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MEETING MINUTES

Brad Peterson, Chair

Joan Centrella, Executive Secretary

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Opening Remarks/Announcements

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

Astrophysics Division Update

Dr. Paul Hertz, Director of NASA's Astrophysics Division (APD), welcomed the Subcommittee members. He explained that under policies recently enacted across the Federal government, NASA must cut back on travel. This will be a major factor in determining which future meetings will be virtual and which will be face-to-face.

Despite the high-profile budget issues in the Federal government, there is still great work being done in APD. The President's Fiscal Year 2014 (FY14) budget request is at a high level, the James Webb Space Telescope (JWST) is on schedule and cost, the Division just selected the next two Explorer missions while continuing to support grant programs, and APD is planning a mission to follow JWST. Nonetheless, the budget is an issue. Rescission and sequestration will impact FY13, and FY14 is constrained to the point that APD must set priorities and make choices.

Missions

Kepler has lost one reaction wheel and another is showing increased friction, indicating that it may also fail. The mission team continues to work on a means of preserving the mission should the second wheel fail. At the moment, if the second reaction wheel does fail, Kepler will start using thruster propellant, which would quickly bring the mission to its end. NASA is working to get around that but currently lacks an operational scenario to operate Kepler with only two wheels. Nor has the Agency determined that two-wheel Kepler science is worth the cost of continuing the mission. The mission is in the extended mission phase and will be up for senior review next year. At the moment, Kepler is working fine, but there is a need for fallback plans. This particular type of reaction wheel has known problems, and other missions using it have had the same problems.

As far as Dr. Hertz knew, the data rate is not an issue. According to Dr. Edna DeVore, there are plans to reduce some of the options if there is a need to reduce the data rate. There is no need to make that decision yet, however. Dr. Joel Bregman asked if the reaction wheel issue had been predicted by the manufacturer. Dr. Hertz said that it had not been, and that in fact the manufacturer had changed its process and did not expect this.

The *Nuclear Spectroscopic Telescope Array (NuSTAR)* mission had a good press conference for the presentation of the first science results about black hole spin. There are also new findings from the *Planck* mission. At a joint press conference, NASA and the European Space Agency (ESA) released the first all-sky map and a dark matter map of the entire sky. The two agencies also revealed that the expansion rate of the universe is slower than the previous best estimates. This means that the universe is slightly older than the previous best estimate.

A presentation on the *James Webb Space Telescope (JWST)* was planned for later in the meeting. Dr. Hertz noted that it is on schedule and making great progress.

The *Stratospheric Observatory for Infrared Astronomy (SOFIA)* mission had just done Cycle 1 science on 2 consecutive nights. The improvements made while SOFIA was down are paying off in terms of better efficiency and better pointing, though image quality has yet to be determined. The mission is scheduled to

deploy to New Zealand in July. APD plans to do an Announcement of Opportunity (AO) next year, possibly in July. NASA's German partners in this mission provided an upgraded focal plane imager that is much more sensitive than the previous one and results in many more guide stars.

The Japanese Space Agency (JAXA) now plans to launch *Astro-H* in February 2015, instead of in 2014. With NASA's help, JAXA is working to resolve some serious cyro-cooler vibration issues. The delay will result in increased costs for NASA's portion of the mission, requiring that the cost cap be raised. Once the various issues have been resolved, JAXA will be able to announce a more defined launch date. The current cost is against the original launch date, so NASA must hold reserves for now.

NASA's collaboration with ESA on the latter's *Euclid* mission is going well, with much testing scheduled for the spring and summer.

Balloon and Suborbital Programs
A full presentation on the balloon program was scheduled for later in the meeting, but Dr. Hertz noted that NASA had had a very successful season. In the sounding rocket/range area, there was a recent anomaly on a motor with a payload from the Goddard Space Flight Center (GSFC), resulting in new flight rules for instabilities. There are launches planned for the White Sands facility, but the Department of Defense (DOD) is furloughing some people there. There are continuing problems with Black Brants, so NASA is looking for alternatives, including developing its own rocket. For now, the Agency is using the Black Brants, however, and flying payloads on them. There are new flight rules about triggers for termination if there is an anomaly.

The Antares launch vehicle was scheduled to launch the next day from the Wallops Island facility. Dr. Hertz showed the sounding rocket schedule and discussed the Peregrine rocket that NASA is developing as an alternative to Black Brants. NASA is doing the design for this rocket through the Heliophysics Division (HPD) and will put it out for commercial manufacture. APD will be a major user of this rocket.

The *Galaxy Evolution Explorer* (GALEX) has been on loan to CalTech for a year, but was returning to NASA within days, at which point the Agency plans to turn it off. The *Herschel* mission was still operating, even though it had been projected to run out of cryogen in March. The Malindi, Kenya, ground station, which is owned by the Italian Space Agency and serves as a link to the *Swift* and NuSTAR missions, has had security issues stemming from the political situation. As a result, there are no night workers at the station, and NASA is relying more on back-up stations in Hawaii for Swift and Singapore for NuSTAR. Dr. John Nousek noted that some night work has resumed at Malindi, and White Sands will be offering support.

Wide-Field InfraRed Space Telescope (WFIRST)
At the end of the month, the Astrophysics-Focused Telescope Assets (AFTA) WFIRST Science Definition Team (SDT) is to present its report on the potential for WFIRST to use the 2.4-meter telescope assets. Dr. Hertz is to brief NASA Administrator Charles Bolden on May 30 so that Mr. Bolden can make a decision about whether and how NASA might use the telescope. Dr. Hertz hoped to be able to provide a cost estimate at the briefing. The Aerospace Corporation is doing the cost assessment. Dr. Hertz noted that the telescope assets have gone by many names. The name "AFTA" was created to capture the study that is being done, not the mission. Should AFTA prove too expensive, the WFIRST Design Reference Missions (DRMs) 1 and 2 are still possible as valid responses to the Decadal Survey (DS). A decision must be made no later than 2015.

A coronagraph is an option. Aerospace is costing the mission with and without it, though that is an internal cost estimate to help determine whether or not to include a coronagraph. NASA instructed Aerospace that science should drive the orbit, and the analysis is considering the impact of making the

design modular. The decision in 2015 will lead to planning for support of a mission to follow JWST in 2017, should funding be available. The AFTA WFIRST Wide Field instrument is significantly larger than the alternatives.

Explorer Program
APD made two selections in the Explorer Program. The *Transiting Exoplanet Survey Satellite (TESS)* will do an all-sky survey of transiting extrasolar planets. The other mission, the *Neutron Star Interior Composition Explorer (NICER)*, will resolve the nature of matter at the threshold of collapse into a black hole. The FY13 budget includes funds for these missions, as does the President's FY14 budget request. Depending on what transpires with funding, there might be delays of up to 6 months; the Principal Investigators (PIs) know this could occur. APD will work through the schedule, set aside reserves, and move ahead with the missions.

Budget
Dr. Hertz explained how the budget cycle works over the course of a year, from APD receiving guidelines and drafting budgets for 5 years out through the President's budget submission to Congress and the enactment of a final Congressional budget that the President signs. Shortly before this APS meeting, the President submitted the FY14 budget request, and NASA is now working on the FY15 budget request. At the same time, the Agency is reporting on metrics for FY12 and showing the General Accounting Office (GAO) that the money was spent well. Because the FY13 budget was approved so late, NASA is both planning and executing it simultaneously.

For FY13, the President requested $649 million for APD and $628 million for JWST. Congress appropriated $659M (before the sequestration and rescission), and the language in the report indicates that the extra $10 million is for WFIRST. There is a 1.8 percent rescission and a 5 percent sequestration cut to be applied to the FY13 appropriated funds across the board. After the President signs an appropriation, NASA has only 45 days to report back to Congress on how much money will go to each program. That was happening at the time of the meeting, so Dr. Hertz was not able to provide funding data. He explained that although, as Dr. Nousek pointed out, "sequester" is a verb that means "set aside," in this case the 5 percent was deleted, not set aside. Between that and the rescission, there was a cut of about 7 percent.

With the President's FY14 budget request having just gone to Congress, NASA is adjusting its plans, since the request does not match what the Agency had been planning for the out-years. Those budgets are notional, but they still have to be adjusted.

As for the sequestration, if JWST's share is not cut, other parts of NASA will receive disproportionate cuts. The 7 percent that NASA must cut due to the rescission and sequestration is applied at the Agency level. The Agency decides how to spread it among the mission directorates, and the mission directorates decide how to spread it among their divisions. There are five budgets in the Science Mission Directorate (SMD): four science divisions and JWST. Dr. Hertz has been given a budget number for FY13, and APD has to decide what to cut in order to avoid overspending.

Dr. Hertz has no say in his target figure, but he decides how to meet the target. First, APD is reducing carry-over for operating missions, including rephasing of Guest Observer (GO) funds. Next, the Division will rephase unneeded FY13 reserves for developing missions. Rephasing is the first choice. Some missions will not need all of their reserves this year. This may put a lien on a future year, however. There was some rephasing of Research and Analysis (R&A) funding; APD asked PIs what funds they need this year and what they can take later. This will happen with TESS and NICER, which have more funding than they need for FY13. However, all of the funds for these programs will be needed at some point.

There will be less new money in FY14 for new selections within R&A. Dr. Hertz has to make cuts of about $40 million total. Some of the impact will be immediate, and some impact can be deferred. There will be less unliened funding in FY14, not less funding altogether. This means that the selection rate will go down across the whole R&A program. Dr. Hertz gives priority to investigations that have already begun. If APS thought of other things he should cut, he wanted that advice. He was not cutting budgets for missions in development or operations, nor was he cutting technology development and mission concept studies in FY13. Due to an earmark, spending will increase over what was planned for studies and technology development leading to a mission doing WFIRST science. He is spreading the budget cut problem over a lot of different fiscal years, and compared it to paying off a credit card.

Every Federal government agency has to address cuts. Some are doing furloughs, some are closing parks, some are shutting Air Traffic Control towers. Dr. Hertz could take APS advice on how to cut, but not on whether. Dr. Nousek explained that he had a similar experience in deferring expenses into a future year. It was painful, but it worked, and while it was inconvenient, it was not as bad as firing people, shutting down missions, etc. Dr. Hertz added that he does not think there was a single wasted dollar in the entire APD budget, so this is indeed painful. In all likelihood, there will be some FY14 rephasing into FY15. He will determine which missions are affected and the impact. The intent is to make the impact not noticeable by the science community.

Following are the FY14 SMD program/budget strategy priorities:

- Provide the most productive Earth and space science program for the available resources;
- Responsibly manage the national investment in robotic space missions;
- Increase efforts to detect and study Near-Earth Objects (NEOs) in support of future Agency initiatives;
- Begin the Mars 2020 mission to build on Curiosity's discoveries;
- Plan for land imaging capabilities beyond the Landsat Data Continuity Mission (LDCM), climate sensors, and Deep Space Climate Observatory Project (DSCOVER) Earth observing instruments; and
- Implement the Administration's proposed Science, Technology, Engineering, and Mathematics (STEM) initiative.

Dr. Hertz compared Presidential budget requests between FY12 and FY14. The total is similar, but the wedges have changed. FY14 changes include the addition of Euclid, the reduction of Fermi, the Herschel rampdown, no SMD Education/Public Outreach (EPO), no Gravity and Extreme Magnetism (GEMS) mission, and the start of TESS and NICER. This all excludes JWST.

APD will cancel the Fermi GO program for 1 year. FY14 does not support selections for the 2012 astrophysics Explorer Mission of Opportunity (MoO) AO. There is a 30 percent reduction to the Cosmic Origins (COR)/Physics of the Cosmos (PCOS) program office budget, commensurate with its reduced scope and content. APD is rebalancing Supporting Research and Technology (SR&T) in all programs.

Asked for more detail about the reduction in Fermi, Dr. Hertz explained that after the 2012 senior review, APD planned to reduce the Fermi budget and intended to phase in reductions over 3 years. However, the President's FY14 budget is short in this area. Therefore, APD might have to cancel the GO program for 1 year. Most of the Fermi GO program involves analyzing data, not operating a telescope program. Dr. Gabriela Gonzalez pointed out that although the pain has been spread around, it still appears that Fermi is singled out. Dr. Hertz replied that this was actually recommended by the senior review. Fermi's prime mission ends in August, 2013. The Chandra mission took similar reductions when it went from prime to extended mission. Dr. Peterson observed that as other missions have gone from prime to extended, they seem to have been better prepared. Dr. Hertz replied that the budget the President proposed is not the

budget APD had planned for or expected.

Plans for the Explorer Program will also change with the President's budget request. Although APD does have an Explorer Program supporting missions that have been selected, the pace at which APD can fund new Explorers is reduced by the President's budget request. The plan is to complete evaluation of proposals responding to the 2012 MoO AO, but not make a selection. While this is painful for proposers, Dr. Hertz noted that the budget request is only a request to Congress. If it is enacted as is, APD cannot make any selections. In answer to a question, he confirmed that the decision point will be resolved in Congress. Dr. Chryssa Kouveliotou asked how the proposals will be handled and whether they might be used later. Dr. Hertz said that the proposals will be evaluated, then held until the budget is finalized. If the final budget is the President's budget, that will cancel the AO. The plan is to have another MoO in a couple of years.

APD will have to figure out TESS and NICER requirements, FY13 cuts, the FY14 budget request, and the elimination of selections from the 2012 MoO AO. There is no Small Explorer (SMEX) AO in 2013. The next Explorer AO will be for a SMEX and MoO in the 2014/15 timeframe, followed by an Explorer and MoO AO in 2016/17. This assumes that the future APD budgets look like the notional run-out from the President's request.

The President has said that the FY14 budget implements deficit reduction in place of sequestration cuts. NASA is not taking a big reduction. The cuts Dr. Hertz described are from the President's budget and did not originate in APD. He explained that he had many opportunities to provide input to these processes. His recommendations were heard, whether or not they were taken. APS should have its own voice, however, and he always wants to hear any recommendations the Subcommittee members might have about changes in his priorities.

Dr. Gary Melnick pointed out that many MoO proposals involve a modest NASA contribution to a much larger partner mission. NASA should be encouraging this to keep the United States involved in cutting edge work. It would be a strategic error not to do so, and NASA might be missing some good opportunities to keep the country involved inexpensively. The United States would rather lead than follow, but if it is not possible to do large missions, then NASA is faced with the choice of looking at what others do or participating as a junior partner, as with Euclid.

Dr. Hertz next discussed the budget trends, excluding JWST, as they apply to balance and programs, noting that R&A looks bigger than it is because it includes the senior review. He also showed APD responses to DS recommendations and how the Division is trying to implement what it can, given the budget realities. The near-term strategies do include collaborations. NASA has made it clear to ESA that APD wants to partner in anything that meets the Division's DS goals. The investment can be up to $100 million, though not in FY13 or FY14. APD will continue studying the 2.4-meter telescopes if the Administrator approves. The Division will also consider the three versions of WFIRST, the exoplanet probes, and an x-ray probe. In spring 2014, APD will receive the interim SDT reports, with the final reports due in 2015. The plan is to then ask the National Research Council (NRC) to evaluate the various options to see if APD is following the DS.

Dr. Melnick asked what kind of filters APD is applying to cost studies in order to avoid another JWST in terms of cost growth. He wanted to know whether there are caps to what the Division will consider worthy of continuing through this chain, or what might bring about termination of a mission if the costs are too high. Dr. Hertz replied that the DS deemed any mission costing over $2 billion as too expensive, and that has not been modified that despite the changes in the budget scenario. The DRMs have looked at WFIRST costs.

In response to a question, Dr. Hertz explained that the Explorer reductions do not affect NASA's contribution to Euclid and Astro-H because Euclid is not an Explorer mission and Astro-H is delayed. As for cutting a mission altogether, that falls under the purview of the senior review. Dr. Giovanni Fazio asked whether it still makes sense to follow the DS. Dr. Hertz replied that the Committee on Astronomy and Astrophysics (CAA) advises APD on that. He is not simply following the DS. For example, the DS included no probes and did not anticipate the 2.4-meter telescopes. He is trying to advance the science to the best of his ability. APS can advise him, but this is the question he put to CAA. The implementation plan he showed APS is the same one he proposed to the CAA. It has no inflation probe, and the DS was clear that it was a low priority if there were a reduced budget. There are balloon and Explorer concepts that can do some of this science.

SMD Science Plan

Mr. Dan Woods, Director of the Strategic Integration and Management Division (SI&MD), talked with APS about crafting the 2014 SMD Science Plan. This is a long process that takes almost a year. The update is necessary because NASA is currently operating from the 2010 Plan and is required to provide an updated strategic plan every 4 years. The proposed contents of the 2014 Science Plan will follow the layout of the 2010 Plan. The structure includes an introduction, national agenda for science at NASA, a plan for science at frontiers, detailed plans by science area, and appendices. Within the plan for science at frontiers, the Plan discusses principles, strategies, and challenges.

The Plan will continue to place emphasis on the Decadal Surveys recommendations as a guide towards its development. The Science Plan team visited all of the advisory subcommittees and the full Science Committee for input and guidance. The strategy is to design and successfully implement programs that accomplish creative science and applications. In addition, STEM education is important, but NASA must now re-examine the process of implementing it. The 2010 report included six challenges; the committee has not yet identified the challenges for the 2014 Plan.

2010 Science Plan challenges include:

- Access to space;
- Availability of Pu-238;
- Unrealized expectations;
- Mission cost estimation and management;
- Technology development and demonstration; and
- National strategy for Earth observation.

There might also be a challenge related to determining what it really costs to implement a mission. Dr. James Bock suggested that cost-effectiveness is also important, as are possibilities for efficiencies among the SMD divisions, which seem stove-piped. Mr. Woods said that his team has weekly meetings with the divisions and talks about best practices. Dr. Hertz added that SMD now has a single culture, with fewer differences between divisions.

Dr. Melnick asked if any steps had been taken to increase the fidelity to cost estimates. Mr. Woods said that data are coming in on the new cost estimating process that was recently implemented, and NASA is starting to see results. Some missions have shown improvement already. NASA does not confirm missions until costs and schedules are defined within 70 percent confidence.

Dr. Nousek reported that he had heard that funds for STEM have been centralized and taken from NASA, leaving only the lowest level processes. Mr. Woods confirmed this, and explained that the Agency is working on re-acquiring funds for proposed educational activities. The education issue is still undefined

and there is no decision yet on how to implement it. Dr. DeVore said that SMD has an ongoing challenge to communicate the discoveries and science of the agency, along with the challenge of funding education for STEM. This is an SMD challenge that she believes should be stated, and that effective communication and engagement of students and the public needs to be covered. After further discussion of the STEM E/PO changes, Dr. Peterson said that APS would talk about the situation over lunch.

Dr. Bregman observed that in reducing costs, there is the issue of risk, like the quality of a component. Mr. Woods said that that is worth considering. There are many options, and this is one of them. As for controlling management and oversight, a Class B mission assumes less oversight than a Class A mission. It might be a good addition to the list. Dr. Gonzalez mentioned that collaboration requires a high level of coordination, which is another challenge. Mr. Woods agreed and said the team would take that as input.

He went on to explain that the Agency's strategic objectives are:

- Space: expand frontiers of knowledge, capabilities, and opportunities in space;
- Earth: understand our home planet and improve life on it; and,
- Agency excellence: serve the American public and science community worldwide.

The draft Astrophysics strategic objective is to "[u]nravel the mysteries of the universe, explore how it began and evolved, and search for life on planets around other stars." The draft science goals are:

- Probe the origin and destiny of our universe, including the nature of black holes, dark energy, dark matter, and gravity;
- Explore the origin and evolution of the galaxies, stars, and planets that make up our universe; and,
- Discover and study planets around other stars, and explore whether they could harbor life.

Dr. Centrella noted that APS had seen some of this and provided input on the science goals at the February 14 teleconference. Dr. Hertz added that when the three science goals were laid out against those of the other SMD divisions, the directors thought APD's were the clearest and best conveyed why this is exciting science.

The Astrophysics strategic objective chapter contents are:

- Strategy
    - Physics of the cosmos
    - Cosmic Origins
    - Exoplanet Exploration
    - Explorer Program
    - Astrophysics Research
- Current Missions
- Missions in Development
- Future Missions

Mr. Woods asked the APS for comments on principles, strategies, challenges and science objectives. Over the next month (May), the team will write the chapter for APD, with the goal of starting reviews in the summer. The complete document will go to the Science Advisory Committee and Subcommittees and OMB/OSTP during July and then the NRC for review from August - December. Final clearance by OMB/OSTP will be obtained at the end of the year before going into publication. NASA hopes to release the Plan in mid-February 2014.

<u>Working Lunch on STEM E/PO</u>

Dr. Hertz said that the Administration has made STEM education a priority. To that end, the Administration has proposed to consolidate the STEM activities currently occurring across 13 or so agencies within 3 agencies: the Department of Education (DOEd) for K-12 education, the National Science Foundation (NSF) for graduate and post-graduate education, and the Smithsonian for informal education. This is part of a Presidential effort to decrease redundancy, overlap, and inefficiency. The total amount of funding for STEM E/PO across the Federal government increased, but it has been reallocated. As the plan has been laid out, the three agencies will decide the best way to accomplish STEM goals. If NASA programs are the best way, for example, they can send funds to NASA.

When asked about the scope of this effort, Dr. Hertz replied that funds were deleted project by project from E/PO budgets to take away STEM funding, but not public affairs or outreach. The intent is to transfer STEM activities. This is in a Presidential proposal to Congress, and Congress can change it in the appropriation. All of NASA's E/PO projects are funded for FY13. However, FY14 remains uncertain, as it has not been finalized by Congress, which could decide not to make the change.

Dr. DeVore said that Dr. Leland Melvin of NASA talked about this at length during a teleconference. The FY13 budget for E/PO was $132 million, and he has negotiated to reserve $94 million for NASA's Office of Education. Some of that is earmarked. NASA has some money for education, but not within SMD. Dr. Hertz agreed, adding that the intent was to transfer all of that, but there are still some E/PO funds left.

Dr. Jason Kalirai said that there are about 30 people working on E/PO for the Hubble Space Telescope, but now the mission only has the press release funding. Dr. Kouveliotou said used Hubble as an example of a mission which has been very successful with public engagement. People know what to ask, which means they are interested. She wondered if it would be similarly effective done through another agency, and believes it would take several years to achieve that level of interest. She is very concerned and not sure about the efficacy of a centralized program. She thought it would lose a lot of the effect that the representatives of the agencies bring to the table.

Dr. Bregman wanted to know the motivation for the shift. Dr. Hertz said that the goal is to realize efficiencies and concentrate funds where the government could develop expertise and eliminate redundancies. The intent is for a positive outcome. Dr. Bregman wondered if it might be a reasonable thing to do, though the information part would have to stay with the specific missions. He noted that the variety of E/PO activities has not penetrated well into K-12 education. He has been frustrated by the fact that the money he can apply to E/PO does not allow him to mount an effective program. In that regard, it might be better to combine funds.

Dr. Gonzalez observed that there is a big difference between education, outreach and public affairs. NASA does public affairs very well. Ms. DeVore noted that there are no cuts to the budget for public affairs, so when discoveries are made, press releases go out, websites will make announcements, and social media will be alerted. However, the education and outreach (E/PO) budgets have been part of the mission budgets, not public affairs. In most cases, education and outreach are funded in a combined budget, not broken out by education versus outreach. In most cases, this means that SMD E/PO funding all leaves the agency as part of the consolidation effort.

There was some discussion as to whether the cuts target SMD; it was determined that they do not. It was noted that this is not a narrow astrophysics issue or decision. If APS wanted to provide input to the NAC Science Committee, this is issue applies more broadly than just APD. Nothing is certain regarding NASA's possible dealings with the three organizations that would conduct the programs.

Dr. Peterson said that he could not see how anyone would have a sustained E/PO program if this is implemented. Dr. Melnick said that with a critical mass of people, it would be possible to do quality

outreach that smaller programs cannot accomplish. Those are the endeavors that might benefit from plugging into an organization with more resources. The disconnect is in how the small project find its way through the labyrinth. It has to be clear how the smaller projects are able to get their science out.

Dr. Bethany Johns, participating via Webex, said that her concern is the actual education line item at NASA. She would not have finished graduate school without its programs. The funding is decreasing even if there are programs that stay within NASA. She was concerned that the students are not represented in this. She would have fellows and others beneficiaries of NASA education programs, who remain in contact, engage in this conversation.

Dr. Hertz explained that the Hubble, Einstein, and Sagan Fellows are part of the research program and remain part of the APD budget. Most of the graduates and post-docs are supported under research grants. The research program funding has not been affected by this. Dr. Terry Oswalt said that the graduate research programs are essential, and that grad programs at some schools might fold without support. NASA and DOEd have completely different approaches. NASA supports individuals, while DOEd supports systems.

Report on the Balloon Program

Dr. W. Vernon Jones, Senior Scientist for Suborbital Research, gave an update on APD's Balloon Program. This was a great season for the program, with three payloads flying a combined 96 days. The Super-Trans-Iron Galactic Element Recorder (Super-TIGER), which studied the origin of cosmic rays, flew for a record 55 days. The Balloon-borne Large-Aperture Submillimeter Telescope (BLAST) Pol mapped polarized dust emissions along the galactic plane during its 16-day mission, and the E and B Experiment (EBEX) spent 25 ½ days probing cosmic inflation and gravitational lensing. Dr. Jones provided photos of the balloons and the Antarctic launch facility near McMurdo Station. NASA paid for the prefab buildings, which were assembled by NSF during the 2005/06 austral winter.

The FY13 flight schedule includes 14 missions, including one carry-over from FY12 plus 8 other missions planned for FY13 launches in New Mexico, the three launched in Antarctic and two planned for Sweden. The Gaskin payload allows a young MSFC scientist to lead a hands-on project. Kopp is a solar physics observation payload. A Planetary Science payload to observe the comet ISON will replace the withdrawn Bale solar payload.

In recent years, the total number of flights has been about half of what it had been in the 1990s and early 2000s. Many of the flights are special projects and test flights. In FY10, NASA had to close the program for a while and shift some missions into FY11. With more funding, there could be more flights, up to twice as many in all of the locations except Antarctica, where there are limitations. Antarctica is the centerpiece of the program, however, with some good science. The Balloon Program has focused on expanding the flights over and around Antarctica, and could have as many as four. The program wants to enable flights to leave Antarctica for possible recovery in South America, New Zealand or Australia, but current capabilities do not include recovery of payloads. There have been 44 load-bearing Antarctic flights since 1991.

EBEX was the heaviest and largest payload ever launched by CSBF. A second flight is proposed for December 16. The cryogens of the BLAST-Pol payload were depleted during the flight, and it experienced solid-state data recorder failures. However, it was an operations and science success, and its rather large payload was fully recovered. In addition to having NASA's longest Antarctic flight ever, Super-TIGER was an operational and science success as well. However, it, too, had problems with solid-state data recorders. The payload was not recovered, although all high-priority data were captured through the Tracking and Data Relay Satellite System (TDRSS). Its proposal for analyzing data and recovering

the payload also includes planning for a December 2016 re-flight. Super-TIGER looked at ultra heavy galactic cosmic ray relative abundances. The data analyses have just begun, but already there is an enormous range of particle fluxes.

Dr. Jones noted that Super-Pressure Balloons (SPBs) are a major technological advance, offering an order of magnitude increase in flight capabilities. They open areas of exploration closed to the zero pressure balloons. Most Long-Duration Balloon (LDB) payloads can be converted to Ultra-Long Duration Balloon (ULDB) flights for modest cost. They help form a science opportunity continuum. Two balloon missions were selected for Explorer Phase A studies, but they did not make it through the down-select. When asked if there might be a way to do these other than proposing for a MoO, Dr. Jones said that the program determined that it could manage a lower cost cap. It depends on the payload. Dr. Hertz elaborated. In the AOs, balloons have been $30-50 million, with the typical cost for an LDB payload around $10 million per year for 5 years. This comes to roughly half the cost of a SMEX. The key is determining the amount of science per dollar. The ULDB is becoming increasingly valuable here, but APD will have to think about it before the next call. This might allow the Division to select more proposals.

Dr. Jones showed the altitude profile of the last SPB compared to BLAST. The BLAST went up and down by a few thousand feet, while the SPB was much more stable with variations of only a few hundred feet which would be true regardless of the location. The NASA scientific balloons are enormous, which Dr. Jones illustrated through photos and data showing, for example, that over 30 acres of film were used to fabricate the latest SPB.

The Wallops Arc Second Pointer (WASP) project was tested at Ft. Sumner, New Mexico, on October 7, 2011, and it flew about 5 hours. This is a generic module that can be adapted as needed. The Solar Hyper Spectral Imager for Climate Science (HySICS) payload will be flown on the WASP in the fall of 2013 fall as part of the Ft. Sumner campaign.

Dr. Jones reviewed publication highlights, and addressed some programmatic issues. Some balloon trajectory modification is needed to take full advantage of SPBs for ULDB flights in non-polar regions. The Program throughput is highly dependent on payload funding, but there is no increase in the Research Opportunities in Space and Earth Sciences (ROSES) budget, which is needed in order to cover more payloads. A study he did a few years earlier on funding found that the Program is underfunded by a factor of three. At the same time, payloads are becoming more sophisticated and more expensive. Funding is the limiting factor.

When asked if there is any reason not to fly some of these packages indefinitely, Dr. Jones explained that the Planetary Science Division (PSD) is looking for a planetary community gondola to do that, although his program has not tried it yet. Foreign partners contribute about 25 percent of the balloon payload costs. Dr. DeVore noted that some commercial interests are developing high altitude ballooning for tourism. Dr. Jones said that the program looked at that possibility several years ago and chose not to pursue it.

Report on Astrophysics Roadmap

Dr. Kouveliotou, Chair of the Roadmap team, explained that APS had voted in February to start a task force in order to create a compelling 30 year vision for APD and its programs. The task force is looking at questions related to how the universe began, the challenges in learning about it, how it is evolving, how galaxies form and evolve, and if there are habitable planets in the universe.

The road map team has begun by building upon the 2010 DS; addressing science and technology challenges, with notional missions; and, soliciting and including community input via public calls. The task force is not creating missions per se, just examining questions.

Team membership involved a complex array of factors, including expertise; seniority levels (early, mid- and senior career); geographical diversity; gender diversity; and theoretical, observational, instrumentation, and outreach capabilities. The team consists of 18 members in addition to herself, plus Drs. Centrella and Peterson as ex officio members. There have been some changes, but Dr. Kouveliotou hoped the group would stay as it stands, although if a gap is identified, they will either recruit a new member or bring in external expertise.

At the first teleconference, the task force was divided into three teams: PCOS, COR, and ExoPlanets (EXO). Each team is examining its area in terms of analysis of the past and present, and synthesis for the future. It is important to study the science and technology leaps of the last 30 years as part of this effort. The teams are also looking at the evolution of partnerships and international collaborations.

For the present, the teams are starting with the DS and determining what has been accomplished in each area. For the future, they are about to begin a virtual town hall meeting to receive input from the community and programs. The task force is including information from the Department of Energy (DOE), NSF, ESA, and JAXA regarding their long-term vision and strategic planning. The teams are also determining their central visions or stories, which will be combined into a continuous story.

The first face-to-face meeting was held in late March at GSFC, where the task force listened to presentations from the programs' chief scientists. They learned several interesting things and confirmed their knowledge that big missions take very long (about 22 years) from conception to operations. There were break-out groups for each team, followed by presentations of their first conclusions.

The task force then developed the following milestones:

- April:
  - Decision on Town Hall abstract selection by April 20
  - First report from all group discussions by the end of April
- May:
  - May 6-7 Town Hall: Web presentations of selected abstracts
  - Major goals/questions/themes by end of May
- June:
  - Second F2F meeting ~ week of June 10 in JPL: Decisional
- July – August:
  - Conclusions presented to APS for approval – develop and incorporate graphics - deliver conclusions to Paul Hertz
- October - November:
  - Report writing
- December:
  - Report publication

The final report will be about 70 pages, no more than 100. For the town hall, the task force has solicited several presentations, including from ESA and JAXA representatives, and may add more. A total of 106 abstracts have been submitted: 82 address science and E/PO, and 24 discuss technology challenges. The town hall will offer opportunities for community input.

The task force will include discussion of the various sizes of missions, and has already talked about cross-cutting missions common to more than one division. The plan is to publish the abstracts except where

individual authors prefer not to do so. However, Dr. Kouveliotou believes that someone with a breakthrough idea should publish it.

Dr. Centrella explained that the idea is not to try to develop a program for the next 30 years, but rather to build multiple futures going forward for the different science areas. The task force is not identifying missions. Dr. B. Scott Gaudi, a task force member, added that they were told to be unconstrained by costs, though they must consider physics. Dr. Bock observed that if one were to look at the last 30 years, it would become apparent that cost-effectiveness has had a big impact on science. His thought is to look at ways of innovating with small satellites and emerging technologies.

It was mentioned that some in the community felt the institutional representation of the task force was not ideal, but the task force needs members with knowledge of broad areas. There was also some concern about the representation of soft x-ray astrophysics, but Dr. Kouveliotou thought it was sufficiently covered, noting that if the task force needs more people, that will be handled. In some cases, individuals who were approached were unable or unwilling to participate.

Dr. Melnick said that he understands that the effort is to remind stakeholders of the excitement that lies ahead. His concern is that people are projecting ahead based on their disciplines. However, if this had been done 30 years ago, they would have missed a lot, like exoplanets, the accelerating universe, etc. He hoped that the report would emphasize that what lies ahead is unpredictable and can change with a single discovery. Dr. Kouveliotou agreed, and said that the team might have something like Dr. Melnick's idea for a section that says there are areas that cannot yet be described, the "unknown-unknowns." Everyone wants to venture into new areas. She wants input from the community, which has many ideas and great intelligence to offer. Dr. Gaudi added that he hoped to emphasize that technology often leads these discoveries.

Report on NICER

Dr. Keith Gendreau, PI for NICER, described the mission for the Subcommittee. NICER, which is now in Phase B, uses the International Space Station (ISS) as a platform. The plan is to launch in 2017. Once on ISS, the mission will be sited on an ExPRESS Logistics Carrier (ELC). At that point, it will have a baseline mission of 18 months (12 months minimum mission) with an optional 6-month GO program. The instrument includes x-ray concentrator optics and silicon drift detectors. It will also have a pulsar navigation demonstration funded by the Space Technology Mission Directorate (STMD). There are no expendables. The project is designing for a minimum of 2 years on orbit.

The core science addresses neutron stars. NICER will determine the radii of several neutron stars to ±5 percent, an order of magnitude better than what is known today, and it will do this with an instrument that opens up a new discovery space in high time-resolution soft X-ray science. The mission will overlap with and/or use information from the Fermi mission and the Rossi X-ray Timing Explorer (RXTE). The science synergies boost the returns from both NICER and Fermi. As a mission, RXTE is done, but it produced 2,500 publications and, after 16 years of operation, the last proposal cycle was still oversubscribed.

When deployed, the payload is about the size of a speaker's podium, only a bit wider. Dr. Gendreau reviewed some of the details of the payload. The Massachusetts Institute of Technology (MIT) is a partner, responsible for the detector readout subsystem. ISS is providing standard hardware for attachment to the ELC. NICER will launch in a stowed configuration; once attached to ISS, it will deploy for science operations, but the payload will be able to return into its stowed configuration for safety reasons whenever a vehicle is visiting ISS or astronauts are outside the Station. At this point, all required

technologies are at or above Technology Readiness Level (TRL) 6. The team is comfortable with the schedule and costing, and has engineering models of much of the avionics hardware in-house.

Dr. Gendreau explained that ISS is a great place to do the NICER science. The team worked closely with NASA's ISS Research Integration Office (RIO) to show that the mission design is consistent with ISS accommodations. For example, the NICER team simulated a 3-month observing program to demonstrate that the ISS platform would provide adequate sky visibility. The observatory efficiency must be over 33 percent, and the simulation—together with information about radiation-belt passages and ISS operational interruptions—showed it would be over 63 percent, offering significant margin. The work with the ISS RIO and the plan to use ISS infrastructure helped the team qualify for the Explorer MoO. STMD support has been going on for a while, as the Directorate management wanted to use NICER's X-ray timing capability as an add-on.

STMD's Station Explorer for X-ray Timing and Navigation Technology (SEXTANT) program will enable NICER to be the first flight demonstration of pulsar-based navigation. This involves no additional hardware. STMD provided more than 90 percent of NICER funding through Phase A and will provide another $15 million or more in Phases B through E. Dr. Nousek called this "Star-Trek style navigation," and observed that the technology is analogous to a Global Positioning System (GPS) that works off of pulsars. Dr. Gendreau agreed, predicting that hundreds of years from now, people will look back on the NICER/SEXTANT mission as the one that validated the technology that will eventually lead humanity out into and beyond the solar system.

NICER will obtain measurements with high-precision light curves. A comparison of the light curve for the millisecond pulsar J0437–4715 from ESA's X-ray Multi-Mirror (XMM) Newton telescope with that expected from NICER shows that the latter will accumulate 10 times as many time-coherent photons, allowing substantially improved rotation-resolved spectroscopy. The high precision light curves help investigators infer the compactness of a star and understand the ultra-dense matter in its interior through soft x-ray timing. The degree to which NICER will fully reveal the interior composition of neutron stars has been modeled. The simulations indicate that the study team should be able to reach their goal with four objects, while the literature suggests that only three are needed. The four targets have been chosen, though the team would be happy to have more as Fermi and ground-based radio observatories continue to discover millisecond pulsars.

Dr. Gendreau expects NASA to be very proud of this mission, as it will provide high-visibility science from ISS. There is a web page with simulation tools: http://heasarc.gsfc.nasa.gov/docs/nicer

Dr. Melnick asked about contamination control. Dr. Gendreau said that the team looked at this. There is a margin of about 100-200 percent at the low-energy end (0.2 keV) of the NICER band. The ISS is cleaning up over time. A partner has seen no evidence of contamination buildup on another payload. Dr. Bregman asked about the source of cost savings. Dr. Gendreau replied that the launch is provided by the Human Exploration and Operations Mission Directorate (HEOMD) and, taking advantage of existing ISS telecommunication infrastructure, there is minimal ground system build-up. NICER will be one of multiple payloads on the launch vehicle. Power and telemetry come from ISS. The mission does have to build its own pointing system. Dr. Peterson observed that the ISS provides half of what NICER needs. Dr. Gendreau agreed, adding that having all the requirements of the interface defined now helps focus the mission design. The team identified two spaces on ISS as likely.

When asked about gravitational waves, Dr. Gendreau said that he once wanted to do this project with gravitational waves, and it remains part of the long-term thinking. Dr. Paul Ray said that small missions like this have a huge science payoff. He was concerned about the ability to do this and the GO program in

terms of the budget issues. Dr. Hertz said that APD will hold that funding in the senior review wedge. Dr. Gendreau added that NICER has both a GO and a guest investigator (GI) program.

Costing of Space Science Missions

Dr. Hertz introduced Mr. Eric Mahr, of Aerospace Corporation. APS is always discussing cost estimation and its importance, and Mr. Mahr was there to answer questions and provide an outline for how costing is done. Mr. Mahr explained that he is an engineer, but he has been involved in costing for 15 yrs.

Estimates are done at different points of a mission lifecycle: SDT, mission confirmation, and launch, for example. However, costs go up as the mission goes forward and complexity grows. The need to anticipate this is one of the difficulties in making estimates. NASA has moved from under-estimating to setting the cost early and accurately in order to plan, while also preventing inefficiencies. In an example, Mr. Mahr showed how substantial differences often exist between the initial concept and the final implemented configuration.

Design changes affect complexity, cost, and schedule. More complex things cost more and take more time. Aerospace has identified parameters that affect complexity. Dr. Hertz noted that failed missions all had too little money spent on them for their complexity. Therefore, it is important to examine whether a mission is of a type that has historically needed more funding than was allocated.

Dr. Peterson pointed out that if a proposal overestimates the spending, it will not be selected. Dr. Melnick said that there are missions for which the complexity grows, and that can be managed. However, in other situations, the understanding of complexity is what evolves, and that is the real challenge; it is an unresolved ambiguity. Even without “mission creep,” the assessment of the mission costs will increase. Dr. Melnick wondered how much APS should trust an assessment of launch costs and how successful Aerospace is in making that assessment early on. Mr. Mahr said that when Aerospace has the correct parameters and knows the complexity, its costs are accurate. Some missions become more complex over time, but they are more often under-scoped at the beginning.

Mr. Mahr presented cost and schedule data from 20 missions, showing a significant increase from the baseline established at Preliminary Design Review (PDR). This reflects the same idea that a lack of understanding early on leads to cost growth at the end. Sometimes it is not the funding profile that is the issue as much as it is a misallocation according to phase. In that case, the funding total is correct but some reallocation is necessary. In accounting for cost increases, the payload has greater uncertainty than the spacecraft. Issues like these help explain why it is hard to make an accurate estimate.

Dr. Melnick noted that spacecraft reuse a lot of equipment, but instruments change a lot from one mission to the next. Mr. Mahr replied that it is rare that something is entirely new, as an instrument is usually an improvement or next step, so the prior instruments are evaluated for the modeling. Dr. Hertz added that APD compared cost assessments and actual costs for Explorers. The study identified items at risk of going over budget. The Division has also assessed predictions of the phases. NASA never uses just one cost assessment, but instead compares two or three. Their scatter shows the areas of uncertainty.

The number of variables that really set the difference is substantial and cannot be narrowed down to a handful that are easy to identify. Dr. Gaudi thought that the real issue is that no one wants to propose a mission that is going to cost what it is going to cost, because it would be too expensive to be funded. Dr. Hertz said that APD is trying to get away from that. The GEMS nonconfirmation might be a step in the culture change. Now that SMD does joint confidence levels, they are doing well at bringing in missions at cost and schedule instead of aggressively underestimating.

Dr. Bregman told of trying to determine if the cost estimate for a particular mission was right. He found a document indicating that the average overrun was 24 percent, but that was skewed by some missions that were spectacularly overrun. If the investigation has its design and has matured the technologies, the PI can cost it out well. Dr. Nousek suggested that there are two separate cultures in NASA. At one level are the Explorer people who estimate and maintain costs throughout. On the other side are the "science dreamers" who define missions without holding back.

There was some discussion of proprietary data and modeling techniques. Mr. Mahr was limited in what he could say about these things in a public forum. He explained that a NASA directive, NPD 7120.5E, requires a new way to budget and manage projects by looking at probabilistic costs and schedules for project funding and mission budgets. Budgeting at the 70th percentile should reduce overruns. The initial cost estimates are spread over the phases. These estimates are done by more than one source. Sometimes they mesh, and sometimes they show differences that become a management tool going forward.

Dr. Julianne Dalcanton asked if it is possible in advance to know where costs will grow most significantly if there is a delay; Mr. Mahr said that it is fairly linear. Dr. Nousek wanted to know about the strength of the individual constituent parameters and how Aerospace explores the sensitivity of the outcome. Mr. Mahr said that part of the art is in picking the comparable data points as analogies for the model. Dr. Hertz added that APD does not hold reserves for hurricanes at the time of launch, but that happened to the Swift mission. It is not possible to budget at the 100 percent confidence level.

Dr. Melnick asked if the fact that APD commissions multiple cost assessments indicates that no single approach is more consistent than the others. Dr. Hertz said that they are trying to predict the future, so it feels better to get multiple opinions. It is nondeterministic. The models are all probabilistic and give a range, so the Division improves its knowledge by using more than one. Nobody ever knows what a mission costs until it is built. Critical people become sick, testing facilities go down, etc., and that has to be built in. There is no obvious best approach; it is inherently stochastic.

The NRC evolved a Cost and Technical Evaluation (CATE) process while writing the APD DS, which Mr. Mahr discussed, noting that some of the same steps are used in developing range estimates. All models are based on history. The CATE process estimates the instruments and spacecraft first, then reserves, mass and power contingency threat, and schedule threat. The process then integrates the results. Early project concepts are typically optimistic about complexity, schedule, and cost. CATE adds reality to these missions to level out the optimism.

Dr. Karl Stapelfeldt said that in the DS process, some mission concepts were costed out by NASA centers and Aerospace, which led to some concepts not being included. Mr. Mahr replied that the team tried to make assumptions about what was possible, and what was not realistic. Dr. Melnick pointed out that the centers were involved in the evolution of the instruments. Unless their costing people were trying to fit the envelope, their visibility into the experiments was likely greater than that of an outside group. Mr. Mahr said that many missions do not accurately account for cost growth. Aerospace will never have their level of knowledge, but did find that they were too optimistic.

Dr. Hertz explained that the NASA cost estimators also provide data that are considered. Dr. Bregman told of a comparison he was involved in using data from GSFC and Aerospace. They came very close. However, the DS had quite different numbers, which may have been due to the lack of interchange. Dr. Hertz said that these differences are discussed in the DS appendices. Dr. Melnick pointed out that one thing that motivated this presentation was whether NASA spends enough in pre-Phase A to get a good cost estimate. He wondered how far down that path Aerospace must go before the projection is accurate. Mr. Mahr said that it varies, and Dr. Hertz referred APS to the Science Office for Mission Assessments

(SOMA) website at the Langley Research Center (http://soma.larc.nasa.gov/), which has the publicly available studies that answer some of these questions.

Although Dr. Oswalt agreed that the historical record is the best place to start, he was bothered by the historical method in that he felt it penalized proposals offering improvements or breakthroughs. Nor will PIs receive credit for coming in under budget. Mr. Mahr said that Aerospace has looked at the possibility of incentives, but there is no consensus. Dr. Hertz added that NASA has discussed this, and it is hard to come up with good answers. The Agency must balance cost performance against technical success. Project managers get lots of credit when a project works, even if they overrun the budget. This makes it hard to figure out where to have the investigators focus. All of the contractors have award fees.

Public Comment Period

No members of the public came forward with comments.

Committee Discussion

Dr. Peterson reviewed the issues that APS would need to discuss further:

1. Most urgent was the loss of mission-specific E/PO programs. Dr. Hertz told the Subcommittee that he had just learned that the loss in the FY14 budget was for the entirety of E/PO, not just education.
2. Loss of the Fermi GO program.
3. Non-selection of the MoO.
4. Cessation of NASA-sponsored meetings.
5. Travel restrictions on NASA employees and contractors.

Adjourn for the Day

The meeting adjourned for the day at 5 p.m.

Wednesday, April 17, 2013

Discussion and Budget Overview with SMD Associate Administrator

Dr. John Grunsfeld, SMD Associate Administrator, said that the Directorate had a great science year. He also thought that SMD did reasonably well in balancing the budget in the last year. However, challenges persist, many of which relate to the budget. At NASA, as in much of the Federal government, budget development for future years occurs when no one knows what the next budget will be. His team was in the final stages of developing an FY13 operating plan with the rescission and sequestration cuts incorporated. An actual spending plan should be ready shortly. He asked APS to remember that, when they look at the budgets, they are there to provide comment on behalf of the science community.

In studying our own solar system, SMD is also gearing up for understanding of exoplanets. This is just one example of the continuum among the divisions, but SMD divides the disciplines in order to keep the budget straight and have orderly project management. Dr. Grunsfeld encouraged APS to work with the other SMD subcommittees because it makes the science stronger.

The President's FY14 budget request leaves NASA relatively flat. The Administration recognizes that NASA does great things. However, there were constraints within the budget. Dr. Grunsfeld advocated that

JWST be allocated the funding it needs in order to be more cost-effective. The project is being managed exceedingly well, and other budget lines must work around it. The Administration has made earth science a priority, while planetary science remains flat from FY13's request. NASA had lowered the priority of PSD, and the Congressional addition of $200 million came too late to make an adjustment, so APD and HPD must take up the slack. The JWST numbers change slightly to accommodate its development.

The most likely outcome is that the budget will be different from the request and that NASA will be under a Continuing Resolution (CR) while it gets sorted out. That said, there is the next sequestration as an issue. Dr. Grunsfeld finds it remarkable that the staff is so resilient in the face of this situation. They have responded to changes almost daily but keep the science community from seeing that in terms of missions and access. This was another area for which he sought APS input.

Commercial crew and space flight are two other priorities. The Administration supports an increase in space technology funding, though Congress provided a lower amount in FY12. Education is removed from SMD due to the Administration's consolidation of STEM activities. The plan for how NASA is to interact with the three agencies receiving those funds is incomplete, and it is not yet clear how it will work. SMD promotes efficient and effective spending – the Directorate is very efficient and still does some amazing things, no one else comes close in terms of providing the most productive science program for the available resources. ISS has been a tremendous asset. Alignment of the NASA workforce is a continuing issue, especially with the large Space Shuttle workforce.

The FY14 budget request includes increased funding for the NEO observing program. NASA has been observing NEOs since 1998 and now has a formal program that is generating support to identify progressively smaller asteroids. The plan is for HEOMD to develop a mission that will redirect an asteroid into lunar space; SMD's role will be to expand our NEO detection and characterization activities to search for an appropriate target.

The Mars 2020 team will build on Curiosity Rover's discoveries. Part of the mission was to find evidence of standing water that would have been suitable for the development of microbial life, and findings indicate that Curiosity has identified a region near its landing site where there once was a large standing body of water. The mission also looked at isotopic abundances of sulfur and hydrogen, and found that the atmosphere was very thick at one point, leading to conclusions about the possible existence of liquid water on the surface, as well as clouds, rivers, and more. The mission made these discoveries in part based on its first drilling analysis. This will lead NASA in the search for similar environments. Curiosity has also discovered organics on Mars, though they may have been introduced by NASA's missions.

NASA inherited from the Department of the Interior (DOI) the requirement to maintain the continuity of land measurement capabilities. The National Oceanic and Atmospheric Administration (NOAA) has transferred to NASA responsibility for funding the refurbishment of two Earth science instruments on the Deep Space Climate Observatory (DSCOVR) mission.

Finally, SMD must implement the proposed STEM initiative. The Directorate loses $42 million, which is transferred to the three host agencies (Department of Education, National Science Foundation, and the Smithsonian Institution). SMD will have the option of writing proposals to have the funding returned.

Dr. Grunsfeld reviewed some details of the budget request, which includes the ramp-down of the Herschel mission and support for the 2013 Explorer selections. The peak funding year for JWST is FY14.

Kepler continues doing great work, but there is the reaction wheel issue discussed previously. TESS will look at our nearest neighbors, examining exoplanets that are transiting in the nearest stars. The expectation is that the mission will find lots of Earth-sized habitable planets. Those discoveries can then

be followed up with spectroscopy. NICER will provide the best resolution thus far. It operates on the idea that if there is an isolated pulsar, these are the most accurate clocks in the universe, and we have a constellation of these. The information coming from this could help with solar system missions requiring accurate navigation

There are things SMD does not do because of budget limitations, but on the other hand, the Directorate has 97 missions and 120 spacecraft in one stage of planning or operations. This reflects the strength of the U.S. science community, Congressional support for NASA, and the Agency's strong team. Still, he and Dr. Hertz are often asked what they might not do if additional cuts are needed. This is where APS comes in, for their advice will be necessary in the event of additional reductions. What comes back from the missions is great and fascinating science. That science becomes cheaper over time. Dr. Grunsfeld encouraged the Subcommittee to talk up NASA's great science discoveries.

Discussion
Dr. Melnick agreed about the efficiencies Dr. Grunsfeld mentioned, and noted that people he knows through his child's school activities talk about NASA's amazing science results. However, everyone wants to squeeze the last ounce of science from the limited budget. No one in 2010 foresaw the drastic changes that took place with the budget, and yet he felt that they are still on autopilot, operating as if the changes are less than what they are. As a Subcommittee, APS was distressed that the MoO line has been put on hold and may be cancelled. In constrained budgets, it is important to be especially clever. The "Plan B" in getting the most science from the budget is to partner with others. The MoO line was specifically constructed to enable that, and so to see it cancelled is more than unfortunate. He understood that it was not done capriciously, but the MoO is a mechanism to allow good science when resources are tight, and so it seems contradictory to cancel it now.

Dr. Grunsfeld replied that the astrophysics community did articulate its vision and priorities through the last Decadal Survey. It contains the science drivers independent of the budget situation. Regarding autopilot, that is used when seas are calm and it is turned off during turbulence. SMD has tried to navigate through very rough waters, and with limited freedom. Trying to maintain balance leads to examining things that are not yet started. It was not certain that APD would be able to choose NICER and TESS. The same situation exists with the HPD Explorers. This is not easy, but at some point they run out of freedom.

NASA is working well with its international partners and does not always need to lead. Euclid is a good example of this. ESA is moving out faster than NASA, they have funds already approved, and they invited NASA to participate. The Agency responded with extremely strong elements as well as some good U.S. science. The same is true with the JUpiter ICy moons Explorer mission (JUICE) in PSD. It is a very effective way to leverage. However, ESA also has funding issues.

Dr. Melnick said that he thought they were in agreement, especially on disengaging autopilot. There are some excellent opportunities out there, and APD needs to think hard about passing them up. Dr. Grunsfeld agreed, and asked APS to let him know what they hear. The B612 Foundation wants to build an infrared survey scope, which is very exciting. NASA has a Space Act Agreement (SAA) in place for providing them support.

Dr. Nousek said that while the funds removed from APD are significant and valuable, he thought that Drs. Hertz and Grunsfeld have done a great job of managing the situation. He was concerned that a lot of what they did consisted of individual tricks for 1 year, putting liens into the long-term development schedule and reducing opportunities. He felt like the programs were teetering on a precipice and observed that Congress dictates cuts without knowing whether there is anything to cut in the first place. He asked how APS might help.

Dr. Grunsfeld showed a chart on recent cost and schedule performance, which he had taken to Congress quite a lot in recent days. When he talks about science system engineering and the rigor, he notes that some missions should be slightly under budget, and about half are. Dr. Nousek said that this is good from the management perspective, but the dynamic is avoiding risk, leading to increased conservatism in the missions selected. He had heard that when NASA began Chandra, no one knew how to build an x-ray telescope mirror. It is important to dream, and this dynamic does not work in the long term. Dr. Grunsfeld replied that there is a new technology mission directorate, along with a good suborbital program, long-duration balloons, and other programs, all of which are preparing for the future.

Astrophysics R&A Update

Dr. Linda Sparke discussed the status of the R&A program. Funding for research awards increased by 9 percent in FY12, and that growth was retained in FY13 and in the President's FY14 budget request. The Long-Term Space Astrophysics (LTSA) program, which awarded grants that could go up to 5 years, was transitioned several years ago to the Astrophysics Data Analysis Program (ADAP), which can make awards up to 4 years.

A new program on Theory and Computational Networks (TCAN) is jointly funded with NSF. The first round of proposals was submitted in February 2013, with a total of 106 proposals for 29 projects. TCAN was a DS recommendation. The awards are for 3 years at about $0.5 million per year. To be eligible, proposals must involve PIs at three or more institutions. NASA is now working with NSF on the selections. NASA and NSF will fund separately, not jointly; investigations may be funded by either or both agencies, but each proposal will be funded by a single agency.

In 2012, three Roman Technology Fellows were selected for a 1-year study; these have submitted proposals for the 4-year development cycle that are now being reviewed.

The Strategic Astrophysics Technology (SAT) program funds mid-TRL technology. There were 39 SAT proposals in FY12, down from 48 in FY11. Dr. Hertz said that, for the Fermi GI program, APD is looking at whether some awards can be made in the current cycle with FY13 funds even without FY14 money. Archival research is allowed with Fermi data under the ADAP program. Regarding Euclid, funding for the science team comes through the Jet Propulsion Lab (JPL), not Dr. Sparke's program.

Dr. Sparke said that APD is receiving many more proposals than it did 5 years ago for its three largest programs: ADAP, the Astrophysics Theory Program (ATP), and Astrophysics Research and Analysis (APRA). This is reflected in the proposal funding rates. More recently, the number of proposals for the Origins of the Solar System (OSS) program is higher due to the increase in data from the Kepler mission. Most other programs are now flat in terms of number of proposals received.

Dr. Melnick asked what would happen to investigators proposing to use Kepler data should the mission end due to its reaction wheel issues. Dr. Sparke explained that Kepler is in its extended mission. The funding options for work on Kepler and Kepler data will not stop with the end of the mission. Already, proposals are coming in for archival research on Kepler data under ADAP.

The ATP selection rate has been going down, as the proposal budgets have crept up and the funding is flat. The low rate reflects both the time of year the proposals come in and the assumption that all of the ATP funds will be spent at the pace that the proposal requested; in fact, spending is often delayed. As the year goes on, it is never quite as bad as envisioned, but ATP must make plans at a time of low optimism.

Dr. Sparke asked for APS input on delaying the July ATP call until December, with a decision the following April. Dr. Sparke explained that there would be relatively scant funds in FY14, so the delay shifts most funding costs for ATP-13 into FY15, which makes it possible to select more proposals. A selection rate of less than 10 percent is wasteful of the community's time, both as proposers and as peer reviewers.

Dr. Gonzalez pointed out that postdocs and students are looking for jobs in the fall, so the funding shift would accommodate that. Others agreed, noting that this more or less follows their hiring patterns. Dr. Nousek did observe that this kind of cycle puts pressure on the peer reviewer pool, but Dr. Sparke explained that it also avoids snowstorm season. Dr. Hertz added that leaving wait-listed awards "in limbo" for an extended period made it difficult for proposers to plan. There is no perfect solution. APD does not start the cycle with the knowledge needed in order to be fair throughout the year.

Dr. Nousek said that ADAP is very important in keeping new members of the profession going.

ExoPAG Report

Dr. Gaudi began by reviewing the ExoPAG charter. The Exoplanet Exploration Program Analysis Group (ExoPAG) was formed in June, 2009, as a community-based, interdisciplinary forum for analysis supporting activity prioritization and future exploration. The long-term ExoPAG goal and primary topic of discussion had been planning for a future flagship-class direct imaging mission. Recently, there has been new emphasis placed on having the widest possible community outreach. Some within the exoplanet community felt unrepresented by ExoPAG. Therefore, the group has revised its focus to:

- Expanding the inclusiveness of NASA's Exoplanet Exploration Program to the wider exoplanet community, beyond the past focus on future flagship missions in space; and
- Considering novel ways in which NASA can address exoplanet research in the short term.

The goal is now to develop a unified and coherent exoplanet roadmap with community consensus, focusing on areas where NASA can contribute.

Dr. Gaudi first reviewed the Executive Committee membership.

In October, 2012, the ExoPAG 6 meeting took place at the Division for Planetary Sciences (DPS) of the American Astronomical Society (AAS) meeting in Reno. Participants looked at current and future missions, what is needed to characterize exoplanets, and the future of the radial velocity method (RV) for exoplanet detection.

ExoPAG 7 met at the January, 2013, AAS meeting in Long Beach. At that meeting, focus was on current and future instruments, characterization of host stars, the role of precision RV, and exoplanet goals for the next decade. These two ExoPAG meetings were held at the larger meetings specifically in order to pull in more members of the community.

During the final session of ExoPAG 7, there was a group discussion about whether or not the community endorses putting a coronagraph on AFTA-WIFRST. At the end of the discussion an informal vote was taken, on the question of "Do you support putting a coronagraph on AFTA-WIFRST, even if it means forgoing some future technology development opportunities or smaller missions?" All votes were in favor. Although this was a self-selected audience, the vote shows significant community support for this idea.

ExoPAG 8 will be in October, 2013, in Denver.

Dr. Gaudi next reviewed the active Science Analysis Groups (SAGs):

- SAG 1: Debris Disks & Exozodiacal Dust
- SAG 2: Potential for Exoplanet Science Measurements from Solar System Probes
- SAG 4: Planetary Measurements Needed for Exoplanet Characterization
- SAG 5: Exoplanet Flagship Requirements and Characteristics
- SAG 8: Requirements and Limits of Future Precision Radial Velocity Measurements
- SAG 9: Exoplanet Probe to Medium Scale Direct-Imaging Mission Requirements and Characteristics

The goal of SAG 5 is to develop science requirements for a direct imaging framework and mission. The mission would look at a nearby star for habitability. Over 60 people were involved in this effort, which crafted 3 overarching science goals and 11 more specific objectives, which were then divided into minimum capabilities and valuable additions. This framework allows a fair comparison of mission concepts with very different strengths and weaknesses.

The three science goals are:

- Determine overall architectures;
- Determine or constrain atmospheric compositions; and
- Determine or constrain planetary radii and masses.

Dr. Melnick noted that this was not the first time that this had been done, but the previous result had been a hugely expensive and complex design. He advised looking at some of the older studies. Dr. Gaudi replied that the exoplanet community knows that this effort will be costly. There are interesting things that cost less, but they want to recognize the expensive goal. This speaks to the larger question of future of NASA missions, and whether to emphasize small missions with great science or a big mission that does something spectacular.

When Dr. Bregman said that there is some overlap with the key issues for ground-based telescopes, Dr. Gaudi replied that most of what the SAG was discussing would be difficult from the ground. Dr. Stapelfeldt agreed. He was at the JPL Exoplanet Office for a long time, where this was studied extensively. The team determined that ground-based direct-imaging studies will never achieve the same contrast as space-based studies. Nor will they be able to get the same characterization, regardless of the technology. It is important to always review what ground instruments can offer but, at the moment, there are limits. European claims to do certain measurements from the ground were shown to be overly optimistic. Dr. Gaudi said that he wants to continually evaluate the options.

SAG 8 looks at the requirements and limits of future precision RV measurements, specifically the short-, medium-, and long-term needs for Doppler measurements to support NASA science objectives. This would address, among others, the controversial questions of “What are the astrophysical limitations on radial velocity precision for measurements of nearby stars?” and “Are habitable planets orbiting solar-type stars detectable via RV?” There were mini-workshops on RV at ExoPAGs 6 and 7 to determine what can be done now and in the near future, and what technology development is needed. There were some tentative consensus points, such as the fact that dedicated facilities with stable instrumentation focused on a small number of targets with high cadence are needed, support for RVs were soundly supported by the Astro 2010 Decadal report, and that precision RVs are a necessary element for TESS follow-up.

SAG 9 is new, and will focus on defining the requirements and characteristics for probe to medium scale direct-imaging missions. The focus is on smaller mission sizes that are shorter and less expensive than a

flagship. The science here is more open, therefore it is more difficult to define the metrics. The SAG will build on the methodology developed by SAG5, and establish the minimum science threshold.

There were some suggestions for new SAGs. One idea was for a SAG addressing the requirements for characterization of exoplanet atmospheres, and another for the required preparations for the WFIRST microlensing survey. These are still conceptual, however, and not ready for APS approval.

With three members leaving the Executive Committee, Dr. Gaudi asked APS for approval of the three nominees to replace them: Drs. Nick Cowan, Amy Lo, and Gene Serabyn. Dr. Oswalt offered a motion for approval; Dr. Stapelfeldt seconded. The vote to approve the new members was unanimous. Dr. Gaudi asked for approval of the final report from SAG 5, which is a report to APS. This will be discussed at the summer meeting.

CoPAG Report

Dr. Dominic Benford, Cosmic Origins Chief Scientist, discussed the recent activities of the Cosmic Origins Program Analysis Group (CoPAG). Four of the 10 members of the Executive Committee end their terms at the end of 2013, and a new Chair is to be announced soon. There have been some good meetings, and CoPAG helped the program office in technology prioritization, along with trying to help unify science drivers in the field.

There are five SAGs, which are being reconsidered as there is a general feeling that they have met their purpose and should be redefined or otherwise changed. These are:

- SAG1: Science Goals, Objectives, Requirements for Cosmic Origins missions. Where are science thresholds and how do they link with mission class / aperture size?
- SAG2: Determine technology focus areas for a monolithic 4m Aperture UV/Optical/NIR mission with Internal Coronagraph for Exoplanet Imaging
- SAG3: Determine technology focus areas for a segmented 8 m Aperture UV/Optical/NIR mission with External Occulter for Exoplanet Imaging
- SAG4: Determine technology focus areas for future Far IR Instruments
- SAG5: What is the scientific case for a set of linked probes and corresponding technology requirements?

Cosmogony is an attempt to organize cosmic origins science to follow the flow of matter from the "cosmic web" to the planets by following the flow of baryons. A Request for Information (RFI) in the form of community input on the UV/Visible Science objectives received 33 great responses. CoPAG held a workshop with more than 50 attendees, resulting in a representative but not comprehensive view of this important area. The Group also looked at UV imaging criteria. The result is a well-defined set of requirements that should inform the building of technologies. This all flows into a program annual technology report at http://cor.gsfc.nasa.gov/

CoPAG identified the following as its top technology development priorities:

- High-QE, large-format UV detectors;
- Photon-counting, large-format UV detectors;
- Development of UV coatings with high reflectivity, high uniformity, and wide bandpasses; and,
- Ultra-low-noise far-IR direct detectors.

CoPAG will continue to refine technology priorities and monitor the NASA Cosmic Origins Program to ensure that the community priorities are reflected. New things are always coming up.

Regarding the mid-DS process, CoPAG notes that there is no Cosmic Origins mission other than WFIRST being considered. Possible directions for the community include:

- Option 1: Community proposes many competing approaches to Astro2020;
- Option 2: Community converges on 1 concept; and,
- Option 3: Community converges on a small set of options (e.g., Probes, 4 m mono, 8 m segmented).

CoPAG might hold a workshop on this. The Group might also form a new SAG on this topic, but there was no proposal at the time of the APS meeting.

Dr. Benford summarized the pending issues in CoPAG:

1. New CoPAG chair to be appointed;
2. Executive Committee members to be replaced at the end of 2013;
3. Planning of community workshops;
4. Direction/terms of reference for SAGs;
5. Consolidation of future mission concepts;
6. Compelling technology development plans; and,
7. Preparation for UV/Visible follow-on to the Hubble.

Dr. Hertz addressed a question regarding how to hold the workshop in face of the Federal travel restrictions. The Agency direction is to have no NASA-sponsored conferences without a waiver, and there have been some cancellations. The plan is to add meetings like these onto an existing non-NASA science conference like AAS. CoPAG will need to work through the details.

Dr. Oswalt asked if CoPAG coordinates with ExoPAG to eliminate redundancy. Dr. Benford said that this does not happen. The model is that there should not be direct linkage, though the idea of changing the model has been discussed. Dr. Gaudi added that there has been interaction in past, with joint meetings, but not for a while. ExoPAG is rebooting, and though there has been talk of a future joint meeting, that idea is on hold until the new CoPAG chair is appointed.

JWST Status

Mr. Geoff Yoder reviewed JWST progress. GSFC Flight Projects Directorate has been the source of some analysis outside the JWST Program and Project offices. Those analyses suggested the Program to increase technical review support, ideally through the Chief Engineer's office, which can pull in the right experts as needed. There are frequent meetings. The program keeps in touch with stakeholders and senior leadership to ensure they all have the same information. There are also all-hands meetings at the centers and with contractors. Cost and scheduling metrics are key to control of the project. The Program looks for consistency, tracking good performance and forecasting problem areas.

The 18 mirror segments are complete, and the team is putting motors on the back of the mirrors. There are about 16 months of margin between delivery of the last mirror and the time it needs to be up. There has been good progress on the five sunshields. The engineering units have been built, and fold testing is underway. It will not be possible to do full verification testing on the ground. Northrup Grumman is having all of the mechanisms reviewed.

In December, the Critical Design Review (CDR) for the spacecraft bus will occur. The idea is to have most subsystems reviewed by summer. The Near InfraRed Camera (NIRCam) will be delivered to GSFC in June, and the Near InfraRed Spectrograph (NIRSpec) will be delivered soon. The latter has a month of margin. When the Mid-InfraRed Instrument (MIRI) and a mirror were tested together, they worked flawlessly.

MIRI was about to be installed into the Integrated Science Instrument Module (ISIM), and the Fine Guidance Sensor/Near-Infrared Imager and Slitless Spectrograph (FGS/NIRISS) was already installed. NIRCam was completing cryovac testing, and NIRSpec had completed the first cryovac test. The team is looking at a few things like kinetic mounts. The telescope elements are all either completed and in process. The primary mirror segments are being installed. Four of the five sunshield templates are complete, and the folded sunshield template is being done. There are two mock-ups conducted before the flight. A lot of subassemblies are done. About 76 percent of the hardware is through the CDR process, and that will be over 90 percent in December.

The replacement of the detectors on NIRCam, Milestone 4, is a year ahead of schedule, and the team is doing characterization now. The long-wave detectors are ahead of the schedule. ISIM Integration and Testing (I&T) is proceeding smoothly because the pathfinder approach of doing trial assemblies with engineering test units of the instruments. Mr. Yoder showed a video of the flight FGS/NIRISS installation. The optical simulator (OSIM) went into cryovac testing a month late but was progressing well. The electronics that go with ISIM were completed.

Mr. Yoder next discussed the Optical Telescope and ISIM (OTIS) test and subsystem progress status, showing the flow of many parts through the different stages of preparing the systems. The pathfinder actions permit full scale tests to take less time by several months. The JWST team has asked an outside group from the NASA Office of Evaluation to look at whether the preparations for the OTIS testing are as on track as the Program believes.

The budget is where it needs to be, and there is still reserve in the critical path of the schedule, about 14 months. There are a lot of things competing for the critical path, however, and three milestones from FY13 will be late. One was ISIM testing, which was delayed in part due to access to the GSFC Space Environment Simulator chamber. This affects two milestones, and the third milestone had to do with a MIRI shield.

Issues with sunshield wrinkles have been resolved. The sunshield is made of five layers of thin material. The primary risk at the time of the meeting was the cryocooler assembly, which involved an intense effort. It is not part of the critical path, however, and the mission team has the flexibility to ensure that they have the right certification. NIRCam issues have turned around since October, 2012, coming out of Cryovac 3. There is now additional mass margin. It is important to get the mirrors right, and so there have been practice activities.

Each year, there is a lot of work to do. This year the focus is on integration, 2014 will be on manufacturing the spacecraft, 2015 will be mirror assembly, 2016 will be assembling the main components, 2017 will be integration, and 2018 will be the launch. Because the mission has had the needed reserve, there has not been a need to push work out, though the team did have to budget for leins into FY14 reserves. There is about 20 percent left from the FY13 unallocated future expenses (UFE) and 50 percent for FY14 UFE. At the program level, it is at about 25 percent, which is where they would want to be. However, FY14 will be tight. The Program is looking at risk reduction and cost avoidance.

On the critical path at this point are the backplanes to install the mirrors, along with ISIM and OTIS. The spacecraft is operating in parallel. There is a standing review board outside the project and program. The members are not NASA people, and this is a non-advocate review. There are integrated review people at GSFC. The standing review board looks at key gate points. NASA has invited the chair to sit in on NASA's quarterly flight program.

TESS

Dr. George Ricker of MIT described the TESS mission that was recently selected. TESS begins with the concept of finding a new Earth-sized planet every month, including binaries and multiples. TESS will enable mankind to know about the conditions on these new worlds. It is meant to be the "people's telescope" and help the science community learn which of the stars in the solar neighborhood has habitable planets.

Partners include MIT, GSFC, and Orbital Science Corporation. Not all science team members are receiving funding. Among them are some prime Kepler team members. TESS was previously selected for Phase A as a SMEX but not funded further. In 2010, it was again selected for Phase A, then selected to continue. The mission will launch in 2017.

Science drivers and goals include the following:

- Discover transiting Earths and super-Earths orbiting bright, nearby stars;
- Discover the best 1,000 small exoplanets; and
- Conduct a target-driven, all-sky survey of bright stars.

TESS and Kepler answer different questions. TESS seeks the nearest transiting rocky planets, while Kepler looks at true Earth analogues. TESS covers 400 times the amount of sky as Kepler, and so examines a greater number of accessible stars. These are brighter stars as well: on average, 30-100 times brighter than Kepler stars. Thus, the TESS planets will be much easier to follow up. The number of potential targets is very large, up to 1 million. The estimate is that TESS will discover more than 300 Earths and super-Earths.

The payload includes four identical wide-field Charge-Coupled Detector (CCD) imaging cameras. Dr. Ricker explained the details of the CCD package and focal plane array. To qualify the cameras, the team built two prototypes that were used for different tests; both cameras were successful. Similarly, the team built a mock-up of TESS, which is approximately 1.5 meters high. To launch by 2017, it is important to have a simple mission design. TESS will utilize a high-Earth orbit, all cooling will be passive, and the solar panels will be the only deployable element, all of which results in a simple payload interface. As shown in a video of how the mission will function (http://www.youtube.com/watch?v=mpViVEO-ymc), alignment is not critical. The observatory will have a 23 x 90 degree field of view.

The cadence will be 28 days per field. TESS will orbit above the radiation belts and use a lunar gravity assist in the transfer orbit to adjust the orbit inclination. The orbit is key for the science. The observing duty cycle is greater than 90% in this orbit. Dr. Gaudi noted that TESS will be able to look at single transits of planets, but some of these are lengthy. The sensitivity is significant.

Dr. Ricker showed the planet radius versus the orbital period. The key is that there are very few characterizable Earths and super-Earths currently known from previous surveys. The two smallest transiting exoplanets with bright hosts were discovered from space. TESS will identify the best and smallest exoplanet targets for characterization of atmospheres using data from JWST, a hypothetical dedicated 1-meter space telescope, and a ground-based 30-meter telescope. The TESS team will provide radial velocities and identifications for a sample of TESS-discovered, Earth-sized planets. The investigation team will characterize 10 percent and leave the rest for the community. By 2020, we should know which of the nearby bright stars are the best candidates for habitable planets. TESS will identify the planets and JWST will characterize the atmosphere. Thus, TESS and JWST can identify the best target(s) for some future NASA robotic interstellar probe.

Dr. Bregman congratulated the team, then asked about the characteristics of the downlink. He was told that TESS will downlink 100GB-200GB per perigee pass, which will require about 2-4 hours. Since the

TESS orbital period is 330 hours, the downlink time is about 1% of the orbit duration. About 5 percent of all of the pixels will be downloaded, utilizing "postage stamps" enclosing pre-selected target stars. This is similar to Kepler. The team will also bring down about a dozen full image frames a day, containing all the objects within the ~2000 square degree FOV. They have considered a few other non-exoplanet studies they might do as secondary science, including observing the early rise of bright supernovae, GRB-related optical transients, and AGN variability. It is a big exploration space.

Regarding avoidance of the Earth's shadow and brightness, the Earth as viewed from the TESS orbit will only subtend a couple of degrees. TESS can avoid the Earth or the moon in its field of view except for very brief intervals. The TESS cameras never view the Earth during maneuvers or during downlink. Camera temperatures during maneuvers could change by a few Kelvin, but will quickly stabilize thereafter. TESS will transmit at perigee and observe at apogee, using its KA band transmitter. The downlink rate is 100 Mb/second, and the DSN time is $1,500 per hour. As a guest investigator program, NASA would have the option of adding several thousand targets that have nothing to do with exoplanets.

PhysPAG Report

Dr. Nousek gave an update on the Physics of the Cosmos Program Analysis Group (PhysPAG), for which he has been the Chair since the February, 2013, meeting. PhysPAG solicits and coordinates with the science community in order to provide input to inform APD's PCOS Program. There are only seven members on the Executive Committee, and each of the other six leads a SAG. The PhysPAG SAGs are more long-lasting than those in ExoPAG or COPAG.

There have been some very large-scale outreach efforts, including a lunch town hall at the American Physical Society in Denver that week, and another at the AAS High Energy Astrophysics Division meeting in Monterey on April 9. There has been much talk about the astrophysics implementation plan compared to the DS, and the fact that conditions have changed since the DS was issued. The individual SAGs are addressing how these conditions affect the communities they represent. At the town halls, participants heard details about the mid-decade assessment of NASA's current implementation plan.

Dr. Kouveliotou cautioned Dr. Nousek to be careful in how he characterizes the x-ray community, because there are some differences, which he acknowledged. He added that while there is not unanimity, the SAGs do discuss programs. It is possible that some ideas are left out, a situation that remains to be resolved.

PhysPAG has discussed the possibilities for detection of gravitational waves by the Laser Interferometer Gravitational-Wave Observatory (LIGO) before JWST launches. Dr. Nousek explained that if what investigators believe they know is right, this ought to fall in the LIGO sensitivity. The question then is the best path forward for a gravitational wave SAG, which depends on external events. At this point, ESA is leading a partnership on L2, with TRL5 by 2018. A NASA-led partnership may occur after the next DS, requiring TRL5 by 2020. The total cost is expected to be $1.6 billion, and this would be a partnership for a scaled-down mission with two arms, not three arms. It would be smaller, with a lower launch cost and shorter arms. The preferred mission is $2 billion. For a mission costing less than $1.6 billion, the science declines faster than the funding. A new ESA consortium is preparing a case.

The X-ray SAG met and determined that x-ray observatories in the $1 billion class that address all or most of the International X-ray Observatory (IXO) science objectives are feasible for start within this decade, but only if the technology risk is controlled through advance development of key technologies to TRL6. WFIRST would have to not go forward and, as Dr. Kouveliotou pointed out, not all x-ray scientists are in agreement with each other. Due to a past failure of mirrors, there is a need to demonstrate a mirror system. The assumption is that the $1 billion mission would be probe-class.

ESA is doing a science white paper for the Advanced Telescope for High Energy Astrophysics (ATHENA) mission, and might allow NASA to participate up to 20 percent. PhysPAG heard about ESA's Euclid mission and the NASA contribution. In return for providing assemblies, the United States gets a seat on the consortium and 40 scientists on the science team.

Public Comment Period

The meeting included an opportunity for members of the public to provide input to APS. No members of the public spoke up.

Dr. Ray passed along a message from Julie McEnery (Fermi Project Scientist) about Fermi. The statement said that with the President's FY14 funding cuts, she expects to fund Cycle 6 of Fermi for about $4 million. However, the mission had been ramping down anyway, and the impact of the budget reduction is less than expected. She also noted the discussion as to whether Fermi should be in ADAP. The Fermi Guest Investigator program is extremely important to maximize the science return of the Fermi mission. The Fermi GI program should remain independent of ADAP due to the many collaborative MOUs and service components in the GI program that go beyond what ADAP allows.

Dr. Peterson took this to mean that Fermi can fund a GO program at about half the cost. Dr. Ray explained that the tricky thing is that fiscal years are not the same as cycles. Julie can use some FY13 funds across boundaries, so she will be able to fund about $4 million of Cycle 6 proposals. Dr. Gonzalez explained that Julie sent an email in which she pointed out that the President's request for FY14 recommended both a reduction for Fermi and a zero budget for GO grants for FY14. Julie then said that within the project, the team can rephase for Cycle 6.

It was suggested that Dr. Hertz needed to weigh in, but Dr. Nousek said that Dr. Hertz had previously said that he had no problem with having a GO for Fermi as long as FY14 funds were not used. It was agreed that if the Fermi team could do this, they should. Dr. Ray added that Julie had said that existing commitments would be met.

Committee Discussion

Dr. Peterson noted that there seemed to be a consensus that APS should endorse funding done through rephasing. He agreed that they should also commend APD for good performance in difficult times. Regarding E/PO funding, Dr. Hertz said that two of the SMD subcommittees met before the budget came out and therefore could not discuss the E/PO change. He suggested that Dr. Peterson might want to determine if the other subcommittee chairs felt the same way about it so that they could develop some joint language on the issue for the NAC Science Committee.

Dr. Bregman saw the E/PO situation as having two parts. First, the general shift to move K-12 STEM education was a high-level decision that APS could not affect. Second, he suspected that in the consolidation move, the Administration probably did not realize that this would take resources from observatories that everyone sees and that are tremendously popular. There are things that educators would not want to develop on their own and that are naturally developed within the missions. He thought APS should argue that it is important for those observatories to continue producing the materials, even if K-12 education is with another organization.

Dr. Bernstein brought up the rescission and sequestration priorities. He saw a side effect of preserving the ongoing missions as large projects going longer and small ones turning over faster. This creates a focus on smaller projects, then on students and postdocs. He wondered if APD knew what the distribution was in this regard. Dr. Hertz said that it was distributed between large and small missions. If projects looked like they would go out of FY13 with funds in the bank, APD would take that from them. This spreads the impact over a number of years, but the funds are not replaced. If the choice is to work at higher risk to future projects versus stopping current ones, APD is going with the former.

Dr. Melnick observed that a thread running through the discussion was the disparity between what they had assumed would be available and what had actually unfolded, all in light of the DS expectations. He believes the mid-decade review must be more than a checklist, and APS and APD must turn off the autopilot. The Division is trying to do things that are not matched well to its resources. He thought that APS should state strongly that the mid-decadal process has to do more than what is traditionally expected. It should recalibrate rather than just grade, or this disparity will continue and APS will continue to complain.

Dr. Hertz said that NASA is spending more than expected on JWST, which has been removed from the APD budget line. Without JWST, APD is getting one-quarter of what the DS recommended over the decade, according to the projection based on budget runouts. Dr. Gaudi said that the DS discussed science priorities and ranked science. Therefore, it has value external to the economic winds. If the DS is to mean anything, it cannot be rewritten halfway through the decade. That sets a bad precedent.

Dr. Melnick said that the DS is not a Biblical document. He wondered if the authors would have written the same document had they known that APD would have one-quarter of the funds. Dr. Nousek pointed out that the DS addressed the probability of inaccurate budgets, but APD is still nowhere near what it predicted. However, the DS also stated that a mid-decadal review should be done if the budget is so low that the DS cannot be done. Dr. Peterson said that APS should then quote the DS.

Dr. Melnick noted that the second recommendation of the DS was the Explorer program, and APS had just heard that portions of the program were being cut or pushed out. They were seeing deterioration in the number two recommendation, which he thought was more substantial than “fraying at the edges.” He believed that intelligent people should reassess it. Otherwise, Dr. Hertz is tasked with the impossible. He expected to hear about more things being cut and moved at the next meeting. He thought the sensible thing to do is to make some intelligent choices based on the real world, and he wanted APS to make a statement to that effect. Dr. Ray agreed.

Dr. Bregman asked Dr. Melnick if what he was saying was that the science goals are not different, but the way to approach them should be different. Dr. Melnick replied that APS cannot go forward as if nothing has changed, which would be like the death of 1,000 cuts. Dr. Peterson said that it went beyond the fact that so much of the funding was missing, and NASA had a couple of telescopes donated. He thought it unrealistic to suppose they can take the document as written and assume it is relevant. It is still the guiding document, however. No one has said to throw it out, and he wanted to be explicit about that.

Dr. Dalcanton agreed that they should reaffirm the science priorities. Her concern was community input. There were 10 APS members in the room having this discussion, while the DS had extensive community input. She shared Dr. Gaudi’s apprehension about large mid-path course corrections. Dr. Peterson said that that would be addressed by starting with a statement that they are not tossing out the DS. Dr. Melnick said that for context, they can point to the specific areas they heard of at the meeting, which were real manifestations of real problems. Dr. Peterson added that the entire budget structure for JWST had changed since the DS.

Dr. Oswalt said that it was not the purview of APS to second-guess the DS. Their orders were to help Dr. Hertz meet as many of the goals as they can. The biggest sacrifice they made was to keep JWST going, and they should reconfirm that commitment. Dr. Peterson said that it did not matter which flagship mission they supported, it was going to look like the one that killed the rest of the program. He agreed that APS should not try to change the priorities.

Dr. Bregman reminded the Subcommittee that they needed to produce a statement about E/PO, particularly the statement about materials produced by the missions. Dr. Dalcanton suggested stating that APS supports efficiency and effectiveness, but does not agree that the way this was set up serves those goals. It would be ineffective to have to keep going to DOEd to explain things repeatedly. Dr. Peterson asked Drs. Bregman, Dalcanton, and DeVore to develop a paragraph to go in the letter. It would be vetted by the whole Subcommittee. Dr. DeVore noted that an essential issue is the separation of the E/PO professionals from the source of the research and discoveries. They should be embedded with the scientists doing the work. Dr. Peterson added that it has taken a generation to get scientists to understand that they have an obligation to explain what they do. Dr. Oswalt noted that NSF, DOEd, and the Smithsonian would benefit NASA more if the proper infrastructure were in place, and Dr. Bregman said it was important to retain the expertise that has been developed. Dr. Peterson pointed out that this is urgent. He asked that the statement be sent to APS quickly.

Regarding other issues, Dr. Hertz said that there were some questions pending from the presentations. APS needed to approve Mr. Woods' presentation on the SMD Science Plan or recommend alternatives. They also needed to weigh in on the funding amounts for ULDB payloads in the balloon program. Finally, Dr. Sparke needed their input on the due date for the theory program.

Dr. Bregman asked if technology development could be accelerated. Dr. Hertz said that over the last couple of years, the Space Technology Program (STP) has accelerated and now has calls for both low- and mid-TRL products. STP has come to appreciate the kinds of things APD is doing in identifying and prioritizing its technology needs. The program is incorporating astrophysics technology into their calls and co-funding several awards with APD and others in SMD. They are looking for high priority technology for science and thinking in terms of investment for SMD's future needs. They are also funding the navigation application for NICER. Dr. Rita Sambruna added that for PCOS, STP is doing x-ray optics and lasers. These are aligned with the Strategic Plan. Dr. Hertz said that this is technology-relevant funding coming to astrophysics technology.

Dr. Peterson next called attention to the concerns about the MoO call. Drs. Kouveliotou and Melnick volunteered to write a piece on that. Dr. Peterson said that he would write the Fermi GO response. Dr. Melnick was to write about the mid-decade review. He said that he would use Fermi and the MoO as examples, and be clear about priorities. The MoO cancellation statement would be separate. Dr. Peterson asked him to mention that APS wants to maintain the science priorities. Dr. Ray added that the goal was to give the mid-decadal review the flexibility to recommend that Dr. Hertz have the ability to address realities. Dr. Hertz explained that CAA is charged with the DS and will be doing the mid-decade review, while APS is the tactical advisory committee, which is more about the near term. They operate in different spheres. However, APS input to CAA is welcome, and he saw nothing wrong with APS suggesting how to approach the mid-decade review.

Dr. Melnick said that APS gets a lot of details of implementation and therefore sees the strains. He wanted to have CAA consider priorities in light of what is happening. Dr. Hertz said that providing input to the CAA might be best done by individual members of the Subcommittee as individuals, but not as APS. They are there to advise him on what he should do. Dr. Kouveliotou asked how APS is to influence CAA. Dr. Peterson said that the issue is that Dr. Hertz cannot implement the DS as originally outlined. Dr. Hertz added that much of what they were commenting on had less to do with long-term funding for

decades and more to do with the fact that the budgets changed on a short time scale. If he had not planned the MoO AO, they would not notice that he was not doing it. He wanted to keep the big picture separate from the short-term planning.

Dr. Nousek said that many of the DS recommendations were contingent recommendations, and one reason to revisit it is that some of the contingent options have changed as well. This calls for interpretation. Dr. Melnick said that it is reasonable, with only one-quarter of the budget, to ask if the DS priorities should still be maintained, and whether they should continue to work off of a checklist generated when people assumed four times the funding. He wondered if it made sense to talk about WFIRST, for example, in that context. This was nothing against WFIRST, it was concern about the entire program. Dr. Gaudi pointed out that they still did not know if the JWST funds would return to APD after the mission launched. Dr. Peterson asked Drs. Melnick, Stapelfeldt, and Kouveliotou to draft language about this. However, it was determined that a proposer should not write about the MoO, so Dr. Gonzalez took Dr. Melnick's place. Dr. Gonzalez wanted to be specific that APS was not happy about the cancellation and its impact, but not specific ways of managing the budget.

Dr. Stapelfeldt said he wanted to express unhappiness that NASA cannot hold project meetings and cannot travel. He agreed to write the piece, as he had a statement from AAS. Dr. Kouveliotou would help him with it. Dr. DeVore did not have a specific education proposal in, so she could write about E/PO.

Dr. Centrella reminded APS that Mr. Woods needed their comments on the Science Plan, since he had to present it to management soon. They had wanted to add something about E/PO and the maturation of technology. Dr. Peterson thought it odd that the Explorer Program had its own section. Astrophysics Research should be above Explorer. Dr. Centrella said that she and Dr. Eric Smith would update the current chapter and send it out for review. They had to have it back to Mr. Woods by May 17 so that he could send it to the management council. APS will have another opportunity for review in July.

Dr. Kalirai suggested that those writing about E/PO consider reaching out to an education lead to find out what they do for K-12 education that might be different from DOEd. He saw NASA as oriented to content, while DOEd is seen as process-oriented. Dr. Hertz agreed with this assessment.

Dr. Kalirai added that there has been discussion of the balance between small and larger programs. He understands that it is attractive to do small projects, and only a small part of the NASA budget comes to APD. He sees the future budget as being different. It could be unconstrained and larger, or even smaller. Therefore, he thought that it was important to think of how to raise the budget. He believes that the big, bold science ideas will provide a chance of doing that in the long run. The absence of big programs could ultimately harm the budget.

Briefing with Astrophysics Division Director

Dr. Melnick said that he wanted from Dr. Hertz the data on what he expects to have across the decade. Dr. Hertz said that the only adjustments would be the runout of the President's budget.

Adjourn

The meeting adjourned at 4:04

Appendix A
Attendees

Subcommittee members
Bradley Peterson, Ohio State University, *Chair Astrophysics Subcommittee*
Joan Centrella, NASA, *Executive Secretary*
Gary Bernstein, University of Pennsylvania
James J. Bock, Jet Propulsion Laboratory
Joel Bregman, University of Michigan
Julianne Dalcanton, University of Washington
Edna DeVore, SETI Institute
Giovanni Fazio, Harvard Smithsonian Center for Astrophysics
B. Scott Gaudi, Ohio State University
Gabriela Gonzalez, Louisiana State University
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
Karl Stapelfeldt, Goddard Space Flight Center

NASA attendees
Paul Hertz, NASA HQ, *Director, Astrophysics Division*
Mansoor Ahmed, NASA GSFC
Marc Allen, NASA HQ
Zaven Arzoumanian, NASA GSFC
T. Jens Feeley, NASA HQ
Keith Gendreau, NASA GSFC
Jim Green, NASA HQ
Richard Griffiths, NASA HQ
Hashima Hasan, NASA HQ
Jeff Hayes, NASA HQ
Cuong Huynh, NASA HQ
W. Vernon Jones, NASA HQ
Jennifer Kearns, NASA HQ
Lia LaPiana, NASA HQ
Cheryl May, NASA HQ
Julie McEnery, NASA GSFC
Marian Norris, NASA HQ
Bill Oegerle, NASA GSFC
Mario Perez, NASA HQ
Larry Petro, NASA HQ
Andrea Razzaghi, NASA HQ
Christy Riviera, NASA HQ
Rita Sambruna, NASA HQ
Wilton Sanders, NASA HQ
Jim Spann, NASA MSFC
Linda Sparke, NASA HQ
Dan Woods, NASA HQ

Non-NASA Attendees
Francesco Bordi, Aerospace
Dom Conte, self
Mary Floyd, Zantech
Jason Kalirai, STSCI
Brad Keeler, British Embassy
Jim Lochner, USRA
Robert Lockwood, Orbital
Eric Mahr, Aerospace
Rachel Osten, STSCI
Guilford Queen, Civil Air Patrol
George Ricker, MIT
Elizabeth Sheley, Zantech

Webex
Gale Allen, NASA
Dana Backman, NASA Ames Research Center
Michael Bicay, NASA GSFC
Mark Brumfield, NASA
Jeff Bryden, JPL
Louis Darbier, NASA
Sean Dreyer, Orbital Sciences
Lamont DiBiasi, Southwest Research Institute
James Green, University of CO
Thomas Griffin, GSFC
Sara Heap, NASA GSFC
Doug Hudgins, NASA HQ
Bethany Johns, Consultant
Mary-Elizabeth Kaiser, Johns Hopkins University
Robert Kellogg, Aerospace Corporation
David Lang, NRC
Peter Lawson, NASA JPL
Greg Lee, Northrup Grummon
Dan Lester, University of Texas
Robert Lockwood, Orbital Sciences
Mackenzie Lystrup, Ball Aerospace
Keith MacGregor, NASA HQ
Matthew Mazur, Goddard
Duane McMahon, AV Tech
David Millman, NA
Stewart Moses, Northrop Grumman
Susan Neff, NASA GSFC
Ronald Polidan, Northrup Grumman
Chris Schardier, GSFC
Marcia Smith, spacepolicyonline.com
Robin Stebbins, GSFC
Leigh Stevens, NASA Tech Support
Wesley Traub, JPL
Jim Ulvestad, NSF
Stephen Unwin, NASA JPL
Michael Werner, NASA JPL

Angela Clark Williams, Zantech IT
JenniferWiseman, NASA

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

Chryssa Kouveliotou
Marshall Space Flight Center

Gary Melnick
Senior Astronomer
Harvard University

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

Terry Oswalt

Professor and Head,
Department of Physics and Space Sciences
Florida Institute of Technology

Paul S. Ray
Naval Research Laboratory

Karl Stapelfeldt
Goddard Space Flight Center

Appendix C
Presentations

1. *Astrophysics Division Update*, Paul Hertz
2. *Crafting the 2014 SMD Science Plan*, Dan Woods
3. *Report on the Balloon Program*, W. Vernon Jones
4. *Astrophysics Roadmap 2013*, Chryssa Kouveliotou
5. *NICER APS Briefing*, Keith Gendreau
6. *Cost of Estimating Space Science Missions*, Eric Mahr
7. *ExoPAG Report*, B. Scott Gaudi
8. *CoPAG Update, Status Report*, Dominic Benford
9. *PhysPAG Status*, John Nousek
10. *JWST Briefing*, Paul Yoder
11. *TESS Mission Status*, George Ricker

Appendix D
Agenda

Astrophysics Subcommittee meeting
April 16-17, 2013

AGENDA

Tuesday, April 16
Discovery II Room, Holiday Inn Capitol, Washington, DC

9:00 – 9:10 am	Opening Remarks/Announcements	B. Peterson
9:10 – 10:45	Astrophysics Division Update	P. Hertz
10:45 – 11:00	Break	
11:00 – 11:30	Discussion with Astrophysics Division Director	P. Hertz
11:30 – 12:10 pm	SMD Science Plan	D. Woods
12:10 – 1:15	Lunch	
1:15 – 2:00	Report on Balloon Program	V. Jones
2:00 – 2:45	Report on Astrophysics Roadmap	C. Kouveliotou
2:45 – 3:15	Report on NICER	K. Gendreau
3:15 – 3:30	Break	
3:30 – 4:30	Costing of Space Science Missions	B. Bitten
4:30 – 4:35	Public Comment Period	
4:35 – 5:00	Committee Discussion	B. Peterson
5:00	Adjourn	

Wednesday, April 17
NASA Headquarters, MIC-6/Room 6H45

9:00 – 10:00 am	Discussion & Budget Overview with SMD AA	J. Grunsfeld
10:00 – 10:30	Astrophysics R&A Update	L. Sparke
10:30 – 10:45	Break	
10:45 – 11:15	ExoPAG Report	S. Gaudi
11:15 – 11:30	CoPAG Report	D. Benford
11:30 – 12:00 pm	PhysPAG Report	J. Nousek
12:00 – 12:30	JWST Status	G. Yoder
12:30 – 1:45	Lunch and Science Talk	
1:00 – 1:45	TESS	G. Ricker
1:45 – 2:30	Committee Discussion & Summary of Meeting	B. Peterson
2:30 – 2:40	Public Comment Period	
2:40 – 4:00	Briefing with Astrophysics Division Director	P. Hertz
4:00	Adjourn	