Minutes of the Meeting of the
Astronomy and Astrophysics Advisory Committee
25-26 January 2018
National Science Foundation, Arlington, VA

Members attending:

Rachel Bean
Dieter Hartmann
Buell Jannuzi (Chair)
Kelsey Johnson
Brian Keating
Eliza Kempton
Shane Larson
Shane Larson
Rachel Mandelbaum (Vice Chair)
John O'Meara
Constance Rockosi
William Smith
Martin White

Agency personnel:

Anne Kinney, NSF-MPS
James Ulvestad, NSF-MPS
Richard Green, NSF-AST
Chris Davis, NSF-AST
Elizabeth Pentecost, NSF-AST
Ralph Gaume, NSF-AST
Nigel Sharp, NSF-AST
Diana Phan, NSF-AST
Joseph Pesce, NSF-AST
Peter Kurczynski, NSF-AST
Jim Neff, NSF-AST
Linda French, NSF-AST
Ed Ajhar, NSF-AST
Jonathan Williams, NSF-AST
Philip Puxley, NSF-AST
Vernon Pankonin, NSF-AST
Matt Benacquista, NSF-AST
Ashley Zauderer, NSF-AST
Ken Johnston, NSF-AST
David Boboltz, NSF-AST
Denise Caldwell, NSF-PHY
Jean Cottam-Allen, NSF-PHY
Vyacheslav Lukin, NSF-PHY
Vladimir Papatashvilli, NSF-Polar
Kelly Faukner, NSF-Polar
Paul Hertz, NASA
Hashima Hasan, NASA
Kartik Sheth, NASA
Lindley Johnson, NASA
Dominic Benford, NASA
Linda Sparke, NASA
Rita Sambruna, NASA
Thomas Statler, NASA
John Karsch, NASA
Daniel Evans, NASA
Kathy Turner, DOE
Patricia Crumley, DOE
Eric Linder, DOE
Brian Morrisey, DOE/AAAS Fellow

Others:

Michael Ledford, Lewis-Burke
Lee Curtis, AURA
David Lang, NAS
Bethany Johns, AIP
Marcia Rieke, U Arizona
Steve Ritz, UCSD
Catherine Pilachowski, Indiana Univ.
Jeff Foust, *Space News*
David Latham, SAO
Steve Unwin, JPL
James Lochner, USRA
David Hogg, NYU
Alberto Conti, Northrop Grumman
Antonella Nota, ESA
Jason Kalirai, STScI
George Helou, IPAC
Azita Valinia
Steve Groom
Neill Reid
Zhou Zhou
Mario Perez

MEETING CONVENED 9:00 AM, 25 JANUARY 2018

The Chair called the meeting to order. Introductions were made.

The minutes from the September 27-28, 2017 in-person meeting and the October 23, 2017 meeting teleconference were approved by the Committee.

Elizabeth Pentecost, the AAAC Recording Secretary, reviewed the list of identified Conflicts of Interest (COIs) for the AAAC and asked that members send their conflicts to her.

Elizabeth will send out a doodle poll to the Committee to gauge their availability for the late spring/early summer teleconference and Fall 2018 in-person meeting.

NSF

Richard Green gave a brief overview of the role of the AAAC, especially for new members. The AAAC was established by Congress in 2002 to advise NSF and NASA; the committee's charter was later amended in 2004 to add DOE. The Committee consists of thirteen members (4 selected by NSF, 4 selected by NASA, 2 selected by DOE, and 1 selected by OSTP). The Committee elects its own chair and meets four times a year either in person or by teleconference. The Committee is subject to the Federal Advisory Committee Act (FACA). The AAAC's main responsibilities are to assess and make recommendations regarding coordination of the astronomy and astrophysics programs of NSF, NASA, and DOE, and how those activities relate to the recommendations of the decadal surveys; an annual report is due to Congress March 15 of each year.

An update on AST activities included some science highlights.

- The binary neutron star merger in NGC 4993 was exciting. The merger was observed by LIGO/Virgo, the Fermi spacecraft, the Chandra X-ray Observatory, with followup by Gemini and the VLA.
- Two of NSF's 10 "Big Ideas" for future investment have astronomy involvement: "Harnessing the Data Revolution," and "Windows on the Universe: The Era of Multi-messenger Astrophysics."
- The DES collaboration analyzed three years of imaging data from the Dark Energy Camera on the NOAO Blanco 4m telescope. In a 5000 sq. deg field observed to g~23.5 with <1% uncertainty, the collaboration discovered 11 new stellar streams out to 50 kpc, along with 4 previously known; the investigation is supported jointly by NSF and DOE.
- Multi-Conjugate Adaptive Optics is under development at Big Bear Solar Observatory. Three deformable mirrors are used to compensate for the turbulence at 3 different heights in the atmosphere. NSO personnel are leading the effort which is funded by NSF through an ATI award that was just renewed. This is a pathfinder for a DKIST next-generation AO system.

NSF continues its cooperation and collaboration with NASA and DOE to exploit synergies and shared science priorities in astronomy and astrophysics. Current examples for NASA include co-sponsorship of the Decadal Survey, joint NSF-NASA FACA review panels (e.g. this committee), cooperation on space weather and solar research, joint ground-space observations of astrophysical objects (e.g., neutron star mergers), collaboration on the exoplanet research program (WIYN 3.5m telescope), cooperation on Near Earth Object detection and characterization (Arecibo, Green Bank, and future LSST Observatories), and semi-annual joint NSF-NASA staff meetings. Current examples for DOE include the Dark Energy Camera, Dark Energy Survey Instrument (DESI), LSST, and the CMB Task Force

AST receives ~1,000 proposals each year; these include proposals for the Astronomy and Astrophysics research grants, mid-scale, ATI, CAREER, AAPF, REU, and PAARE. AST received 637 proposals in response to a proposal call in November 2016. Panel reviews are complete and all awards have been

made for 2017; the proposal funding rate for FY2017 was ~19.3%, a slight increase from FY2016. AST is running a "no proposal deadline" pilot for the Planetary/Exoplanetary and Solar portions of the Astronomy and Astrophysics Research Grants (AAG) program; the pilot will continue in FY2018. The success of this pilot will be assessed at the end of the year. The Mid-Scale Innovations Program (MSIP) solicitation has been released for FY2018, though the Advanced Technologies and Instrumentation (ATI) and Partnerships in Astronomy and Astrophysics Research and Education (PAARE) deadlines have been postponed with the programs being reviewed. AST's forefront facilities include Gemini, the 4m telescopes in Arizona and Chile, ALMA, JVLA, and legacy telescopes in New Mexico and Arizona. AST has two major construction projects in progress, the Daniel K. Inouye Solar Telescope (DKIST; science operations begin in 2019) and the Large Synoptic Survey Telescope (LSST; science operations to start in 2022).

Shane Larson asked how the pilot for the no-deadline for the Solar and Planetary proposals was going. Richard Green responded that the quality of the proposals was very good and the division is looking at how to measure the success of the program. Ralph Gaume is pleased with how the process is going and the Division is continuing the program in FY19.

NSF is currently under a continuing resolution through February 8. The AST budget and operations after February 8 may be affected by the decisions made by Congress on NSF's funding, sequestration, control of the debt ceiling, and the possibility of another shutdown or more continuing resolutions.

Rachel Bean asked what would be affected by the 63% reduction in the MREFC account. Richard Green replied that LSST and DKIST would not be affected but if the number of research vessels is reduced in the MREFC account then the ceiling on the MREFC would be lowered to to take into account the reduction; wedges would not open up to start new projects. In the short term, the reduction in the FY18 President's budget was allocated to Individual Investigator and instrumentation grants, with some restoration possible if Congressional appropriations levels allow. With no restoration, the success rate would drop below ~20%. There are no delays in making awards; most of the awards are usually made later in the financial year.

The 2012 Portfolio Review report recommended divesting a number of telescopes from the AST budget. Divestment is needed to enable support of the newest high priority facilities, while balancing support for individual investigator science. The process does show that AST is serious about changing the complement of cutting edge national facilities and is potentially scoped to save ~$10-15M per year for new operations. AST has been pursuing funding collaborations aggressively and has solicited input on many different innovative operations models. AST has carried out engineering feasibility studies and baseline environmental reviews for many of its facilities. Because of the major changes to the operations of several of these facilities, NSF has embarked on formal Environment Impact Statements (EIS) as part of the decision-making process for three facilities; Arecibo, Green Bank, and Sacramento Peak. With regard to divestment:

- A Dear Colleague Letter (DCL) was issued in April 2017 providing an update on the divestment process. NSF was near its conclusion for the Arecibo EIS when Hurricane Maria hit Puerto Rico; the facility sustained significant damage though less than first anticipated. The Record of Decision was signed November 15 with the preferred alternative being continued operations with reduced NSF participation; negotiations are now nearly complete with the preferred proposal team for transition to a new cooperative agreement on April 1.
- For Green Bank Observatory, the Draft EIS was released on November 10 with public meetings held on November 30; the public comment period ended in early January with a Final EIS

anticipated in Fall 2018 and a Record of Decision in early 2019. NSF is currently working to secure additional funding commitments.

- For Sacramento Peak Observatory, the draft EIS is expected to be released in early February with public meetings held at the end of February. NSO will manage the Sacramento Peak facilities as long as there is operation of the Dunn Solar Telescope. The EIS process for Sacramento Peak is expected to conclude in the second half of 2018.
- The Long Baseline Observatory has operated the VLBA since 2016 with funding from the US Naval Observatory for their program on determination of earth orientation parameters.
- The Mayall 4m telescope on Kitt Peak will have its last public access night on January 31; it will then undergo an upgrade in support of the DOE-funded operations of the Dark Energy Spectroscopic Instrument (DESI) starting in 2019.

Rachel Bean noted that NanoGrav uses both Arecibo and Green Bank. She asked how NSF factors in maintaining both for NanoGrav? Richard Green replied that AST's intention is to continue investing for some level of access to both facilities and NanoGrav is a part of this. NanoGrav are about halfway through their grant. When they apply for a renewal, NSF will consider the operational support being provided to Green Bank and will see if the new operating partner for Arecibo would like them as a formal operating partner when the time comes.

Buell Januzzi asked about the McMath-Pierce telescope. If no one steps up to partner it, what happens to the telescope? Richard Green replied there was a proposal submitted to AURA by an organization but it was turned down because it was not financially viable; AURA is considering another approach for continued use; right now there are no plans to demolish this telescope and restore the land to a natural state. Buell asked if there is an impact on the FY18 and FY19 budget. AST replied there are funds for transition and there would be no impact if the telescope is taken down.

Planning for the next Decadal Survey is well underway. NSF and NASA are the primary sponsors of the survey with the DOE Cosmic Frontier in the Office of Science also a sponsor. The agencies provide a charge to the National Academies and then they organize the process; a proposal (anticipated in spring) is submitted for NSF's share and is reviewed jointly on behalf of NSF and NASA. In preparation for the Decadal Survey, NRAO has held a series of Kavli-sponsored workshops to identify and prioritize the key scientific problems the Radio-Millimeter-Submillimeter (RMS) wave community would address in the coming decade. Many of the scientific goals can be achieved with a concept called Next Generation VLA (ngVLA); funded technical concepts are underway within NRAO. NOAO, meanwhile, is collecting OIR community white papers and plans to have a discussion and planning meeting in late February. The CMB science community is looking for a next generation experiment that will test inflation, determine the number and masses of neutrinos, provide precise constraints on the nature of dark energy, and test general relativity on large scales; the two sites recommended in the report to the AAAC are the South Pole and the Atacama desert in Chile.

The necessity for divestment has been driven by the scientific community's success in winning support for development of new facilities, which require operational support. NSF/AST remains optimistic that that can leverage a vital competitive research program for the community.

William Smith asked if there will be an effort to revisit the Portfolio review. Richard Green replied that shortly after the Decadal Survey is released AST will have another portfolio review to plan how to move forward.

Kelsey Johnson noted that Arecibo and its staff did some heroic things after Hurricane Maria for the surrounding community, including providing water to the community, serving as a landing port for

helicopters, bringing in food and supplies for local hurricane victims, etc. It is important for the public to see that scientists do care about the community around them and not just about science. Kelsey asked if any acknowledgment was going to be given to the scientists who helped during the hurricane; should it be mentioned in the AAAC report? Richard indicated that commending the entire observatory staff for their efforts after the hurricane would be an important addition.

Ralph Gaume provided an update on LSST and NCOA. LSST will be the flagship of the NSF Astronomy night-time optical/infrared program in the next decade; it will have a huge impact on transient astronomy. Construction is progressing well on LSST. The progress review in September 2017 showed no significant concerns. The NSF/DOE-supported scope is 50-to-75% complete. The Monte Carlo analysis shows a >90% confidence level of completing on time and within budget. The survey starts in October 2022. The operations ramp starts in FY2019 with full operations in the next decade. An operations proposal was received in August 2017; the first review, held in December 2017, went well, though costs analyses continue. The next commissioning review will be held soon.

AURA delivered an Organization, Management, and Operation (OMO) Plan for NCOA to NSF as a conceptual model that describes how AURA will manage and operate NCOA. The OMO Plan was reviewed by an external panel that concluded that the plan satisfied expectations, complied with guidance, and satisfied all boundary conditions established by NSF. The Gemini Board endorsed the NCOA concept at their meeting in November. The restructuring action goes to the NSF Director and the National Science Board in February as a prerequisite to implementation. Implementation continues in FY2019 and FY2020.

NASA

Paul Hertz provided an update on NASA activities. At the request of the AAAC, the agencies were asked to address the issue of diversity and inclusion. The NASA Astrophysics Division is actively taking steps to advance diversity, inclusion, and equal opportunity in the NASA workforce and among NASA grantee institutions through recruiting a diverse division staff, promoting diversity on NASA-selected groups, sharing best practices in peer reviews with other agencies, and working with groups within NASA to address unconscious bias in peer reviews. The Division has seen through demographics of R&A proposers and awardees, that the inferred general balance of awardees does reflect that of proposers and the inferred gender balance of proposers does not always reflect that of the community. NASA continues to monitor these demographics.

The FY2018 budget request would provide funding for NASA astrophysics to continue its programs, missions, projects, research, and technology. The total funding for the Astrophysics Division, including the James Webb Space Telescope, remains at ~$1.35B. This fully funds Webb for a March-June 2019 launch, WFIRST formulation, Explorers mission development, continued operating missions, increased funding for R&A, suborbital missions technology development, and mission studies. The FY2018 PBR balances current science and future missions; Congressional markups, if enacted, would put that balance at risk.

Science highlights included the Fermi discovery of merging neutron stars, the Trappist 1 discovery by Spitzer (with a 20-day plus long-look at Trappist 1 that allowed it to confirm 2 of the 3 exoplanets discovered by the Trappist telescope), the Kepler final catalog release in 2017 (with over 4,300 exoplanet candidates; data are archived at MAST), and a Chandra discovery of a very close compact binary with a black hole primary and a white dwarf secondary at the core of the globular cluster Tucani.

The current Astrophysics program comprises a strategic plan that balances operating missions, both large and small, in order to continue to deliver changing science. The plan provides for large strategic missions

under development and continues the high cadence of Explorers. It also includes international partnerships that extend science opportunities for the science community and invests in research, technology and development, and supporting science capabilities. Finally, the strategic plan provides for future planning that includes new mission concept studies and technology investments.

Plans for FY2018 for JWST include completing the spacecraft element testing, receiving and reviewing Cycle 1 Guest Observer proposals, and integrating the science payload to the spacecraft element forming the Observatory. For WFIRST, the three-year technology development activities are completed and the science working group and science investigation teams have been selected. An independent external technical/cost management review has been conducted; WFIRST has been directed to modify its current design in order to reduce cost and complexity to stay within the $3.2B cost target set at the beginning of Phase A. A new spending profile has been negotiated with the WFIRST team.

NASA is maintaining a cadence of four astrophysics Explorers AOs per decade as recommended by the Decadal Survey and as validated by the Midterm Assessment. The LISA Preparatory Science is a new program element in the ROSES-2018 program. It will provide support for US investigators involved in analysis and interpretation of simulated LISA data. The suborbital and balloon programs continue, although weather prevented the launch of the Super-TIGER balloon in Antarctica (this payload will winter over and relaunch next year).

The FY18 PBR supports a Science Mission Directorate (SMD)-wide CubeSat/SmallSat initiative that uses smaller, less expensive satellites to advance science in a cost-effective manner. Two CubeSats were selected in FY18 for Phase A with funds in FY19 to move them forward toward implementation.

Proposal success rates are increasing. In FY16, to address the problem of low selection rates, the Astrophysics Division decided to compete its Astrophysics Theory Program (ATP) in alternate years. Competing the program only in even years reduces the burden on reviewers and proposers and provides opportunities to select more proposals from the other programs. For 2018, mandatory notices of intent are required for the R&A program. There are also plans to integrate the results of high risk/high-impact research reviewed by advisory committees.

For the FY18 appropriation, both the Senate and the House told NASA to follow the Decadal Survey recommendations, and make sure that NASA spends $533.7M on JWST and not overrun. The House markup called for an increase in the code R&A program, an additional $5.3M for SOFIA and $126.6M for WFIRST with $20M on starshade technology. The Senate markup called for more funding for WFIRST and Hubble, and at least $10M for "life detection technology." All of this must fit within a budget of $1.35B. If enacted by Congress, the plan would have to be enacted within FY18.

Buell Januzzi asked, if NASA's budget stays flat, how does NASA determine internally how it plans for future budgets. Paul Hertz replied that he could not discuss future budgets but he could describe the process which is: (1) the Astrophysics Division prepares a budget plan (guidance is sent to programs and NASA centers) and sends it to the head of the Science Mission Directorate; (2) SMD sends the request to the Agency; (3) NASA sends the request to OMB; (4) NASA receives passback and negotiates final numbers; (5) the PBR is released; and (6) budget resolutions and allocation hearings are held; and (7) Congress passes appropriation bills.

Dieter Hartmann asked how the Astrophysics Division promotes for more funding. Paul Hertz indicated that the overguide process is informal and it changes depending on who is in charge. For example, many years ago, there were new initiative programs which were initiated internally for additional funding, but these no longer exist.

NASA is conducting large and medium mission concept studies for the 2020 Decadal Survey.

DOE

Kathy Turner gave an update on DOE activities. The FY 2018 High Energy Physics (HEP) PBR ($672.7M) is guided by priorities set by the Administration, the DOE Office of Science, and the Particle Physics Project Prioritization Panel (P5) plan. Congressional language was supportive of the HL-LHC accelerator project, the ATLAS and CMS upgrade projects, LBNF/DUNE and the Cosmic Frontier projects such as LSST and DESI.

Operating experiments continue to advance and produce science results. Priority is on executing the four P5 recommended Major Items of Equipment (MIE) projects, currently in fabrication phase: LSSTcam, DESI, LUX-Zeplin (LZ), and SuperCDMS (Cryogenic Dark Matter Search)-SNOLAB. The FY2018 PBR prioritizes efforts on LZ, while slowing DESI and SuperCDMS-SNOLAB. Efforts are also underway to plan the next phase to develop and review each project's experimental operations plan and to put together a task force to investigate optimizing computing needs across the Cosmic Frontier program. HEP is laying the groundwork for the future through science studies; R&D funds are very limited.

The Dark Energy program consists of the Dark Energy Survey (DES), LSST (camera), and DESI. DOE leads the DESI experiment. The DESI project will provide the new spectrographs and associated systems to be mounted and operated on the Mayall telescope at Kitt Peak. HEP has an MOU with NSF to lease the Mayall telescope, ramping up partial support in FY16-18 with full support for operations starting in FY19. For dark matter detection, several third-generation experiments are underway. CMB experiments are supported as part of the core particle physics program. HEP has research-only activities on Euclid, WFIRST, and supernovae surveys.

Some science highlights were presented:

- The Dark Energy Survey probes dark energy via a survey of 300 million galaxies and 3000 supernovae, using the Dark Energy Camera on the Blanco 4-meter telescope in Chile. Year 1 cosmology results from galaxy clustering and weak lensing set constraints that are competitive with Planck CM, with WiggleZ, with BOSS, and with BAO measurements. The first three years of survey data for the full 5000 sq. deg. are also now public. There are over 100 papers submitted and accepted for publication.
- The extended Baryon Oscillation Spectroscopic Survey is a cosmological survey on the 4th generation of the Sloan Digital Sky Survey. In May 2017, the first measurement of a BAO between z = 0.9 and 2.2 was done and in January 2018 the first measurement of redshift space distortions using quasars between z = 0.8 and 2.2 was completed; both are consistent with Planck.
- Axion Dark-Matter eXperiment Generation 2 (ADMX-G2) at the University of Washington used a strong magnetic field and resonant cavity to convert dark matter axions into detectable microwave photons. This was one of the three G2 dark matter experiments following P5. ADMX reached the Dine-Fischler-Srednicki-Zhitnitsky (DFSZ) sensitivity limit at 650-680 MHz. This was the first time this limit was reached for any axion mass range.

As recommended by P5, HEP is planning to participate in a next-generation, 10x more sensitive array, the CMB Stage 4. The AAAC approved the CMB-S4 Concept Definition Taskforce report in October 2017. DOE/HEP and NSF have held meetings to discuss the move forward. HEP lab groups have set up a pre-Project Design Group in coordination with the CMB-S4 collaboration for pre-conceptual planning.

HEPAP was charged in October 2017 to carry out a portfolio review, modeling on NSF's Portfolio Review and NASA's science reviews. Given the current budget outlook, HEO thought it was imperative

to take a close and critical look at currently operating HEP experiments and how effectively they are advancing the P5 plan. There will be an independent peer review of currently operating experiments supported by HEP that will focus on scientific impact and productivity of HEP-supported contributions. HEP will use the results to define a detailed implementation plan for the P5 strategic vision in the FY2019 to FY2022 timeframe. Proposals and materials are due in February with subpanels meeting in February and March; reports are due to HEPAP in May.

The DOE Office of Science (SC) sent out a Dear Colleague Letter in November 2017 on Quantum Information Science (QIS), which was identified as an important cross-cutting topic with potential impact across all of the SC program offices. The Office of Science is encouraging submission of innovative research ideas in QIS. The FY2018 budget request includes ~$15M for QIS prioritized as foundational concepts of quantum information, field theory and analog simulations, experiments and emulators, and supporting technology for HEP.

HEP had 11 early career awards in FY2017, three in the Cosmic Frontier program. FY18 grants are being processed; funding is constrained while DOE waits for an approved budget. William Smith asked, given HEP's portfolio, what the consequences would be if there was a full year continuing resolution. Kathy Turner replied that the research and operations could be squeezed because of HEP's projects; once a project is approved (baselined in preparation for fabrication), HEP keeps to that funding profile if at all possible. If project costs go up, then HEP would have to make adjustments in research and operations.

NSF-Physics Division

Denise Caldwell provided an update on activities in the Physics Division, specifically the science that the Physics Division is doing with regard to the Origin and Structure of the Universe. It has been an exciting year for LIGO. The second observational run ended in August 2017 with an impressive collection of achievements, from detecting the 3rd binary black hole merger, to the first detection of a binary neutron star merger, to the Nobel Prize in Physics for Ray Weiss, Kip Thorne, and Barry Barish. The joint observation of the first binary neutron star merger by gravitational wave (GW) and electro-magnetic observatories was a milestone in astronomical history, bringing forth a new era in multimessenger astronomy. Only 1.7 seconds after the GW detection, a gamma-ray burst was detected by the NASA Fermi spacecraft. LIGO and Virgo are currently undergoing commissioning tasks to prepare for observation 3, to start in late Fall 2018; Virgo is expected to join in the observations from the start. LIGO-India is currently in land acquisition process and ground breaking is planned for mid 2018.

Last year, IceCube has another "first" in multi-messenger discoveries, when MAGIC and Fermi-LAT measured very high energy gamma rays coming from a direction consistent with a UHE neutrino event detected by IceCube.

There have also been advances in laboratory plasma astrophysics. A key astrophysical mechanism that is responsible for generation of the cosmic magnetic fields is being recreated in a terrestrial laboratory. Guided by three-dimensional numerical simulations, experiments are being conducted in the largest laser facilities in the world to demonstrate and characterize the turbulent dynamo mechanism. The plasmas have long path lengths, allowing for measurements of simultaneous absorption and emission over a range of densities and temperatures characteristic of white dwarf photospheres.

Looking ahead, NSF has put forth ten "Big Ideas," several of which will involve the Physics Division: *Windows on the Universe* and *Harnessing Data*. There will be multiple forms of investment by the Physics Division in *Windows on the Universe* that will include individual investigators, facilities, centers, partnerships with other federal agencies and international. *Harnessing Data* will involve developing a cyberinfrastructure that will support data streaming in from the various experiments. This will be

essential for handling large data sets from LIGO, LHC, and LSST and will be closely coordinated with the CISE Directorate. It is important that the domain science be connected with the computational data (interpreting and analyzing the data, producing data pipelines, etc.) that will be necessary.

Buell Januzzi noted the partnerships that the Division of Physics has with other organizations and asked how the Division internally is adding new partnerships. Denise Caldwell replied that one of the things the Division has done over the past few years is focus on building partnerships; the program directors who manage these programs are very entrepreneurial in this area. For example, last year the Physics and Astronomy divisions established a joint review panel for proposals that relate to gravitational waves. That panel is taking place again this year; the panel is being observed by NASA, and NSF is observing how NASA handles its panel reviews. Other collaborations include the Plasma Physics partnership (which has been ongoing for 20 years) and partnerships with the Geosciences solar wind programs. The Division also receives advice from HEPAP and the Nuclear Physics committee.

Rachel Bean asked how the Division works with other directorates and divisions at NSF if Physics is not the primary lead on a project. Denise Caldwell replied that the groups come together and discuss and review all of the programs, thereby coming to a mutual understanding.

Antarctic Infrastructure Modernization for Science (AIMS)

Kelly Faukner showed a video of the proposed modernization of McMurdo Station in Antarctica. The Office of Polar Programs is moving out on modernizing the infrastructure at the Antarctic station. OPP has many constraints on its budget as they move forward with the modernization that may affect the science program, specifically the Cosmic Microwave Backgound (CMB) activity.

NSF/PLR Programs

Vladimir Papitashvili provided an update on the astronomy and astrophysics activities in Antarctica. There are quite a few on-going programs in Antarctica, IceCube, SPT, BICEP, and the long duration balloon program being a few of them.

- IceCube was completed in 2010 to search for very high energy neutrinos created in the most extreme cosmic environments. In 2013 there was a discovery of the first high energy (>30 TeV) cosmic neutrinos; in 2017 IceCube issued an alert upon detecting a cosmic neutrino (0.3 PeV) within 0.1 degree of the flaring blazar 3FGL_J0509+0541. The energy density of neutrinos in the non-thermal universe is the same as in gamma rays.
- Using the Askaryan Radio Array, radio detection of neutrinos is seen to complement the optical techniques at very high energies. The Office of Polar Programs (OPP) and the Physics Division are deploying an array of ~1000 autonomous stations on the snow surface of Antarctica to measure the flux of ultra-high energy neutrinos from astrophysical sources; the array can make unique contributions to multi-messenger campaigns by detecting high energy neutrinos generated by neutron star mergers.
- Upgrades to the South Pole Telescope (SPT) include improved detectors, readout electronics, and AR coated lenses. SPT successfully participated in the first global black hole Event Horizon Telescope (EHT) experiment in April 2017.
- Hardware upgrades to BICEP include optics and a new 270 GHz frequency band.
- The 0.6m aperture High Elevation Antarctic Terahertz telescope, operated robotically at Ridge A summit, is delivering spectroscopic data from 150 to 500 microns. This was a joint project between U.S. and Australian scientists.
- There have been a total of 54 long duration balloon and super pressure balloon payloads flown

from McMurdo Station over the past 25 years. However, the payload scheduled for the 2017/2018 austral summer season was cancelled because the upper atmospheric vortex did not appear.

Decadal Survey Planning

Marcia Rieke provided an update on Decadal Survey activities and the role of the Committee on Astronomy and Astrophysics (CAA). The CAA reports to the National Academies Board on Physics and Astronomy (BPA) and the Space Studies Board (SSB). The CAA is not the Decadal Survey committee, and it does not set policy for the Survey. It does, however, help the National Academies and the Agencies think through relevant issues as they generate the statement of task, stimulate and gather community inputs in advance of the Survey, and pave the way to the Survey. A proposal from the National Academies is expected to be delivered to the Agencies in early Spring, with a call for white papers in summer/fall 2018 and community outreach activities in 2019. The time for completing the Survey process through to report release is around 2 years.

A Consultation Group (CG) will work closely with National Academies staff by assisting with the drafting of the statement of task and prospectus for the next decadal survey of astronomy and astrophysics, Astro2020. The CG will meet primarily by teleconference but will have the option of holding one in-person meeting in Washington, DC. The CG's work is likely to include interaction with the survey's potential federal government sponsors. A well-developed draft of the survey statement of task and prospectus will be made available to the CAA and the survey's potential sponsors. The CG's work will conclude upon the receipt of funding for the survey from the agencies.

The CAA continues to explore which parts of the task could be done before the formal start of the survey in December 2018. There will be meetings on the Cost and Technical Evaluation (CATE) process in Spring 2018, providing some specifics about CATE prior to the start of the Survey. There will be early-career colleague engagement events and other outreach to the community. A CAA subcommittee is developing a plan on how to handle state-of-the-profession activities before and during the survey.

John O'Meara asked when the Academy would know when the State-of-the-Profession discussion would be and when things would be finalized on that effort. Marcia Rieke responded that a few months ago this issue was discussed with, among others, Paul Hertz, and he was reluctant at the time to fund any activities related to State-of-the-Profession as part of the survey; but as part of the Town Hall his view has changed and the Academies may be able to use part of the funding for this activity. In the 2010 survey, there were persons who looked at state-of-the-profession questions but were not fully inpaneled Academy groups so there were no funds to really publish the results. This time those groups would be elevated to a full Academy panel and their results would be published.

Richard Green noted that he and Paul Hertz receive actionable recommendations as funding agencies, whereas, conclusions about state-of-the-profession are more in the realm of the university community and are not necessarily actionable directly by the agencies; for example, if the Academy were to say that a funding grant should have some criteria that the panel thinks it should have, then the agency could consider that actionable. NSF and NASA would like to see such recommendations.

John O'Meara inquired as to what the Academies will be doing to address diversity among the panels being established for the 2020 Survey. He noted that the last Survey had little representation from non-PhD granting institutions. It is frustrating that, eight years after the Survey was done, there still is no definitive analysis of whether the Survey was successful in making sure that all voices are being heard in the right way; that it was inclusive as much as possible, because the Survey effects early career scientists as much as late career scientists. Marcia Rieke indicated that the Academies has a list of diversity criteria

they try to match for every panel they set up, including subject matter diversity, geographic diversity, gender diversity, type of home institution diversity, etc.; the Academy makes a huge effort to try and get a broad range of people including younger scientists but one must remember that participation is voluntary and if young scientists need salary support for doing this, then that is not something the Academy can support. David Lang (National Academies) is taking the issue of diversity in the panels very seriously and is looking at ways to include those who cannot participate in the panels directly in the decision making process, i.e., early career scientist events.

Ground-based TESS Follow-up Observing Program

David Latham provided an update on TESS, the Transiting Exoplanet Survey Satellite. TESS is an all-sky survey to identify the nearest systems of transiting planet candidates. The best targets for follow-up work to confirm and characterize the planets are planet masses from precise radial velocities and spectroscopy of planetary atmospheres; astroseismology is an area for TESS follow-up. The TESS science office prepares the TESS Input Catalog and candidate target list, identifies TESS objects of interest, orchestrates TESS follow-up observing programs, organizing the TESS science team, and coordinates the science publications. There are working groups that provide community input to TESS, including the Follow-up Observing Program Working Group, are invited to participate in science team meetings, and have access to the TESS wiki. All TESS data products are archived a STScI.

Buell Januzzi asked whether the model that has been set up between agency-funded followup and collaborator-funded followup is something other missions should emulate, or is there something about TESS that made it the right approach. David Latham replied that they are trying to use the lessons from Kepler and K2 to make TESS the best mission and to encourage people to collaborate better.

Electromagnetic Spectrum Management

Ashley Zauderer and Jonathan Williams gave a presentation on electromagnetic spectrum management (ESM). NSF funds a wide variety of programs that require usage of the radio spectrum across divisions. Usage is especially heavy in astronomy, physics, polar programs, atmospheric and geospace sciences, and ocean and earth sciences; usage is both passive and active. The research utilizes commercially marketed instruments and communciations devices and services as well as original design instrumentation. ESM resides in the Division of Astronomical Sciences because historically spectrum usage has been focused primarily around the needs of a few large facilities and the National Radio Quiet Zone.

Protected frequency bands include the most important spectral lines for studying the local universe, but Doppler-shifted lines from sources further away in the Universe fall into non-protected bands. Frequencies used for observations are often non-interchangeable, and observations done opportunistically. It is imperative that the increasing demands for spectrum take into consideration the challenges to scientific progress. NSF appreciates efforts to coordinate and to limit out-of-band emissions; astronomy observations also include continuum emission (thermal, non-thermal). The United States has significant scientific assets/large facilities outside its national borders, e.g. ALMA. Even though observatories tend to be in geographically remote sites, radio emission from moving emitters will be an increasing challenge. The past two decades have seen a huge increase in the number of end users of popular applications such as cell phones and GPS; the result has been significant contamination of much of the frequency space, with unpredictable and broadband emissions from an array of communication services. In the future we can expect constellations of thousands of satellites, mobile telecommunications, and high altitude platform systems.

There are national, regional, and international radio regulations that govern the radio spectrum. NSF's position on radio spectrum is brought before several committees including the Committee on Radio

Frequencies (CORF) and the International Committee on the Allocation of Frequencies (IUCAF). NSF also works with the spectrum managers at its radio telescopes. NSF participates alongside other federal agencies in the Interdepartment Radio Advisory Committee (IRAC). Every four years, over 160 International Telecommunication Union (ITU) members participate in treaty-based modifications to the ITU radio regulations. US regulators oversee conference preparations by the federal government and the private sector; there are bi-annual preparatory meetings in Geneva and monthly national preparatory meetings leading up to the international meetings. NSF and NASA co-fund CORF for of the National Academies.

Ralph Gaume indicated that NSF is working to coordinate agency-wide ESM activities within all of the Directorates.

Data Archives & Future Management of Large Datasets

David Hogg provided his perspective on data archives and the future management of large datasets. The CMB missions need large scale structure surveys. The data from the Large Hadron Collider is exceedingly complex. This all complicates the ability to provide simple solutions to comlex problems. Astronomical data is growing in complexity; as scientific goals get more mature, projects produce data that is harder to process. As the data becomes more complex, the knowledge of the system builders becomes more valuable; the data is responsibly used by the experimental team for their goals, and the team knowledge is enclosed in the data analysis procedures applied to the data. Giving tools and data products to the experimental teams that are useful for all scientific investigators is essential. Data releases only make sense with appropriate, rich, associated software releases; this permits arbitrary future joint analyses and new discoveries and provides tools for pre-registration and reproducibility.

David Hogg was asked how often the data archives exist and are successful and are useful enough for a non-experienced user. He replied that there are cases where the data archives have been successful though he does not have clear evidence; extensive resources should not be given to data re-use tools because some of them have not been successful; the Lambda Archive was highly successful for cosmology research, and the Sloan and HST data archive have produced more papers than the PIs for both.

Martin White asked, given the data release issue and releasing the software, how long does it remain the responsibility of the given survey (maybe privately funded) to hold all of the data on disks and available on-line to the advanced graduate student. David Hogg replied that long term data storage is an unsolved problem; some university libraries are now looking at long-term curation of data and some alliance between university libraries and projects might happen. Personnel, funding, and structural changes will be critical to issues of curation and data storage and retrieval.

John O'Meara commented that he would like to see the same attention be given to instrumentation in that new instrumentation should not be funded and built without the appropriate software documentation and pipelines. David Hogg agreed with this.

Discussion and Report Planning

The Committee spent the remaining time discussing preparation for the annual report. Writing assignments were handed out to the Committee. Buell Januzzi and Rachel Mandelbaum provided guidance to the members as they started preparing their write-ups for the report.

MEETING ADJOURNED AT 5:00 PM, 25 JANUARY 2018
MEETING RECONVENED AT 9:00 AM, 26 JANUARY 2018

Anne Kinney addressed the Committee. She became the Assistant Director for the Directorate for Mathematical and Physical Sciences in early January. She was at the first AAAC meeting in 2002. The AAAC serves as a forum for conversations between NSF, NASA, and DOE. The AAAC is important but her suggestion for the future is to disband the Committee as is described in the current charter and re-form the Committee as a forum for real coordination among the three agencies; as the lead agencies for astronomy research, it is important that they are talking to each other on a regular basis. Buell Januzzi was not sure whether the Committee should be disbanded but the Committee does meet at least four times a year and the Agencies participate in the meetings.

Jim Ulvestad informed the Committee about his new position as Chief Officer for Research and Facilities. NSF has a Large Facilities Office that works with the directorates and divisions on project assurance, i.e., making sure the project is managed well, helping with management of contingency on the MREFC projects, working with the program officers on monitoring earned value, etc.; it has not been focused on strategic NSF-wide issues or operating facilities (focused on construction facilities). Congress felt there was a hole in complete lifecycle oversight in the Director's office so in the last NSF authorization bill, they said NSF should have a senior official in the Office of the Director who has complete lifecycle oversight of major multi-use research facilities; Jim Ulvestad is that person. He is defining the role to make sure that there is the same type of knowledge for each of the facilities and that there are no facilities that are not being monitored; he will help the overall strategic oversight flow better.

NASA/LSST Near-Earth Object Collaborations

Lindley Johnson (NASA) provided an update on activities in the Planetary Defense Coordination office. His office was established in January 2016 to oversee planetary defense related activities across NASA, and coordinate both US interagency and international efforts and projects to address and plan a response to the asteroid impact hazard. LSST will fit into the detection and followup of the catalog of objects. The Near-Earth Objects (NEO) observations program began with NASA's commitment to the House Committee on Science in May 1998 to find at least 90% of the 1 km and larger NEOs by the end of 2010; the NASA Authorization Act of 2005 increased NASA's scope for the effort. NASA uses a variety of telescopes and platforms to search for and characterize NEOs, including Pan-STARRS, NEOWISE, the Catalina Sky Survey, Arecibo, and LINEAR/SST (.4m-to 8-m telescopes and platforms). The IAU Minor Planet Center receives the positional measurements of small bodies from observations made all over the world and is responsible for identification, designation, and initial orbit computation. JPL's Center for Near-earth Object Studies computes the high-precision orbits of NEOs, performs long-term analyses of possible future orbits of hazardous asteroids, and computes the orbits of new potential asteroid discoveries to determine any impact hazard. There have been 2,053 NEO discoveries with 53 objects coming between the Earth and the Moon; 4 came closer than geosynchronous orbit and there were another four that would have been worrisome if they had been on an impact trajectory. In October 2017, the first interstellar object, 1I/2017 U1 ('Oumuamua), was discovered by the Pan-STARRS1 telescope during near-earth object survey operations; `Oumuamua's speed and trajectory indicate that it originated outside of and is not bound to our solar system. 538 NEOs were added to the catalog in 2017 with a total of around 17,500 objects, 8,000 being over 140m or larger, and around 1,900 potentially hazardous asteroids (PHAs) coming within 7.5 million kilometers of Earth orbit.

Over the past year, a quasi-independent study (independent reviews vetted a study plan and final report) was done by JPL and the University of Washington (UW) to determine: how many NEOs could be discovered by LSST under various assumptions relating to system performance, presuming *a priori* that multiple individual detections could be linked to obtain object orbits; the efficiency of the linking process and its robustness to the likely numbers of false detections resulting from the optical system and difference-imaging approach; and whether altneratives to the baseline LSST survey cadence might

substantially change the NEO discovery performance. Both the UW and JPL teams agreed on the big picture result; LSST would bring additional capability to the effort. LSST would reduce the distance to the goal in 2032 roughly by half, compared to where NASA would be with the currently operating surveys alone.

Buell Januzzi asked if the study teams looked at coordinating PanSTARRS, Catalina Sky Survey and LSST, i.e., PanSTARRS and Catalina Sky Survey making the third observation on fields LSST was targeting every night, and not just both trying to do their own surveys. Lindley Johnson replied that the study teams did not look at this option; the telescopes and platforms tend to self-coordinate.

The results of the study concluded that assuming that existing NEO surveys continue to operate and incrementally improve, the H < 22 NEO catalog was likely to surpass 75% completeness after LSST's 10-year baseline survey (based normally on 2 visits per night per field after 12 days of data collection), PHA completeness would be about 5 percentage points higher than NEO completeness, and changing the observing strategy to 3 or 4 visits per night per field would not improve linking efficiency, and therefore would reduce survey completeness due to reduced sky coverage. The final report (comprised of 3 documents, the JPL team report, the UW team report, and consensus report) was delivered to NASA in March 2017.

The NEO Survey Science Definition team report found that satisfying the 140 meter cataloguing objective will require space-based search systems; ground based systems only achieve around 85%. IR sensors located at L1 achieve the best cost/benefit and lowest risk option and the fastest completion of the 140 meter objective and the best warnings provided by large aperture systems are at L1. The addition of a single ≥4-meter ground-based search system aids the completion timeline for any space-based option.

Buell Januzzi noted that LSST can do it, but is the LSST plan as funded to analyze the data going to do it? Lindley Johnson replied that this is what they are looking into now. NASA wants to take advantage of the capabilities of LSST, but NASA still needs to complete the NEO survey analysis of alternatives, learn the outcome of the FY2019 budget submittal, begin discussions with NSF/AST for LSST collaboration, and determine the best course of action for incorporation of LSST data into the NEO observations search and survey pipeline. LSST, with its current budget, does not have the resources that are needed to fully bring up a NEO pipeline, so they will be looking at the support needed to do that.

Kelsey Johnson asked: if she sees something in her data and looks in the on-line catalog to see if it is known or not, where should she send this observation to. Lindley Johnson replied that she should send the observation to the Center for NEO Studies (CNEOS).

Richard Green noted that the NSF Director and the Secretary of the Air Force will announce shortly a Letter of Intent to collaborate on scientific research on a number of topics, one of which is situational awareness, in particular, using the LSST data stream to get population studies of earth orbiting objects.

Gravitational Wave Follow-up Observations Planning

Buell Januzzi noted that there will be a section on multi-messenger astronomy in the annual report since this is an important topic. Dieter Hartmann indicated that it is important to make sure that the use of multi wavelengths in astronomy research be articulated clearly in the report.

Other Business

Liz Pentecost indicated that she will send a doodle poll to the Committee and Agencies inquiring about the availability for the June telecon and September meetings.

Further Discussion and Report Planning

The Committee spent the remainder of the session working on the annual report, discussing topics to be added to the report, suggestions for science highlights, etc.

MEETING ADJOURNED AT 12:00 PM, 26 JANUARY 2018