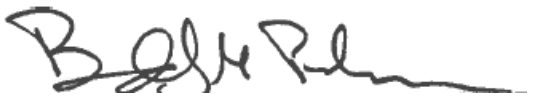
NASA ADVISORY COUNCIL

ASTROPHYSICS SUBCOMMITTEE

July 16-17, 2013

Goddard Space Flight Center
Greenbelt, MD

MEETING MINUTES



Brad Peterson, Chair

Joan Centrella, Executive Secretary

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Tuesday, July 16, 2013

Opening Remarks/Announcements

Dr. Bradley Peterson, Chair of the NASA Advisory Council (NAC) Astrophysics Subcommittee (APS), opened the meeting by welcoming the participants and asking them to identify themselves. He noted that there would be a public comment period at the end of the second day of the meeting.

Ethics Briefing

Ms. Katie Spear, representing NASA's Office of General Counsel (OGC), presented the mandatory annual ethics training session to the Subcommittee members.

SMD Science Plan Discussion

Mr. Dan Woods, Director of NASA's Strategic Integration and Management Division (SIMD), sought APS input on NASA's science plan, which the Subcommittee members had received a few days before the meeting. The plan is to send the draft plan to the National Research Council (NRC) Space Studies Board in early August in order to receive the Board's comments in late November. The final document will be released in February 2014.

Each Science Mission Directorate (SMD) Division subcommittee, including APS, had previously weighed in with suggestions for challenges to be included in the document. These include the following:

- Increasing fidelity of cost estimates and implementation;
- Effective communication with and engagement of students and the public;
- Balancing of risk and science payoff; and,
- Collaboration requires a high level of coordination.

For each of these, the recommendation was addressed, though balancing risk and science payoff had the least done on it, as the feeling was that the current fiscal situation does not allow taking on more risk. Other recommendations were addressed more extensively. For example, there are some recent examples of success in the fidelity of cost estimates.

The challenge addressing communication and engagement is in limbo due to the President's recommendation that education and public outreach (E/PO) be consolidated government-wide. Congress has been cool to this concept, however, and the situation remained uncertain at the time of the meeting. It is unclear when it will be resolved. The three government agencies that were asked to take over E/PO are making plans to do so, and NASA is working closely with them. If the President's recommendation is not implemented, there is an issue with the Fiscal Year 2014 (FY14) budget, in that the funds have been taken from programs on the assumption that Congress will approve the consolidation. If E/PO is kept with the programs, it is not clear what the funding situation will be. Dr. Paul Hertz, Director of the Astrophysics Division (APD), agreed that there is a great deal of uncertainty, and that uncertainty would remain under a Continuing Resolution (CR). So far, the three agencies charged with managing E/PO have made no announcements regarding continuity. The FY13 E/PO funding has not been affected beyond the sequestration cuts.

Dr. Joel Bregman noted that some of these cuts originated with Government Accountability Accounting Office (GAO) reports that have some support in Congress because they are considered objective. The reports point to duplication and lack of communication. It might be helpful for NASA to show that the Agency is addressing these reports and solving this problem. Dr. Hertz explained that the Office of Science and Technology Policy (OSTP) has a working group that has been coordinating on the issue for

the past 2 years. The group has not yet issued a final report, but the President proposed this consolidation in anticipation of the report.

Mr. Woods explained that NASA has two councils that have been collecting E/PO information from the Agency to ensure that there is no duplication of effort. NASA addressed the issue long before GAO did. Dr. Hertz added that the NASA E/PO programs are need-based, metric-driven, and evaluated, so that they can prove they are achieving results.

Mr. Woods listed additional challenges to be addressed in the 2014 Science Plan:

- Access to space;
- Mission cost estimation and management, reflecting the results of new policies established in 2010;
- Technology development and demonstration;
- Impediments to international collaboration on space missions;
- Meeting scientific and societal needs;
- National science and technology workforce development; and,
- The unstable budget environment.

The astrophysics chapter contents will be consistent with the previous Plan, but with "Program Implementation" as a new chapter heading. Although APS had revised the APD strategic objective to include the phrase "Unravel the mysteries of the universe," that was replaced with "Discover how the universe works." Mr. Woods asked for APS comments to be sent to him before the deadline of July 30.

Astrophysics Division Update

Dr. Hertz began his presentation with a review of science highlights. The Hubble Space Telescope (HST) found a "true blue" exoplanet. Although it is quite blue, this exoplanet is otherwise like a hot Jupiter. The blue comes from the specular reflection off of silicate flying through the winds in the atmosphere of the planet. The Kepler spacecraft announced the discovery of three "super-Earths" that are up to 60 percent larger than Earth and either in or just slightly outside the habitable zone. These are just some of the Earth-size planets being found in habitable zones around Sun-like stars. Dr. Hertz showed data that have come in on the Orion B molecular cloud, He also showed a gamma ray burst that is the third brightest ever seen, and the brightest detected by the Fermi mission. It broke several records for very high emissions from a gamma ray burst. Dr. John Nousek noted that this is still going on and being watched. Dr. Hertz added that the Swift spacecraft observed an anti-glitch. Usually, when a magnetar glitches, it speeds up, but this one slowed down. That was unprecedented and challenging.

Division Update

This remains a time of opportunity for NASA in astrophysics. The President's astrophysics budget request for FY14, including the James Webb Space Telescope (JWST), remains at a high level. JWST has stayed on schedule and is fully funded for launch in October 2018. APD has identified the next two Explorer missions, the Transiting Exoplanet Survey Satellite (TESS) and the Neutron Star Interior Composition Explorer (NICER). APD maintains individual investigator programs and is preparing for the strategic mission that will be developed to follow JWST.

The budgetary future remains uncertain, however. The cuts from the FY13 sequestration and rescission had an impact. FY14 is constrained, and sequestration below the President's FY14 request will require program reduction.

Dr. Hertz next addressed the Astrophysics-Focused Telescope Assets (AFTA) study on use of the 2.4-meter telescope assets that the National Reconnaissance Organization (NRO) provided to NASA. Since Fall 2012, NASA has been studying these assets. The studies indicate that for about the same cost, NASA can realize a Wide-Field Infrared Survey Telescope (WFIRST) mission with science capabilities beyond the baseline mission described in the Decadal Survey (DS). In addition, the 2.4-meter telescope assets are of higher quality and larger than the baseline, thus allowing the addition of a coronagraph. Dr. Hertz presented the study results to the NASA Administrator on May 30 and has since received direction to continue preformulation activities for a mission using the 2.4m telescope assets. A decision on an actual mission will come no sooner than 2016.

The strawman mission described in the DS is reflected in Design Reference Mission 1 (DRM1), which the WFIRST science definition team (SDT) delineated, using existing technology and keeping costs to what the DS advised. The aperture of that telescope is 1.3m unobstructed, and the cost is about $1.6 billion. This puts the AFTA WFIRST cost estimate, excluding the coronagraph and launch vehicle, in about the same range. Dr. Nousek expressed concern about costs shooting up as they did with JWST. Dr. Hertz explained that that conversation will be ongoing over the next 3 years. The Division has allowed itself to consider a larger, more capable mission that might cost up to 20 percent more. APD will want to ensure an upper limit with a new start.

Dr. Nousek clarified that he was not raising the issue that the same technology issues on JWST will beset WFIRST. However, he observed, human nature is such that early in mission conception, everyone is eager to get as much as possible. This goes back to Hubble and, over the years, NASA has seen that lack of discipline leads to strategic cost issues. Dr. Hertz agreed. If he takes worst-case costs, he gets an unacceptable number. It is important to understand that and to balance the science appetite against what the political process will approve, and also to consider what percentage of the APD budget goes into a single mission. The Division will have to look at that, as program balance is a key element in the DS. The AFTA team will need to keep in mind descope options if they are necessary to stay within the cost range.

Dr. Kenneth Sembach said that without a science appetite, one does not do extraordinary things. Dr. Hertz agreed. NASA needs to unravel the marvels and mysteries of the universe. The question is, what does this take? Dr. Terry Oswalt asked how the AFTA study came to add the coronagraph. Dr. Hertz said that this was an option requested by SMD and presented to the Administrator. The science of the coronagraph is exciting, though it is descopable since it is not required to meet the science objectives prioritized for WFIRST in the DS. No one yet knows what it will cost or if the coronagraph is affordable. But the science potential is good enough that it is worth studying whether to include a coronagraph, if possible. Dr. Gary Melnick said that flagship missions are important, but the science return does not always scale with the cost. When people talk about costs, they usually assume an optimal funding profile, but costs go up.

Dr. Hertz said that the schedule is set to allow the President to request the budget for a start in FY17. The SDT reports are available online. “Focused technology development” means ensuring that technology readiness levels (TRLs) are achieved at certain junctures, and this is reflected in the strategic budget line and investment into the technologies to move forward on this schedule. The Space Technology Mission directorate wants to partner with APD to mature the coronagraph technology. Whether the partnership goes forward is part of the embargoed budget process. Dr. Hertz would appreciate the help, however. If NASA moves down this line, in order to mature coronagraph technology, APD will have to down-select the number of coronagraph technologies in which it invests. The Division has begun that process, and will be down to two from five by the end of the calendar year.

In early 2015, NASA will ask the Committee on Astronomy and Astrophysics (CAA) to review the SDT reports in the context of the DS recommendations. A cost appraisal and technical evaluation (CATE) will

be due in late February 2015. The highest priority is to respond to the WFIRST recommendation in the DS. However, if that is not affordable, APD should still follow JWST right away with a strategic mission. The Division is therefore studying probe-class missions that cost $1B and respond to DS priorities. DRM2 does about 60 percent of the DS recommended WFIRST science, for example. The Division will start an x-ray probe study soon, and will look at two exoplanet probe missions. He wants the NRC to weigh in on the cost/science-benefit balance.

Dr. Nousek described the AFTA study as "WFIRST plus," going beyond the DS. In that context, one cannot really ask about meeting the DS requirements. Dr. Hertz elaborated, saying that if one starts with the 2.4m telescope assets, the question is whether one can do the DS science. If so, and these telescope assets allow one to do more science than is also recommended in the DS, then there is an opportunity to do better than the minimal WFIRST described in the DS, and for about the same cost. If APD can get more exciting science for the same cost, that is great. If it is prohibitively expensive, it will not happen.

Dr. Bregman said that there are large missions accomplishing some really great things for $2 billion, as well as smaller things like TESS, an Explorer. So if there is an opportunity to spend $1 billion, does it make sense to do one big thing or five smaller things? There are also different technologies. APD has a number of different areas that have been brought along at NASA, and as they all become more expensive, NASA may become a minor partner in international collaborations. He wondered if they might be marching to abandon certain areas of former strength that the Agency can no longer afford.

Given a choice, Dr. Hertz said that he wants both Explorers and a large mission. Many things drive APD out of balance, however. The Division wants to partner with other agencies doing missions addressing APD's strategic objectives. The European Space Agency (ESA) may choose a mission that follows some DS priorities, and NASA does not always need to lead. If budgets continue decreasing, can NASA afford to maintain all the capabilities we have as a nation in doing space astrophysics? Or does the Agency have to look at which are most likely to pay off in the near term? He does not know. Stakeholders will have to weigh in, and the science community might have to have this discussion about the long-term health of the profession.

The Kepler spacecraft completed its prime mission and went beyond baseline. It is not now taking science data, but it was fully successful, and there is a wealth of data in hand. The mission lasted beyond the design lifetime, but not the design hopes. Reaction wheel 4 stopped on May 12, another reaction wheel had previously shut down, and the mission cannot take science data with only the two remaining reaction wheels. The science data processing continues. There will be one more attempt to recover the two wheels, but the prognosis is poor and there is no optimism about this. However, this has to be attempted. If it fails, the mission team will have to plan for a two-wheel mode, though it will not allow the exoplanet science that Kepler has been doing up until now. At that point, NASA must decide if the possible operations will be worth the investment. That decision has not been made because the alternative operation mode is still being determined.

The Stratospheric Observatory for Infrared Astronomy (SOFIA) mission is in the midst of Cycle 1 and has received proposals for Cycle 2. It was deployed in New Zealand to conduct its first southern hemisphere campaign. The High-resolution Airborne Wideband Camera (HAWC+) instrument is at the Jet Propulsion Lab (JPL) for upgrades. The hardware failures experienced this spring have been resolved. There were lost science opportunities, and Dr. Hertz was not sure how those will be handled. There are spare parts and a maintenance program for this reason. There have been over 100 proposals at about a 4-to-1 ratio of U.S. to German, and oversubscription works out at the same level.

The Astro-H mission is working well at the U.S. end and NASA is on track to deliver its instrument to the Japanese Space Agency (JAXA) in February. However, there were vibrations detected during spacecraft

testing in Japan. NASA is supporting engineering tests to resolve the vibration issue. The JAXA schedule has slipped, so there is cost growth for NASA, and NASA will have to reset the life cycle costs for the project. The projected launch date is in late 2015. The heat switch issues mentioned previously have been resolved.

JWST remains the highest astrophysics priority, and APS was to hear more about it the next day.

APD has launched five sounding rockets so far in 2013. All of the operating missions are doing fine except for Kepler. ESA closed down Herschel and will shut down Planck in October. The Galaxy Evolution Explorer (GALEX) mission was completed at Caltech and shut down by NASA on June 29. This established both a precedent and a process for private funds extending missions after NASA is done funding them.

Dr. Hertz noted that APD had selected postdoc fellows in the Einstein, Hubble, and Sagan Fellowship programs. He also gave the selection rates on proposals for each research program. There will be two senior reviews next spring, one on missions and the other on archives. The Division is evolving the Virtual Astronomical Observatory with the National Science Foundation.

The Analysis Groups (AGs), advisory committees, and SDTs are all ways for the community to give input. APD is updating the Physics of the Cosmos Program Analysis Group (PhysPAG) and Cosmic Origins Program Analysis Group (COPAG) charters. The current subgroups in PhysPAG are not the typical task-oriented subgroups, so the updated charter recognizes that by calling them “Science Interest Groups” instead of “Science Analysis Groups.”

Dr. Hertz showed the most recent SMD organizational chart and reviewed some SMD highlights. The Heliophysics Interface Region Imaging Spectrograph (IRIS) Explorer was launched, and the Lunar Atmosphere and Dust Environment Explorer (LADEE) and the Mars Atmosphere and Volatile EvolutioN (MAVEN) mission will launch this year. LADEE and MAVEN are both Planetary Science Division (PSD) missions; that Division also recently confirmed the Origins-Spectral Interpretation-Resource Identification- Security-Regolith Explorer (OSIRIS-Rex) mission. Congress had two hearings of note: one on exoplanet discoveries, and the other on science, technology, engineering, and math (STEM) education and the proposed reorganization of E/PO. The transcripts are available online.

Budget
For FY13, Congress has still not approved an operating plan. Congress appropriated $659 million for APD and $628 million for JWST, $10 million more for APD than the President’s request. The extra funds went specifically to WFIRST. Minus the 1.8 percent rescission and 5 percent sequestration cuts, along with other budget adjustments, however, the result is a significantly lower APD budget. He still does not know his final number, but suspects it will be about $40 million less than the appropriation. APD has already reduced spending to get into the ballpark. Without an operating plan, he does not have all of the funds available; there is about 5-10 percent that he cannot yet distribute to the projects.

APD will take reductions in FY13 for missions that were carrying over funds, in which case the funds were removed; some missions in development that have reserves not being spent in FY13; some R&A funding; slowdown of announcements of opportunity (AOs); and, postponement of needed upgrades in infrastructure programs. Some missions have funds for guest observers but were not going to spend the money until FY14, so APD made an accounting move with those funds.

The next Explorer AO will be no earlier than fall 2014. The suspended mission of opportunity (MoO) is not a consequence of sequestration but of the FY14 budget request for the Explorer Program being $60 million less than APD had planned to. Impacts from sequestration mean that APD has to permanently lose

$40 million of content. In research and analysis (R&A), there have been fewer selections in FY13, and no money is being given this year if the PIs do not yet need it. Delayed finalization of the budget means that some new awards cannot be started in FY13 and will be deferred to FY14. Some specific impacts include fewer selections from Research Opportunities in Space and Earth Sciences (ROSES) 12 in theory and origins of solar systems, with some new selections delayed until FY14. Theoretical and Computational Astrophysics Networks (TCAN) has all new funding starts delayed until FY14. The potential impacts of sequestration in FY14 include fewer selections in Astrophysics Research and Analysis Program (APRA) 12; Astrophysics Data Analysis Program (ADAP) 13 and Origins of Solar Systems (OSS) 13 will have fewer selections; the Astrophysics Theory Program (ATP) 13 will have new funding starts delayed to FY15; and, the Roman Technology Fellowship impact is yet to be determined.

Welcome from Goddard Center Director

Dr. Chris Scolese, Director of Goddard Space Flight Center (GSFC), welcomed APS to the Center. On the second day of the meeting, APS members were to have a tour and see JWST. Two JWST instruments are in at this point. The Near Infrared Camera (NIRCam) is being looked at for what seems to be a minor issue, and the Near InfraRed Spectrograph (NIRSpec) is on the way in. Both instruments will undergo cryovac testing. Detector replacement is coming along better than expected, and the microshutters appear to be meeting the specifications. The spacecraft critical design review (CDR) is proceeding well, and the Johnson Space Center (JSC) facilities are getting ready and can even take JWST ahead of schedule. The sunshields are also doing well. So JWST is in good shape. The concern is budget stability. The latest House bill cuts the budget, which is a concern. Dr. Hertz added that both TESS and NICER are being managed by Goddard, as is the science portion of the asteroid retrieval mission.

Astrophysics Division Update continued

Budget continued

Dr. Hertz said that APD is protecting its technology investment, while also shifting from proposal-driven projects to investments that support strategic mission candidates in acknowledgement that future strategic missions are the priorities. This means that APD will not fund as many SAT proposals, but the work will be funded consistently. Dr. Nousek said that he counted three potential budgets to deal with: FY13, the President's FY14 budget that was being marked up, and a CR. There are conflicting cuts and priorities among those budgets. Dr. Hertz said that APD talks about this constantly. The budget numbers that the House and Senate are marking up are very, very different. Neither bill has been passed by the full chamber, so there is no conference committee. No one expects a NASA bill to be passed by either chamber, which means the Agency will probably have a CR. There will be an additional sequestration cut factored in at about 8 percent below the President's FY14 request. This makes it necessary to think about what to do if the budget is less than the President's request. These scenarios are all planning exercises. Dr. Hertz is fine with hearing APS wishes, but he is to follow the DS, maintain a balanced program, and address near-term priorities. The cost of interrupting development of a program that is far along is much greater than the cost of delaying new programs. It is important to keep commitments to selected PIs.

The other thing he thinks about a lot is how JWST plays into this. JWST is the most important astrophysics mission. The best thing for astrophysics is for it to launch on cost and on schedule. Failure to meet the cost and schedule commitments means significant difficulty going forward down the line. So he would not cut JWST if it were up to him.

Dr. Peterson asked if APD could add funds to JWST if the House gave it too little to sustain the mission on its current path. Dr. Hertz replied yes, that could be done through an operating plan change, and that would have to go to Congress for approval. Whether they would accept it depends on the people and circumstances. It would be a challenge. It is not possible to plan for all of the possible futures. What

NASA can do is think about priorities and where cuts can be taken, in order to respond nimbly. An APS discussion of priorities would be useful.

The proposed FY14 budget has not changed since the last APS meeting. The Fermi team was able to replan its operations within the budget they were given in order to avoid cancellation of the Fermi Guest Observer program, and they did a great job of maintaining the science. The President's FY14 budget request has requested that JWST be funded at the level needed to stay on plan. Unless there is a budget deal achieving deficit reduction other than sequestration, sequestration will continue each year. The President's budget request assumes it replaces sequestration. Despite all this, during the course of this Administration, NASA has done well, about third-best among the various agencies. It is an Obama Administration priority.

Regarding the near-term strategy, now that the AFTA study has been approved, APD is doing additional SDT studies of AFTA, along with studies of exoplanet probes and an x-ray probe. An interim SDT reports will be presented to NASA and CAA next spring. APD would also like to partner with ESA on a large mission, if an astrophysics mission is selected for the next large ESA mission. In FY15, the SDTs will do their final reports, followed by an NRC study on the responsiveness of the Design reference Missions to the DS. That same year, APD and NSF will kick off the mid-decade review. Regarding funds for ESA opportunities, there is a "strategic missions" line in the years after the JWST launch, which can be used to fund both the NASA mission and any contribution to ESA large missions. Dr. Hertz hopes that in 2015, during the public discussions of what will follow JWST, the right path will be clear. His goal is to have the studies so transparent that everyone will end up in the same place. The NASA decision will be part of the budget formulation activity, and it will therefore be embargoed.

Dr. Melnick said that another option is the fuzzy middle ground of the "balanced program." He was not sure how APD would get there without a strategic mission. Dr. Hertz presented a slide of the current balanced program without JWST. The purple Supporting Research and Technology (SR&T) wedge is for the next big mission, and the total for APD remains the same. JWST costs would be decreasing at that point. He expects the mid-decade review to provide feedback on what the program will look like. That is the opportunity to review the balance and where the Division is going. The mid-decade review's prime purpose is to compare what the Division is doing with what the DS said to do, factoring in constraints like the reduced budget.

Dr. B. Scott Gaudi asked how the decision would be made to do a probe if WFIRST does not go forward. Dr. Hertz replied that the decision will be during the embargoed budget process. If there are two probes, they will occur sequentially, not simultaneously. In a highly optimistic scenario that is unlikely, APD could do WFIRST and a probe together. There will be no gravitational wave probe, by the way; the Community Science team report said that there is no compelling mission for $1B.

Dr. Nousek asked what the mid-decade review will do, given that there are already answers from the SDTs. Dr. Hertz said that there are dozens of recommendations in the DS, including many smaller missions and activities. The review could say that the balance is all wrong, and that after JWST, money should go into R&A, for example, though that is not what the DS says. The mid-decade review is a statutory requirement, and as NRC has always resisted revisiting DS's at the midpoint, he will ask for a review of NASA's performance against the DS recommendations in the context of the fiscal constraints.

Dr. Chryssa Kouveliotou was to discuss the roadmap the next day. The roadmap team will submit to APS a complete draft no later than October 21. APS will then give comments, and the roadmap team will provide the final report at the APS November meeting. The purpose of the roadmap is to show why continued astrophysics investment is critically important. There is a lot of fabulous science that could be done, and this needs to be articulated to astrophysics' stakeholders and to the public.

Two exoplanet probe science and technology definition teams (STDTs) were just started, one for an internal occulter and the other for an external occulter. APD expects to start an x-ray probe STDT this year. This will look at a probe-sized mission that will advance the science of an International X-ray Observatory (IXO). If ESA moves forward with an x-ray mission that NASA partners on, APD will not pursue an x-ray probe at all.

Government Performance and Results Act (GPRA) Modernization Act (GPRAMA)

Ms. Jennifer Kearns, a Program Analyst within SMD, explained that GPRA was passed in 1993, with an update in 2010. GPRA requires each Federal entity to provide a strategic plan, an annual performance plan, and an annual performance report. This Act was geared more to other agencies, not those with an R&D orientation, but NASA has adapted. The Agency measures mission milestones that are objectively verifiable, and also looks at science results through the SMD advisory subcommittees.

Dr. Joan Centrella, APS Executive Secretary, had sent out some draft text to serve as a starting point for the APS. The evaluation should be based on key accomplishments and disappointments, with results evaluated in context of the available resources. The period under consideration is the previous 12 months. APS was to consider results from NASA-funded activities only, with a strong preference for results published in peer-reviewed journals.

For each performance goal, SMD needed an official recorded vote from APS in terms of green, yellow, or red. A rating of green meant that the expectations of the research program were fully met in context of the budget; yellow meant that there were some shortfalls but some science was achieved; and red meant that there were major disappointments or shortfalls in scientific outcomes in context of resources invested, uncompensated by any positive results.

Dr. Centrella provided examples of the supporting text that is needed. For any rating less than green, SMD had to have a clear explanation. The color ratings will appear in the Agency's annual performance report. Not all of the examples offered will appear, so if some items are critical, APS was to note those. Both the NASA office that compiles the report and the Office of Management and Budget (OMB) tend to select the most public-friendly examples that will appeal to the intelligent layperson. That sometimes makes it necessary to advocate inclusion of some key science results.

Ms. Kearns further explained that this is not the place to consider future work or issues such as under-investment. There have been instances in which delays and missed milestones were noted, but this is not supposed to be about the consequences of the level of investment. Dr. Centrella explained that she followed the pattern from the previous year, with text first, based on the strategic plan. Dr. Peterson said that once the grades were voted upon and the examples selected, he would assign writing to individual APS members. The pieces were due to him by July 26. Dr. Centrella had provided summaries based on press releases, which is what the writing assignments were to address. She then listed press releases that she had selected with assistance from the APD public affairs specialists.

Dr. Peterson began with the first Objective and Performance Goal:

> **Objective 2.4.1:** *Improve understanding of the origin and destiny of the universe, and the nature of black holes, dark energy, dark matter, and gravity.*
> **Performance Goal APG 2.4.1.1: AS-11-1:** *Demonstrate planned progress in understanding the origin and destiny of the universe, and the nature of black holes, dark energy, dark matter, and gravity. Progress relative to the objectives in NASA's 2010 Science Plan will be evaluated by external expert review.*

There was some concern about the absence of material on gravitational wave studies, and a question arose about how to show that NASA is pursuing it. Dr. Centrella suggested that there might be a bullet noting that NASA has commissioned feasibility studies in this area. This led to discussion about how to address situations in which there is interest on the part of APD and the science community despite NASA having no active missions. It was pointed out that the purpose of the GPRA review was to evaluate what is being done. Specific examples were necessary for the report, but most important was the color rating. Even a brief paragraph would meet the criteria. The detail level was entirely up to APS.

Dr. Nousek motioned to vote on the grade for PCOS; Dr. Bregman seconded the motion. The motion to vote was approved unanimously. Another motion was made to vote for a green rating, which was also approved unanimously.

Among the suggested examples were two for the Nuclear Spectroscopic Telescope Array (NuSTAR) and one for the Planck mission. Dr. Gary Bernstein agreed to write some text on Planck for the preface, and Dr. Nousek said he would do the same for NuSTAR. Dr. Nousek also committed to a review of the Swift examples for the larger text, Dr. Kouveliotou took on the gamma ray burst, Dr. Bregman was assigned the Chandra mission, and Dr. Paul Ray said he would write about cosmic fog and supernovae.

The next objective and performance goal were:

> **Objective 2.4.2:** *Improve understanding of the many phenomena and processes associated with galaxy, stellar, and planetary system formation and evolution from the earliest epochs to today.*
> **Performance Goal APG 2.4.2.1: AS-11-3:** *Demonstrate planned progress in understanding the many phenomena and processes associated with galaxy, stellar, and planetary system formation and evolution from the earliest epochs to today. Progress relative to the objectives in NASA's 2010 Science Plan will be evaluated by external expert review.*

There was discussion of the SOFIA mission, which has done engineering flights but has generated few published papers. It was agreed to add a note in the preface and write about SOFIA in the next GPRA evaluation. The Subcommittee chose to write about several Great Observatory findings, including black hole discoveries by Chandra and Spitzer. Dr. Giovanni Fazio moved to take a vote, Dr. Sembach seconded, and APS voted unanimously for a green rating.

The third objective and goal were:

> **Objective 2.4.3:** *Generate a census of extra-solar planets and measure their properties.*
> **Performance Goal APG 2.4.3.1: AS-11-5:** *Demonstrate planned progress in generating a census of extra-solar planets and measuring their properties. Progress relative to the objectives in NASA's 2010 Science Plan will be evaluated by external expert review.*

It was noted that the Kepler mission was responsible for almost all of the discoveries in this area, though Dr. Karl Stapelfeldt pointed out a Hubble discovery in this category. He, Dr. Gaudi, and Dr. Edna DeVore agreed to work on this objective together. Dr. Kouveliotou moved to vote, Dr. Nousek seconded, and the vote for a green rating was unanimous.

Dr. DeVore took on the assignment of writing something about E/PO for the preface.

The meeting adjourned for the day at 3:28 p.m.

Wednesday, July 17, 2013

Space Technology Mission Directorate (STMD) Presentation

Dr. James Reuther, Deputy Assistant Administrator for Programs within the Space Technology Mission Directorate (STMD), explained that the Directorate was established at the beginning of 2013. It had been a program in the Office of the Chief Technologist (OCT). OCT is now the advisory and policy office for technology, and STMD manages programmatic content. The Directorate supports some technology in the area of astrophysics, where Dr. Reuther works closely with Dr. Hertz.

The Directorate's primary purpose is to invest in support of a new class of NASA missions beyond low-Earth orbit (LEO). STMD also works on emerging technologies that will enable future missions, seeks innovative solutions, and tries to make technology more affordable and more reliable, thus leading to additional opportunities that are currently out of reach. The Directorate also tries to re-engage the universities in developing technology, and to cultivate the future workforce in this area.

Dr. Reuther listed nine challenges for deep space exploration, not all of which apply to science. These include communications; radiation mitigation – a current significant limitation on human exploration; propulsion – another limitation for deep space; entry, descent, and landing beyond what has been done with Mars Rovers; and power generation and storage.

STMD has a portfolio approach across the range of TRLs and investments, as part of maintaining a balance across the pipeline, investing in the best technologies for missions on the horizon, and enabling missions in the distant future. Low TRL activities are typically low-cost studies, but not many will succeed. The Directorate relies on a stakeholder strategy to set up technology roadmaps that were vetted and prioritized by NRC.

STMD follows the SMD model of merit-based and open competitions. In crafting the Directorate's early solicitations, Dr. Reuther talked with Dr. Hertz about how to do this well. Projects are structured, addressing another criticism of NASA, that the Agency has done too much open-ended R&D without tracking what is done with the budget. STMD funds particular projects with clear milestones, start dates, end dates, and defined budgets. If a project fails to meet its milestones, for example, STMD will hold talks to determine whether to continue the effort. This forces a competitive environment within NASA.

STMD tries to either infuse rapidly or fail fast. If there is no customer willing to use a technology that has succeeded in tests, STMD will cancel the project. There is no interest in doing things that will sit on a shelf and waste tax dollars. Some projects are always challenged to maintain a relationship with infusion customer, especially at high TRLs.

Dr. Reuther showed the investment breakdown into core technology (72 percent), adjacent areas (18 percent), and complementary areas (10 percent), the latter having an uncertain outcome but possible tremendous value in the early stages. This ratio tracks closely to the NRC recommendation. NRC also identified 16 top technologies, which STMD has aligned with its priorities.

There are five early-stage programs at low TRLs, some of which is related to human spaceflight. However, detectors and focal planes, optical systems, high-contrast imaging and spectroscopy, and *in situ* instrumentation projects are very science-oriented. STMD sees the SMD divisions as where the high TRL work resides. So if APD needs an identified instrument, APD should lead. STMD will focus on high-risk technologies, and do studies and prototypes.

Dr. Reuther mapped out STMD's nine programs according to TRLs. Lower TRL work includes space technology research grants for universities, which are being used as part of an effort to strengthen the

relationship between NASA and academia. The NASA Innovative Advanced Concepts program supports studies of concept feasibility, usually TRLs 1 and 2. The Center Innovation Fund is for NASA researchers to explore concepts, but they still have to achieve milestones within a set time. Other programs focus on marketplace development and new business models. For example, the Flight Opportunities Program invests in payload technology demonstrations and flight providers in the commercial reusable sub-orbital sector.

An example of the science-related work in STMD is a solar sail being developed in collaboration with the National Oceanic and Atmospheric Administration (NOAA) and SMD's Heliophysics Division (HPD). This has the potential to monitor weather that is otherwise hard to detect and evaluate, and is much larger than any previously flown solar sails. The demonstration will test deployment of a solar sail, along with attitude control, passive stability, and other features. The Directorate's reporting requirements are based more on what the aerospace industry has done with its best engineering practices and processes, rather than more traditional NASA processes.

Dr. Reuther noted some additional projects with relevance to astrophysics. These include work on advanced membrane active mirrors, and a holographic optical method for exoplanet spectroscopy. The former is a $100,000 award to study feasibility, and the latter is a concept study for $100,000 to determine whether this can be done. There are also two early stage innovations awards that have been granted in the astrophysics area. These are low TRL but beyond the level of a paper study. One is wavefront control for high performance coronagraphy on segmented and centrally obscured telescopes; the other is integrated control electronics for adjustable x-ray optics. APD helped select these. STMD also has 200 graduate student fellowships, 21 of which are in astrophysics.

APD's NICER mission team wants to try a new X-ray concentrator demonstration on the International Space Station (ISS). Seeing good technology development potential, STMD offered to co-fund NICER at 25 percent and add an x-ray navigation technology demonstration, using the same hardware and looking at the same pulsars. In addition, STMD is working with APD on two studies that examine optics: adjustable grazing incidence x-ray optics, and advanced laser frequency stabilization using molecular gasses. The latter could apply to gravitational wave studies that APD might do in the future.

Among the potential initiatives for STMD/APD collaboration is one for AFTA-WFIRST, examining the possibility of adding a coronagraph – at least as a test – and getting atmospheric spectroscopy of exoplanets. The goal is to develop an advanced high-contrast coronagraph and occulter. If the funding becomes available, STMD would like to do this for technology development purposes. It would be a huge leap forward with coronagraphs and support the future of this technology. STMD has looked at AFTA stability issues. Pushing the current coronagraph technology could result in spectroscopy for a Jupiter-class exoplanet 100 light years away. The technology development needs to start soon, though not at a high level. STMD is pushing hard to make this happen. Dr. Hertz added that APD support for this technology development is being reprioritized within APD, though budget issues remain. Dr. Reuther pointed out that it would be helpful if APS made it known that this is important. STMD is here to serve NASA mission directorates, and this effort is an extremely important part of that. At the same time, the current budget situation is very difficult.

STMD has no problem doing joint collaborations in technology development work where it is clear that NASA could work out the relationship of the technology demonstration. What the Directorate cannot do is use government funds to support technology development or demonstrations by an international entity. However, within these boundaries, STMD does have some collaborations with ESA.

Dr. Nousek asked if the STMD support for NICER affected the Explorer competition. Dr. Hertz explained that funding from outside SMD is allowed by the AO within certain limitations. The existence of the

technology demonstration opportunity in the selection of NICER was not part of the criteria for selection. Dr. Nousek remained concerned that this may affect neutrality in selection.

Dr. Hertz explained that STMD's priorities are publicly available, and anyone can see the potential for leverage. Dr. Reuther explained that there are some open competitions for Directorate opportunities. Game-changing technology is largely competed, and the technology demonstration missions are partly competed. If someone has an idea, they can bring it directly to STMD and do not have to wait for a call.

Astrophysics Roadmap Presentation and Committee Discussion

Dr. Peterson explained that APS and the Roadmap team were asked to produce a compelling vision of astrophysics for the next 30 years. This effort was not to be representative, determine specific missions, or present priorities. He noted that all members of the Roadmap team and APS have been chosen to look at the big picture. Dr. Centrella added that APS will give input on this draft, receive the final report on October 21, have 2 weeks to provide comments, and receive the amended final report the week of November 18.

Dr. Kouveliotou, the Roadmap team chair, explained that it is not an implementation plan. The Roadmap is to present a compelling, 30-year vision, using the DS as a starting point. It is science-based, with notional missions, and takes into account community input. It is not a mini-DS or implementation plan, but it is a long-range vision document.

The Roadmap team asked three questions:

- Are we alone?
- How did we get here?
- How does our Universe work?

The document is organized around those questions.

To determine if we are alone, NASA will identify and quantify the abundance and diversity of planetary systems, find which of the nearest terrestrial exoplanets are habitable and might be inhabited, and map habitable environments and possibly biospheres on nearby worlds.

To learn how we got here, NASA will map newborn stellar and planetary systems across the Milky Way, decode the assembly of the Milky Way galaxy, and characterize the nature of the Universe's first galaxies and the subsequent growth of galaxy components thereafter.

Conveying to the public how the universe works is difficult. To answer this question, NASA will try to understand the imprints of the Big Bang to shed light on the origin of our universe, try to understand the nature of dark matter and dark energy, open new windows on gravitational waves, and explore extremes of gravity and matter.

Dr. Kouveliotou presented six "daring visions" that the Roadmap team would like to have accomplished 30 years from now:

- Map the surface of an Earth-like planet;
- Find evidence of life beyond the solar system;
- Reconstruct the formation and history of the Milky Way and its neighbors;
- Tell the complete story of the galaxies;
- Chart the warped space of a black hole and explain how black holes power the greatest outflows of energy; and,
- Sense the ripples in gravity to the edges of the Universe.

The Roadmap team addressed three eras: present to near future era (now to 15 years), formative era (15-30 years), and visionary era (30+ years).

For the Present, the Roadmap notes several options for looking at whether we are alone. This includes finding our nearest neighbors/exoplanets, continuing Kepler's work, and doing ground surveys of nearby planets and dust in the habitable zones of nearby stars. The team listed a number of space-based surveys that incorporate the capabilities of TESS, JWST, and WFIRST with the coronagraph.

To determine how we got here, the Present timeframe includes study of star and planet formation, characterization of nearby protoplanetary disks, and various studies of the Milky Way and its stars, the galactic neighborhood, and the galactic assembly.

In studying how the Universe works, missions in the Present will examine the interdependence of galaxies and their supermassive black holes (SMBHs), fundamental physics, and cosmology.

The bulk of the work envisioned in the Roadmap will occur in the Formative era. In asking "are we alone?" NASA will go to much higher resolution in spectra and imaging, locate planets with evidence of water, and try to find atmospheric biomarkers to establish evidence of surface life.

Very high resolution spectroscopy and imaging will address how we got here, as well. This is needed to understand star and planet formation, the locations of the nurseries for new stars and planets, and the physics of this process. A lot of work will involve studying the Milky Way, such as fully characterizing surviving and disrupted Milky Way relics, the stars and their velocities, and other factors. In the galactic neighborhood, NASA will resolve the entire Hubble sequence with about 100 galaxies of all Hubble types. Theoretical and computational astrophysics will be essential in much of this work. Another challenge will be to identify first light and how the galaxies came together and built up.

To understand how our universe works, the Formative era will strive to learn how the SMBHs and their host galaxies came to be and interact. NASA will also study fundamental physics and extremes of nature, and will probe the dynamics of cosmic rays. In the area of cosmology, NASA will use gravitational waves to develop a history of the universe and detect the emergence of structures.

Capabilities required include X-ray missions with high resolution and large collecting areas, ultraviolet infrared telescopes, and a mid-to-far infrared space-based interferometer. NASA will need a cosmic microwave background (CMB) polarization mission, a gravitational wave mission, probes or Explorer missions to study CMB blackbody spectrum distortion measurements, a 21-cm lunar orbiter observing from the other side of the moon, and an X-ray and gamma ray transient monitor and polarimeter.

The Visionary era will call on NASA to map the surfaces of habitable worlds identified in the previous era. The Agency will need space interferometry to distinguish biomarkers, land, water, clouds, ice, and other features. There will be further advances in fundamental physics and studying extremes of nature. NASA will need direct imaging of powerful accretion flows around SMBHs, and the ability to do simulations. There should be the capacity for direct detection of primordial gravitational waves to listen to inflation. The area of Cosmology will address a precise map of universe expansion and a detailed map of structure formation. There will be surprises and new phenomena before we reach the Visionary era, and these requirements may be changed according to the 30 years that go before.

Needed capabilities will include a microarcsecond x-ray imager, optical and infrared space interferometer, high-sensitivity, multi-element imaging gravitational wave array, and 21-cm lunar surface radio telescope array.

Visionary era outreach is an ongoing discussion. It is very important to convey all of the results to the public and stakeholders. The Roadmap team will recommend three way ways of doing this. First is to adapt how we distribute data to reach the public effectively in a digestible format. Second will be to foster learning in formal and informal settings. Third will be to engage the widest audience possible using technologies and methods conducive to learning in a variety of settings so that people of all levels of engagement can participate.

Discussion
Dr. Bregman expressed concern about elements of the science community that might feel they were overlooked or could do the work better in a different manner. Dr. Kouveliotou replied that her presentation was a summary that did not include all of the missions being discussed. It would not be possible to change the slides to include it all. Everything the team has will be expanded upon in the written report, where APS members can make sure they did not miss anything. She did not want to discuss specific missions.

Dr. Gaudi added that the audience is not the science community, and that he thought they probably would end up offending someone in the community. The real audience for the Roadmap is those who can affect funding. That is the bigger picture – to inspire interest and get more financial support. Dr. Ray said that the Roadmap should address why NASA needs to do this, because that is the Congressional question. Dr. Kouveliotou added that they did not include international concepts, since this is a NASA roadmap. However, she expects collaboration; these concepts do not have to be completely NASA-driven. The Roadmap says "we need that" in order to move ahead with the vision. Yet some of these things will be superseded as we learn more and make progress. The vision is constantly changing.

Dr. Melnick said that the best strategy for ensuring that this document is heard is to make sure that groups in the community do not declare it faulty. Dr. Oswalt observed that core interests are present: exoplanets, Milky Way structure, and the physics of matter and energy. He did not see much about stars, however. Dr. Kouveliotou said that they were among the concepts that did not make the presentation, but are definitely an important part of the near future and formative era studies. The report will call them out. If APS members give input, the team will make sure it is in the text. Dr. Oswalt was very pleased to see reference to a continued need for existing missions and facilities.

Dr. Sembach said that it was obvious that lots of work had gone into this, and the presentation told a good overall story. When he thinks of a roadmap, however, he thinks of milestones. Even if this is more of a vision, a vision has an endpoint. He worries that the public and funders will say "you just want to do everything," and he was concerned about some things being diluted. Parts of the presentation were specific in representing the intermediate goals. He also wondered about the use of the word "fully" on some of these, which did not strike him as realistic. As they promote a vision, someone will want to know the endpoint. He advised being careful about having enough structure that it does not look like they are asking for the world.

Dr. Kouveliotou agreed. The text should establish that what the team puts in the Roadmap is feasible and reasonable. She expects the written report to be about 100 pages, though it will not include the milestones. Dr. Hertz noted that there are preconditions for some of the longer term work. Dr. Gabriela Gonzalez commended the Roadmap team. She suggested that there be more emphasis on outreach. Dr. DeVore went further, urging the team to be bold, especially in terms of how this is communicated to the public, teachers, and students. It is important that this be a strong statement. They should not be fearful or feel constrained. Dr. Centrella agreed that they want to be bold, but the team does not want to use the wrong words to get the report thrown out.

Dr. DeVore added that many of her colleagues and stakeholders feel that when one asks whether we are alone, then stop at characterizing planets, it does not go far enough. Dr. Kouveliotou said that the Roadmap will mention the Search for Extraterrestrial Intelligence (SETI). Dr. Oswalt agreed that this was necessary. He thinks we will know whether we are alone within 30 years. Dr. Bernstein recommended separating what we

will know and what we want to know, with less on process and more about the great questions and the answers NASA would have if they get what they want.

Working Lunch and JWST Briefing

Mission status
Dr. Jonathan Gardner, Deputy Senior Project Scientist for JWST, gave an update on the mission's progress. JWST is the successor to Hubble and Spitzer, with a 6.6m telescope and four instruments. It will launch in late 2018 and is complementary to the large ground-based telescopes. Fourteen countries are delivering hardware for the mission, which is based at GSFC.

Mr. Geoff Yoder, the previous Program Director, has moved into another SMD position; Dr. Eric Smith is the Acting Program Director. Dr. Gardner mentioned other notable personnel on the mission, pointing out that the science working group for JWST is half external, half ex officio.

JWST's science was written in the science requirements document about 10 years ago, with four themes, all of which are still compelling:

- End of the dark ages: first light and reionization;
- The assembly of galaxies;
- The birth of stars and protoplanetary systems; and,
- Planetary systems and the origins of life.

The original idea was that JWST would find the first galaxies that formed in the universe, which can be determined by redshift. In studying reionization, JWST will conduct spectroscopy and look for the patchy absorption of "bubbles." JWST will also examine where and when the Hubble sequence formed and how the heavy elements formed. The mission will contribute to studies of dark matter and dark energy using gravitational lensing and measurements of the Hubble constant.

NIRSpec will allow a better look at the physical processes that determine galaxy properties, including starbursts and black holes. JWST's infrared instruments will help map star density through the clouds and dust in star-forming regions, while also looking at the smallest brown dwarfs. The Mid-Infrared Instrument (MIRI) will study how planets form and how habitable zones are established. The selection of the TESS mission will locate bright stars with transiting Earth-like and super-Earthlike planets for JWST to look at as targets.

Dr. Gardner noted that recently added capabilities by the team's Canadian partner will allow defocused spectroscopy for exoplanet transit studies. JWST will also take images of "young Jupiters," as the mission will have the capability to study gas giant science. Within our solar system, JWST will examine a number of features, such as the moons of outer planets. Within the orbit of Mars, the mission will be able to view comets.

The schedule from now to the launch follows yearly themes: 2013 is for instrument integration; 2014 will be devoted to manufacturing the spacecraft; the mirror will be assembled in 2015; the observatory will be assembled in 2016; 2017 will be the time for observatory testing; and, 2018 will be the countdown. Dr. Gardner showed the top level schedule, with the months of funded schedule reserve. He noted the additional funded reserve for the Integrated Science Instrument Module (ISIM). The schedule milestones are included in monthly reports. Since the replan, the program has hit most of the milestones on time; when milestones are missed the program has always been able to accommodate them within the schedule reserve.

Science operations will be managed by the Space Telescope Science Institute (STScI), which will command the observatory and process data. Targets will be selected annually, through calls for general observers. This is

all similar to HST. A mix of small to large programs is likely. To test the scheduling procedures, a full year of test observations has been developed. Workshops will begin at STScI starting in March 2015, and observing proposals will be due 1 year before launch.

The science operations design reference mission (SODRM) involves 1 year of realistic JWST science projects, developed by about 50 scientists. This is a tool for investigating JWST's capabilities for daily data volume, efficiency, schedule availability, and maintaining propellant. It includes 70 science programs and exercises all four JWST instruments.

A photometric performance sensitivity chart compares JWST's capabilities to those of Hubble, Spritzer, SOFIA, and Gemini; a similar chart shows relative spectroscopic sensitivities. Dr. Gardner listed a number of publications and white papers with additional information, and noted that there have been two conferences. There is also an active web page, a strong social media presence, and a webcam of the clean room. STScI has a web page with astronomer software tools related to the mission.

Dr. Nousek asked if the replan had resulted in any lessons that could be applied to APD's next flagship missions. Dr. Gardner said that having sufficient contingency has made a difference, as it allows the team to address problems without them becoming a crisis like they did previously. Dr. Hertz added that the 70 percent confidence and annual reserves are important as well. At NASA headquarters, it is apparent that there is an effort to meet milestones and solve problems now. Dr. Nousek said that he also sees that, and hopes the next flagship can learn from this. Dr. Hertz explained that Dr. John Grunsfeld, SMD's Associate Administrator, has a chart comparing recent launches to their plans and measuring how closely they track. It is almost Gaussian the way the ones that go over and under their plans balance out. The reserves will raise the cost on WFIRST, but they will keep the WFIRST team from depending on everything always going right.

Dr. Gardner further explained that the replan has reserves for each year, and the team is on track. While he could not and would not speak to the budget and politics, he noted that the project is committed to the replan. If the mission does not receive the replan budget profile in the future, then the program will not be able to stay within budget and schedule.

Outreach

Dr. Amber Straughn, Deputy Project Scientist for Communications and Outreach, spoke next, noting that outreach on this project is broad and falls into four categories: E/PO, communications, legislative affairs, and outreach to the science community. The categories each have different audiences. Much of the outreach is done by the partners, especially STScI. Communications encompasses the media, an online presence, and advocacy/conference support. Legislative affairs includes events, such as "Lunch and Learn" for Congress and tours at GSFC. Products also fall into this category. Outreach to the science community is conference support, newsletters, and the web page. Social media cuts across all of these categories.

Dr. Straughn gave the example of JWST's presence at South by Southwest (SXSW), which is one of the largest cultural festivals in the country and had a science and space exploration theme this time. In addition to having an interactive technology area, the mission sent a full-scale model to the free gaming expo part of the festival. There was a great turnout. This effort reached a new, highly engaged audience that was tech savvy but not a standard "NASA geek" audience. The success of this outreach effort was due to the teamwork between GSFC, STScI and Northrop Grumman. While this outreach effort addressed several categories, it was not targeted to scientists. Instead, the team had a strong presence at the last American Astronomical Society (AAS) meeting.

Dr. Straughn also reviewed the social media efforts, which include Facebook, Twitter, YouTube, and more. As to gauging social media effectiveness, there are metrics of public interest, which the project's social media person uses.

Instrument status
Dr. Mark Clampin, the JWST Observatory Project Scientist, described the status of the observatory. All of the flight mirrors are complete and gold-coated. They meet the requirements and will all be delivered to GSFC by the end of the year, where preparations are being made for testing and integration. The high-speed curvature interferometer (COCOA) has been developed, and the aft-optics system (AOS) is complete and has been fully integrated. The AOS will be stored until 2015, at which point final testing begins at JSC.

The telescope's backplane includes two wings, a center section (CS) and the backplane support fixture (BSF). These pieces are complete, and the critical path runs through the backplane schedule. The CS & BSF pieces must be cryo-cycled twice and the joints tested. The wings have been cryo-tested already. The difference in weight between the two wings is minute, only 0.005 kg. The primary mirror backplane assembly (PMBA) center section has been mated with the support fixture. Telescope integration will start at GSFC in 2015.

The spacecraft bus has been the center of attention this year. The bus provides power, attitude control, propulsion, and other important functions. A key milestone is the CDR in December 13. On the sunshield, the main activity is flatness testing of the five template membranes. The team has been verifying the 3-D shape for each layer under tension, and verifying the folding/stowing concept for the membranes. The fully tensioned sunshield layers are not flat, and the five layers should not touch each other t maintain thermal performance, and the edges must correctly align to avoid thermal stray light.

Dr. Clampin next discussed the optical telescope element (OTE), and ISIM integration and test flow, and showed the OTE + ISIM (OTIS) test configuration. The main goal is to verify that the proper cryo-alignment of the OTE and instruments. Systems level deployment is under review and the timeline for each deployment is being optimized. The launch window per day is not that long, since the precise orbit is affected by the time of day of the launch. JWST will not use the moon for a gravity assist. There are a lot of launch windows during the year, except around the solstices.. Northrup Grumman is doing a lot of the deployment hardware testing. Things that take a lot of time include various alignments, like observatory alignments.

Dr. Clampin reviewed the integration and testing (I&T) process, and closed by noting that the Observatory is executing to the baseline.

ISIM status
Dr. Matt Greenhouse, ISIM Project Scientist, explained that ISIM will weigh about 1.4 metric tons, which is about 20 percent of JWST by mass. It includes MIRI, the fine guidance sensor (FGS), NIRCam, NIRSpec, and nine instrument support systems that can be shared. MIRI, FGS, and seven of the nine support systems are complete. NIRCam is the main infrared imager, with a very wide field of view and some redundancy. The primary mirror consists of 18 segments that have to be periodically adjusted in flight. NIRCam will arrive at GSFC at the end of the month.

NIRSpec is unique. It will acquire near-infrared spectra of up to 100 objects in a single exposure. This instrument is being developed in Europe and includes 250,000 microscopic trapdoors that can be individually opened or closed, as well as fixed long slits and an image slicer. MIRI does mid-infrared and was the first instrument to be delivered. MIRI picks up where NIRCam and NIRSpec leave off. It also supports coronagraphic imagery. Because it has to operate colder than the NIR instruments, it has a mechanical cryocooler. The FGS is being developed by Canada and has slitless spectroscopic imagery.

NASA and its partners had to invent a composite structure to meet the mission requirements. Another challenge is the electronics for instruments. Some have to be close due to cable length restrictions. The 11 boxes are warm, so they are on the back side of a radiator to create a shaped beam pattern that prevents

disruptions. Another challenge is the harnessing between the boxes and the instruments. To address this, the team developed an approach to route the harness out to where the heat could be diminished.

An upcoming first element level test will involve nine subsystems and two instruments. This will be first time having the elements together. The first verification test will occur between April and August 2014, followed by rework and more verification testing about a year later. Delivery to OTIS is planned for November 2015.

Dr. Greenhouse next discussed ISIM testing at GSFC, where the sensors had to be reworked. There will be spare equipment for diagnostics and trouble-shooting.

Public Comment Period
An opportunity was provided for members of the public to speak to APS. Dr. Peterson received no response when he asked if any members of the public had comments.

ExoPAG Report from SAG-5 on Exoplanet Imaging
Dr. Gaudi, ExoPAG Chair, explained that SAG-5 looked at the requirements for a flagship direct imaging mission. This mission would be far down the road, but the SAG is set up to list science baseline requirements, along with things scientists would like to do. At the previous APS meeting, he sent the report to the members and asked for approval.

Dr. Nousek asked whether he was asking them to endorse the report or accept that it had been done. It was the latter. Dr. Gaudi said that there is a current SAG to do something similar but on a smaller scale, and APS approved it. Dr. Kouveliotou motioned to accept the report, and Dr. Oswalt seconded.

The document is posted on the ExoPAG website. It is input to NASA to use at the Agency's discretion as a resource. It is not advice or a roadmap, just a technical document. The vote was in favor of acceptance, aside from one abstention, from Dr. Stapelfeldt.

Committee Discussion and Summary of Meeting
Dr. Peterson suggested APS return to the subject of the roadmap. Dr. Kouveliotou reiterated that APS comments should go to her. Subcommittee members can continue sending comments until the document is final, though anything received in the next month or so would be very helpful. She is allowed by FACA rules to send answers to all of APS, along with clarification. The presentation will be posted on the APS website.

Dr. Peterson next asked what APS wanted to include in the letter to the NAC Science Committee. Approval of the Roadmap will be addressed at a future meeting, but it was agreed that the letter would note that the project is on track. The letter would also mention acceptance of the ExoPAG SAG-5 report. On JWST, it was suggested that the letter include approval of the mission's progress and verbiage supporting STMD on coronagraph technology development.

For the GPRA report, Dr. Peterson said he would circulate what he received from the various writing assignments. When Dr. DeVore brought up E/PO and the lack of clarity for FY14, Dr. Peterson noted that this had been addressed at length in the last letter, so it remains unresolved. Dr. Melnick then asked if there had been any feedback on that letter, which raised several issues. Dr. Peterson said that there had been none, though the E/PO issue was taken by the Science Committee to the full NAC. The Science Committee was meeting in 2 weeks, and he would find out what happened.

Dr. Bregman said it would be helpful to have NRC do a study examining the asteroid retrieval rationale. Dr. Hertz observed that, as this is an Obama Administration priority and it is not being done for science reasons, he would be surprised if an NRC study happened. The mission will test other systems such as solar electric propulsion. SMD's role is to discover and characterize an appropriate target for the mission. Dr. Bregman

withdrew his suggestion. When Dr. Nousek said that he understood that Congress had reacted negatively to the mission, Dr. Hertz explained that the House reauthorization bill directed NASA not to do the mission. There has not yet been a cost analysis.

Dr. Oswalt expressed his thanks for the tour of the JWST working area that APS took during one of the lunch breaks. It was agreed that this was very helpful. As the new chair of COPAG, Dr. Sembach wanted clarification on how to create and disband SAGs. He was told that Dr. Hertz can approve new ones, as can APS. The Subcommittee can disband dormant or unproductive SAGs. Dr. Peterson asked the PAG chairs to look at the SAGs to see if there are some that should be dissolved.

There will be another meeting with STMD to allow more time for questions. The next meeting will be the week of November 18 and will be a teleconference of about 6 hours.

Adjourn

The meeting was adjourned at 3:40 p.m.

Appendix A
Attendees

Subcommittee members
Bradley Peterson, Ohio State University, *Chair Astrophysics Subcommittee*
Joan Centrella, NASA, *Executive Secretary*
Gary Bernstein, University of Pennsylvania
Joel Bregman, University of Michigan
Edna DeVore, SETI Institute
Giovanni Fazio, Harvard Smithsonian Center for Astrophysics
B. Scott Gaudi, Ohio State University
Gabriela Gonzalez, Louisiana State University (via WebEx)
Chryssa Kouveliotou, Marshall Space Flight Center
Gary Melnick, Harvard University
John Nousek, Pennsylvania State University
Terry Oswalt, Florida Institute of Technology
Paul Ray, Naval Research Laboratory
Kenneth Sembach, STScI
Karl Stapelfeldt, Goddard Space Flight Center

NASA attendees
Paul Hertz, NASA HQ, *Director, Astrophysics Division*
Dominic Benford, NASA GSFC
Padi Boyd, NASA GSFC
Mark Clampin, NASA GSFC
Julie Crooke, NASA GSFC
Michael Garcia, NASA HQ
Jonathan Gardner, NASA GSFC
Neil Gehrels, NASA GSFC
Mike Green, NASA HQ
Matt Greenhouse, NASA GSFC
Hashima Hasan, NASA HQ
Jennifer Kearns, NASA HQ
Billy Lightsey, NASA HQ
Stefan Immler, NASA GSFC
John Mather, NASA GSFC
Cheryl Moy, NASA HQ
Susan Neff, NASA GSFC
Marian Norris, NASA HQ
Bill Oegerle, NASA GSFC
Larry Petro, NASA HQ
Rob Petre, NASA GSFC
James Reuther, NASA HQ
Jane Rigby, NASA GSFC
Rita Sambruna, NASA HQ
Wilton Sanders, NASA HQ
Chris Scolese, NASA GSFC
Jeremy Schnittman, NASA GSFC
Amber Straughn, NASA GSFC
Ira Thorpe, NASA GSFC

Michael White, NASA GSFC
Dan Woods, NASA HQ

Non-NASA Attendees
Edward Belte, Orbital Sciences
Francesco Bordi, Aerospace
Dominic Conte, Millennium Space Systems
Orlando Figueroa, OLELLC
Kathryn Flanagan, STSCI
Rachel Osten, STSCI
Ronald Polidan, Northrup Grumman
Elizabeth Sheley, Zantech

Webex
Natalie Batalha, NASA Ames
Ed Belte, Orbital Sciences
Dominic Benford, NASA
Michael Bicay, NASA Ames
Kaitlin Chell, Cal Tech
Dominic Conte, Millennium Space Systems
Alan Dressler, Carnegie Institution
Mike Fanelli, NASA Ames
Enectali Figueroa, MIT
John Gagosian, NASA HQ
Gabriela Gonzalez, LA State University
Kathy Hartman, NASA Goddard
Dieter Hartmann, Clemson University
Cuong Huynh, NASA HQ
Jason Kalirai, STScI
Louis Kaluzienski, NASA
David Lang, NRC
Peter Lawson, NASA JPL
David Leisawitz, NASA
Dan Lester, University of Texas
Mackenzie Lystrup, Ball Aerospace
Jason Marley, STScI
John Mather, NASA
Michael Moloney, NRC
Leonidas Moustakas, JPL
Stephen Murray, Johns Hopkins University
Michael Niemack, Cornell University
Mario Perez, NASA HQ
Miriam Quintas, Cal Tech
Richard Rogers, Stellar Solutions
Paul Scowen, ASU
Katie Spear, NASA
Bob Stachnik, Testex
Amy Svitak, Aviation Week
Theodore Swanson, GSFC
Harley Thronson, NASA Goddard Space Flight Center
Kathy Turner, DOE

Michael Werner, JPL

Appendix B
NAC Astrophysics Subcommittee Members

Bradley Peterson, Chair
Department of Astronomy
Ohio State University

Joan Centrella, Executive Secretary
Astrophysics Division
Science Mission Directorate
NASA Headquarters

Gary M. Bernstein
Professor of Physics and Astronomy
University of Pennsylvania

James J. Bock
Jet Propulsion Laboratory

Joel Bregman
Department of Astronomy
University of Michigan

Julianne Dalcanton
Professor of Astronomy
University of Washington

Edna DeVore
Director of Education and Outreach; Deputy CEO
SETI Institute

Giovanni Fazio
Harvard Smithsonian Center for Astrophysics

B. Scott Gaudi
Department of Astronomy
Ohio State University

Gabriela Gonzalez
Professor, Physics and Astronomy
Louisiana State University

Fiona Harrison
Professor, Physics and Astronomy
CalTech

Chryssa Kouveliotou
Marshall Space Flight Center

Gary Melnick
Senior Astronomer
Harvard Smithsonian Center for Astrophysics

John A. Nousek
Professor of Astronomy & Astrophysics
Pennsylvania State University

Terry Oswalt
Chair, Department of Physical Sciences
Embry-Riddle Aeronautical University

Paul S. Ray
Naval Research Laboratory

Kenneth Sembach
Space Telescope Science Institute

Karl Stapelfeldt
Goddard Space Flight Center

Appendix C
Presentations

1. *Astrophysics Division Update*, Paul Hertz
2. *Update 2014 SMD Science Plan*, Dan Woods
3. *Space Technology Mission Directorate Overview Briefing*, James Reuther
4. *Enduring Quests – Daring Visions: Astrophysics Roadmap*, Chryssa Kouveliotou
5. *The James Webb Space Telescope*, Jonathan Gardner
6. *James Webb Space Telescope Outreach*, Amber Straughn
7. *JWST Observatory Status*, Mark Clampin
8. *Integrated Science Instrument Module Status*, Matt Greenhouse

Appendix D
Agenda

Astrophysics Subcommittee meeting
July 16-17, 2013

AGENDA

Tuesday, April 16
Goddard Space Flight Center, Building 1, Rooms E100D and E100E

9:00 – 9:05 am	Opening Remarks/Announcements	B. Peterson
9:05 – 9:15 am	Welcome from Goddard Center Director	C. Scolese
9:15 – 10:15 am	Ethics Briefing	K. Spear
10:15 – 10:30 am	Break	
10:30 – 11:15 am	SMD Science Plan Discussion	D. Woods
11:15 – 12:45 pm	Astrophysics Division Update	P. Hertz
12:45 – 1:45pm	Working Lunch and Discussion with Division Director	P. Hertz
1:45 – 3:30 pm	Government Performance and Results Act (GPRA) Modernization Act (GPRAMA)	J. Centrella J. Kearns
3:30 – 3:45 pm	Break	
3:45 – 5:00 pm	GPRAMA, continued	
5:00 pm	Adjourn for the day	

Wednesday, July 17
Goddard Space Flight Center, Building 1, Rooms E100D and E100E

9:00 – 10:00 am	Space Technology Mission Directorate (STMD) Presentation	J. Reuther
10:00 – 10:15 am	Break	
10:15 – 11:45 am	Astrophysics Roadmap Presentation and Committee Discussion	C. Kouveliotou B. Peterson
11:45 am – 1:00 pm	Break in FACA meeting	
1:00 – 2:30 pm	Working Lunch & JWST Briefing	J. Gardner A. Straughn M. Clampin M. Greenhouse
2:30 – 2:45 pm	ExoPAG Report from SAG-5 on Exoplanet Imaging	S. Gaudi
2:45 – 2:50 pm	Public Comment Period	
2:50 – 3:30 pm	Committee Discussion and Summary of Meeting	B. Peterson
3:30 – 4:00 pm	Briefing with Astrophysics Division Director	P. Hertz
4:00pm	Adjourn	