



11 July 2017

Dr. Paul Hertz
Astrophysics Director
Science Mission Directorate
National Aeronautics and Space Administration (NASA)

Dear Paul,

The NASA Astrophysics Advisory Committee (APAC) met at NASA HQ on April 24 and 25, 2017. The following members of the APAC were present: Natalie Batalha (first day only), Marshall (Mark) Bautz (via telecon), James (Jamie) J. Bock, Alan Boss, Patricia Boyd, Asantha Cooray, Neil Cornish, Brenda Dingus, Debra Fischer (via telecon, second day only), Scott Gaudi (APAC Chair), Jason Kalirai, Feryal Ozel, Paul Scowen, Yun Wang, and Beth Willman (via telecon). Hashima Hasan (APAC Executive Secretary) was also in attendance.

Dr. Hasan opened the meeting by welcoming the APAC members. She noted that a few APAC members had conflicts of interest with specific topics on the agenda. During those presentations, the conflicted members would be allowed to listen to the presentation, but they could not participate in discussion. Dr. Hasan then reviewed the Federal Advisory Committee Act (FACA) rules.

Dr. Gaudi added that offline conversations cannot form the basis for APAC recommendations. Dr. Rachel Somerville recently resigned from the (now defunct) Astrophysics Subcommittee (APS); Dr. Gaudi thanked her for her time and service.

Astrophysics Division Update

Dr. Paul Hertz (Director, Astrophysics Division (APD)), presented an update APD on activities. He welcomed the APAC members, noting that APS had been rechartered as a Federal advisory (FACA) committee. As they now advise him, their letter with findings and recommendations should be addressed to him, and he then acts on the advice, recommendations, and conclusions of the letter, as appropriate. Dr. Gaudi added that, as chair of the APAC, he would take broader issues to the NAC Science Committee, which will now naturally focus on topics that cut across the Science Mission Directorate (SMD) divisions.

Dr. Hertz then discussed several science highlights, noting in particular the discovery of seven terrestrial planets orbiting the very low mass star TRAPPIST-1 and the unprecedented amount of media attention surrounding that discovery.

Dr. Hertz also conveyed the vision of Dr. Thomas Zurbuchen (the Associate Administrator [AA] of the SMD), for the SMD as whole. Dr. Zurbuchen's vision of the SMD is as an integrated science organization with cross-cutting science. He believes there should be a place for all good science proposals. Dr. Zurbuchen's cross-



cutting themes include: safeguarding and improving life on Earth; searching for life elsewhere, and generally expanding our knowledge of the Earth, our Solar System, and our Universe.

Dr. Hertz then noted that, as of the meeting, SMD now has all of its leadership positions filled.

- *Funding and Legislation*

Dr. Hertz reminded the APAC that, at the time of the meeting, the Federal government was operating under a Continuing Resolution (CR) for Fiscal Year 2017 (FY17), implying that the APD budget was about the same as that for FY16. The James Webb Space Telescope (JWST) is fully funded and the Wide Field InfraRed Survey Telescope (WFIRST) formulation continues. The details of the FY18 President's Budget Request (PBR) were set to go to Congress in mid-May.

Dr. Hertz noted some of the astrophysics highlights from the NASA Transition Authorization Act of 2017. The Act includes language to balance the portfolio and follow the Decadal Survey (DS), notes the value of both JWST and WFIRST, and requires NASA to continue the Stratospheric Observatory for Infrared Astronomy (SOFIA) through the end of 2017. The Agency now has 10 official purposes, as the Act added astrobiology. The Act changes the cadence of Senior Reviews (SRs) to every 3 years instead of every 2 years, as had been recommended by a National Academy of Sciences (NAS) study. NASA must contract with the NAS to develop science strategies for astrobiology and for the study and exploration of extrasolar planets, and both reports are due in 18 months.

- *Research and Analysis (R&A), and Fellowships*

Research and Analysis (R&A) funding is now just under \$90 million, up about \$12 million from 2010.

There is an agreement with the Planetary Science Division (PSD) to share funding of the Exoplanet Research Program (XRP). APD, which funds about 60 percent of XRP, tends to do spectroscopy and work that leads to observationally characterizing bodies. PSD funds theory, and interpretation of observations could be either division.

Dr. Hertz also addressed some of the topics and recommendations that were discussed in the final APS telecon in October 2016. In particular:

- After 2017, APD will begin alternate year calls for the Astrophysics Theory Program (ATP). APD will provide twice the amount of funding half as often as before, resulting in the same number of proposals funded at the same funding level, only with a different cadence. The goal is to reduce the amount of work done by the proposing and reviewing community without reducing the amount of funding or science.
- As recommended by the APS, there is a new model for selection of Roman Technology Fellowships (RTFs). Astrophysics Research and Analysis (APRA) Program research proposals are now a requirement for RTFs. Dr. Hertz replied that the reviewers will be informed which APRA proposers also applied for an RTF fellowship, and there will be a separate review of RTF eligibility. He further noted that he will ensure that there is a balance of early career awardees.
- There is now a smaller number of NASA named astrophysics postdoctoral fellows overall. There will be a single selection process and a single application process. The new fellows will be called the Hubble Fellowships and there will be tracks accounting for what were previously the Sagan and Einstein fellows. There will be no predetermined balance between the various topical themes.

The latter topic (regarding the NASA named astrophysics fellows) solicited significant discussion amongst the APAC. Dr. Gaudi thought that the new structure should be made very clear to the community. Some were surprised by the announcement, especially given that it was enacted immediately rather than having a grace



period. Dr. Feryal Ozel noted that she still gets questions about whether the fellowships are being eliminated. She would like more emphasis on the fact that the fellowships cover all of the disciplines. Dr. Jason Kalirai noted that many potential applicants receive their information from university department heads. He suggested asking the department heads to lead a discussion, which Dr. Hertz considered a good idea. Dr. Gaudi reminded Dr. Hertz that in October, the APS had mixed opinions on whether reducing the number of named fellows was a good idea, but did recommend that Dr. Hertz reconsider allocation of the saved funds to R&A funding opportunities other than APRA, as was originally suggested. Dr. Hertz acknowledged the recommendation, but pointed out that he cannot discuss future budgets until they go to Congress. When asked about community reaction to the changes, Dr. Kartik Sheth said that informal feedback indicated concern about the funding reduction, but that other feedback indicated that potential applicants are pleased with the single application and the joint review. Dr. Neil Cornish said that if the umbrella fellowships are called “Hubble,” that buries the message that the Sagan and Einstein fellowships still exist. Dr. Sheth replied that 70 percent of the Einstein and Sagan applicants applied for Hubble fellowships as well. The named fellows will go back to the alignment of science questions. Dr. Asantha Cooray asked about institutional allotment.

- *Suborbital Program and Explorers*

Dr. Hertz described the sounding rocket program, noting that there would be a separate update on the balloon program. He noted that Dr. Zurbuchen is very interested in cubesats and wants to foster an SMD-wide approach to ensure consistent, realistic processes and expectations, as well as a multi-disciplinary approach. NASA has selected cubesat missions through APRA. NASA has selected HaloSat (PI P. Kaaret, U. Iowa) to study the hot galactic halo, and the Colorado Ultraviolet (UV) Transit Experiment (CUTE) (PI K. France, Colorado U.) to study “hot Jupiters” during transit in the UV.

Dr. Hertz showed the rideshare catalog for the recent Explorer Mission of Opportunity (MO) solicitation. For the Explorer program, NASA did a downselect from the 2014 Small Explorer (SMEX) AO. The Imaging X-ray Polarimetry Explorer (IXPE) will address questions about the polarization of light from various sources. The Galactic/ Extragalactic Ultra-Long Duration Balloon (ULDB) Spectroscopic Terahertz Observatory (GUSTO) is the next ultralong balloon mission, which will launch from Antarctica and fly over the Southern Hemisphere. The Medium-class Explorer (MIDEX) program had an AO in 2016, and the proposals were under review. NASA will make selections for Phase A and down-select in early 2019. The next Explorer Announcement of Opportunity (AO) will be in the winter of 2018/19, depending on the European Space Agency’s (ESA’s) M5 downselect. Future AOs will be released every 2.5 years, assuming an appropriate budget.

Dr. James Bock asked about the status of the question sent to the NAS Committee on Astronomy and Astrophysics (CAA) regarding small Explorers. Dr. Hertz replied that there had been no response as yet. He asked the CAA to determine if there was still compelling astrophysics to be done in the SMEX area. He noted that the answer will influence the SMEX cadence, particularly if they recommend going to MIDEXes or something else.

- *Civil Servant Scientist Funding Model*

Dr. Hertz next reviewed the new internal funding model for NASA civil servant scientists working at NASA centers. NASA employs about 1,000 civil servant scientists who contribute to missions, do original research, as well as other activities. Only 15 percent of the Full-Time Equivalents (FTEs) are supported by competitive R&A. NASA plans to increase the amount of directed R&A, resulting in a decrease in R&A proposals from NASA center scientists by roughly one-third. He noted that this will have no impact on the external community. All directed R&A will be planned between the centers and the Headquarters divisions, and will be peer-reviewed, but not competed. Directed work will not be science that is easily done or competed outside of the centers; rather these will be strategic projects that can best be done at the centers in order to enhance NASA objectives. There will be a new method for negotiating with the centers, and every 3 to 5 years, NASA will put



together an ad hoc peer review panel to judge its effectiveness and ensure that the work that is being funded is compelling.

Dr. Gaudi observed that at the recent NAC Science Committee meeting, this topic of the new civil servant funding model engendered the most discussion, confusion, and criticism. This was also true for the APAC. Dr. Gaudi noted that the decision was not made by SMD. Rather it came from higher in NASA. Dr. Hertz confirmed this. Dr. Gaudi remained concerned that the noncompetitive aspect limits the ability of the community to adjust, while also limiting funds and opportunities available to the community. Dr. Hertz reminded the APAC that this is an experiment that will be re-evaluated in 3 years. Dr. Kalirai was concerned about unintended consequences, such as isolating the NASA community and limiting their opportunities. This decision could make it harder for NASA to recruit the best scientists from the community. Dr. Paul Scowen asked for clarity on the nature of the work involved.

- *Mission Updates*

Dr. Hertz reminded the APAC that NASA has eight astrophysics missions in development. The next to launch is the Neutron-star Interior Composition Explorer (NICER), which has been handed over to SpaceX for transport to the International Space Station (ISS) around the end of May. The Cosmic-Ray Energetics and Mass investigation (CREAM) was set to launch in August, also via SpaceX. The Transiting Exoplanet Survey Satellite (TESS) was in integration mode, with a launch planned for 2018. NASA shipped the first set of instruments for Euclid to ESA.

For WFIRST, NASA will conduct a cost and impact review during an independent cost review of the entire WFIRST mission. NASA must decide by end of the year whether to fund design of starshade compatibility capabilities, which cannot be added in later. The question is whether to spend money to maintain the compatibility. The mid-term DS assessment said not to if the increase in cost disrupts program balance, as the starshade is not a high priority and keeping costs down is more important.

NASA is studying three partner missions. The X-ray Astronomy Recovery Mission (XARM, pronounced “charm”) has received approval in Japan, while the APS, the NAC Science Committee, and the NAC all recommended that NASA move forward with the partnership. The Japanese Space Agency (JAXA) is setting up a formal project, and NASA will establish a project to rebuild the hardware designed for Astro-H. The U.S. community should expect a high level of involvement, as the science belongs to the community rather than to a Principal Investigator-led team. There will be a Guest Observer program.

NASA is participating in ESA’s formulation of Athena, but there was nothing to report at the moment. On the other hand, ESA’s Laser Interferometer Space Antenna (LISA) has been an active area. NASA now has a study office and technology development program. ESA and NASA are discussing which agency will provide which components. There are 21 U.S. scientists in the total group of 82 on the mission concept proposal submitted to ESA. The NASA L3 study team recently did a technology roadmap and is completing a science roadmap. These detail the study team’s preferences for NASA contributions, which NASA will revisit.

- *Preparations for the 2020 Decadal Survey*

There are four science and technology definition teams (STDTs) for the large mission concepts that will go before the DS panel. The missions are: the Habitable Exoplanet Imaging Mission (HabEx), the Large UV/Optical/IR Surveyor (LUVOIR), Lynx (formerly the X-ray Surveyor), and the Origins Space Telescope (formally the Far-IR Surveyor).

There were 27 compliant proposals for probes, which were peer-reviewed, resulting in a selection of eight mission concept studies and two partial selections. The eight concept study teams will have the opportunity to



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further develop the concepts at the Jet Propulsion Lab (JPL) and the Goddard Space Flight Center (GSFC) mission design labs, after which the concepts will be subject to cost assessment before being submitted to the DS.

Science Talk: TRAPPIST-1

Dr. Michael Gillon described the Search for habitable Planets EClipsing ULtra-cOOl Stars (Speculoos) transit survey. Although ultracool stars have mostly been previously unexplored, they make up a significant fraction of the Galactic population (10-15 percent), their habitable zones are close to the star, and atmospheric characterization of habitable zone, Earth-sized planets is possible. Speculoos set out to study 800 stars and 200 brown dwarfs, with transit durations as brief as 10 minutes.

The project started with a prototype survey from Chile, where the team found three Earth-size, temperate planets at the end of 2015. The host star, Trappist-1, is very small, about the size of Jupiter. The team found a fourth planet in 2016, as well as new transits in a photometric follow-up. At that point, the limitations of ground observations became a factor, and the Spitzer mission became part of the project. After 20 days of nearly continuous observation, Spitzer found 34 transits. Kepler 2 (K2) observations then led to a more complete understanding of the architecture of the Trappist-1A system. Several of the seven planets observed are in the habitable zone, and three could have liquid water. HST and, eventually, JWST, will conduct further investigations of these worlds. Dr. Gillon detailed the estimated time that may be needed for ambitious JWST programs to characterize molecules in Earth-sized transiting planets.

Dr. Gillon noted that an important lesson from the TRAPPIST-1 discoveries is that Spitzer played a key role, as it was the only facility that could provide long, high-precision observations. On that basis, Dr. Gillon advocated that NASA consider prolonging Spitzer's life, if possible.

The APAC would like to thank Dr. Gillon for his presentation.

PAG Updates

Drs. Mark Bautz (MIT, chair of the Physics of the Cosmos PAG, or PhysPAG), Alan Boss (Carnegie DTM, chair of the Exoplanet Exploration PAG, or ExoPAG), and Paul Scowen (ASU, chair of the Cosmic Origins PAG, or COPAG) presented updates from all three PAGs.

COPAG

The COPAG Executive Committee (EC) reported the transitioning of membership since the October (final) meeting of the NAC Astrophysics Subcommittee. Members Dennis Ebbets, Daniela Calzetti, Sally Heap and James Green have rotated off.

These people had led Science Analysis Group (SAG) efforts and all had completed their tasks and delivered reports that are archived on the COPAG website. Daniela Calzetti had led SAG #9 on Science Enabled by Spitzer Observations Prior to JWST Launch; Dennis Ebbets had led SAG #6 on Cosmic Origins Science Enabled by the WFIRST-AFTA Coronagraph; James Green had led SAG #7 on Science Enabled by Operations Overlap of HST and JWST; and Sally Heap had led SAG #8 on Science Enabled by the WFIRST - AFTA Data Archive.

The COPAG wished to express their thanks to these people. In addition member Chris Howk who had been appointed in 2015 left the EC by mutual agreement because of changes in his commitment level at work at U. Notre Dame.



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To replace people on the COPAG EC a search was led in Fall 2016. The selected replacements are: Paul Lightsey – Ball Aerospace – known expert in mission design and systems engineering; Tom Megeath – U. Toledo – FIR observer of star formation; John O’Meara – St. Michael College – Cosmology and Lyman Limit Systems (LUVOIR); Claudia Scarlata – U. Minnesota – Ly-a emitters and galaxy evolution; and Sarah Tuttle – U. Washington – technology and smallsat development.

At the October meeting of the APS the COPAG had requested the creation of a new Technology Interest Group (TIG) to help with the technology gaps review process each year, as well as building stronger connections between scientists and technologists in the COR community. That request had been deferred at Paul Hertz’s request so his staff could assess the technology gaps process across the Astrophysics division. We repeated this request of the new Astrophysics Advisory Committee (APAC). The charter was presented, and the measure passed after a unanimous vote by the APAC members present.

The ongoing activities of the three active SIGs in the COPAG were presented. The work was focused mainly on the community meetings held at the January 2017 AAS meeting in Grapevine, TX. Communication in both directions has been ongoing. It was noted that many (most) members of each SIG have been actively engaged in the ongoing STDT study work either as members of the teams or as members of the science working groups (SWGs).

The COPAG noted the activity by the Planetary Sciences Division (PSD) in soliciting concept studies for Cubesat development. Paul Hertz was asked what the plans were for the Astrophysics Division (APD) along the same lines. Paul responded that Cubesat proposals were already been solicited and selected through the ROSES APRA opportunity. It was discussed that a possible SMD-wide workshop that focuses on the outcome of the 2016 NRC study on science possible with Cubesats would be instructive to understand what science the rapidly developing cubesat technologies might enable. Paul Hertz took this under advisement and said he would talk with the other Division Directors.

ExoPAG

Dr. Boss reported that the Executive Committee for the Exoplanet Exploration PAG (ExoPAG) is once again at full strength, after losing three members upon the expiration of their three-year terms (Rus Belikov, Maggie Turnbull, and Lucianne Walkowicz) and gaining four new members (Eliza Kempton, Michael Meyer, Chris Stark, and Johanna Teske).

Dr. Boss summarized the status of the Study Analysis Groups (SAGs) as seven being complete with final reports online, seven being active, and a SAG ready for closeout. Eduardo Bendek presented the closeout report on SAG 12 on astrometry at the ExoPAG #15 meeting held on January 2-3, 2017, prior to the AAS meeting in Grapevine, TX. This closeout presentation was made available to the APAC prior to this meeting. Dr. Boss requested APAC approval of the SAG 12 closeout from Dr. Gaudi, and the APAC subsequently unanimously agreed with this action.

Dr. Boss noted that the ExoPAG is now part of the annual technology gap process and will review the technology gap list (TGL) plan during the ExoPAG #16 meeting, to be held prior to the KepSciCon in Mountain View, CA, on June 18. In conjunction with the Exoplanet Exploration Program Office, the ExoPAG will be holding splinter sessions at the AbSciCon meeting in Mesa, AZ, the week of April 24, at the American Astronomical Society meeting in Austin, TX, the week of June 5, and at the KepSciCon at NASA Ames the week of June 19. The purpose of these “send and receive” sessions is to afford the wider exoplanet community an opportunity beyond the ExoPAG meetings to learn about NASA’s present role in supporting and advancing exoplanet research, and to hear from community members about how to strengthen this support.



Dr. Marshall Bautz presented the update on the activities of the PhysPAG. Dr. Bautz noted that the PhysPAG membership represents a diverse group segmented into various studies on dark energy, inflation, black holes and general relativity, and behavior of matter in extreme environments. He further noted that, in contrast to, e.g., the ExoPAG, the PhysPAG tends to have Science Investigation Groups (SIGs) rather than SAGs. SIGs are long-term groups addressing many of the PAG's activities.

Dr. Bautz reported that there will be several upcoming PhysPAG-related meetings at the upcoming AAS High Energy Astrophysics Division meeting in Idaho in August. These include PhysPAG and Gamma-Ray SIG Town Halls, an X-ray SIG meeting, and two special sessions involving members of the Gravitational Wave (GW) and Gamma-Ray SIGs, respectively. Members of the Cosmic-Ray SIG are looking forward to the International Conference on Cosmic Rays in Seoul in July.

Dr. Bautz next updated the APAC on the activities of the various SIGs. He noted that five of the ten Probe Mission Concepts recently selected for study by NASA addresses Physics of the Cosmos science areas. These include an Inflation Probe, to test models of inflation via cosmic microwave background polarization measurements, three X-ray Probe concepts (Strobe-X, for time-domain astrophysics; Transient Astrophysics Probe, for electromagnetic location and follow-up of gravitational-wave sources and other transients; and AXIS, for high-resolution X-ray imaging), and a Probe of Extreme Multi-Messenger Astrophysics via measurements of high-energy cosmic rays and gamma-rays. Members of the GW SIG worked as part of the LISA consortium to prepare the LISA mission concept proposal for ESA's L3 mission. The proposal was submitted to ESA in January and features APAC member Dr. Neil Cornish and GW SIG co-chairs Dr. John Conklin and Dr. Kelly Holley-Bockelmann as core team members. The X-Ray SIG is following a number of developments, including the NASA role in Athena, the upcoming ISS-NICER launch, and potential U.S. participation in the X-ray Astrophysics Recovery Mission, and is active in support of the Lynx large mission concept study. The Inflation Probe SIG is following two Explorer mission concepts. The Cosmic Ray SIG is awaiting the ISS-CREAM launch, and the Cosmic Structure SIG is supporting the large mission studies.

WFIRST Telescope Update

The Acting Project Scientist of WFIRST Jeff Kruk presented an update on the status of WFIRST to the APAC. WFIRST has met all its schedule milestones, with SRR/MDR upcoming on July 11, and KDP-B (Phase B start) expected on October 1, 2017. The currently assumed launch date is 2025.

WFIRST cost control processes have been established, in response to the NAS midterm decadal assessment recommendations. The total mission cost is currently allocated \$3.2B in real year funds.

The WFIRST technology development program has been completed. The WFIRST infrared detectors (Teledyne H4RG arrays) have completed all necessary testing for the space flight environment, and are now at TRL-6. The coronagraph technology development has demonstrated full system level performance in a simulated WFIRST dynamic environment, and is now at TRL-5.

Trade studies have improved performance and simplified the WFIRST mission design. The mission concept is maturing and on track for design review in July 2017. In particular, the telescope assessment results are positive, and the instrument prototyping is progressing. WFIRST does not have a starshade, but the project is studying accommodating one for next Decadal Survey's consideration.

The science simulation and science center work are underway. The existing Formulation Science Working Group (FSWG) will be disbanded in early 2021. The "Operations Science Investigation Teams" will be selected



in 2022 through open competition, to design and implement the major surveys. The FSWG only establishes a design reference mission; the actual time allocation and balance between the science programs on WFIRST will be determined by a committee selected through open competition in 2022, along with the “Operations Science Investigation Teams”, GO teams, and GIs. The WFIRST project is pursuing closure on international partnerships (ESA, CSA, JAXA, Australia) for System Requirements Review in July 2017. "

The APAC would like to thank Dr. Kruk for his presentation.

James Webb Space Telescope Update

Drs. Eric Smith and Nikole Lewis presented updates JWST. Dr. Smith said that the mission team is down to two hardware flows: the Optical Telescope element/Integrated Science (OTIS) module, and the spacecraft sunshield. The critical path is a tie between the telescope and the spacecraft. The OTIS was being prepared for packing and shipping to Johnson Space Center (JSC) for integration and cryotesting. The other piece is the spacecraft bus, which includes the sunshield. The radiator shields are the pacing items. There are 4.75 months of funded critical path schedule reserve, and some liens on the OTIS and spacecraft lines.

The team continues watching the nonexplosive actuators, which had issues and had to be redesigned. There was a vibration anomaly that had a ripple effect, and a problem with a test of the propulsion system. The ground system passed mission operations review, which was a milestone. There is still a lot of verification that must take place with the testing program. Because JWST is too big to test fully assembled, NASA is testing piecemeal and conducting analysis. This results in a larger test program than what is typical.

The amount of ground support equipment constructed for testing deployment is quite extensive and intricate. There are many elements that will be deployed, more than in other missions. There have been several cryogenic testing steps, and the team must verify launch survival by vibration and acoustics testing. There will be additional testing, including many prelaunch hardware tests, about half of which are done. Everything is on track, but the project is moving into a difficult period of testing.

Dr. Lewis, the JWST Project Scientist at the Space Telescope Science Institute (STScI), reviewed the Institute’s Science and Operations Center (S&OC) flow, which will enable outreach to both the science community and the public. The observatory test bed simulator has been tested, and a suite of proposal tools was released.

Dr. Lewis described the Astronomer’s Proposal Tools (APTs), which should be familiar to HST users. There is an exposure time calculator, and investigators can test different observing modes to see what is produced. They can also pick up where they left off with previous work. There have been more than 100,000 calculations since this became available in January. The JWST Help Desk will support users by helping to pinpoint the area needed. The documentation system is called JDox, and it is extensively hyperlinked. There are 230 pages of documentation at this point.

The Director’s Discretionary Early Release Science (DD-ERS) program will accelerate diffusion of data and expand early opportunities for the community to gain experience with JWST data. The program received 200 notices of intent to propose. Proposal teams had an average of 18 scientists per team, and came from 24 countries and 34 states. Dr. Lewis listed their topics. Galaxy assembly and evolution is largest, along with star formation and black holes. This is preliminary, however. The website has been evolving. There is a proposal planning toolbox, as well as an events page with archives of past webinars. The next AAS meeting will have a JWST event, along with six sessions and a pre-meeting proposal planning workshop.

Dr. Gaudi noted that, from his perception, everyone seems to have a different concept of the DD-ERS program. Dr. Lewis said that it is purposefully vague. The goal is to inform Cycle 2 proposals by getting out data from the most widely used modes. It will involve community input, and it is not likely that every mode will be tested



due to concerns about time allocation. There is so much community input and excitement that it will be hard to compose peer review panels.

The APAC would like to thank Dr. Smith and Dr. Lewis for their presentations.

TESS Telescope Update

We heard an upbeat update on the Transiting Exoplanet Survey Satellite (TESS) from Stephen Rinehart. The project is on-pace to deliver the spacecraft on the original schedule, though the launch will be no earlier than March 20, 2018 due to delays from the launch contractor. Schedule and budget reserves are healthy. Despite the launch delay, TESS is still well positioned to provide multiple planetary transit candidates for detailed characterization by Hubble and JWST. The target catalog continues to be developed, and will fold in GAIA data releases as they become available. There was a discussion of plans for extension beyond the nominal 2-year mission, potentially providing longer period systems for follow-up study. There is currently some uncertainty as to when TESS would enter the Senior Review, but Dr. Hertz said that would be settled by the end of May this year. The committee looks forward to seeing the first results from TESS.

The APAC would like to thank Dr. Rinehart for his presentation.

SOFIA Update

Kimberly Ennico-Smith of NASA Ames Research Center, and Project Scientist for SOFIA, presented the recent results and activities from SOFIA. SOFIA remains the only community-access observatory that operates in the mid to far-IR wavelengths between 28 and 320 microns. At that wavelength range SOFIA bridges the gap between ALMA and JWST with a current and planned instrument suite that is aimed at complementing those facilities. SOFIA began its scientific operations in 2014 and is now conducting prime operations till Sep 30, 2019. The program is presently in SOFIA's Cycle 5 of science observations.

During the transition to Phase E and prime operations in 2013-2014 SOFIA underwent several reviews. As a result of those recommendations SOFIA project has substantially improved the observing efficiency and has met its Level 1 science research hour observing requirements since transition to Phase E. The current operations are expected to allow close to 800 hours of science observations with a Level 1 requirement of 80% of the baseline hours. Due to the same 2013-2014 reviews SOFIA project has also modified a number of policies and processes to optimize the program for scientific productivity. These policies include tripling the GO grants starting with Cycle 4 (now \$6.5M/yr) and increasing the funding available for instrument development to upgrade or add new observing or instrument capabilities in an every few year cycle. HAWC+, a second generation instrument, was recently commissioned on SOFIA and is expected to open up extragalactic observations of the distant bright galaxies for the first time in current Cycle 5, and adds a new capability to the Observatory, with its multi-wavelength polarimetric channels. The German instrument, GREAT, has also seen multiple enhancements with the latest heterodyne technology. Its most recent science capability, enabling mapping, was only made possible by an upgraded configuration commissioned last year. In 2019, SOFIA will commission a third generation instrument HIRMES that will provide high-resolution spectroscopic capabilities to study the gas mass, water ice, and ice to rock abundance of proto-planetary disks, and H/D ration of stellar outflows, among others.

The APAC thanks Dr. Ennico-Smith for the science summary and update related to SOFIA science operation. APAC expressed concerns about the scientific productivity of SOFIA, in relation to quantifiable metrics adopted by other NASA observatories. APAC was also concerned that the proposal acceptance rate was relatively high compared to other observatories and requested complete statistics to properly compare both the science publication rate and the proposal submission and acceptance rates. Other requests for information from



APAC to Dr. Ennico-Smith and the SOFIA project included proposal pressure by instrument and by science discipline. Dr. Ennico-Smith committed to providing the requested information.

Balloons & Suborbital

We would like to thank Dr. Thomas Hams for providing a presentation on the sub-orbital program that described its capabilities and its breadth of research. In the discussion following, the committee felt that more information would be helpful to better understand the role of the suborbital program in the astrophysics portfolio. Specifically we would like a follow-on presentation at the next meeting to address the following:

1. Examples of successful science programs carried out with the unique capabilities of the sub-orbital program,
2. Examples of how technologies and instrumentation developed under the sub-orbital program have flowed into space missions, and
3. Explanation of how technology development factors in APRA proposal evaluations for selection.

Aerospace Costing and Technical Evaluation

Dr. Debra Emmons, Principal Director of NASA Science and Technology Programs at Aerospace Corporation, presented the Cost and Technical Evaluation (CATE) process and the support Aerospace is currently providing for the Decadal Study Large Mission Concept teams. CATE process has been in effect since 2010, when congress required National Academies to use an independent review of technology, cost, and design. Currently, Aerospace is working with the four large missions under study for the next decadal survey.

Dr. Emmons explained the role CATE plays in NASA's science and budget planning. Using examples, she discussed how CATE assesses technology development and the technical risks and folds these into high-level budget and schedule estimates. Factors include the mass and power contingency, schedule risks, technology readiness levels (TRLs), and a cost risk assessment. Dr. Emmons also showed historical data that is used to assign payload mass contingencies, which aim to take into account design growth and launch vehicle threats.

Dr. Emmons then explained the objectives for the support provided to the large mission concept study teams. In this process, the prime objective of Aerospace is to achieve better understanding of the technical risks, cost risks, and the trades for the mission concepts. She outlined the agreement between NASA and Aerospace in terms of schedule and effort dedicated to the large mission support in Phases 1 and 2 of the studies. She concluded by summarizing the support already provided to the studies.

The committee discussed the benefits of the CATE process but also recognized the challenge of evaluating emerging technologies a decade or more in advance of a mission. Aerospace faces an ongoing challenge to calibrate its cost and schedule estimates against the reality of some missions. It was also acknowledged that the estimates are probabilistic and that Aerospace follows the technology development processes closely to provide the feedback about viability. The committee positively noted the steps taken by Aerospace to prevent conflicts of interest between the support provided for the large missions and the CATE process for the National Academies.

The APAC would like to thank Dr. Emmons for her presentation.

Universe of Learning

Dr. Denise Smith discussed SMD's science education program, the Universe of Learning (UofL), which operates through a Cooperative Agreement Notice (CAN). This effort seeks to enable NASA scientists and



engineers to engage more effectively with learners of all ages. SMD has selected 27 teaming partners, as well as external evaluation partners. The UofL spans all of astrophysics.

Phase 1 involves laying the foundation. The vision is to engage learners of all ages and backgrounds in exploring the universe for themselves. The target audience is informal and outside of the classroom. The work is grounded in the themes of astrophysics, and the model is to integrate NASA astrophysics into audience-driven programs. The focus is on four categories: data tools and participatory experiences; multimedia and immersive learning experiences; exhibits and community programs; and professional development. Dr. Smith described projects within each category.

The partnership provides a direct connection to science, which in turn enables guided interactions with data. Dr. Smith described a prototype of this and of visualizations. She also described the resources that lead to the education programs. Subject Matter Experts (SMEs) play a key role in these programs. After describing Museum Alliance briefings, Dr. Smith turned to the goal of broadening audiences, noting partnerships in areas of special needs, rural areas, and minority-serving institutions.

The APAC would like to thank Dr. Smith for her presentation.

Discussion of Ground-Based Support for Space Missions

Although there is a general understanding that the NSF supports ground-based observatories while NASA carries out space missions, modern astronomical research from exoplanet characterization to dark energy is based on deep synergies between the ground and space. In fact, accomplishing the strategic goals of NASA's Astrophysics program often requires supplementary ground-based data. However, because the NSF does not have a strategic plan that aligns with the goals of NASA missions, there are frequently gaps in mission support that NASA has addressed through dedicated investments in ground based facilities (e.g. the IRTF, a share of Keck time), the procurement of critical observations (e.g., radial velocities and adaptive optics observations to support Kepler), and data archives (e.g., the Keck Observatory Archive). Today, there is a growing gap between past or current investments in ground-based data and the needs of future NASA missions to efficiently achieve their science goals. There are two issues: access to state of the art data sets including their associated high-level science products and investment in technology development for new data needs. Three members of the APAC, Debra Fischer, Scott Gaudi, and Jason Kalirai, will put together a request for information from NASA HQ that will be used to quantify the gap in available ground-based data for new missions and to address the following questions:

- Are existing NASA investments in ground based facilities sufficient for achieving the broad science goals for the next wave of missions (TESS, JWST, WFIRST etc)?
- Is there the right balance of instruments with the right wavelength coverage on the right suite of telescopes?
- How are ground-based facilities supported for ongoing maintenance and modernization?
- Is there adequate geographical coverage?
- Is there sufficient investment in data archives to take advantage of upcoming complex and survey data sets?

Major Actions, Requests, and Recommendations

Actions

- The proposition to close-out ExoPAG SAG12 was approved.
- The proposition to approve the creation of the COPAG TIG was approved.



Requests

- The APAC was concerned about the change in the funding model of civil servants and so requests more information about the details of the implementation of this change.
- The APAC requests complete statistics to properly compare the science publication rate and proposal submission and acceptance rates of SOFIA to other major APD Missions. In particular, the APAC would like to see proposal pressure by broken down by instrument and by science discipline.
- For the next suborbital report, the APAC would like to hear more about the science, and how the technology developed from that program flows into the large missions, with examples. The APAC would also like to hear how the awards line up with technology gaps.

Recommendations

- The APAC recommends that SMD initiate an SMD-wide workshop to connect cubesat capabilities with the broader science community, which would focus on what science the rapidly developing cubesat technologies might enable.
- The APAC recommends that the PAGs consider highly qualified early career stage scientists as EC members, without increasing the size of the EC significantly.

Sincerely,

Scott Gaudi
APAC Chair
The Ohio State University