June. Dr. Moustakas mentioned the perspective of human psychology. He said that he understands that JWST is important, but there is the whole portfolio to consider. He would be concerned about waiting to demonstrate JWST versus leveraging an entire portfolio that is ready to go. Dr. Zurbuchen said that that was a valid opinion. The DS is about the whole portfolio. There are good arguments in both directions. Some parts of portfolio will be hurt by a delay,

including the ground-based piece. He still wanted to have a rigorous discussion. If the answer was to go forward, he would be fine with that. Dr. Gaudi said that APAC can write down the pros and cons, then when things become clear, they will be prepared. There are positive and negative aspects to waiting versus staying on schedule. As a committee, APAC needed to decide what the benefits are to the community. He added that, in the face of a delayed DS, there might be a need to do intermediate studies of the four proposed flagship missions.

Dr. Moustakas sought to confirm that Dr. Zurbuchen wanted rigorous discussion and feedback from the community, and the APAC role is to advise APD. He asked if part of that charge was to make analyses, recommendations, and suggestions. Dr. Gaudi replied that it was, and that the PAGs could help. Dr. Hertz noted that there are multiple ACs involved in the question of whether to alter the timing of the APD and PSD DSs. SMD has asked CAA to look at this, and APAC should funnel its input to that Committee. He expected CAA to come forward with pros and cons, not recommendations. APAC represents the community, as do the PAGs.

Dr. Willman said that the JWST delay was rather extreme, and she expected there to be lessons learned. She asked if they were in process yet, or being applied. Dr. Zurbuchen said that the lessons from JWST are already informing the way SMD runs its science projects. What NASA is learning concerns I&T of a very complex system. He does not want to go through this again. There is a system for looking at it that involves a complicated discussion beyond technology or oversight. This is a schedule breach. When a mission moves 6 or more months beyond its schedule, NASA has to take it to Congress. A breach of the JWST cost cap can be triggered by a single dollar. That leads to attempts to force missions to not breach. When there is evidence that a breach could occur, NASA must write a letter to Congress. SMD is learning how this experience helps or hurts. He is confident in the leadership chain, and will give an answer after the IRB report. NASA needs to have this mission succeed. Accountability starts with the individual, so the first question is “how can I do better?” The Agency needs to align talent with that in mind. He is optimistic about the project. It is late in the process for this to happen, but I&T is where the final issues appeared. The IRB reports to him; he chartered it. Had the Acting Administrator for NASA, Robert Lightfoot, not been planning to step down, the IRB report would go to him instead, but having it go to Dr. Zurbuchen supports a stable reporting situation.

Dr. Ozel noted that the topline of the FY19 PBR is greatly reduced, and it cancelled APD’s 2010 DS flagship mission. She wanted to know how APAC could deal with that as a committee, given that he wants astrophysics to be smart and ambitious while respecting DS recommendations. Dr. Zurbuchen replied that this is not the first time a community has faced these challenges, and there are opportunities even within these challenges. APAC’s job is to identify where the challenges and opportunities exist, and the priorities. The Committee should discuss the smartest way to go forward with the constraints, and how to address downturns. He urged them to be optimistic. There is a sense of history at NASA that comes from leaders who stood out when things were not going well and rose to the opportunity. He wanted APAC to look at the reality, but with a sense of optimism.

Diversity and Inclusion

Dr. New described SMD’s approach to diversity, inclusion, harassment, and discrimination. SMD wants to be a leader in science by focusing on impact, enabling innovation, and being interconnected. Organizations that support Diversity and Inclusion (D&I) are much more likely to excel than are more homogenous organizations. While NASA does not reflect the diversity of the nation, it is improving. SMD is discussing all sorts of diversity. The Directorate looked at the gender of proposers and grantees of ROSES 15 across all four science divisions, inferring the gender based on names and making the results

more reflective of name sorting rather than gender identification. That will sometimes be wrong, but the results showed that the fraction of grantees and proposers that were female were about equal. While the percentage of female proposers does not reflect the percentage of female PhDs, there was not evidence of bias against women in this analysis. In addition, the percentage of women is similar across all divisions, which was a surprise. Dr. Willman noted that other analyses have found a statistically significant difference. Dr. New explained that 2 years ago, the Office of Chief Scientist (OCS) received OMB permission to ask about gender, and those data will be more accurate. Dr. Willman said that the comparable studies went on perceived gender based on first name. Dr. New noted that there are issues with him publishing these data, and OCS, not SMD, was empowered by OMB to collect gender data. Presumably, their data will be sharable and APAC might ask for a presentation.

SMD reviewed competed mission proposals from 2001 to 2017. Here, NASA is doing badly. Out of 301 proposals, only 30 had female PIs, and almost all of those came through PSD. SMD needs more data to determine how one becomes a PI, and has a data scientist working on this, as well as Dr. Joan Centrella, who is on detail. The effort is starting with APD. If a pattern appears, SMD can identify pinch points and address them. He will report back to APAC once the data analysis is done, but it will take time to build the database with every proposal submitted over the last decade, tagging the criteria of co-Is and PIs, the kind of proposal (technology, theory, etc.), selected versus non-selected, gender, etc. That is the kind of database that will be needed to trace pathways. For example, the NASA Solicitation and Proposal Integrated Review and Evaluation System (NSPIRES) is not built to look at information over time. There is an assumption that the path goes through suborbital and technology development, but this has not been analyzed.

Dr. Dingus advised looking into other actions that could be done while waiting for the answer, like studying the paths of the successful women. Dr. New agreed that this was a good idea, but noted that he does not have any staff and can only borrow people. He thought it would be worse to do it wrong than not at all. Dr. Dingus disagreed, stating that he could get the 30 women on an email chain and acquire some examples. Others agreed that this would be interesting. Dr. Moustakas suggested engaging and leveraging other organizations, such as AAS. Dr. New said he would consider it. Dr. Willman recommended looking at what has been done elsewhere rather than doing something that is not crisp.

Dr. New explained that the IRB requirements are now extended to surveys. SMD has other D&I efforts as well. There is language endorsing diverse teams in all solicitations, and all panels are now briefed on cognitive biases and shown an OCS video on the subject. SMD is developing processes to ensure D&I in SRBs and ACs. The ACs are diverse now, and ad hoc committees must also be diverse. The ACs should reflect the diversity in the community, which is not the same as that of the nation. Dr. Boyd asked if there would be any analysis to see if this new language has an impact. Dr. New replied that it would, but this is not an evaluation criterion due to numerous legal issues. Such an evaluation process would be onerous, and SMD would rather not have lawyers involved in the review panels. Dr. Willman said that NSF has long considered broader impacts. The fact that this is so important for early career investigators has had a great and visible impact. She advised APAC to consider “broader impacts” as a criterion. Dr. New noted that NASA does not officially share NSF’s core mission to grow the next generation of scientists.

SMD is also developing approaches to increase the D&I of the future workforce and science community. Some of this is through NASA’s small business programs, to build on networks and get the SMD message out to a variety of organizations. They are also looking at partnering with NSF and nonprofits. Dr. New

noted some of the programs SMD is studying, and said that the Directorate is trying to expand the Headquarters paid internship program, while also talking to the centers about what they want to do.

In the area of anti-discrimination and harassment, SMD is collaborating with NASA's Office of Diversity and Equal Opportunity. NSF recently issued a policy on discrimination that requires grantee institutions to report discrimination claims and investigation results, and SMD is working with Agency lawyers and NSF on adopting that statement as well. Future ROSES releases and AOs will include a new statement on what individuals should do when they believe they have been faced with discrimination or harassment. If an individual or their alleged harasser is on a NASA grant, there is a web form the individual can fill out. This applies to any kind of NASA funding. SMD will communicate this effort through "Dear Colleague" letters, newsletters, and NASA communications. Dr. Jones added that department chairs should be on the list. Dr. Hertz agreed. Dr. New said that Dr. Zurbuchen had met with some early career people about this. In answer to a question, he confirmed that individuals will go through the host institution when there is a complaint to NASA. Each proposal must provide assurances that the institution is in compliance with a range of civil rights laws. If a complaint comes in, the institution will have to demonstrate that it is investigating. He was not sure if NASA will do independent investigations, but the new NSF policy has teeth, and SMD wants to adopt it. Dr. Sheth is working on a code of ethics for peer review panels, and that could be expanded. APAC can see that once it has been drafted. He urged APAC members with examples of policies and statements to provide them to Dr. Sheth.

There is also a workforce development working group that is trying to see what early career investigators need to be successful, while also looking at training and incubators. The oceanography community has programs to train new PhDs for their future, and has also created networks and proposal communities. This is a good "PI 101" model. The incubator idea would be similar to business incubators, teaching early career people the tasks they will need to master, while allowing them to network with peers and a range of others, including organizations. SMD is also trying to assess the competitiveness of early career PIs and wants to reinvigorate the Hands-on Project Experience (HOPE) program for 2019. Meanwhile, SMD is partnering with the centers to develop a more diverse cadre of future project managers. Another action is to take a more strategic approach to stakeholder interactions, like outreach to colleges and universities that are not normally part of the NASA world. The funding needed for such an effort is unknown until it is clear what form the actions will take. The PI 101 course and the incubator might be funded through a call for a contractor or organization, but it is too early to know the scale, budget, or boundaries. This is not a mission-level activity.

Dr. Batalha said it sounded like he was assuming that women are less prepared to lead missions. It is very important to understand why they are not proposing. She assumes that PIs tend to be more senior. It is essential to grasp the process, like how institutions decide what moves forward. That process needs to be extended, and the focus should not all be on the people at the bottom rungs. Dr. Boyd added that each NASA center has Equal Opportunity (EO) organizations and science organizations that do not necessarily talk to each other. Dr. New said that he talks to science directors and center directors. The efforts to diversify the cadre of project managers needs their support.

<u>WFIRST Update</u>

After the APAC members with COIs for WFIRST moved away from the table, the remaining members were Drs. Holley-Bockelmann, Dingus, Cornish, and Conklin.

Dr. Jeff Kruk, WFIRST Project Scientist, explained that the 2010 DS ranked WFIRST as the top flagship mission for astrophysics. This mission will be transformative. The DS recommended four areas of focus:

wide-field infrared science surveys of the universe; dark energy and the fate of the universe; full distribution of planets around stars; and technology development for exploration of new worlds. Acquisition of the 2.4-meter telescopes supports the technology development area, as will the coronagraph. Dr. Kruk listed the science goals and explained that there will be a funded GO program accounting for at least 25 percent of observing time. WFIRST will also provide a robust archival research program with access to all data from the mission. The cosmology surveys will study the expansion history of the universe and the growth of structure. WFIRST has multiple probes that can cross-check astrophysics and instrumental systematics. No other dark energy observatory will be this comprehensive. Dr. Kruk showed microlensing data, which is complementary to that of Kepler, with some overlap. A free-floating planet model demonstrated observations that can only be done via microlensing, and there was an example of what might be done with the GO program.

WFIRST will survey nearby galaxies 100 times faster than HST and will be able to reconstruct the assembly of galaxies. The coronagraph will be a pathfinder, paving the way for HabEX and LUVOIR's direct imaging of Earth-like exoplanets. The final design could affect the predicted performance curves in characterizing exo-Earths, so some of what Dr. Kruk presented showed the possibilities of what could be achieved. He described the observatory concept, which assumes a mission of 5 to 10 years. He also gave graphic representations of the likely orbit from two perspectives.

In the previous month, the program completed the system requirements review and mission definition review to determine whether the right requirements have been identified and if the mission design meets those requirements. KDP-B was planned for May. The notional schedule has a 2025 launch, though the team would like to launch sooner. The WIETR effort took place in 2017 and was very involved. The report, issued that October, led to a few changes in the mission baseline. The team then began delivering materials to the SRB for system requirements review. The post-WIETR direction from HQ was to maintain the basic architecture of the mission but take savings where possible. Therefore, the project team reduced the baseline cost to $3.2 billion, taking savings where possible that did not affect the science return. This was accomplished in part by taking 6 months taken off of the original schedule. Dr. Kruk gave some examples of the optimization of the design, integration, and test flow. Certain elements of the mission architecture will remain unchanged, such as the 2.4-meter telescope.

WFIRST will be a Class A mission with tailoring. The team will use a proto-flight approach to qualify most items in engineering, and most parts will be at Level 1. The coronagraph is now a Class D instrument with tailoring. There has been some simplification of the wide-field instrument, and the mission will order fewer detectors, where the savings is more about schedule and less procurement cost. The focal plane operating temperature has been reduced slightly, using the margin in the present design. The baseline now has the integral field channel coming from an international partner. Prior to WIETR, the team eliminated the cryocooler. The coronagraph is area of the greatest changes coming from the WIETR. As noted, it is now a technology demonstration instrument. There is also a big reduction in the mask and filters to shorten the I&T flow. The participating scientist program eliminates most associated science operations center costs. However, WFIRST retains the basic coronagraph architecture and functions.

Regarding science investigations, there is a 10 percent cut for science team funding. The GO program will be limited to only the modes required for the baseline surveys and will have three calls and five archival research calls. A few capabilities of the wide field science operations center were significantly reduced, but the mission will still have a data management system that provides direct access to the data by users. Observing time will be selected competitively, data will be public immediately, and

science priorities will be updated throughout the mission. These are unchanged. Changes under consideration include models for time allocation to large programs and models for structure of teams for large programs; the team is seeking community input on both of these topics. Near-term activities begin with execution of the project plan for FY18, and a response to Congress with the plan for the FY18 appropriation. If the mission is not terminated for FY19, it has to keep running, and the work must go full speed to make the cost cap. NASA continues negotiations with international partners. There is also a need to flow requirements to lower levels and complete optimization of instrument design parameters.

Dr. Cornish asked if any of the three reviews identified which elements had the greatest uncertainty and the elements with the greatest risk of being cost drivers. Dr. Kruk replied that the biggest risks identified by the IRB and WIETR were for requirements that will show up later, like a starshade. In addition, the mission must be serviceable, but NASA does not have a servicing organization, so the team is writing those requirements based on assumptions that might not be true. Only one item on the coronagraph is below TRL6, so that lowers the risk of delay. However, history shows that there will be surprises that will set the schedule back, and he cannot predict what those might be. It is also possible that the team is being overly conservative.

Dr. Conklin asked if the additional FY18 funds might be used to advance the schedule. Dr. Kruk replied that they have started growing the flight detectors and some subsystems. As those are internal to NASA, they can be done when it is convenient. Dr. Holley-Bockelmann asked about how observing time and GO time will be allocated. Dr. Kruk said that they will be competed. The decision has not yet been made in regard to early release time. Some work can be done as a data set during commissioning. There will have to be a Design Reference Mission (DRM) to move forward in NASA. For review panels, the DRM is just proof of the ability to meet the science objectives in the timeline, and that is not going to reflect the observing program that is ultimately selected.. Regarding the coronagraph, there has been some examination of other types of science to do with it, but he does not have the full picture yet. One always worries about reductions, but that was the direction from the WIETR. The main things affecting coronagraph performance are details of what the telescope will look like, so the team is very much in the middle of deciding that. Dr. Dingus asked what happens when the budget gets tight. The coronagraph seems to be subject to funding cuts, and she wondered what else might be cut. Dr. Kruk said that the team gave a list of other items to Drs. Hertz and Zurbuchen. Dr. Hertz added that descope options are a standard part of the KDP-B process. Dr. Cornish asked about the interfaces between a Class A mission and a Class D instrument. Dr. Kruk said that the science and mission safety requirements will be met, and the secondary mirror requirement will not be sacrificed. However, the strut width factors into tolerances of thermal controls. The design trades are not complete, and the team will accommodate the coronagraph to the extent they can.

Approve Senior Review TOR

Dr. Hertz explained that a subcommittee of APAC will conduct the SR, which will report to APAC. The Committee first needed to approve the Terms of Reference (TOR). Two other ACs have gone through a similar process.

Dr. Jeffrey Hayes then presented a list of the 11 APD missions in operation. There will be 9 or 10 in the SR, depending on the clarification of the language about SOFIA from Congress. The SR, which looks at the suite of operating missions, will occur in the first half of 2019. Four subcommittees will report to the SR: one each for Chandra, HST, and SOFIA (if it is included), along with a subcommittee for the remaining missions. Previously, Chandra and HST were exempt from competing with the other missions, but now they will be treated the same. This is a fundamental change. Essentially, the SR is a cost-benefit analysis.

The chair of each subcommittee will be on the SR panel, along with other members. Dr. Hayes needed APAC approval in order to develop the panel. He expected to call for proposals later in 2018, with a due date in early 2019. The subcommittees will then meet, the SR panel will meet, APAC will receive a report to approve, APAC will approve or disapprove with formal recommendations, and the final report will go to NASA.

Dr. Boyd asked to have a map of the new structure to the old. Dr. Hayes explained that the subcommittees to the SR were the committees of the past. The SR is the consolidating organization, and it will provide a ranking. All four subcommittees will have comprehensive reviews to make them equal. The exact number of members on the SR committee is yet to be determined. Dr. Gaudi asked if there were any concern about double jeopardy due to missions being ranked twice. Dr. Hertz said that this is not a concern. If the SR committee accepts the order of the six missions in the remaining-missions subcommittee, it will insert the others into the overall ranking. The SR does not make the financial decisions, but instead assesses the costs and benefits of extending the operating missions, producing a ranked list. APD will then make funding decisions based on the output, which is what has occurred previously. The SR provides the findings, which are the ranked list and verbiage. That report goes into APD budget formulation. The APAC role is to accept or reject the report before it goes to APD, and Committee members can add comments. The HST and Chandra budget lines are planning budgets, and APD uses the SR to decide whether or not to extend them. The change is driven by the determination that the SR must be done under a FACA umbrella, and the Agency has decided to have the SRs report to the ACs. The divisions cannot continue as they did before.

Dr. Boyd still had concerns. In the past, the remaining-missions panel was put together carefully, but she was hearing that HST and Chandra are being worked in. Dr. Hertz said that APD has thought about that. The Division has not yet populated the panels, and will make sure to have the right people on them. One thought is to have the whole remaining-missions panel be on the SR, along with the Chandra and HST chairs, but that is still being worked out. APD wants to make sure that SOFIA, HST, and Chandra are treated fairly by the remaining-missions panel.

Dr. Gaudi said that there was an action item to approve the TOR. He asked if there were any members opposed. As there were none, APAC unanimously approved the TOR.

Webb Update

Dr. Eric Smith, JWST Program Officer, said that the most significant of the recent activities was the SRB assessment, at the 70 percent confidence level, of a launch readiness date of about May 2020. This assessment triggered a schedule breach that required a letter to Congress, along with a new plan. The IRB is examining remaining activities; its findings will form part of the input to establish the new launch date. There have been changes across the program to improve performance. The breach triggers a formal process of who gets notified when, which is why the community did not hear of it right away. Dr. Hertz explained that the letter to Congress said that JWST definitely breached the schedule and will likely breach the cost cap. Because there is a breadth of opinion about the latter, the wording was “likely” instead of “definitely.”

Dr. Smith then reviewed the testing schedule. The environmental tests will take up to 4 months, and the telescope has a few more deployment tests before it is ready for integration. The Optical Telescope element/Integrated Science (OTIS) payload is off the critical path. The Cycle 1 GO proposal due date has been moved to February 2019. Dr. Smith showed a rough accounting of the reasons for the delay in the launch, which involves 15 months of technology issues and 3 months of additional funded schedule

reserve. The repairs to sunshield tears are assumed to take 2 months, with budgeted extra time. As for tears that might occur on deployment, the two largest tears resulted from mis-threading, and the others were from handling. The team is assuming that those will occur again, but they were very small and unlikely to affect performance. The sunshields do not have to be 100 percent with no tears to meet Level 1 requirements; there are perforations (for membrane release devices for example) by design.

Commissioning will be an extremely slow process, and the lessons learned have not yet affected the commissioning timeline. There were three separate propulsion system issues. First was a damaged pressure transducer that occurred in late 2016, requiring reproduction. In May 2017, the dual thruster modules were found to be leaking and went back to the manufacturer. Another problem was identified during testing. These all took about a year to resolve, but they ran in parallel to sunshield delays, and prior to thermal vacuum testing. The membrane tensioning system during the first deployment system had a snag in which cables went awry, so the team designed channels for the cables. All of this must be tested now. Dr. Smith showed the remaining I&T activities, noting that this is where they learn things and activities slow down. The whole thing has to work, so they are going to be careful and deliberate. Some of the activities could change following the IRB report. The spacecraft element testing will occur after the rebuild of the thrusters. Everything will be verified to work before environmental testing, and everything is tested twice.

Dr. Gaudi thought some of the mistakes seemed rather amateur, and wondered how they would be prevented in the future. Dr. Smith replied that there were two kinds of mistakes. First, there were errors on the floor, largely in propulsion by Northrup Grumman, which has acknowledged this. A procedure that was poorly written has now been fixed. He gave the example of an unverified cleaning solution being used on valves. There will now be more people involved in procedure review. The second type of mistake had to do with the sunshield, which is totally new. Some aspects of it did not behave as predicted. This is why they test – in order to learn. The first category of mistake was avoidable, and the second is initial learning.

Dr. Jones asked if there were subsystems or components that can only be tested in a thermal vacuum. Dr. Smith referred to the mate of the spacecraft and the science payload. This involves three things: the hardware mate, electrical, and the field joint. There is not a workmanship issue here that a thermal vacuum test will reveal. A full-up system has tested the compressor lines for the cryocooler. Dr. Gaudi asked about the reserve rundown chart. Dr. Smith said that that that went to zero when they moved the launch date because all of the schedule reserves had been consumed. The process now is to say they have X months to launch, and ask how much reserve they need. Once the Agency sets a new launch date, he will be able to share the new schedule information, though not the cost reserves. The team will build in both cost and schedule reserves for the new launch date. Dr. Batalha asked why APAC was just now hearing about some of the errors that happened a while ago. Dr. Smith replied that the earlier presentations had a step, 13 or 14, that bit into the schedule. There were other bites, and additional needs or liens from Grumman. A lot of this happened late in the summer of 2017, so the chart was no longer meaningful and he quit showing it.

Dr. Alan asked why OTIS was at the Johnson Space Center (JSC) for thermal vacuum testing rather than at Grumman. Dr. Smith said that the decision was made years ago so as to not set up conflict with demands for the Grumman chamber. Dr. Jones asked whether the fully integrated telescope would fit into the largest chamber. Dr. Smith said that it would not, due to the ground equipment also needed. Undeployed, it would fit in at JSC. He described the deployment process, beginning with the solar array

coming out at 30 minutes after launch, then the antenna after several hours. It is a months-long process to phase up the mirrors, with a lot of temperature-balancing activities.

TESS Update

Dr. George Ricker, TESS PI, explained that the mission was scheduled to launch early the next week. He listed institutions involved in the program and noted that, in addition to the people directly involved, TESS has what they jokingly call "groupies" who follow the mission. Dr. Gaudi said he worried that the overlap between TESS and JWST will be lost. Dr. Ricker agreed that this is a concern, though if TESS gets an extended mission, some of the targets can be refreshed. He showed a photo of TESS in the clean room. The mission is quite compact. It was to go up on a Falcon 9, the lowest-cost launch vehicle. The two fairing halves take a long time to align on Earth but will be faster on orbit.

The number of articles referring to TESS was fairly strong, given that it had not yet launched. TESS is the highest etendue space mission flown, and will survey the solar neighborhood. He compared TESS and Kepler. Many of the Kepler/K2 targets are too faint for TESS, which will survey closer objects primarily. The Level 1 requirements include surveys of smaller planets and shorter distances. TESS will search for exo-Earths, super-Earths, and mini-Neptunes; provide photometric data for about 20 million stars and 10 million galaxies; and provide data for ground-based analyses of transiting planets. The mission will have a novel high-Earth orbit, which will both enable and simplify TESS. Dr. Ricker described the observational scenario, which is away from the sun, and the likely field of view. The focus shift, which had been discussed at a previous meeting, is not a problem. The detection, imaging, validation, and measured masses have been worked out extensively. Dr. Ricker also described the depth on timescale and luminosity.

Dr. Ozel asked about the status of the ground-based support. Dr. Ricker said that there must be quick identification of the targets of interest. Both U.S. and international facilities and organizations will be involved. Dr. Gaudi was concerned about smaller planets, which might justify an extended mission. Dr. Ricker said the team wanted to make TESS as simple as possible, including the operations. The Level 1 requirements are for smaller planets, but TESS will also focus on systems with bright host stars. As for telescope time, some facilities have contributed large blocks of observing time, and there are multiple facilities that will help the effort.

Update: NAS Astrobiology and Exoplanet Studies

Dr. Meadows explained that the new NASA Authorization Act of 2017 added an objective to search for life in the universe, which led to formation of an exoplanet committee and an astrobiology committee. The astrobiology strategy involves international partners, as well as the private sector. The charge from NASA to NAS included: identification of key scientific questions, technology challenges, and research goals in astrobiology, emphasizing the search for life beyond Earth; discussion of which key goals could be addressed by NASA and its existing and potential international partners; and recommendations for advancing research and obtaining measurements needed to address NASA's goal of seeking signs of life in the universe. This work is to be done in consultation with the committee concurrently working on the exoplanet science strategy charge.

The NASA charge to NAS for the exoplanet science strategy was similar, and included: surveying the status of exoplanet science, to consider current and planned missions such as TESS, JWST, and WFIRST; outlining the key scientific questions for exoplanet science, research, measurements, and technologies; and discussion of which of the goals could be addressed by current DS priorities. Again, there was an emphasis on collaboration with international, commercial, and not-for-profit partners.

Dr. Meadows listed the membership of the committees. The study schedule is quite ambitious, and the two committees have a joint subcommittee to study coordination.

Public Comment Period

The meeting was opened for public comment. Dr. Kimberly Ennico from the Ames Research Center (ARC) spoke regarding Dr. New's presentation on D&I. She suggested that for workforce development, NASA have each mission, whether already in operation or in development, support an active mentoring program for a period of 6 months.

Discussion

Dr. Gaudi said that he had crafted an email to Dr. Zurbuchen regarding the COI issue, similar to what he said at the start of the meeting. Most APAC members had signed it, and the others were welcome to do so, though there was no obligation. The letter stated that over time, the COIs have been more restrictive and applied more broadly, and some of these instances were hard to understand. APAC was unable to make recommendations regarding WFIRST because the COIs prevented the Committee from having a quorum for the presentation. The Committee discussions are general. It is hard for APAC members to do their jobs with this level of scrutiny. The COI rules hamper their effectiveness, and APAC would like Dr. Zurbuchen's help in brokering a compromise. Dr. Gaudi said that he would send it to Dr. Hertz before sending to Dr. Zurbuchen. If it changed significantly after Dr. Hertz's review, he would send it out to APAC members again.

Recommendations, Actions

Regarding SOFIA, Dr. Boyd suggested that APAC recommend having a review of some sort, even if it does not involve comparison to other missions. Dr. Moustakas pointed out that the TOR would involve a close look at the cost, and he was not sure how APAC might ask for it in a different review. He would want to see explicit science return and potential. Dr. Bautz thought APAC should decouple SOFIA and the SR. Dr. Moustakas repeated his desire to have a sense of future potential, but Dr. Jones said he would prefer to avoid being speculative. Dr. Gaudi was concerned that this would take a lot of work to be complete and, in fact, APAC did want SOFIA to go to SR as stated in a previous recommendation. Dr. Wang advised stating the core criteria from the SR TOR in the APAC recommendation, and Dr. Dingus said that any review should be done within the next 2 years. Dr. Bock suggested saying that APAC expected SOFIA to go to the SR, and if that is not appropriate, there should be a formal review. There was debate about wording, the Congressional direction, and the existing law stating that SOFIA must be reviewed. It was eventually agreed that APAC would say that reviews provide useful feedback, the SOFIA mission team wants a review, and APAC wanted input to the TOR for whatever review occurred with SOFIA.

It was also agreed that it was too soon to say anything about Spitzer. The letter to Dr. Hertz would note that APAC approved PhysPAG's new SAG. Regarding input on possible delay of the DS, Dr. Sheth noted that Dr. Zurbuchen's request that NAS consider this was a recent development. CAA will discuss it at one of their regular meetings. Dr. Gaudi planned to ask the PAGs to discuss the impact of any delay, adding that the APD DS had already been delayed by 6 months. Dr. Meadows pointed out that Dr. Hertz wanted any input to go to CAA; she thought this should be stated in Dr. Gaudi's communication with the PAGs. It was noted that if the word got out, the community will talk about it and go to the CAA anyway. Dr. Gaudi left his statement as it was.

The PAG responses on interdisciplinary and interdivisional research had been quite varied and there was no consensus. Dr. Sheth said that APD was collecting data, and that Appendix E of the ROSES call is for APD/PSD crossovers. Dr. Gaudi said that since APAC did not have a coherent answer, he would state that there is no need for additional funding. APAC also felt like most COPAG and PhysPAG input was anecdotal and therefore inappropriate as the basis for a decision. When Dr. Moustakas said that he did not feel the community was polled sufficiently, Dr. Gaudi noted that SMD wanted APAC to make the decision, and he was not comfortable with that. The Committee's attempt to get input resulted in a mess. He advised letting APD get the data, and then APAC can react to those data.

Dr. Gaudi thanked Drs. Wang, Bock, Batalha, Cornish, and Kalirai for their service on APAC and its predecessor, the Astrophysics Subcommittee (APS). He would be completing his term as well.

The letter from APAC was to go to Dr. Hertz. Dr. Gaudi would summarize the presentations given and thank the presenters, then make the points APAC had discussed. Everything would go into that letter aside from the separate letter to Dr. Zurbuchen. There would be a few iterations and some editing.

Adjourn

The meeting was adjourned at 3:47 p.m.

Appendix A
Participants

Committee members
B. Scott Gaudi, Ohio State University, *Chair, Astrophysics Advisory Committee*
Natalie 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
John Conklin, University of Florida
Asantha Cooray, University of California, Irvine
Neil John Cornish, Montana State University
Brenda Dingus, Los Alamos National Laboratory
Kelly Holley-Bockelmann, Vanderbilt University
William Jones, Princeton University
Jason Kalirai, Space Telescope Science Institute
Victoria Meadows, University of Washington
Leonidas Moustakas, NASA JPL
Feryal Ozel, University of Arizona
Paul Scowen, Arizona State University
Yun Wang, NASA JPL
Beth Willman, University of Arizona

NASA attendees
Paul Hertz, NASA HQ, *Director, Astrophysics Division*
Zaven Arzoumanian, NASA Goddard
A.F. Barghouty, NASA
Dominic Benford, NASA HQ
Rita Carter, NASA GSFC
Joan Centrella, NASA HQ
Tony Comberiate, NASA JPL
Valerie Connaughton, NASA HQ
Lucien Cox, NASA HQ
Patricia Daws, NASA AFRC
Debra Fairbrother, NASA Goddard
Mike Garcia, NASA HQ
Shahid Habib, NASA
Thomas Hams, NASA HQ
Hashima Hasan, NASA HQ, *Executive Secretary, APAC*
Jeffrey Hayes, NASA HQ
Richard Kelley, NASA Goddard
Patricia Knezek, NASA HQ
Jeanette Le, NASA AFRC
David Leisawitz, NASA GSFC
Stefan Miller, NASA HQ

Susan Neff, NASA Goddard
Michael New, NASA HQ
Mario Perez, NASA HQ
Rob Petri, NASA Goddard
Aki Roberge, NASA Goddard
George Sarver, NASA AFRC
Kartik Sheth, NASA HQ
Eric Smith, NASA HQ
Martin Still, NASA HQ
Eddie Zavala, NASA Ames

Non-NASA attendees
Grace Hu, OMB
John O'Meara, St. Michael's College
Elizabeth Sheley, Zantech
Jason Tomlinson, STSci
Nicholas White, USRA
Ashlee Wilkins, AAS
Harold Yorke, USRA

Webex/Telecon
Sara Barber, U.S. House of Representatives
Tim Beach, NASA Goddard
Jeffrey Booth, NASA
Teresa Brandt, NASA
Lisa Bryant, NASA Goddard
Stephen Clark, Space Flight Now
Dominick Conte, Millennium Space Systems
Brendan Crill, JPL
Monty DiBiasi, SWRI
Shawn Domagal-Goldman, NASA
Debora Fairbrother, NASA
Jeff Foust, Space News
David Gaba, Stanford
Jonathan Gardner, NASA
Timothy Gehringer, USAR
Ellen Gertsen, NASA
Lizzie Gringuala, NASA
Thomas Hanns, NASA
Colleen Hartman, NASA
Liz Hays, ESF
Joanne Hill-Kittle, NASA Goddard
Grace Hu, OMB
Misha Intabosh, European Space Agency
Bernard Kelley, NASA
David Leisawitz, NASA
Shari Lifson, Aura
Charles Lillie, Lillie Consulting

Sara Lipscey, Ball Aerospace
David Leisawitz, NASA
James Lochner, USRA
Jonathon Lunine, Cornell University
John Mather, NASA Goddard
Michael McElwain, NASA Goddard
Julie McHenry, NASA Goddard
Richard Mushotzky, University of Maryland
Susan Neff, NASA
Thai Pham, NASA
Naseem Rangwala, NASA Ames
Neill Reid, STSCi
Mitsene Rodewala, NASA Ames
Nick Saab, Louisburg Associates
Rita Sambruna, NASA
Rick Schwarz, B V Ventures
Kendra Short, JPL
Marcia Smith, Space Policy Online
Karl Stapelfeldt, JPL
Massimo Stiavelli, STSCi
Craig Towney, NASA
Ben Tucker, Brown University
Azita Valinia, NASA
Nicholas White, USRA
Ashlee Wilkins, AAS
Rogier Windhorst, Arizona State
Alexandra Witze, Nature Magazine
Erick Young, USRA

Appendix B
NAC Astrophysics Advisory Committee Members

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

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

Natalie Batalha
NASA-Ames

Marshall (Mark) Bautz
Massachusetts Institute of Technology

James J. Bock
Jet Propulsion Laboratory

Alan Boss
Carnegie Institution of Science

Patricia Boyd
Goddard Space Flight Center

Laura Brenneman
Goddard Space Flight Center

John Conklin
University of Florida

Asantha Cooray
University of California, Irvine

Neil John Cornish
Montana State University

Brenda Dingus
Los Alamos National Laboratory

Debra Fischer
Yale University

Kelly Holley-Bockelmann
Vanderbilt University

William Jones
Princeton University

Jasonjot (Jason) Singh Kalirai
Space Telescope Science Institute

Victoria Meadows
University of Washington

Leonidas Moustakas
Jet Propulsion Lab

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. *ExoPAG Report*, Victoria Meadows
3. *PhysPAG Report*, John Conklin
4. *COPAG Report,* Paul Scowen
5. *HabEX STDT Update*, Scott Gaudi
6. *Lynx STDT Update*, Feryal Ozel
7. *OST STDT Update,* Asantha Cooray
8. *LUVOIR STDT Update,* Debra Fischer, Aki Roberge
9. *Response to the High-Risk/High-Reward Challenge,* Scott Gaudi
10. *Balloon Program Update*, Debora Fairbrother
11. *Diversity and Inclusion*, Michael New
12. *WFIRST Update*, Jeff Kruk
13. *2019 Astrophysics Senior Review*, Jeffrey Hayes
14. *NICER Update,* Zaven Arzoumanian
15. *James Webb Space Telescope,* Eric Smith
16. *TESS Update,* George Ricker
17. *Astrobiology Science Strategy Committee and Exoplanet Science Strategy Committee Updates,* Victoria Meadows

Appendix D
Agenda

Astrophysics Advisory Committee
April 11-12, 2018
NASA Headquarters
Washington D.C.

Wednesday, April 11, 2018

9:40 a.m.	Introduction and Announcements	Scott Gaudi/Hashima Hasan
9:45 a.m.	Astrophysics Division Update	Paul Hertz
11:45 a.m.	Discussion	APAC members
12:00 p.m.	Lunch	
1:00 p.m.	ExoPAG Report	Vikki Meadows
1:20 p.m.	PhysPAG Report	John Conklin
1:40 p.m.	COPAG Report	Paul Scowen
2:00 p.m.	HabEx STDT Report	Scott Gaudi
2:15 p.m.	Lynx STDT Report	Feryal Ozel
2:30 p.m.	OST STDT Report	Asantha Cooray
2:45 p.m.	LUVOIR STDT Report	Debra Fischer
3:00 p.m.	Break	
3:15 p.m.	APAC Report on High Risk/ High Reward R&A Charge	Scott Gaudi
3:30 p.m.	Discussion	APAC members
3:45 p.m.	Balloon Program Update	Debora Fairbrother
4:15 p.m.	Public Comment Period	
4:20 p.m.	Discussion	APAC Members
5:00 p.m.	Adjourn Day 1	

Thursday, April 12, 2018

8:50 a.m.	Opening Remarks	Scott Gaudi
9:00 a.m.	Q&A with SMD AA	Thomas Zurbuchen
10:00 a.m.	Diversity & Inclusion	Michael New
11:00 a.m.	Break	
11:15 a.m.	WFIRST Update	Jeff Kruk
11:45 p.m.	Approve Senior Review TOR	Jeffrey Hayes
12:15 p.m.	Working Lunch	
12:45 p.m.	*Science Talk: NICER*	Zaven Arzoumanian
1:15 p.m.	Webb Update	Eric Smith

2:00 p.m.	TESS Update	George Ricker (remote)
2:30 p.m.	Update: NAS Astrobiology & Exoplanet Studies	Vikki Meadows
2:45 p.m.	Public Comment Period	
2:50 p.m.	Break	
3:05 p.m.	Discussion	APAC members
4:00 p.m.	Recommendations, Actions	Scott Gaudi
4:30 p.m.	Brief to Hertz	Scott Gaudi
5:00 p.m.	**Adjourn**	