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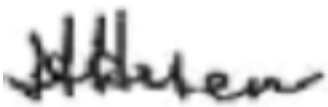
MEETING MINUTES

4/20/2015

B. Scott Gaudi, Chair



4/9/2015

Hashima Hasan, Executive Secretary

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Tuesday, March 17, 2015

Introduction and Announcements

Dr. B. Scott Gaudi, Chair of the Astrophysics Subcommittee (APS) of NASA's NASA Advisory Council (NAC), opened the meeting by reviewing some of the Federal Advisory Committee Act (FACA) rules. These included the following: the meeting was open to the public and therefore no proprietary information was to be discussed; only public discussion among APS members was to factor into APS decisions; the public would have a comment period but otherwise only APS members were to speak unless recognized by the chair; and government ethic rules applied. Dr. Gaudi next asked the APS members to introduce themselves. New members as of this session were Dr. Alan Boss, Dr. Patricia Boyd, and Dr. Marshall (Mark) Bautz.

Astrophysics Division Update

Dr. Paul Hertz, Director of NASA's Astrophysics Division (APD), began his update of Division activities with a brief review of the budget. Although he has heard concern about the fact that the budget does not allow full implementation of the 2010 Decadal Survey (DS), Dr. Hertz is pleased that the DS lays out priorities. APD has been using the time well in order to have a better Wide-Field InfraRed Survey Telescope/Astrophysics-Focused Telescope Assets (WFIRST/AFTA) than the Division would have had otherwise. Other investments have been driven by the DS as well, including partnerships, the Explorers program, the Research and Analysis (R&A) program, and all other investments. There is a lot that can be done with a flat budget and crisp priorities. The budget is $1.3B, which is a lot. Even with half of that spent on the James Webb Space Telescope (JWST), it is a large amount.

Science Highlights

The Chandra mission recently detected a record-breaking outburst from the Milky Way's black hole. The Hubble Space Telescope (HST) has found distortion of a circumstellar disk by a planet, which is a preview of what astronomers will see with JWST and WFIRST/AFTA. The Nuclear Spectroscopic Telescope Array (NuSTAR) has produced the first spatially resolved hard x-ray image of the sun. This helps map the source regions. A citizen-scientist project examining Spitzer data found a "yellowball," which is a stage of star formation. Astronomers do not always have time to pour over all of the data, but citizen-scientists often look at these and find items that a computer cannot identify. This shows the value of making data public and sharing training tools. The Kepler mission continues to find more small, rocky planets in habitable zones, while it also finds planets in longer periods.

Dr. Hertz added that at each APS meeting, he updates the status of DS implementation. Two years ago, APD published the DS implementation plan, and updated it again at the end of 2014. APS reviewed this at the last meeting, and he appreciated their help.

Budget

Both the Fiscal Year 2015 (FY15) appropriation and the President's FY16 budget request maintain APD spending at about the $1.3 billion level, fully support JWST on a track to launch in late 2018, and support pre-formulation activities for WFIRST. In addition, both restore the Stratospheric Observatory for Infrared Astronomy (SOFIA) mission to the budget. SOFIA had been taken out of the FY15 budget request, but Congress restored most of that money. The FY16 budget request includes SOFIA funding, but it also requires that SOFIA go into the 2016 Senior Review.

The Science Mission Directorate (SMD) education programs are being restructured and put into a single budget category that is incorporated in the APD budget. This is consistent with the SMD practice of including certain items within the budgets of specific divisions. In the FY15 request, the White House

sought to pull education out of SMD altogether, but Congress kept it there. The FY16 request keeps education in SMD at a lower funding level. The White House had wanted to consolidate all education activities across agencies in FY15, but Congress disagreed in regard to NASA. The exact funding amount in FY16 will result from the appropriations process. SMD intends to select and begin funding education in the current fiscal year. Some of that is transitional from the previous mode of each mission having its own educational component, but some funds will go to the awardees immediately in order to start at high level as the budget process plays out.

The FY15 appropriation provides $77 million more than the President's request. APD was directed to spend $50 million on pre-formulation of WFIRST/AFTA, an increase of $36M over the Administration request. Other directed spending included $70 million for continued SOFIA operations, $98 million for HST, and $38 million for scientific balloon operations. The directed spending required APD to reduce the rest of the Division budget by about $40 million. The difference was made up by a lower-than-expected cost for the TESS launch vehicle and by projects that were underspending in the current year and could roll over funds. This roll-over occur on a continual basis because most projects do not spend as quickly as anticipated in their initial budgets.

The appropriations language directed APD not to terminate any missions without a review. This was in response to the SOFIA decision. If the budget were to decrease substantially and APD could not terminate a mission, that would be a major problem. The rule of thumb is that costs moved into the future will triple because of the replanning. That is why negotiations for the funding profile are so important, and the reason that NASA sometimes does not know what something will cost. There may seem to be more directed items this year, but that was not unexpected. If there is a big budget cut, the main safety valve is new R&A selections. APD's priority is keeping commitments to those projects and research investigations that have already been selected. Most funds go to prior commitments.

Missions

Continued successful integration of JWST is one of NASA's primary expected Agency-level accomplishments in FY16. The Neutron-star Interior Composition Explorer (NICER) launches next year and the Transiting Exoplanet Survey Satellite (TESS) launches the year after. In the budget, the funding profile required for WFIRST is referred to as "the Astrophysics Decadal Strategic Mission." The amount of spending in the current year on WFIRST primarily affects the risk posture and should not affect the launch date. APD is working on retiring technology risk and investing in engineering trade studies. The coronagraph is considered a high-risk item, but a recent design reference mission (DRM) assessed by Aerospace Corporation did not rank the coronagraph among the top three concerns and expressed confidence in the plan. The funding for JWST is a major factor in the WFIRST launch date, as the JWST spending must roll over in order for the WFIRST budget profile to grow. With a flat budget, it would be very difficult to change this by advancing the WFIRST launch date.

APD hopes to select two small Explorer (SMEX) missions and two Missions of Opportunity (MoOs) this year, with a down-selection later. Funding for SOFIA is included in all of the out-year budgets, and funding exists for HST to overlap JWST. TESS has been re-labeled as a mid-sized Explorer (MIDEX) and has a better launch vehicle than previously planned. APD has maintained the cost caps for SMEX and MIDEX missions, but the cost caps do not include launch vehicles.

NASA will partner with the European Space Agency (ESA) on the Athena mission and hopes to partner on the gravitational wave mission ESA will do. However, these partnership commitments will not show up in the budget as projects until NASA has formally started the project with a KDP-A decision. At this point, it is not yet clear what NASA will contribute on Athena. There is a hardware limit of $100-150 million, however. As for funding for Hubble postdoc fellows, that money is fenced off and cannot be traded with Hubble mission operations. Congress will start the budget mark-up process soon.

JWST is doing fine in terms of cost and schedule. The mission still has reserves and no one is expecting to miss the launch date. There are challenges, however, including the Mid-infrared Instrument (MIRI) cryocooler and the telescope harnesses. In 2014, mission accomplishments included the third cryovac test of the Integrated Science Instrument Module (ISIM) and deployment testing of the full-scale engineering unit sunshield. The team also practiced mounting the mirrors into the backplane. The engineering unit has been shipped. In 2015, the mission team is testing ISIM prior to integration into the observatory, preparing for the 2016 test of the full telescope and instruments, completing the MIRI cryocooler, and beginning assembly of the primary mirror. Dr. Jason Kalirai noted that although much of the current emphasis is on hardware, the science and community activities are also coming into focus.

Dr. Hertz explained that events are being planned for the 25th anniversary of HST, and gave some examples. Dr. Kalirai added that he had just returned from the large South by Southwest (SXSW) event, at which thousands of people visited the NASA exhibit. A NASA panel discussion had a line outside, and everything went amazing well. Dr. Hertz noted that the HST celebration will take over Times Square in one of the events.

The K2 version of the Kepler mission is going extremely well. Over the life of the mission thus far, Kepler has discovered approximately 4,200 exoplanet candidates, with more than 1,000 of those confirmed as exoplanets, and more than 100 exoplanets discovered in their star's "habitable zone." ESA's Laser Interferometer Space Antenna (LISA) pathfinder mission is ready for launch in September. Integration of Astro-H instruments is going well in Japan. This is a very large and impressive observatory. The Japanese Space Agency (JAXA) will announce the launch date 2 months ahead of time. NICER is on track and integration has begun, moving toward a 2016 launch. TESS is also going very well. Supporting ESA's Euclid mission has been challenging. NASA is providing the detector assembly for the near-infrared spectrometer and photometer (NISP) according to ESA specifications, but this is taking longer than expected at their end. On Athena, NASA could contribute the sensor array to the x-ray integral field unit, portions of the x-ray mirror, and/or the U.S. science data center. This is still under discussion.

NASA and the National Science Foundation (NSF) have signed an MOU for a facility-class Doppler spectrometer on the WIYN telescope. APD has received about 25 Explorer proposals. Dr. Priscilla Cushman would talk to APS the next day about a study on proposal pressures. Dr. Hertz showed the relative balance of R&A selections. The DS advised increases in the suborbital area. Funding has grown slowly, while the number of proposals has doubled and the percentage of selections has gone down. Growth in the Astrophysics Data Analysis Program (ADAP) is the largest driver of the increase in proposals.

DS and Mid-Decade Review

The mid-decade review is moving forward. The National Research Council (NRC) is likely to announce the committee and schedule soon, with the first meeting to be held in Washington, DC, during the summer, the second meeting in Irvine, CA, in the fall, and the third meeting in the winter. APS should expect a report next summer. Dr. Hertz added that he has no role in setting up the study committee.

At the last meeting, Dr. Hertz charged the program analysis groups (PAGs) with generating comments and input for the next DS. The initial short list of large mission concepts that he asked the PAGs to consider include: a far IR surveyor, a habitable exoplanet imaging mission, a UV/optical/IR surveyor, and an x-ray surveyor. He would like probes to be considered later.

Ten years ago, in preparation for the 2010 DS, there were two rounds of probe studies, the second being a 2007 Research Opportunities in Earth and Space Science (ROSES) call for astrophysics mission concepts

studies. APD conducted 19 of these studies in addition to one that was already underway. This time there may be a call for real mission concept studies, paper mission concept studies for probes, and/or white papers submitted to the DS committee. Dr. Hertz would like the DS committee to recommend that APD have a probes program similar to the Planetary Sciences Division (PSD) New Frontiers program, with the DS suggesting the best science objectives. However, this was suggested for the previous DS, and it was rejected. Dr. Joel Bregman said that he would like to see more frequent research opportunities across a range of levels, with specific guidance as to what constitutes a SMEX, a probe, etc. Dr. Hertz noted that this would have to be for the next DS, as the mid-decade review does not change DS priorities.

Balloon Program Update

Dr. Vernon Jones, Senior Scientist for Suborbital Research and Balloon Program Scientist, presented an update on the balloon program. Antarctica is the centerpiece of this program. Since 2002, 15 flights have lasted at least 30 days, with a 96-day campaign in FY13. The FY14 campaign was stopped by the shutdown of the Federal government. In FY15, there were three Antarctic launches: the Antarctic Impulsive Transient Antenna (ANITA), the Large Angular Scale Millimeter-wave Polarimeter (SPIDER), and the Compton Spectrometer Imager (COSI) on a Super-Pressure Balloon (SPB). There are only two candidates for the FY16 campaign at this point.

NSF supports the program through a range of logistics activities for which NASA provides reimbursement. As the payloads become larger and larger, NASA would like to have a third payload facility. The funding for such a facility is available, and the goal is to have it established for FY17. NASA has been working with NSF to ensure three launches each season.

Dr. Jones explained the distinction between super-pressure balloons (SPBs) and ultra-long duration ballooning (ULDB), which are sometimes mistaken for the same thing. SPBs offer increased capabilities, and ULDBs last 60-100 days. COSI was planned as an extended flight of 60-100 days, with potential recovery off of Antarctica. However, it ran into problems and only lasted for two days. ANITA lasted just over 22 days, and SPIDER went for 15 days. The British Antarctic Survey (BAS) recovered a portion of the SPIDER payload; retrieval of the remainder is still being worked out. The Australians picked up ANITA's large structure. For COSI, everything that will be recovered has been recovered.

The inflated SPB is huge, with a pumpkin shape. Dr. Jones compared its altitudes and temperatures with those of zero-pressure standard balloons; the SPBs are very steady, with a constant altitude and longer duration. They are also more expensive. The SPB balloon is completely sealed, with enough helium to keep it fully inflated at the coldest temperatures.

The program has other launch sites in Australia, New Zealand, Sweden, Canada, Texas, and New Mexico. The New Zealand site is new. Although fewer balloon missions are launched now than in the 1990s, the average float hours per flight have gone up. NASA has agreements in place with Southern Hemisphere countries so that the Agency can fly the balloons over them and recover the payloads. Simulations indicate a 75 percent chance of landing in South America, but NASA assumes that payloads will be lost. The payloads are constructed to sink, taking the balloon with them, when they land in the ocean.

Highlights of the past year include the successful test flight of the Low Density Supersonic Decelerator (LDSD), two successful Wallops Arc Second Pointer (WASP) test flights, and the ninth High Altitude Student Platform (HASP) mission. The LDSD test was conducted in Hawaii by NASA's Space Technology Mission Directorate (STMD). This is a new capability that relates to STMD's Mars efforts. Orbital Sciences also became the new contractor for the Columbia Scientific Balloon Facility (CSBF), hiring many of the employees already working on the contract.

The suborbital research program is managed by SMD, and balloons are part of that. Since FY11, SMD has launched 114 sounding rocket and balloon missions, providing 3,900 undergraduate and graduate students with opportunities to participate. The program is involved in all of the research disciplines one might think of, such as gamma ray research and cosmic ray investigations.

Dr. Hertz noted that the budget augmentation involves the vehicles, not the payloads, while the latter constitute the primary limitation for the program. Dr. Boss asked about the impact of the new safety recommendations that stemmed from an accident a few years ago. Dr. Jones replied that NASA has implemented the recommendations, and although a base needed to be shifted, the new safety policies have not caused issues. He added that NASA must notify the safety offices in all of the countries that the balloons fly over.

ExoPAG/PhysPAG/COPAG Updates

ExoPAG

Dr. Gaudi presented an update on Exoplanet PAG (ExoPAG) activities, beginning with a list of the executive committee membership. Dr. Boss is taking over as chair. The overarching goal is to "[d]evelop a holistic, broad, unified, and coherent exoplanet plan for the next decade, with community consensus, focusing on areas where NASA can contribute." Since the last APS meeting, ExoPAG held its eleventh meeting, closed out two study analysis groups (SAGs), and introduced new topics for SAGs. The PAG also held a mini-workshop on what investigators need to know about exoplanet host stars, and had a joint meeting with the Cosmic Origins PAG (COPAG). Finally, ExoPAG began planning for the next DS, initiated a science interest group (SIG) discussion, and discussed Dr. Hertz's charge to the PAGs.

ExoPAG has determined that a lot of telescope time is needed for precision radial velocity (RV) work. It is important to understand how this work ties in with other surveys, what is needed to characterize exoplanets, and what JWST will enable. As for the SAGs, SAGs 1, 2, 5, and 11 are completed. SAGs 9 and 12 are ongoing, and SAGs 8 and 10 are waiting to be closed out. SIG1 was approved a year ago in order to develop a holistic, broad, unified, and coherent for exoplanet exploration, focusing on possible NASA contributions. The idea is to build community consensus for a coherent plan for exoplanets over the next 5 to 10 years.

One of the two closing SAGs, SAG10, addressed characterization of transiting planet atmospheres through 2025, and a paper has been accepted for publication. The SAG determined that JWST will characterize the atmospheres of dozens of short-period planets with transits, eclipses, and phases. Some of this will also be done by TESS. JWST will provide interesting constraints on a few habitable zone (HZ) rocky planets transiting M-Dwarfs. Future flagship missions must be able to constrain the habitability of these worlds. This will be a topic in responding to Dr. Hertz's charge. SAG8 addressed RV, showing specific missions that will or do support certain mission science objectives. The conclusions included several ways in which to address the gaps.

In response to Dr. Hertz's charge regarding large missions, ExoPAG was already working on this through the SIG. The group hopes to understand how any large missions they might recommend will fit into the entire range of missions, and have done some thinking about this, taking into account the Astrophysics Roadmap. Thus far, there have been many suggestions. A meeting at the Jet Propulsion Lab (JPL) had 45 participants. Discussion was animated, resulting in a consensus that a broad range of direct imaging mission apertures and architectures should be studied. There was no consensus about how to organize the study teams. Participants discussed whether they should attempt to prioritize direct imaging mission concepts or if this can even be done at the PAG level. There was a diversity of opinion on this issue. Dr. Hertz noted that he is not setting priorities, but rather creating a list of what should be studied.

Dr. Gaudi gave a timeline for upcoming ExoPAG activities, including a joint executive committee session with COPAG, a draft SIG report to APS in the fall, and the final SIG report in January 2016. The majority viewpoint is that the selected mission should do some direct imaging, although adding spectroscopy might not cost that much more. The transiting planets will be disjoint from the direct imaging planets. The science technology definition team (STDT) should study whether there might be innovations that can be done in optical and IR that will allow very large IR mirrors at lower weights and costs.

Dr. Kalirai observed that, regarding JWST, anyone trying to predict forward 5 years ago to today would be wrong. So when he looks at what people might propose, he thinks there are lots of galaxies and planets that have not yet been looked at and wonders if there is a benefit in looking at more. Dr. Gaudi replied that investigators want to compare planets and learn about them along various axes. At this point, the information remains fragmentary. Dr. Nathalie Batalha said that exoplanets seem to need strategic thinking, making it hard to balance the priorities. She suspected they might end up with a statistical survey. Dr. Chryssa Kouveliotou asked if the suggested missions, which appear to be the Large UV Optical IR (LUVOIR) and Habitable Exoplanet (HabEx) mission, are $2 billion missions. She also wondered if any probe ideas warrant implementation soon. Dr. Gaudi replied that ExoPAG will suggest three or four missions. Dr. Hertz added that APD just completed two probe studies for exoplanet imaging missions. At this point, he is interested in larger missions, not probes, as the top priority DS mission should be larger than a probe.

Dr. Gaudi asked if APS was ready to approve the two SAG reports. Approval means that the Subcommittee accepts them as input and is not an endorsement or their content. There is no publication requirement for these reports. Dr. Batalha motioned to approve, Dr. Boss seconded, and the Subcommittee approved both reports.

Physics of the Cosmos (PhysPAG)
Dr. James Bock began the PhysPAG update by listing the executive committee membership. PhysPAG covers many disciplines, so the PAG has sub-teams in areas like gravitational waves (GWs), dark energy, etc. There are currently five active SIGs dealing with inflation probes, GWs, x-rays, gamma rays, and cosmic rays. PhysPAG would like to shift the dark energy group into a Cosmic Structure SIG (COSSIG). This would formalize a group that has always been part of PhysPAG. COSSIG will collect the input of measures of cosmic structure based on various techniques to measure the physical parameters of the universe. There is some overlap with the inflation probe SIG, but the experimental community has little overlap. The science that would be covered under COSSIG has been influential in the development of Euclid and WFIRST.

Regarding possible large missions recommendations for the next DS, PhysPAG is getting community input, and is formulating questions and issues for the report, which will be written over the summer. There has already been some input on the large mission PhysPAG themes of a far IR surveyor, HaBex imaging, a UV/Optical/IR surveyor, and an x-ray surveyor. There are some technical synergies among these, and PhysPAG continues to address these themes.

The SIGs have generated reactions and questions about the large missions. These include how the x-ray surveyor relates to Athena; the GW L3 mission implementation; and the inflation probe, for which the SIGs need to know what will go forward even though this would be a probe rather than a flagship mission. The probe mission line is of strong interest to PhysPAG. It comes up in all discussions with some enthusiasm.

Dr. Bock closed by noting upcoming PhysPAG events. APS voted to approve the proposed COSSIG.

COPAG

Dr. Kenneth Sembach discussed COPAG activities, starting with a list of the executive committee members. COPAG currently has two active SAGs. SAG8 is Cosmic Origins Science Enabled by the WFIRST/AFTA Data Archive. This SAG is collecting input and use cases from the community, organizing that input into query form, finding common themes, and drafting findings. The SAG has focused on the kinds of data that are needed and what the community expects and can use. SAG8 has concluded that the WFIRST/AFTA data processing system must include Levels 1, 2, and 3. Level 1 involves data capture, error checking, formatting, etc., Level 2 concerns data reduction, flux, and wavelength calibration, etc., and Level 3 addresses object classification and measurement. The real need is for Level 3 data, which APD has not always supported. Dr. Kalirai said that the SDT agrees. The footprints for WFIRST/AFTA and the Large Synoptic Survey Telescope (LSST) will likely overlap, so joint analysis should be part of it.

SAG9 is Science Enabled by Spitzer Observations Prior to JWST. The activities have been grouped by science topics, with leads for each assigned and already active. The group is looking at key questions and has gotten good community input, which has been solicited via email and meetings. A draft report will be available by fall at the latest and could feed into the JWST science plan.

There are two SIGs. SIG1 is Far-Infrared Cosmic Origins Science and Technology Development, and SIG2 is UV-Visible Cosmic Origins Space-Based Science and Technology Development. SIG1 met in January and focused on the large mission call. The goal is to provide coordinated input. Planning is underway for the next far-IR community workshop. There were eight related presentations at the American Astronomical Society (AAS) meeting.

SIG2 had an initial call for participation in December, which resulted in recruitment of 79 scientists and 40 technologists from multiple countries, academia, and government labs. The initial meeting was in January, and it was very lively, with good interactions. Action items included what a flagship UVOIR mission could mean for the field; what can be done in a shorter development timeframe; coordination among the PAGs; and disseminating roadmap information to the science and technology communities.

COPAG has requested a SIG on cosmic dawn science in order to identify science cases that provide programmatic focal points and build the long-term technology roadmap. After being asked how this differed from PhysPAG's newly approved COSSIG, Dr. Sembach explained that "cosmic dawn" deals with the first stars in the first galaxies. Dr. Hertz thought this might be too narrow and was concerned about differentiating issues. He would like to see cross-disciplinary discussions rather than technique-specific groups. Dr. Neil Cornish suggested that the name reflect dark universe issues. Dr. Gaudi said that because the PAGs are self-organizing, the community should decide what makes the most sense. Dr. Sembach proposed that this go forward, noting that he and Dr. Bock will communicate, and Dr. Gaudi suggested a joint meeting, after which they could determine whether the SIG should be joint or separate. Dr. Yun Wang pointed out that the science goals are different, with little overlap, but she also thought that "dark universe" sounds more inclusive.

Dr. Sembach added that the PAGs had joint sessions at the AAS meeting. Regarding Dr. Hertz's charge to identify flagship missions, COPAG has had biweekly telecons, released a call for white papers, had one virtual town hall outlining the charge, and will have another town hall. The three PAG executive committees were to meet jointly the day after the APS meeting in order to identify shared activities, schedules, findings, and plans. This is a logistics meeting, and the community will have other input opportunities. All white papers will be posted on the COPAG website.

The motion to approve the proposed SIG passed.

JWST Update

Mr. John Durning, JWST Deputy Program Manager, said that the schedule is healthy, with 10 months of critical path slack. The milestones are such that a lot of hardware will be delivered in FY16. FY14 was difficult, but the deferred milestones have been recovered. No items have yet been deferred in FY15. Almost all hardware has passed critical design review (CDR). There was a late thermal challenge with the radiator, but that is catching up. The mission is deep into building and testing at this point.

Mr. Durning next reviewed the more prominent components and their status, beginning with the Optical Telescope Element (OTE). The flight telescope build begins in August. Dr. Durning showed how the segments will be assembled. All flight backplane components are built and are at Northrop Grumman for integration. The wings are on already. As part of risk reduction activities, the team has practiced with spare mirrors.

The sunshield is making good progress and the team has done a practice deployment, including integration onto a practice spacecraft. There is a lot of testing and verification going on, as this is a key risk reduction activity. The flight membranes are in varying levels of completion. The fabrication of the big clamshells needed for storage is almost done as well. The booms that go out from the side are being fabricated. The sunshield and telescope were done early, as they carry the highest risk.

Four instruments make up the ISIM payload: the Fine Guidance Sensor (FGS) from Canada, the MIRI from Europe, the Near Infra-Red Camera (NIRCam), and the Near Infra-Red Spectrometer (NIRSpec). There were three major cryovac programs: Cryovac1-Risk Reduction, which was successfully conducted in FY13; Cryovac2 for all four instruments for 2,800 consecutive hours, done successfully in FY14; and Cryovac3, which starts in September 2015 as the final run for verification with all flight systems. There will be vibration, acoustics and electromagnetic susceptibility tests conducted before then. The spacecraft is not as far along in integration and testing, but the components are coming together.

There will be three risk reductions tests this year for the Optical Telescope and ISIM (OTIS). Each test establishes the procedures and processes for higher level assembly, giving confidence that the procedures work. The three tests will verify instrument-to-telescope alignment, complete OTE cryo verification, and evaluate thermal balance. The secondary mirror and wings are deployed during cryovac testing. The chamber, which is at Johnson Space Center (JSC), was used in the Apollo program. The OTIS facility work is complete, so the next 2 years will focus on building and testing the flight hardware. Concerns and issues include the cryocooler delivery schedule; the NIRSpec micro-shutter control electronics boards rebuild; the NIRCam discharge event; the shock margin; and ISIM.

Two of the three MIRI cryocooler components have been delivered, but the compressor assembly is taking longer than expected. Still, it should be delivered to JPL this summer. On the NIRSpec microshutter control electronics, there was a shorted wire during testing. The team is therefore rebuilding the affected board and the adjacent board; these will be delivered next month. The NIRCam detector system tests found that two of the four detector chips on one of the instrument channels had anomalous readings. Replacement of those units will be completed by the end of the month.

The Non-Explosive Actuator (NEA) shock device that releases the telescope from the spacecraft in orbit had too great a shock during performance testing so had to been redesigned. While this is near completion, it is taking longer than expected. The test results should be in around the end of the month.

Finally, testing found that one of the heat strap fasteners on ISIM did not have the required preload, and other fasteners were found to have lost preload. The team is now redesigning and testing these items, which will take 6 or more weeks. Other issues will arise, and the JWST team will retire them. The

mission team has been on track since the replan more than 4 years ago and still expects to launch in October of 2018.

Discussion
In answer to a question about removing modules in order to test the heat straps, Mr. Durning explained that the team removes instruments during this test as a matter of course. There are many simulators available. Dr. Bregman asked what keeps him up at night. Mr. Durning replied that near-term, it is is the cooler delivery schedule. Long-term, it is the integration and testing program. The testing program is quite complicated, and until those tests are executed, NASA will not be assured that the mission will work. There is not a specific issue, but JWST is complex and a major challenge. Dr. Bock asked about how representative the thermal test is. Mr. Durning said that it is quite representative. The instruments will be at their operating temperatures, just as cold as space. The total effort takes 4 months. Mr. Durning was asked if there was a need to stop the vacuum testing would there be sufficient time to restart the test and complete on time. His response was there is time to repair and rerun some level of testing but that would depend on the nature and timing for stopping the testing. Mr. Durning was ask how much fuel will the observatory carry. His response was the conservative estimate is that there will be 10 years of propellant; he was unwilling to make any optimistic projections.

The replan has been smooth, but there is no plan for acceleration. Dr. Hertz added that sometimes NASA projects do not spend all of their reserves, and there are examples of this. The missions that overspend get lots of attention, but some come in under budget.

<u>James Webb Space Telescope Exclusive Use Period Policy</u>
Dr. Eric Smith, JWST Program Scientist, discussed the exclusive use period. The goal is to maximize the science. Each year, JWST will select a pool of General Observers (GOs). The Space Telescope Science Institute (STScI) director recommended that the GO exclusive user period be set at 6 months, based on advice from the JWST Space Telescope Advisory Committee (JSTAC). Up to this point, the exclusive use period has typically lasted for 12 months. However, JSTAC showed how changing to a 6-month exclusive use period would dramatically affect the amount of public data available for Cycles 2 and 3 of the JWST proposal timeline. With a 12-month exclusive use period, Cycle 2 proposers would only have very early release data. It is thought that shifting the timeline would help investigators produce stronger proposals. Guaranteed Time Observers (GTOs) will have a different exclusive use period.

The Science Working Group (SWG) also assessed the difference between 12 and 6 months, and endorsed the shorter program. The JWST team has discussed this with ESA and the Canadian Space Agency (CSA), and they are talking to their communities. GOs will have 10 percent of the time. Dr. Hertz added that the international trend is toward shorter periods of limited access. It could be that there will be no exclusive use period on WFIRST and LSST. The 12-month exclusive use period in astrophysics is anomalous compared to other NASA science disciplines. Dr. Smith observed that CSA is enthused about this idea, while ESA may be somewhat reluctant due to the way they fund their scientists.

Dr. Bregman expressed concern about the training of graduate students, who have a greater learning curve. Dr. Smith said that this was the main downside and one of the reasons for not going to zero proprietary time. However, proposers can ask for more time, or less. The software development is going well and workshops will soon start to get the community prepared. Dr. Kalirai added that STScI is developing data analysis tools and simulations. The tools are being mapped to specific applications for JWST and are expected to be robust.

Dr. Gaudi agreed that the graduate students are a concern. There may be a need to train them differently as missions move to zero exclusive use period, but he was not sure what that would look like. Dr. Kalirai said that a driver of this change is to enable more students to do archival analysis, which is most of what

the HST work is these days. Dr. Sembach suggested that another way to make more data available is to make sure more science parallels exist. Dr. Smith said that JWST did not have parallel science observations when first conceived, but the team is now evaluating what would be involved in parallel, multiple-instrument observations. There have been some strong letters supporting parallel science. The clock starts when the data hit the archive. If there is a collection of complete data that are needed for an analysis, that could go into the proposal.

Dr. Gaudi said that this is the default policy under discussion, and investigators can still request something different. Dr. Sembach moved to vote that the exclusive use period be set at 6 months. The motion passed.

Dr. Boss said that he would like to hear more about the proposal aspect of JWST. Dr. Hertz said that if APS wants a presentation from JSTAC, the members can ask for one. Dr. Bregman asked about the conditions of extending JWST beyond 2025. Dr. Smith replied that the propellant is the limiting condition. The accuracy of orbit insertion will be a primary factor, and the next thing will be momentum wheels. If there is good insertion, the mission could last for 15 years, though he was uncertain about what might be possible beyond that.

NICER Update

Dr. Keith Gendreau gave an overview of the NICER mission. The mission will come in under budget, and the instrument will work for 24 months once it is installed on ISS. There will be 1 year of neutron star observations and a year of GO time. About a quarter of the funding comes from STMD. The mission is on schedule and passed CDR in the fall. There are additional safety elements and reviews due to astronaut safety considerations, but the last such review praised NICER as an example of a mission with a good safety process.

NICER will determine the radii of neutron stars to 5 percent, an order of magnitude better than known today. The light curve modeling will help investigators understand ultra-dense matter. XMM Newton is now the best mission for light curve analysis, but its clock drifts. The NICER resolution will be 1,000 times that of XMM Newton. The payload combines high-heritage and derivative components. The optics are concentrating, not imaging, and are paired to commercial silicon drift detectors.

There are two primary constraints: passing review, and space on ISS. There are disposal requirements for restowal and jettisoning into the upper atmosphere. The ISS spot that NICER will take has not been used in a long time, but there are now more proposals for it. The mission will include an optical bench and a star tracker. As for platform stability, these are arc-minute objects. The configuration focuses on maintaining torque, and the pointing system is good despite the jitter inherent on ISS. One consideration is the background and planning the observations. Most targets are isolated point objects.

NICER has had to adapt to power source issues on ISS, requiring a new converter. ISS is paying for that, so NICER is still on track with the budget. The mission will go launch on a SpaceX Dragon and Falcon 9 rocket, sharing space with other payloads. ISS policy is that the Station can change this up to 6 months before launch, which could pose a challenge. Beyond modeling, there is no way of knowing if the instrument is below survival temperature.

Installation on ISS will be robotic, employing the Special Purpose Dextrous Manipulator (DEXTRE). NICER will not have power during that time, requiring more modeling. During the course of an ISS orbit, NICER will look at two to four objects, and the team will work a plan for each week. Installation involves a robotic arm that will plug NICER onto a frame with a bolt that locks in place. The arm locks the bolt. There are also magnets involved.

NICER will restow whenever astronauts are in the vicinity. Sharp edges have been minimized but not entirely eliminated. The great accuracy available with NICER can be applied anywhere in the solar system. The mission will do high-visibility science, result in many papers, and connect with the public. If the mission can go beyond 24 months, it will go to the Senior Review.

Public Comment Period

The meeting offered members of the public an opportunity to speak. Dr. John Nousek, a former APS member, encouraged APD and the community to avoid locking in a particular probe. The Explorer class has been very productive, with a short lifecycle between selection and data production. If more probe class missions are selected, they ought to have a short timeframe.

Discussion

Dr. Hertz explained that when the NAC was restructured, it eliminated the Education Committee and created a task force instead. The task force is like a PAG for education, and it is made up of external people like a FACA group.

Dr. Bregman said that the timing of the last DS was unfortunate because the budget situation was unknown. Looking forward to the next DS, he was not sure that 2020 is the best year for it and wonders if there should be another year. Dr. Hertz said that if APD were to assume a flat budget, it should be simple to determine what funding will be available after the launch of WFIRST. APD could be starting such a mission in 2022 or 2023. Dr. Kalirai said that he would like to see the next DS pushed back so that the community can see what JWST will bring.

Dr. Cornish advised that suggestions for missions in the next DS cover high, medium, and low budgets. Dr. Sembach said that he hopes the DS will focus more on science ranking rather than on fitting missions into a notional budget like the last one did. That has been a source of dissatisfaction with the 2010 DS. The DS should not assume a budget. He would like to see if JWST opens up any new ideas, but cautioned against waiting too long to do the next DS.

Dr. Gaudi wondered when to stop waiting for the next new thing. In addition, Dr. Hertz follows the DS. As the decade wears on, that becomes harder as the landscape changes. Going longer might make his life more difficult. Dr. Hertz said that 10 years is arbitrary, but it is not a bad time to take stock, nor is it excessively long to maintain priorities. It is too much work to have a DS more frequently. However, adding another year is not a big issue, although going to 15 years is a nonstarter. There is a law saying that this must occur every 10 years. Under the circumstances, 11 years might be possible, but no more than that. He suggested that the mid-decade review look at this. One problem might be the timing of the PSD DS. It would be too much of a burden for NRC to do both at once.

WFIRST/AFTA is going to happen, but APD also wants a mission to follow as the next budget wedge opens up. The notional planning budget is for a flat budget through the end of the decade. Congress has worked off of the assumption of doing WFIRST/AFTA. It is important to identify early the technology issues and make investments now so that the DS can consider the mission concepts. The Division needs to have candidates to follow WFIRST/AFTA in order to start work on strategic technologies that can go to Technology Readiness Level (TRL) 6. He would like to see the next mission begin in the early 2020s after WFIRST/AFTA approaches launches. By 2018, APD will know more about WFIRST/AFTA and the future budget, which will allow the Division to take a fresh look. This is the right conversation to have now for the mid-decadal review, but for the next DS, the discussion should take place in 2018. It takes up to a year of planning for the DS to start, and another 2 years after that to generate the report. APD will have to negotiate with NRC in 2017 for a 2020 report or decide then whether to delay it.

Regarding international partnerships, NASA cannot partner bilaterally with China, but does have partnerships with other agencies and nations. NASA plans on partnering on the next ESA L-class missions, for example, and expects ESA to partner on NASA missions. Each agency takes into account what the other is doing in order to complement each other. The DS seeks international input, usually by inviting a representative to talk about their plans. Dr. Bregman pointed out that ESA can plan and commit for longer than APD can, and can define ESA turf in a way that NASA cannot. That has given them leadership of two fields. He asked if there might be a way APD can plan and select in order to avoid more loss of leadership.

Dr. Sembach said that the decision about what to pursue this decade was set by the DS. Dr. Cornish added that NASA has to look at Europe to see the extent to which ESA covers the DS priorities. APD has a risk in that if Europe does not go forward, the lower priority items might not be done. APD should have its own contingencies and not depend on ESA. Dr. Bregman countered that ESA has chosen their next two missions, while APD has only chosen the next one. It might be that NASA should be making decisions further down the line. Dr. Gaudi said that if ESA changes its plans for Athena, NASA could decide to do it. He wondered what would happen if APD wanted to do a much larger mission that blows the budget cap. That would require a high level of strategic planning, but NASA cannot work closely with ESA to do that. Dr. Hertz said that the issue of how to do larger projects goes across NASA and is not unique to APD.

There used to be a budget line for partnering with international agencies, but that line was eliminated in the mid-1990s and is now filled by the MoOs. The Athena and Euclid partnerships are their own NASA projects, not MOOs, however, because this is determined on a case-by-case basis. The partnership agreements are non-binding commitments of intent, and they all have exit clauses. NASA and its partners all recognize that they are subject to political processes. The 1-year funding is a problem at NASA, but the Agency does long-range planning. A 10-year planning horizon has proven to work. The agreements are not even splits because it works best to have one agency in charge.

Dr. Kalirai returned to the issue of education funding, which is the subject of some angst in the community. He asked about the communications and public outreach work that has been so strong, and how that work remains a high priority. Dr. Hertz explained that what was once Education/Public Outreach (EPO) has been divided into education activities for education goals like science, technology, engineering, and math (STEM) literacy, and communications. Outreach falls under both of those. Communications covers public affairs, the booths at AAS meetings, and other activities communicating what the mission is about, the results, and the benefits. It is not the same as education. Communication is a function of a mission, and NASA asks missions to write plans for this. There are requirements, but not a set percentage of the mission budget. This transition is harder for existing projects.

Dr. Gaudi adjourned the meeting for the day.

Wednesday, March 18, 2015

Opening Remarks

Dr. Gaudi opened the second day of the APS meeting with a brief review of the FACA rules he noted the previous day. He added that a public comment period would occur that afternoon.

Exoplanet Probe Study Report

Dr. Aki Roberge of the Exo-S team presented the final report from the team's study. The discovery of exo-Earths has long been a priority goal at NASA. The Exo-S concepts for space missions including a telescope and starshade for starlight suppression, to allow high-contrast observations of exoplanets. The

study had a single broad science goal of a mission producing compelling science that cannot be done from the ground. The study was also to generate design input for the next DS.

Dr. Roberge listed the STDT and JPL design team members. The study team examined two cost-constrained mission concepts. In the "dedicated" mission, the starshade and telescope would launch together in a 3-year mission. In the "rendezvous" mission, the starshade would launch to rendezvous with an existing telescope, which the study team assumed to be WFIRST. The starshade would be slightly larger in this scenario. The study team tried to keep the impact on the WFIRST design as minimal as possible.

Dr. Roberge showed a video modeling the "dedicated" mission concept, illustrating how the starshade unfurls and moves into position as the telescope looks at the designated target star. To retarget, the starshade must move in an arc, which takes time and fuel. The coronagraph and starshade are complementary starlight suppression technologies.

Next, Dr. Roberge reviewed the basics of starshade design and operation. Because it blocks unwanted starlight before it enters the telescope, there is no need for a high-quality telescope or high-precision wavefront control. Still, retargeting takes days to weeks, and fuel can be a limiting factor. Starshades are flexible but not nimble. Another simulation showed what the telescope would see when pointed at an exoplanet system similar to the Solar System. There would be a need to address background galaxy light and determine which unresolved dot is the exoplanet of interest.

The science goals are to discover new exoplanets, from giants down to Earth-size, while also characterizing both new and known planets. The starshade will also study planetary systems, including circumstellar dust. A figure showed the range of planet spectra the mission could obtain. The rendezvous mission is limited by photon noise and the time the mission could spend on a single target. The three instrument functions needed for a starshade observations include a wide field imager (WFI), an integral field spectrograph (IFS), and a guide camera. Dr. Roberge presented a chart comparing the parameters and observing bands of the two concepts.

The DRM strategies include planet detections, planet characterization, and addressing high levels of dust by switching to the wide-field camera to observe the dust structure before moving on to the next target. The three target prioritization strategies are Earths in the HZ with a 1.1-meter dedicated telescope; maximum planet diversity with the dedicated telescope; and Earths in the HZ with a 2.4-meter rendezvous telescope.

For the dedicated mission, there would be a 3-year observing sequence, with the third year reserved for follow-up and revisits, while the rendezvous mission would have 2 years for observing. An example of a 2-year observing sequence showed 55 stars visited, with 12 known giants planet host stars and the rest blind search targets. Of the latter, Earth-like planets can be discovered around 28 stars. These are calculations based on current information that could be refined as more data come in. The priority is the HZ, not just planetary detection, but priorities would need to be set regarding Earths versus larger planets. Observations with the starshade would not preclude WFIRST from doing other observations, due to the long starshade retargeting times

Dr. Roberge next described the design and mechanical points, which are discussed in greater detail in the final report. A schematic showed how the starshade is stowed for launch through unfurling and full deployment. Of the total error budget allocation, 32 percent is unallocated reserve. The design team identified five technology gaps; plans are in place to get four to bring TRL5 by 2017, and these four are fully funded. Modifications to WFIRST for the rendezvous mission are minimal, as that mission can use

the existing coronagraph IFS and imager can be used with the starshade. Issues regarding the overall optimization of science are in the final report.

The STDT, JPL, and the Aerospace Cost and Technical Evaluation (CATE) developed cost estimates. The STDT found that the dedicated mission went slightly over the $1 billion cost cap, while the rendezvous mission would be $627 million, including the launch and about $5 to $10 million in WFIRST modifications. The CATE estimates were similar and noted no problems with the planned schedule.

Exoplanet Probe Study Report

Dr. Michael McElwain presented the report from the Exo-C coronagraph probe mission study, which is an approach to direct imaging using an internal coronagraph. Exo-C will use a coronagraph with precision wavefront control for high-contrast imaging at visible wavelengths in order to characterize known RV planets and search nearby stars for more. The mission will image hundreds of circumstellar disks with a state-of-the-art coronagraph. The internal cost estimate came in at $950 million, just below the $1 billion cost cap. The Aerospace Corporation's estimate was slightly over the $1 billion cost cap..

A video simulation showed that the stars are so far away that the angles are very small. The telescope can address distortions and distinguish between starlight and planet-light. The 1.4-meter aperture can be very effective if coronagraph requirements can drive the mission design. Community interest is high.

In 2024, the exoplanet landscape is likely to include both direct imaging and indirect detection, disk imaging, and transit targets. Young planets that are warm can be detected from the ground, and ground-based ELT systems have the advantage of angular resolution. The science campaign will involve looking at known planets discovered with the radial velocity technique, searching for cool planets in reflected light and imaging circumstellar disks.

Dr. McElwain next discussed the technical capabilities. The limitation on the 1.4-meter telescope is cost; its contrast stability is good. The mission lifetime is 3 years, but the components are designed to 5 years, and the annual operating budget is expected to be $30 million. The characterization of known exoplanets would receive about 1 year of mission time, discovery surveys would get about 1.2 years, and imaging surveys of circumstellar disks would have about 0.6 years of mission time. With commissioning time, this will result in 3 years for the mission. It is anticipated that there will be scattered light, and some new noise reduction strategies have been proposed. The observatory could also do general astrophysics. The planet yield is comparable to that of the starshade.

Exo-C will have an Earth-trailing orbit like Kepler and an unobscured 1.4-meter telescope. At this point, the mission is likely to have a hybrid Lyot coronagraph due to its TRL level, though two other options have not yet been eliminated. The mass and volume are under the limit for the Falcon 9 launch vehicle, so there is the option of a larger payload with more funds.

The final report has been submitted to NASA and will eventually be released after it is cleared for containing no proprietary information. Dr. McElwain presented a graphic depiction of the changes made during the study. The instrument has a thermally stable configuration. There are issues with controlling wave fronts and scattered light, and the models need to be validated. The TRL is very mature and demonstrations have been ongoing. Costs are approximately $1 billion. The STDT will continue studying a larger aperture. Much of the testing for WFIRST/AFTA is relevant here.

Dr. Boss said that while the Exo-S and Exo-C concepts are both interesting, it is important to have a comparison to what can be done from the ground. If the work can be done better from space, that must be shown. Dr. McElwain said that he would send out that information. Dr. Sembach noted that HST has a

stability disturbance issue, which can be due to a number of variables. Investigators must take this into account when they need precision with stability. He would like to see more thought on this.

AAAC Proposal Pressure Study Update

Dr. Priscilla Cushman, Chair of NSF's Astronomy and Astrophysics Advisory Committee (AAAC), discussed a study that is in progress to examine R&A proposal pressure. The goal of the study group is to gather and analyze the data needed to evaluate how the funding environment of the last 10 years has affected researchers and projects, leading to an understanding of proposal trends and the development of potential solutions. The study is considering APD, NSF, and other organizations. Dr. Cushman noted that APD data are segregated by competition, NSF has a strong database, and the Department of Energy (DOE) information is hard to connect. The study team reviewed data going back to 1990, with an emphasis on data from 2004 forward.

The team found that the number of proposals at NSF has gone up, so that the success rate is now about 15 percent. Without the NSF facilities, the success rate is more stable. Three SMD divisions – APD, PSD, and the Heliophysics Division (HPD) – have gone from a success rate of approximately 30 percent to a rate of around 15 percent. DOE high-energy physics proposals have higher success rates, with most funds going to universities and much of the funding for renewals of ongoing 3-year grants. The three SMD divisions are consistent with each other.

Most proposals at NSF and APD are from principal investigators (PIs) who have sent in a single proposal. In fact, the number of unique PIs is going up. Only about 15 percent of the proposals are from a PI who has submitted two or more proposals, although PSD has experienced a burst of multiple proposals. That SMD division recently implemented a two-step proposal process.

Dr. Cushman next presented a demographic analysis of PIs, which indicates that there is no "postdoc problem," in which fellowships resulted in a large cluster of PIs, nor is there a discernible gender bias. There has been a slight increase in the proportion of younger women submitting proposals. In looking at the age and academic status of the PIs, there is a good increase in the number of women and a slight increase among younger PIs. Institutional affiliation data do not indicate an increase in the proportion of PIs from smaller institutions.

An analysis of proposal ratings seems to indicate that the number rated Excellent (E) is going down, but this has been difficult to quantify. The main loss has been in the proportion of Very Good (VG) proposals that are funded, but VG/E and E proposals are stable in their funding rate. The study also looked at the resubmission rate for unsuccessful proposals. The data indicate that the number of non-repeat proposals remains steady, while PIs with unsuccessful proposals often reapply the following year. This reapplication rate can be as high as 70 percent. This creates an "evil spiral" in which the resubmitted proposals accelerate the rise in proposal numbers and the falling selection rate.

At the same time, review panels have become difficult on some axes, though they have become more efficient. Conflict of interest (COI) is not a problem at this point, and recruitment works best if done in advance. The study team will survey PIs over the summer. Dr. Cushman presented some of the questions being considered. The team will have its final report by the end of the year, and will then continue work on refining data from the agencies.

Discussion

Dr. Bregman said that the presentation answered many questions. He thought one of the slides showed that proposal pressure at NASA was flat since 2010. Dr. Cushman said that the number of PIs submitting more than one proposal has not changed much. However, the total number of proposals is rising. Dr.

Gaudi observed that the success rate is not declining as fast as the rate of proposals is increasing, and it seems like something else is going on.

Dr. Kouveliotou said that the average amount per funded proposal would be useful. Dr. Cushman said that these are preliminary results, but funding per proposal is difficult to determine. Dr. Sembach thought that the main driver appears to be repeat proposals. He asked if the study team had thought about an action to take based on the survey data. Dr. Cushman replied that the team will be looking for correlations, including demographic data on who is leaving the field. The team is also looking at the impact of funding levels on researchers, and the impact that different mitigation strategies might have on PIs.

Dr. Boss compared the astrophysics selection rates to those in biology, which are much lower. He observed that two-step processes seem to be working. Dr. Hertz pointed out that government funding decisions have specific requirements, and though the triage resulting from a two-step process is not precluded, the requirements must be observed.

WFIRST/AFTA Update

Dr. Neil Gehrels presented the final report of the WFIRST/AFTA SDT, beginning by listing the team members. This was an international group with much expertise. The PAGs, JAXA, and CSA have shown a great deal of interest. WFIRST is the highest-ranked large space mission in the DS. The AFTA element involves the National Reconnaissance Organization (NRO) telescope assets and the coronagraph. WFIRST/AFTA will make deep observations that will be complementary to Euclid and LSST, and synergistic with JWST. The design has matured a lot.

Congress appears to support the mission, and the team is preparing for a rapid start and shortened development time. The risk concerns identified in the NRC/Harrison report are being addressed, and the preparatory science is well-funded. NASA has challenged the mission team to use the telescope as-is. WFIRST/AFTA will cover a number of science areas: Baryon Acoustic Oscillations (BAO), which complements Euclid; supernovae, which complements LSST and Kepler; a microlensing survey also complementing LSST and Kepler; gravitational lensing, complementing Euclid, LSST, and Kepler; coronagraphy; and a GO program. The WFI and the coronagraph are the two main instruments.

Dr. Gehrels presented an example of an observing schedule, in which WFIRST/AFTA will spend 2 years doing the high-latitude survey with imaging and spectroscopy, six microlensing seasons, 0.6 years on supernovae, 1 year for coronagraphy throughout the mission, and 1.3 years unallocated to include the GO program. WFIRST/AFTA will detect many more clusters than HST, with a huge dynamic range.

Dr. David Spergel spoke about the dark energy research this mission will conduct. The intent is to look at growth ratios and redshift. The sources will be higher redshift and allow a probe of their evolution. The weak lensing complements LSST and Euclid; the mission team will try to coordinate with their teams and there have already been meetings to discuss this. The goal is to have the fields of supernovae overlap some of the deep fields for energy work. These will find targets for other missions. WFIRST/AFTA will find about 2,700 supernovae, and the redshift effort will survey about 16 million galaxies.

In regard to exoplanet surveys, Kepler and WFIRST/AFTA are highly complementary; WFIRST/AFTA also complements TESS and ESA's PLAnetary Transits and Oscillations (PLATO) effort. WFIRST/AFTA will look at outer regions. The coronagraph will be important in characterizing exo-Earths. Coronagraph development has been an area of growth. The exoplanet yields will reflect some of the RV work being done over the next few years. The GO program will account for 25 percent of mission time. WFIRST/AFTA covers many other DS science goals, including 5 discovery science areas and 20 key science areas.

The SDT presented NASA with two options for team selection on the Science Working Groups (SWGs), and concluded that 15 to 20 members would be optimal. These members would ideally include a project science team from the NASA centers; project, instrument, telescope, and detector scientists; science center leads; PIs of selected investigations/instruments; interdisciplinary scientists; foreign representatives; and others. The SDT report also presented options for SWG selection.

Data rights considerations include the fact that many investigators will want these data. The SDT is encouraging open data for the community. Science team data needs will be different, and there might be a need for a separate coronagraph team that is dealt with differently from the others.

Mr. Mark Melton, an SDT member and an engineer at GSFC, discussed the DRM, noting that the full report is available online. Key elements of the WFIRST/AFTA observatory concept include the telescope, the WFI/spectrometer and integral field unit (IFU), and internal coronagraph with IFS. The payload is designed to minimize risk to the telescope. An overview of the WFI included a graphic showing placement of the elements. There has been a lot of focus on maturing the detectors beyond what is being used on JWST. The team has established five maturation milestones and is running experiments to determine the optimum detector composition.

Mr. Melton also gave an overview of the coronagraph instrument and presented the technology development highlights for the coronagraph. The team is making excellent progress and will be adding milestones beyond the first five. In the maturation process, NASA has made significant investments in deformable mirrors, detectors, low order wave-front control, and other elements essential for high-contrast coronagraphy. The team is developing an IFS test bed at GSFC.

The recent analysis focus has been on integrated modeling on the coronagraph structural/thermal/optical performance (STOP) and jitter. The WFI STOP stability specifications were met with a strong margin even for an extreme worst-case model uncertainty factor (MUF), which is used in modeling that has not been fully tested. Jitter control was good on the MUF, but not to the same degree, so the team continues working on this issue. The path forward begins with optimizing the reference design. Steps for this are all in the SDT report as areas of focus.

Mr. Melton summarized by noting that a recent infusion of funds has allowed significant progress in technology maturation and additional fidelity in the DRM. The 2.4m telescope and coronagraph will enable a more exciting science program, and overlap with JWST will provide great opportunities for science return.

Discussion
Dr. Bautz asked whether the technology development endpoints will bring the technologies to TRL6. Mr. Melton said that this is the case with the detectors. The endpoint is to validate the "yield lot" and to validate costing on the WFI. For the coronagraph, the endpoint is validation of the architecture in the test bed. That might not be final, but it will be in a test bed using flight-like parts. Dr. Bautz asked if there was an estimate for the technology development budget to the end of Phase A. Ms. Catherine Peddie, Deputy Project Manager, offered to pull that together, though it is tracked differently. Dr. Bautz said it was not worth a lot of work.

Dr. Sembach observed that it was wonderful to see the enthusiasm for WFIRST/AFTA at AAS. COPAG is helping to determine how the community wants to use the archive, including the desire to see high-level science products created beyond the pillars of the mission into general astrophysics.

Planck Science

Dr. Charles Lawrence gave an update on the Planck mission, an ESA mission with NASA participation. The goal of this mission is to measure the temperature anisotropies of the cosmic microwave background (CMB) to fundamental limits, while providing strong measurements of polarization. NASA contributed critical components of Planck's science instruments, including bolometers for the mission's high-frequency instrument; detector technology; a cryocooler; an amplifier technology for the low-frequency instrument; and supercomputing.

The CMB is obscured by other frequencies. Dr. Lawrence showed differences in the 2013 and 2015 data release information, which in part reflects that there are now more data. However, the most important point is the proliferation of checks on consistency and systematics, as well as better beams and improved calibration. Systematic errors in polarization on large angular scales at 100, 143, and 217 GHz have not yet been fully characterized. As a result, the polarized CMB maps (Stokes Q and U) that have been released so far have been high-pass filtered, and the time-ordered data at those three frequencies have not yet been released.

Dr. Lawrence showed the nine operating frequencies, with maps in polarization at seven frequencies. The mission is now able to use more of the sky than in 2013. A simple 6-parameter ΛCDM model still fits the Planck data extremely well in both temperature and polarization. The temperature and other measures are consistent with each other in this construct. Dr. Lawrence also showed the power spectrum with the best-fit model, as well as the cosmic variance. The model has not been adjusted. Uncertainties in cosmological parameters have gone down by more than 25 percent. The reionization optical depth in now measured by Planck for the first time, and is lower by about 1 sigma than the value measured by WMAP used by Planck in the 2013 release. However, if the WMAP data are cleaned of foreground dust using the Planck 353 GHz data, the reionization optical depth decreases and agrees well with the Planck value. Five of the six ACDM model parameters are determined to better than 1 percent.

Deflection of light by matter is well-observed in astronomy, and the CMB is the most distant light source, with a precisely known redshift. Dr. Lawrence explained the extent to which Planck is consistent with other data in the areas of BAO measurements, primordial nucleosynthesis, Type Ia supernovae, measures of helium fraction, redshift distortions, and galaxy clusters. Planck's determination of the Hubble constant from the CMB and lensing is lower than determined by direct measurements. Constraints from Planck CMB measurements on Omega_matter and sigma_8 remain somewhat different than those from galaxy cluster counts. That situation remains murky and unfinished.

Addition of more parameters to the ΛCDM model does not result in significantly better fits.

Dr. Lawrence called attention to the new tighter constraints on neutrino masses. For the tensor-to-scalar ratio, the strongest Planck constraint is still from CMB temperature. A joint Bicep2/Keck--Planck analysis provides an independent constraint. The only way of improving these limits is through direct B-mode measurements. The dust polarization information was a bit of a surprise to investigators, in that the fractional polarization exceeds 20% in some places.

The Planck 2013 data had a huge impact on inflationary models. With Planck 2015, measurements are more precise: the constraints on non-Gaussianity are tighter, new types are considered explicitly, and constraints on isocurvature modes are tighter. The result is more precise knowledge of the universe.

The final data release will be in 2016. Dr. Lawrence said that Planck was a great international collaboration, and that neither ESA nor NASA could have done this alone. A pioneering agreement between NASA and DOE on supercomputing was also a critical component for the mission.

Discussion
Dr. Gaudi summarized what had been accomplished at the meeting and what was pending. APS approved the revised GO time frame for JWST, and voted to approve two SAG reports and two new SIGs. The proposal pressure report will go to the AAAC first, at the end of the year. AAAC will publish it in March.

Dr. Gaudi said that he felt unclear as to the reason for the decreased R&A proposal selection success rates. The numbers did not seem to add up. The proposal pressure is not due to a glut of postdocs, which APS had been assuming, nor was it due to people at non-major research institutes, more proposals per person, or more individual PIs. Dr. Sembach said that it could be that there are more multi-disciplinary proposals that are being submitted more broadly, but there were not a lot of new proposals. The only thing left was resubmission of rejected proposals, which is what he now considered most likely. Dr. Gaudi said that that would require either multiple proposals per PI, which did not seem to be the case, or more new PIs. Dr. Bock suspected it was mission money. Dr. Sembach noted that HST has had the same pattern. There was discussion of how overhead, salaries, graduate student tuitions, and a flat budget could combine to account for some of the proposal pressure, and it may be that this information is hard to get. Dr. Sembach pointed out that more than half of all papers currently rely on archival data.

Dr. Hertz said that Dr. Bradley Peterson, former APS Chair, is still the APS representative to this task force. Dr. Hertz suggested that someone on APS provide these questions to Dr. Cushman, stating that the Subcommittee is interested in where this goes. APS has an interest in identifying the problem and examining the kinds of solutions that APD might implement.

Dr. Gaudi concluded that APS probably still does not have enough information about this issue. Dr. Cornish wondered about the extent to which NASA is not getting the full benefit from the missions that are flying. Dr. Bregman was concerned about the amount of science that is not getting done. Dr. Hertz replied that the data reflect the NSF situation more than that of APD. The number of APD proposals is growing, unlike NSF. At the same time, funding in GO programs fluctuates.

After Dr. Bregman stated that the data now are much more useful than they once were, and more easily accessed more rapidly, Dr. Cornish said that the costs for dealing with richer data sets are significant. Dr. Hertz pointed out that a growing community will have difficulty with a flat budget in which only the best science is funded. Dr. Wang wondered if the agencies might collaborate on discouraging the submission of nearly identical proposals to multiple agencies. Dr. Hertz replied that he cannot tell someone that they cannot submit to APD because they applied at NSF. APD and NSF already communicate in order to prevent double funding. In answer to another question, he explained that virtual panels cost SMD less and are easier on the reviewers.

Public Comment Period
No members of the public came forward during the public comment period.

Discussion, continued
Dr. Hertz provided APS with APD's response thus far to the Office of the Inspector General (OIG) report dealing with SOFIA. There were 10 recommendations:

1. Develop new instruments: to be done by April 30.
2. Pick date for senior review: will be 2016.
3. Science outreach plan: done and accepted.
4. Look at formula for GO program: to be done by April 30.
5. Assess backlog in processing data: more or less done.
6. Have formal policy and process for when an observing run is cancelled: done and accepted.
7. Reassess requirements for flight hours: to be done by late April.
8. Clarify who oversees the USRA contract: done and accepted.

9. Clarify procurement policy: done and accepted.
10. Develop acquisition plan for end of USRA contract: promised by June 30.

As a side note, Dr. Hertz said that SOFIA had some down time due to a thruster anomaly. The SOFIA staff therefore flew to Houston and took the piece from the Shuttle Carrier Aircraft – which belongs to the SOFIA program –which is currently in a museum.

Recommendations, Actions

Dr. Gaudi suggested that the letter to Dr. Hertz mention the new SIGs, note that JWST is on track, and state the action taken regarding the exclusive use period. The summer APS meeting will be a teleconference, and the face-to-face meeting in the fall will have a JWST science presentation. The letter would also praise the Exo-S, Exo-C, WFIRST/AFTA, and Planck presentations.

Dr. Hertz said that APD is extending the WFIRST/AFTA SDT for up to a year to look at specific trades or studies, at which point the team will be disbanded. The probe studies are finished, but there is a small add-on for a starshade working group to look at technology development plans to get to TRL5 or 6. All of these reports will be available once they have been cleared for export controlled and proprietary information. By the next meeting, there will be an update on the NRC's progress in putting together a new committee for the mid-decade review.

Dr. Gaudi said that he would summarize the APS questions regarding proposal pressure. He asked if anyone could replace Dr. Peterson on the task force; Dr. Kouveliotou volunteered to do so. Regarding work across the SIGs, the three PAG chairs agreed to let it grow organically. Dr. Sembach expressed concern that when the WFIRST/AFTA SDT breaks up and the SWG is in place, there will be only a single person representing the broad area of general astrophysics.

Dr. Gaudi said that since this was a straightforward meeting, he would draft the letter for Dr. Hertz himself and send it to the APS members, though FACA rules preclude them from discussing it via email and making new arguments. The content must reflect the meeting.

Dr. Bregman said that in listening to the presentations, he was struck by the urgency and sequence, especially regarding planet imaging. The WFIRST/AFTA coronagraph goes up in about 2025. The next step would be based on that, which then pushes the next big mission launch into 2030 or beyond. Waiting to 2030 is too long, and it seemed like the presenters wanted to do something sooner. He wondered if the coronagraph on WFIRST/AFTA is an essential step. It could be that there are surprises or that something does not work as planned. He was concerned about whether the technology demonstration might slow NASA's progress too much, leaving the next big exoplanet mission to ESA. He added that the starshade makes him nervous, and he wondered if APD might be moving too slowly.

Dr. Gaudi observed that the rendezvous mission does not fit into any existing area and is not in the DS beyond technology development. Dr. Hertz said that if the DS committee sees it as attractive, the report will say so. The funds are not available before then anyway; they are limited. When he commissioned the probe studies 3 years ago, they were alternatives to a flagship mission after JWST, as it was not clear that there would be support for WFIRST/AFTA. That was before the NRO telescope assets became available.

Dr. Boss added that the exoplanet community views AFTA as speeding things up, not slowing them down. The mission will be ready to apply what is learned. Dr. Bregman said that his concern is that APD will get to 2027 or 2028 and have to pull the trigger on a mission. There could be ground-based advances sufficient to obviate a mission. Dr. Boss pointed out that that was why he sought the ground-based information for comparison. Dr. Gaudi was unclear how the information would come any faster than

through WFIRST/AFTA with the coronagraph. Dr. Giovanni Fazio noted that ground-based investigations will be no faster. WFIRST/AFTA is the next opportunity. Dr. Bautz agreed.

Dr. Hertz said that the next DS mission will launch in the late 2020s. APS should be thinking about APD's investments today to ensure that the Decadal Survey Committee has all the data and technology necessary for when it comes time to make an intelligent choice. Formulation for the post-WFIRST/AFTA mission could begin in 2022/23. It is important to look at what is needed to follow up. One of the DS recommendations was to do the precursor science to support the missions for the DS. No one knows if WFIRST/AFTA data are required in order to move beyond WFIRST/AFTA. These things all take money. The working group that will think about starshades will consider what testing is needed. In addition, the DS has said that Explorers are important science missions, which is why Explorers are not used for non-science technology demonstrations.

Dr. Cornish asked if the in-person fall meeting could include an update on the Athena/L2 progress and studies, and the Gravitational Observatory Assessment Team (GOAT). Since APS will be looking at planning for the next DS, that would be useful. Dr. Hertz said that the white papers will be available then for discussion. The summer meeting is virtual.

Adjourn

Dr. Gaudi thanked everyone and adjourned the meeting at 2:57 p.m.

Appendix A
Attendees

Subcommittee members
B. Scott Gaudi, Ohio State University, *Chair, Astrophysics Subcommittee*
Hashima Hasan, NASA HQ, *Executive Secretary*
Natalie Batalha, NASA Ames
Marshall (Mark) Bautz, Massachusetts Institute of Technology
James J. Bock, California Institute of Technology
Alan Boss, Carnegie Institution of Science
Patricia Boyd, NASA GSFC
Joel Bregman, University of Michigan
Neil J. Cornish, Montana State University
Giovanni Fazio, Harvard Smithsonian Center for Astrophysics
Jason Kalirai, Space Telescope Science Institute
Chryssa Kouveliotou, George Washington University
Kenneth Sembach, Space Telescope Science Institute
Yun Wang, California Institute of Technology

NASA attendees
Paul Hertz, NASA HQ, *Director, Astrophysics Division*
Dominic Benford, NASA HQ
Peter Bertone, MSFC
Shawn Domagal-Goldman, NASA GSFC
John Durning, NASA GSFC
T. Jens Feeley, NASA HQ
Jonathan Gardner, NASA GSFC
Jeffrey Hayes, NASA HQ
W. Vernon Jones, NASA HQ
Janet Larson, NASA HQ
Charles Lawrence, NASA JPL
Michael McElwain, NASA GSFC
Susan Neff, NASA GSFC
Mario Perez, NASA HQ
Aki Roberge, NASA GSFC
Rita Sambruna, NASA HQ
Wilton Sanders, NASA HQ
Eric Smith, NASA HQ
Thomas Statler, NASA HQ
Martin Still, NASA HQ
Harley Thronson, NASA GSFC
Keith Warfield, NASA JPL
Dan Woods, NASA HQ

Non-NASA Attendees
Mary Floyd, Zantech
James Lochner, USRA
John Nousek, Penn State
Elizabeth Sheley, Zantech

Webex
Louis Barbier, NASA Goddard
Jay Bookbinder, NASA Ames
Casee Burke
Joan Centrella, NASA GSFC
Julie Crooke, NASA HQ
Priscilla Cushman, University of Minnesota
John Davies
Michael Fanelli, NASA
Andrew Follett, House
Jonathan Gardner, NASA
Neil Gehrels, NASA GSFC
Ryan Green, House Space, Science, Technology Subcommittee
Fiona Harrison, CalTech
Kate Hartman, NASA GSFC
Grace Hu, OMB
Ben Kallen, Lewis-Burke Associates
Kathy Hartman, NASA HQ
James Lochner, USRA
John Mather, NASA HQ
Gary Melnick, Harvard
Alison Nordt, Lockheed
William Oegerle, NASA Goddard
Cathy Peddie, NASA Goddard
Robert Petre, NASA Goddard
Christian Rice, House Committee on Space, Science, and Technology
Aki Roberge, NASA GSFC
Richard Rogers
Robin Stebbins, NASA HQ
Rita Sambruna, NASA HQ
Sarah Seager, MIT
Nick Siegler, NASA JPL
David Spergel, Princeton
Mark Thomson, NASA JPL
Marcia Smith
Stephen Unwin, NASA JPL
Roland Van Der Marel, Space Telescope Science Institute
Michael Warner, CalTech
Stuart Wiens

Appendix B
NAC Astrophysics Subcommittee Members

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

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

Natalie Batalha
NASA Ames Research Center

Marshall (Mark) Bautz
Massachusetts Institute of Technology

James J. Bock
California Institute of Technology

Alan Boss
Carnegie Institutution of Science

Patricia Boyd
Goddard Space Flight Center

Joel Bregman
University of Michigan

Neil J. Cornish
Montana State University

Giovanni Fazio
Harvard Smithsonian Center for Astrophysics

Fiona Harrison
California Institute of Technology

Jasonjot (Jason) Singh Kalirai
Space Telescope Science Institute

Chryssa Kouveliotou
George Washington University

Kenneth Sembach
Space Telescope Science Institute

Rachel Somerville
Rutgers University

Yun Wang
California Institute of Technology

Appendix C
Presentations

1. *Astrophysics Division Update*, Paul Hertz
2. *Balloon Program Update*, W. Vernon Jones
3. *Exoplanet Program Analysis Group Report*, Scott Gaudi
4. *Physics of the Cosmos Report for the Astrophysics Subcommittee*, James Bock
5. *Cosmic Origins Program Analysis Group*, Kenneth Sembach
6. *James Webb Space Telescope Mission Status*, John Durning
7. *JWST General Observers Exclusive Use Period Policy*, Eric Smith
8. *NICER*, Keith Gendreau
9. *Exo-S Final Report Presentation to NASA APS*, Aki Roberge
10. *Exo-C Coronagraph Probe Mission Study*, Michael McElwain
11. *AAAC Proposal Pressures Study Group*, Priscilla Cushman
12. *WFIRST-AFTA Science Definition Team Final Report*, Neil Gehrels/David Spergel/Mark Melton
13. *Planck 2015 Results*, Charles Lawrence

Appendix D
Agenda

Astrophysics Subcommittee Meeting
March 17, 18 2015

Tuesday, March 17, 2015

8:30 a.m.	Introduction and Announcements	Scott Gaudi
8:40 a.m.	Astrophysics Division Update	Paul Hertz
10:00 a.m.	Break	
10:15 a.m.	Balloon Program Update	Vernon Jones
10:45 a.m.	ExoPAG/PhysPAG/COPAG Updates	Scott Gaudi/Jamie Bock/Ken Sembach
12: 15 p.m.	Working lunch	
1:30 p.m.	JWST Update	John Durning
2:00 p.m.	James Webb Space Telescope Exclusive Use Period Policy	Eric Smith
2:30 p.m.	Break	
2:45 p.m.	NICER Update	Keith Gendreau
3:15 p.m.	Public Comment Period	
3:25 p.m.	Discussion	APS members
4:30 p.m.	Wrap up for Day 1	Scott Gaudi

Wednesday, March 18, 2015

9:00 a.m.	Opening Remarks	Scott Gaudi
9:10 a.m.	Exoplanet Probe Study Report	Aki Roberge
9:40 a.m.	Exoplanet Probe Study Report	Michael McElwain
10:10 a.m.	Break	
10:25 a.m.	AAAC Proposal Pressure Study Update	Priscilla Cushman
10:55 a.m.	WFIRST/AFTA Update	Neil Gehrels/David Spergel/Mark Melton
11:30 a.m.	Planck Science	Charles Lawrence
12:00	Working Lunch	
1:00 p.m.	Discussion	APS members
2:00 p.m.	Public Comment Period	
2:10 p.m.	Recommendations, Actions	Scott Gaudi
2:30 p.m.	Brief to Hertz	Scott Gaudi
3:00 p.m.	Adjourn	