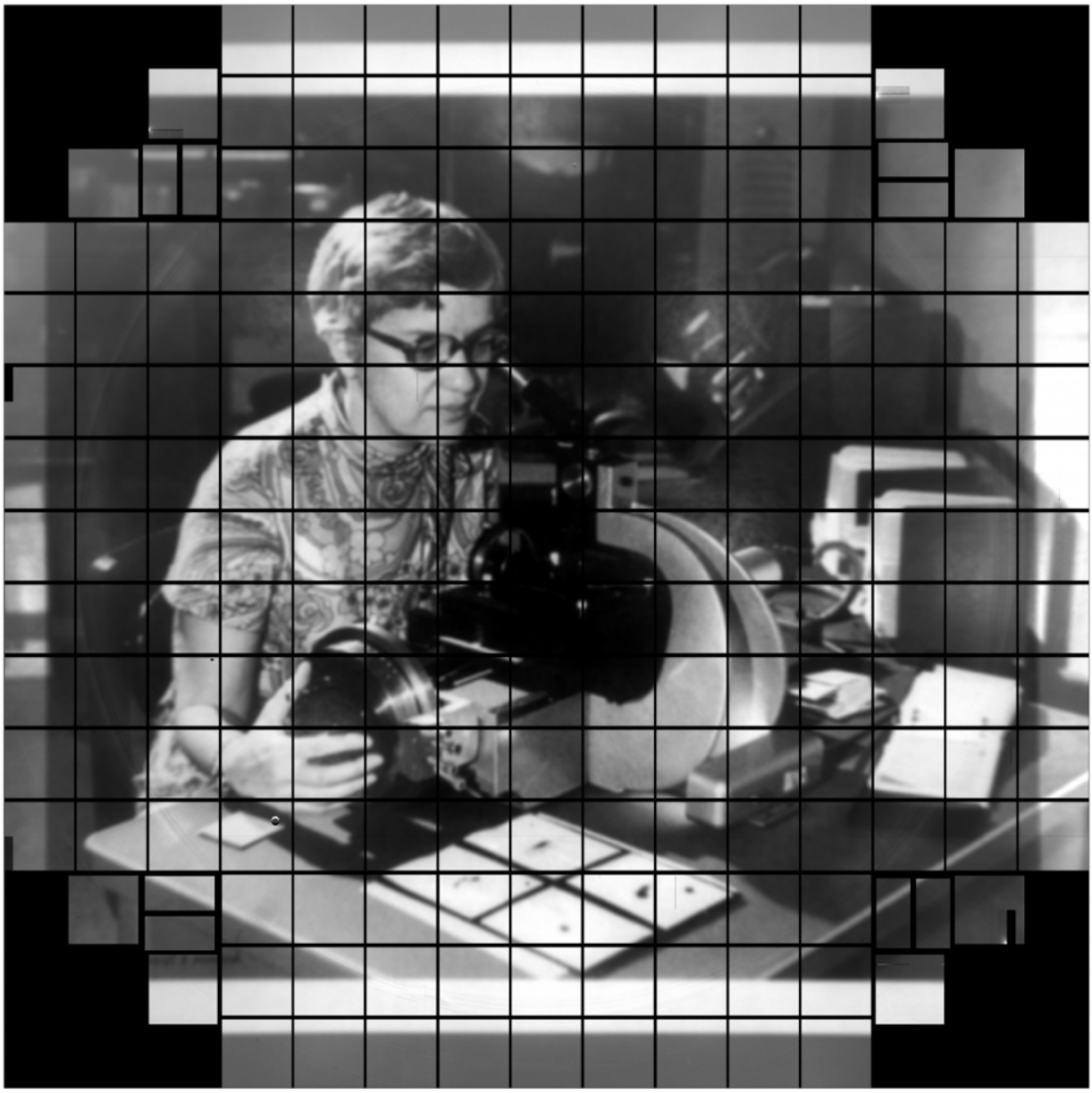
Report of the Astronomy and Astrophysics Advisory Committee

March 15, 2021



Executive Summary

Our findings and recommendations are listed and described below. The body of our report serves to support our findings and recommendations. All acronyms used in the text and are defined in Appendix A.

Collected Findings and Recommendations

1. Finding: The impacts of COVID-19 on science productivity by astronomical facilities at every scale, along with the impacts of development, integration, and test of future major facilities have been significant and will be long-lasting.

2. Finding: NSF, NASA, and DOE Office of Science have made significant and impactful efforts to mitigate the impacts of the COVID-19 pandemic on agency functions, facility operations, and research grant awardees, particularly those at an early career stage.

3. Recommendation: NSF, NASA, and DOE Office of Science should continue their efforts to mitigate the impacts of COVID-19, with a focus on early career scientists to the extent possible.

4. Recommendation: Congress should consider appropriations augmentations to fund NASA, NSF, and the DOE Office of Science in their efforts to mitigate the impacts of COVID-19 on the astronomical sciences.

5. Finding: The AAAC expresses deep gratitude to NASA, NSF, and DOE for their commitment to service to the astronomical community during the COVID-19 pandemic, and for their ability to deliver on those commitments.

6. Finding: Supporting the strategic goals for open science, NASA has initiated an open science data initiative that includes direct financial support for community developers.

7. Recommendation: NASA, NSF, and DOE/Cosmic Frontier should support community efforts that increase public access to data, software, and data products across surveys.

8. Recommendation: The three agencies should coordinate on guidelines and expectations for the public releases of data, access tools, and software associated with observations and simulations.

9. Recommendation: The agencies and the AAAC should review priorities for access to data and simulations after the release of the 2020 Decadal Survey recommendations.

10. Finding: The AAAC supports increased NASA/DOE efforts to explore collaborative activities as outlined in the October 2020 Memorandum of Understanding.

11. Finding: The AAAC supports increased NASA/NSF efforts to explore collaborative activities as outlined in the January 2021 Memorandum of Understanding.

12. Recommendation: NASA, NSF, and the DOE Office of Science should continue to collaborate on inter-agency initiatives that have significant community impact.

13. Finding: The AAAC endorses the recommendations of NASA's Strategy for Data Management and Computing for Groundbreaking Science on the long-term curation of data and its public availability, the need for the support of open source software, and the necessity of investments in the training and education of the astronomical community in data science. The AAAC encourages the development of this and related initiatives at all three agencies.

14. Finding: The AAAC reaffirms its view that the agencies and the AAAC should, after the release of the Astro2020 Decadal Survey recommendations, jointly review and update the Principles of Access recommended by the AAAC in 2013.

15. Finding: Continued outreach and connections with private corporations planning and deploying satellite megaconstellations is required.

16. Recommendation: The AAAC recommends continued and augmented cross-agency efforts to provide data-driven recommendations for telecommunication satellite constellations that would have the lowest impact on astronomical studies.

17. Finding: The goal of detecting 90% of NEOs > 140 m diameter has not been met, and will take decades to meet at the current rate of discovery with the current slate of facilities.

18. Finding: The potential contributions of current and future ground-based astronomical surveys to the discovery of NEOs and to the achievements of the goals set forth in the George E. Brown Act are significant.

19. Finding: The potential contributions of the NASA NEO Surveyor mission to the discovery of NEOs and to the achievements of the goals set forth in the George E. Brown Act are significant. The AAAC expresses concern over the delay of the Key Decision Point milestone for the mission.

20. Recommendation: The AAAC encourages ongoing NASA/NSF coordination, through the Planetary Protection Coordination Office, to clearly define the role that existing and future ground and space-based astrophysics surveys and facilities can play in the discovery and characterization of NEOs.

21. Finding: Radio quiet zones and the preservation of the protected regions of the radio spectrum are critical for the future of radio astronomy.

22. Recommendation: The AAAC recommends that NSF and NASA should continue to work with international astronomy agencies and coordinate with the relevant IEEE technical committees involved in to create and preserve geographical radio quiet zones for radio astronomy.

23. Recommendation: We recommend that the current definition of radio quiet zones, and the federal legislation establishing them, be modernized and updated to include radio emission from satellites and high-altitude transmitters (e.g. drones and high-altitude balloons) and not just terrestrial signals.

24. **Recommendation: The AAAC recommends that the agencies continue the development of AI and ML initiatives across astrophysics including the potential creation of institutes focused on AI in the context of astrophysics.**

25. Finding: The AAAC supports the expansion of dual anonymous reviews at NASA.

26. Recommendation: The AAAC recommends continuation of the expansion of dual anonymous reviews within NASA, and requests that NSF and DOE develop and adopt similar reviews or other practices that provide the committee with sufficient evidence of bias mitigation in their review processes.

27. Finding: The current lack of public access to demographic data for federally funded research in the astronomical sciences severely hampers the ability for review of efficacy of diversity, equity, and inclusion initiatives at NASA, NSF, and the DOE Office of Science.

28. Recommendation: The AAAC recommends that the NASA Office of the Chief Scientist share its demographic data or at a minimum provide the results of analysis of the

data to the directors within NASA's Science Mission Directorate so that the divisions can evaluate the effectiveness of their processes and policies for DEI.

29. Recommendation: The AAAC requests that the NSF and DOE collect and disseminate demographic data for astronomy and astrophysics awardees of funds from those agencies.

30. Recommendation: AAAC recommends that NASA, NSF, and DOE work with OMB to collect the needed fine-grained demographic data to understand the proposal pool and the awardee pool for its entire portfolio of grants.

31. Recommendation: The AAAC requests that NASA, NSF, and DOE provide regular updates to the committee on demographic data and DEI initiatives.

32. Finding: Although constrained by the resources available, the MSIP program has consistently been over-subscribed and variably funded. MSIP has proven to be an important avenue for funding the current generation of astronomy surveys, instruments and projects, and for realizing the science goals put forward by the Decadal Surveys.

33. Recommendation: We recommend that NSF continue to offer the MSIP program within the AST division in parallel with, but separate from the NSF-wide MRI and MSRI calls. We further recommend that NSF strive to stabilize, and ideally increase the MSIP funding level cycle-over-cycle.

34. Recommendation: NSF should provide to the AAAC data summarizing the proposal success statistics for MRI, MSIP, and MSRI awards to better gauge the impact of these programs. Furthermore, NSF should provide a summary of any significant astronomy focused infrastructure awards outside the MRI, MSIP, and MSRI programs along with the source of those funds, namely whether they come from within the AST budget or outside of it.

35. Finding: The AAAC is gratified to see continued, significant progress by the NSF and DOE toward completion of the highest priority decadal ground-based facility, the Vera C. Rubin Observatory, which is advancing toward the start of survey science operations in 2023.

36. Finding: Operations of the Rubin Observatory may place significant strain on the ability for NSF and DOE/Cosmic Frontier to maintain a balanced portfolio of facilities and other funding.

37. Recommendation: The AAAC urges NSF and DOE to put in place a long-term operations plan that will, while maintaining a balanced overall portfolio, ensure that the US science community can capitalize on the substantial investment in the Rubin Observatory.

38. Finding: The collapse of the 305-m reflector telescope at Arecibo Observatory represents a significant loss to both the astronomical community and the people of Puerto Rico.

39. Recommendation: The AAAC strongly supports the proposed discussions among the various stakeholders to ensure that they will all continue to have a voice in the ultimate fate of Arecibo Observatory.

40. Finding: The AAAC strongly supports the goals of the Facility Operation Transition activity, but expresses concern that the funds allocated to this activity, even as a pilot, are insufficient.

41. Recommendation: Congress should provide sufficient appropriations to NSF to ensure that NSF's strategic commitments to operations and maintenance of its major facilities can be met, but not at the expense of the research and instrumentation funding portfolio within NSF-AST. The AAAC recommends a significant augmentation of the Facility Operation Transition activity.

42. Finding: The AAAC strongly endorses the renaming of WFIRST to the Nancy Grace Roman Space Telescope.

43. Recommendation: The AAAC encourages inter-agency initiatives to maximize the scientific yields of the Vera C. Rubin Observatory and Nancy Grace Roman Space Telescope by considering survey designs that maximize the synergy between these two facilities.

44. **Finding: The AAAC is encouraged by the popularity of the Pioneers program, and the success in bringing the first CubeSat projects to fruition. We are also encouraged that the program is serving as a way for first-time PIs to gain experience with NASA missions that will help with future missions. We are particularly encouraged that 100% of both the CubeSat and Pioneer programs have first-time PIs, with diversity across multiple axes.**

45. **Recommendation: The AAAC recommends that NASA Astrophysics continue to maintain the Pioneers program at least at its current level, and continue its efforts to recruit new mission PIs that move into leadership positions for the larger missions of the 2020s and 2030s.**

46. Finding: NASA has made significant positive progress towards the completion of the JWST mission activities leading to a late 2021 launch. As of this writing the expected launch date remains as scheduled to be October 2021.

47. Recommendation: The AAAC recommends that SOFIA undergo senior review including a decision on mission extension, in line with normal NASA review procedures.

48. Finding: The Astro2020 Steering Committee has made significant progress towards completing and delivering the survey to the community in spite of the significant challenges of the COVID-19 pandemic.

49. Finding: Leadership by the United States in the astronomical sciences is significantly threatened by budget uncertainty, lack of growth, and increasing international competition.

50. Finding: Absent appropriate and robust planning, resources, and resource phasing, the agencies will be unable to effectively implement an ambitious and transformative set of recommendations from Astro2020.

51. Finding: The policies surrounding reporting of proposed and implemented fiscal year budgets are not uniform across the agencies the AAAC is charged with advising. In particular, the NSF budget reporting cycle lags by a year that of the other agencies, significantly hampering the AAAC's ability to meet its charge.

52. Recommendation: NSF should report their budget forecasts and implementations to the AAAC so as best to overlap with the other agency report timelines.

53. Finding: The statutory deadline, March 15th, for the submission of the AAAC annual report does not allow sufficient time for the committee to react to budget developments that typically occur in the first two months of each calendar year.

54. Recommendation: the AAAC recommends that the annual report deadline be changed from a fixed date to a deadline 45-60 days following the submission of the President's budget, so as to enable sufficient opportunity for the committee to interact with the funding agencies, understand the impact of the President's budget, and formulate recommendations. The AAAC would endeavor to still meet the current deadline of March 15th when possible.

1. Introduction

The Astronomy and Astrophysics Advisory Committee (AAAC) was established in the National Science Foundation (NSF) Authorization Act of 2001. Its charge is to monitor and evaluate the performance of the NSF, National Aeronautics and Space Administration (NASA), and the Department of Energy (DOE) on issues relevant to the field of astronomy and astrophysics, especially those requiring coordination of the three agencies' efforts. The AAAC annually assesses progress in implementation of the recommendations of the most recent decadal survey, *New Worlds, New Horizons in Astronomy and Astrophysics (NWNH)* in this case, its predecessors, and relevant reports from similarly constituted non-decadal advisory committees. The AAAC reports to the Secretary of Energy, the NASA Administrator, the NSF Director, and to relevant committees in the House and Senate. This communication represents the annual report of the 2020-2021 committee reviewing activities in 2020 and early 2021.

A few notable science highlights from the past year, both in research and in engagement with the public, are outlined in Section 2. The cover photo of this report is one of the verification images from the full 3200 megapixel array of detectors in the LSST camera that was named to honor the intellectual legacy of Vera Rubin as the Vera C. Rubin Observatory.

Since March 15, 2020, the AAAC has had four meetings, all held remotely due to the impacts of COVID-19 on travel and in-person gatherings. In addition to regular briefings from NASA, NSF, and the DOE Office of Science, the AAAC heard reports from other divisions within NASA and NSF, along with other targeted briefings, such as an update on the NSF efforts to understand the catastrophic structural failure at Arecibo Observatory.

The AAAC notes that some sections of this report repeat discussion, findings, and recommendations from previous years. The committee continues to find these discussions important, and continues to support the findings and recommendations originally made.

Given the proximity of this report to the findings from the Astro2020 Decadal Survey, whose release is anticipated in a few month's time, this report will focus on specific issues of interest and concern to the AAAC as opposed to a general discussion of the agencies' responses to *NWNH*. We have significantly shortened those sections, or eliminated them for brevity. Nevertheless, if a finding or recommendation is listed with little discussion, it is still found to be of importance to the committee, and worth consideration by the agencies and other stakeholders.

Finally, we note the addition of two new sections not tackled in previous reports. The first focuses on the impacts of COVID and efforts to mitigate them by all three agencies. The second focuses on new and continuing efforts at increasing Diversity, Equity, and Inclusion (DEI) in the astronomical sciences.

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[1] https://www.nsf.gov/mps/ast/aaac.jsp

[2] https://www.nap.edu/catalog/12951/new-worlds-new-horizons-in-astronomy-and-astrophysics

2. Science Highlights of 2020-2021

Perseverance Lands at Jezero Crater
On February 18, 2021, the Mars 2020 mission met a major milestone with the successful completion of Entry Descent and Landing (EDL) at Jezero Crater on Mars. At the time of writing, the Perseverance rover has completed multiple checkouts of its major systems, and the Ingenuity helicopter is being prepared for its first flight in April. In addition to its prime mission, slated to last at least one Martian year, the rover will collect samples that will be returned to Earth by the Mars Sample Return mission. Despite the constraints of the pandemic, the landing and subsequent deployment were shared virtually worldwide and generated enormous public interest globally.

Arecibo
The Arecibo Observatory in Arecibo, Puerto Rico was an important scientific and cultural facility in its 57 years of operation. With the collapse of the suspended platform above the radio telescope that housed many of the scientific instruments, the main telescope was seriously damaged and the future use of the observatory to conduct science is undergoing evaluation and assessment by NSF. The loss of this telescope is painful for the scientific and local communities; it gave us wonderful science for almost 6 decades and was an iconic telescope for many. The scientific achievements of Arecibo are too many to list here, but many key discoveries include the discovery of the first extrasolar planet around the pulsar B1257+12 in 1992 and the first indirect detection of gravitational waves from the spin-down of the pulsar PSR 1913+16, a discovery that led to Hulse & Taylor's Nobel Prize in 1993. Both these discoveries opened up entirely new scientific fields - exoplanets and gravitational waves from merging compact objects - that are at the cutting edge of astronomy and astrophysics today.

The Nobel Prize in Physics
The 2020 Nobel Prize in Physics was awarded for the theoretical and observational exploration of black holes. In addition to Roger Penrose, of the University of Oxford and Reinhard Genzel, of the Max Planck Institute Extraterrestrial Physics, Andrea Ghez of the University of California, was awarded the prize for her work on definitively proving the existence of a supermassive black hole at the center of our own Galaxy, the Milky Way. All prize winners have received significant NSF funding over many decades.

Rubin Camera Completion
As of writing, the workhorse camera for the Vera C. Rubin Observatory's Legacy Survey of Space and Time (LSST) is very nearly complete, with only the delivery of the filters and testing remaining. The very large array of CCD detectors has been assembled and tested, and the complete camera is slated to finish in 2021. The cover image of this report comes from image tests of the detector package. The camera is a major DOE contribution to the joint NSF/DOE Rubin Observatory project.

DESI
The Dark Energy Spectroscopic Instrument (DESI) is the first stage IV dark energy experiment and will collect tens of millions of spectra from galaxies and quasars. The imaging component of DESI used to define DESI spectroscopic targets is complete and publicly available. DOE-HEP contributions to the DESI imaging program have included the upgrade of the MOSAIC camera on the Mayall Telescope and data processing at the National Energy Research Scientific Computing Center. This data release represented more than 2 billion objects from three public imaging

surveys over half of the sky. These data can be viewed at https://www.legacysurvey.org/viewer. These images are not only a key part of the DESI mission, but will also enable a number of other astronomical studies. DESI was successfully commissioned in 2020 and started science survey operations and spectroscopic data collection on Dec 14, 2020. DESI has since taken thousands of science exposures and plans to complete science validation by April 2021. Following science validation, the DESI survey will begin, providing constraints on the equation of state of dark energy as well as on theories of modified gravity and inflation, and limits on the sum of the neutrino masses.

DKIST

The construction effort for the National Science Foundations' 4m Daniel K. Inouye Solar Telescope (DKIST) on Haleakala, Maui experienced significant delays due to the impact of the COVID pandemic. The project is progressing on the integration, testing and science verification of three spectro-polarimeteric instruments. The start of the operations commissioning phase is now scheduled for fall of 2021. The community response to the first call for proposals was excellent resulting in significant over subscription of the facility.

Neutrinos traced back to tidal stripping event in the universe

In a rare instance, neutrinos detected by NSF's IceCube Neutrino Observatory in Antarctica could be traced back to a specific astrophysical event. The tidal disruption event AT2019dsg is the most likely neutrino source, discovered in 2019 by the Zwicky Transient Facility (ZTF), a robotic camera at Caltech's Palomar Observatory. The event occurred over 690 million light-years away in a galaxy located in the Delphinus constellation. As part of a multi-wavelength follow-up survey - visible, ultraviolet, and X-ray observations with NASA's Swift satellite commenced, including X-ray data from ESA's XMM_Newton satellite and radio measurement with NRAO's VLA array and the South African MEERKAT array. Multi-wavelength observations, particularly the detection by NASA's Swift satellite revealed the possible origin of neutrinos from this source.

SOFIA

In October 2020, NASA's Stratospheric Observatory for Infrared Astronomy (SOFIA) announced the detection of water on the sunlit surface of the Moon. This first discovery indicates that water may be distributed across the lunar surface, and not limited to cold, permanently shadowed places as previously believed. SOFIA detected water molecules (H2O) in Clavius Crater, one of the largest lunar craters visible from Earth, located in the Moon's southern hemisphere. Previous observations of the Moon's surface detected some form of hydrogen, but were unable to distinguish between water and its close chemical relative, hydroxyl (OH). Data from this location reveal water in concentrations of 100 to 412 parts per million – roughly equivalent to a 12-ounce bottle of water trapped in a cubic meter of soil - spread across the lunar surface.

Gravitational Waves

The LIGO-Virgo Collaboration detected their most massive black hole yet after a 66 solar mass black hole was found to have merged with a 85 solar mass black hole to produce a 142 solar mass black hole. LIGO-Virgo also discovered a merger that included either the lightest black hole or the heaviest neutron star ever discovered in a double compact-object system. The mass of the smaller black hole in the merger had a mass of 2.5 solar masses. The latest catalog was released by LIGO and Virgo with 39 additional events giving us 50 measured gravitational wave

events so far. NANOGrav also presented results showing the first hints of detection of the low-frequency gravitational wave background.

3. 2020-2021: COVID and Social Disruption

The effects of COVID-19 on the nation and the world are too numerous and broad to detail here. As with nearly every enterprise, the astronomical sciences have been severely impacted. We highlight three major impacts here: the impacts on schedule for major facilities, the impacts on scientists, and the impacts on major strategic initiatives.

In terms of facilities, COVID has either slowed or entirely halted every major facility or mission under development. Some examples include:

- A multi-month near total work stop on construction of the Vera C. Rubin Observatory main facility in Chile, leading to an approximate one year slip to the start of science operations from 2022 to 2023, along with some delays in completion of the workhorse camera.
- A delay in commissioning activities for DKIST in Hawai'i due to travel restrictions on commissioning scientists and staff.
- A halt to balloon-borne experiment campaigns
- Delays in assembly, integration, and test of a variety of NASA missions, including JWST and Roman.

Additionally, nearly every ground based observatory facility had operations severely impacted, or entirely halted. While some facilities like Gemini North, Green Bank, and GONG were able to come back online in the spring of 2020, others like ALMA are only now beginning to return gradually to science operations.

Finding: The impacts of COVID-19 on science productivity by astronomical facilities at every scale, along with the impacts of development, integration, and test of future major facilities have been significant and will be long-lasting.

Naturally, COVID-19 also significantly impacted the scientists in the astronomical community. In particular, the AAAC expressed concern in the 2020 report that COVID-19 would have a disproportionately strong negative impact on early career researchers: graduate students, postdocs, and junior faculty. Fortunately, NASA, NSF, and DOE all put in significant efforts to try to minimize the impact on researchers, with extra efforts made on behalf of early career scientists. Examples include:

- NASA SMD prioritizing funding extensions to support graduate students, postdocs, and junior faculty, along with a temporary expansion of the NASA Postdoctoral Program and extensions as needed of premier fellowship programs such as the Hubble Fellowship Program
- DOE/HEP and NSF implementation of flexibility for changes in current and new research awards, extended student and postdoctoral terms, and modification of doctoral thesis experiments due to delays in the arrival of previously planned experimental data.

The efforts on behalf of early career researchers by the agencies have made a significant positive impact. Nevertheless, they are not without cost. For example, NASA SMD has identified a notional 15% reduction in 2021 new research award spending to offset the spending on COVID impact mitigation.

Finding: NSF, NASA, and DOE Office of Science have made significant and impactful efforts to mitigate the impacts of the COVID-19 pandemic on agency functions, facility operations, and research grant awardees, particularly those at an early career stage.

Recommendation: NSF, NASA, and DOE Office of Science should continue their efforts to mitigate the impacts of COVID-19, with a focus on early career scientists to the extent possible.

Recommendation: Congress should consider appropriations augmentations to fund NASA, NSF, and the DOE Office of Science in their efforts to mitigate the impacts of COVID-19 on the astronomical sciences.

Even with the impacts at every level by COVID-19 on the astronomical sciences, NASA, NSF, and DOE all maintained an admirable level of service to the community, in most cases with their staff working from home and under the same pressures facing the nation they serve.

Finding: The AAAC expresses deep gratitude to NASA, NSF, and DOE for their commitment to service to the astronomical community during the COVID-19 pandemic, and for their ability to deliver on those commitments.

Finally, a number of strategic initiatives were significantly impacted by COVID-19. Of key importance to the AAAC were the one year delay in the Particle Physics Community Planning Exercise (a.k.a. “Snowmass”), and a multiple month delay in the delivery of the Astro2020 Decadal Survey.

4. Overview of Issues relevant to Interagency Coordination and Cooperation

4.1 Interagency coordination and collaboration to maximize return on investments in survey datasets

Large projects such as those within the NASA, DOE, and NSF portfolios will generate massive, complex datasets that have many uses beyond the key science drivers that motivated the construction of these projects. The potential impact of these individual datasets increases when combined with other samples to provide a multi-dimensional view of the cosmos. As the number of significant archival datasets grows, issues of accessibility and interoperability become increasingly important.

The archives that have seen the most use (e.g. SDSS, HST, Chandra) have a set of convenient tools for accessing the data and matching to samples from other programs or archives. Given the multitude of archive sites and the many different flavors of the data, it is important that these tools be accessible and easy to use in combining data from different archives.

In last year's report, we called attention to NASA's "Strategy for Data Management and Computing for Groundbreaking Science". The strategy document identified three goals for data management systems and made several recommendations for action: to implement the capabilities for open science, to evolve data and computing systems, and to harness community partnerships to enhance innovation.

In the last year, NASA advanced the initiative of open science in several ways. A new procedure has been established for evaluating proposed Data Management plans as part of the intrinsic merit of ROSES-2020 proposals. Two new ROSES calls were announced to support open-source tool development and the opening of legacy software. Finally, NASA is developing a policy to ensure that the results of its Federally funded scientific research and technology development are shared openly. This policy will cover information produced by NASA Science Missions and from NASA-funded research awards, publications, data, and software.

Finding: Supporting the strategic goals for open science, NASA has initiated an open science data initiative that includes direct financial support for community developers.

The strategies described in the document are important beyond NASA, as study of astrophysical phenomena often requires multi-mission study that crosses agency boundaries. For example, multi-messenger astrophysics is soon going to make use of NSF-funded gravitational wave and neutrino detectors, NSF and DOE-funded wide-field imaging with the Vera Rubin Observatory, and space-based imaging and spectroscopy supported by NASA.

Recommendation: NASA, NSF, and DOE/Cosmic Frontier should support community efforts that increase public access to data, software, and data products across surveys.

Recommendation: The three agencies should coordinate on guidelines and expectations for the public releases of data, access tools, and software associated with observations and simulations.

Toward the goal of harnessing community partnerships, NASA has signed an MOU with DOE:
https://www.energy.gov/articles/department-energy-and-nasa-signmemorandum-understanding
And with NSF:
https://www.nasa.gov/sites/default/files/atoms/files/2020_nasa-nsf_mou.pdf

One immediate product of the NASA/DOE MOU was a joint NASA/DOE call for community input on collaborative partnerships in the following three focus areas:
1. Sensitive radio telescopes or sensors on the Moon's far side to explore the early eras of the universe or test the standard cosmological model
2. Small experiments to carry out space-based probes of fundamental physics in a microgravity environment of the International Space Station
3. Enhance or extend the dark energy science reach of data from the Vera C. Rubin Observatory, the Nancy Grace Roman Space Telescope and the Euclid observatory when considered together, including development of a common library of simulations, and/or capabilities to enable joint data processing & analysis.

Finding: The AAAC supports increased NASA/DOE efforts to explore collaborative activities as outlined in the October 2020 Memorandum of Understanding.

Through the NASA/NSF MOU, these two agencies will continue working together to advance NASA- and NSF-sponsored science programs in astrophysics, planetary science, astrobiology, quantum technology, heliophysics, and Earth science. Those activities that continue to make use of NSF-managed facilities will be emphasized, including those in the Antarctic.

Finding: The AAAC supports increased NASA/NSF efforts to explore collaborative activities as outlined in the January 2021 Memorandum of Understanding.

Recommendation: NASA, NSF, and the DOE Office of Science should continue to collaborate on inter-agency initiatives that have significant community impact.

4.2 Response to recommendations on open software and open data

In previous reports, the AAAC has recommended that the three agencies should coordinate on developing guidelines for the release and support of open software and open data. This has included providing funding to support access to the software and data products from current and planned surveys and missions. We appreciate the attention that the agencies have given to these recommendations both within their astrophysics programs and more broadly across the agencies as a whole. While progress has been made, there is wide divergence in how the different agencies approach these issues.

The AAAC commends NASA for the creation of the supplemental open source software awards to support the conversion of legacy software into open-source code and the development of the initial “Support for Open Source Tools, Frameworks, and Libraries” program. We also commend NASA for the inclusion of an explicit requirement for an open source license in proposals to NASA that require a data management plan.At DOE, the creation of the software repository *DOE Code* provides a mechanism for making DOE software publicly available.

Finding: The AAAC endorses the recommendations of NASA’s Strategy for Data Management and Computing for Groundbreaking Science on the long-term curation of data and its public availability, the need for the support of open source software, and the necessity of investments in the training and education of the astronomical community in data science. The AAAC encourages the development of this and related initiatives at all three agencies.

The committee notes that, at present, the NSF-AST’s advice for data management plans makes no recommendations or requirements on the licencing of software or data generated through its awards. The committee remains concerned about the long-term curation of data from large astronomical surveys (beyond the lifespan of the individual experiments) given the enormous resources put into the creation and operation of these surveys. Given the release of the Decadal Survey in the coming months and the strong likelihood of recommendations around software and data within it, the committee defers specific recommendations at this time. Nevertheless, the committee finds this to be an important issue, and that the current Principles of Access put forth by the AAAC in 2013 to be increasingly in need of scrutiny and update.

The AAAC reaffirms its view that the agencies and the AAAC should, after the release of the Astro2020 Decadal Survey recommendations, jointly review and update the Principles of Access recommended by the AAAC in 2013.

4.3 Satellite Mega-constellations

The extremely rapid increase in the deployment of telecommunications satellite constellations, with plans for tens of thousands of satellites to be launched in the coming decade, poses a grave challenge to optical, NIR, and radio astronomy from the surface of the Earth, and hence presents a substantial risk to the astronomical sciences enabled and funded by all three agencies. This risk is already with us; as of January 2021, SpaceX had exceeded 1000 satellite launches (out of more than 10,000 planned) of its constellation of Starlink telecommunications satellites. Because of its long-standing role in electromagnetic spectrum management and protection, NSF is currently leading the tri-agency response, with additional advocacy and participation from the American Astronomical Society (AAS) through its Committee on Light Pollution, Radio Interference, and Space Debris. These efforts are complicated by the fact that there is no legislative guidance regarding these satellites, and therefore the AAS and the agencies have been reaching out directly to the satellite manufacturers in an effort to communicate their concerns.

Two conferences have been organized under the auspices of NOIRLab and the AAS to bring together astronomers and engineers from the telecommunications companies to discuss mitigation strategies. The first conference, SATCON1, was held in June-July 2020 while the second is planned for early-mid 2021. The focus so far has been on decreasing the brightness of the satellites in final orbit so that the persistence effect on detectors is minimized and studying trades between altitude and visibility to minimize the impact on nighttime observations. Several independent simulation efforts demonstrated that the satellite constellations with the greatest impact for any given observatory are those with orbits at higher altitude and with orbital inclinations close to the latitude of the observatory. Significantly, the key takeaway from SATCON1 was that *no combination of mitigations will eliminate the impact of satellite constellations on optical-infrared astronomy.* In summary, the impact on major survey science from existing (e.g. Zwicky Transient Facility) to imminent projects (such as the Rubin Observatory's LSST) will be very significant. Additionally, a JASON report highlighting potential mitigations strategies is slated for public release in 2021.

Furthermore, the impact of satellite constellations extends beyond the optical and infrared spectral regimes to include radio frequencies. The 11 GHz region that will be used for satellite downlinks, as well as the V-band (40-75 GHz) expected to be used for inter-satellite communications, are both in frequency regions that are vital to radio astronomy observations. Radio telescopes are thus highly susceptible to these unwanted signals that will impinge upon bands being used for astronomical observations, with little protection from federal or international policies.

Ongoing coordination between all stakeholders and across all phases of satellite approval, design, build, and launch processes is critical for understanding and minimizing the impact of these satellites on astronomical observations.

Finding: Continued outreach and connections with private corporations planning and deploying satellite megaconstellations is required.

To achieve increased connections, the agencies are considering the formation of an e-institute to bring stakeholders at the companies and astronomical observatories together to model and then actually observe the effects of satellites on astronomical observations.

Recommendation: The AAAC recommends continued and augmented cross-agency efforts to provide data-driven recommendations for telecommunication satellite constellations that would have the lowest impact on astronomical studies.

4.4 Planetary protection

The Planetary Protection Coordination Office, established in 2016 at NASA, is charged with leading national (interagency) and international efforts to detect, track, and mitigate asteroid impact hazards. The National Near-Earth Object Preparedness Strategy and Action Plan, issued by the White House in 2018, provided updated guidance concerning enhancing Near-Earth Object (NEO) detection, characterization and deflection, modeling and information integration, international cooperation, and emergency protocols. Although by 2010 NASA had successfully fulfilled the 1994 Congressional mandate to find at least 90% of the potentially hazardous NEOs larger than 1 km diameter, the population of smaller NEOs remains underdiscovered.

The George E. Brown Jr. Near-Earth Object Survey Act, a section of the 2005 NASA authorization act, directed NASA to detect at least 90 percent of NEOs at least 140 meters in diameter by the end of 2020; it will take more than 30 years to achieve this goal at the current discovery rate. While NASA is exploring the development of a dedicated space-based infrared survey telescope with the goal of finding 90% of the potentially hazardous asteroids within 10 years, it is recognized that major ground-based astronomical surveys such as the Dark Energy Survey (DES) and the Vera C. Rubin Observatory can also play a significant role in discovering NEOs > 140 m diameter. Including the anticipated return from the Rubin Observatory by the end of its 10-year baseline survey, existing dedicated ground-based NEO surveys will achieve a catalog completeness of roughly 75% by 2032. Clearly, additional facilities on the ground and in space will be needed to meet the George E. Brown Act's completeness goals, even though the deadline to meet those goals has passed.

Finding: The goal of detecting 90% of NEOs > 140 m diameter has not been met, and will take decades to meet at the current rate of discovery with the current slate of facilities.

Finding: The potential contributions of current and future ground-based astronomical surveys to the discovery of NEOs and to the achievements of the goals set forth in the George E. Brown Act are significant.

In addition to ground based surveys for NEOs, NASA is planning on two missions of significant importance to planetary protection. The first mission, the Double Asteroid Redirection Test (DART) is nearly complete, and is slated for launch in 2021. The second mission, the NEO Surveyor, is an infrared surveying telescope that will add key capabilities beyond those of the ground based surveys, in particular, the ability to look closer on the sky to the Sun, and the ability to more accurately determine an object's size. The NEO Surveyor mission was slated to meet the Key Decision Point milestone in late 2020, but has now been postponed due to external budget factors, adding uncertainty and likely significant delay to the mission launch date.

Finding: The potential contributions of the NASA NEO Surveyor mission to the discovery of NEOs and to the achievements of the goals set forth in the George E. Brown Act are significant. The AAAC expresses concern over the delay of the Key Decision Point milestone for the mission.

Given the gaps in existing capabilities and some uncertainties in future capabilities on both the ground and in space, continued coordination between NASA and NSF will be essential to meet the goals set forth in the George E. Brown Act.

Recommendation: The AAAC encourages ongoing NASA/NSF coordination, through the Planetary Protection Coordination Office, to clearly define the role that existing and future ground and space-based astrophysics surveys and facilities can play in the discovery and characterization of NEOs.

4.5 Protecting the electromagnetic spectrum for Astronomical Research:

On behalf of the US astronomical community, NSF has been proactive in safeguarding the radio portion of the electromagnetic spectrum. With the on-going deployment of 5G technology, there is increased pressure on the high frequency portion of the spectrum. The continuing efforts include working both with the national astronomy community and international radio astronomy projects like the SKA to highlight the need for the protected bands. One action item to emerge from these efforts is the proposal for a vote at the next World Radio Conference (WRC, expected in 2023) to protect bands within the 275-450 Ghz window where there is great pressure from mobile telephones. Currently there are very few regulations for frequencies >275Ghz. At the 2020 Annual Meeting of the IEEE-GRSS Frequency Allocations in Remote Sensing Technical Committee (FARS-TC), the international spectrum manager at NASA re-iterated protection for remote sensing activities and astronomy.

In addition to protecting frequencies, there is also a significant need to maintain the existing geographic protected regions. In addition to the region surrounding Green Bank, trans-national astronomical projects with large US involvement like ALMA will need additional protections.

The current protected region designation carries protection from ground-based signals, but a significant additional threat to these radio quiet zones is represented by high altitude (balloon-based) broadcast platforms and by the deployment of satellite constellations (see also Section 4.2 above). NSF is working with international agencies towards a plan for WRC 2027 to regulate the bands satellite constellations can use to communicate to Earth--given the broad coverage of their signal and the increase of satellites, even by 2027 there is the likelihood that multiple satellites will always be “visible” in the radio sky over every radio observatory. Because the current regulations do not constrain the transmission from satellites, it is crucial that the spectrum protection conventions be modernized.

Finding: Radio quiet zones and the preservation of the protected regions of the radio spectrum are critical for the future of radio astronomy.

Recommendation: The AAAC recommends that NSF and NASA should continue to work with international astronomy agencies and coordinate with the relevant IEEE technical committees involved in to create and preserve geographical radio quiet zones for radio astronomy.

Recommendation: We recommend that the current definition of radio quiet zones, and the federal legislation establishing them, be modernized and updated to include radio emission from satellites and high-altitude transmitters (e.g. drones and high-altitude balloons) and not just terrestrial signals.

4.6 The role of AI in astronomy and astrophysics

Machine learning (ML) and Artificial Intelligence (AI) are becoming increasingly prevalent within astronomy and astrophysics for use in the analysis of large astronomical survey data, the development of generative models for cosmology and astrophysics, and the creation of physics informed machine learning techniques. Advances in these computational approaches will require collaboration across academia and industry to ensure that the methodologies map appropriately to the needs of astrophysics (e.g. with a focus on the interpretability of AI and ML models and features and the development of uncertainty quantification). For this to occur will require investment in training (across all career stages) in the development and application of statistical methodologies, the use of modern computational frameworks, the adoption of emerging technologies (computational and statistical), and the adoption of best practices in software development.

NSF has a number of “Big Ideas” programs including Harnessing the Data Revolution and Quantum Leap that could directly impact astronomical research. In previous announcements for AI institutes under these programs, AST was excluded from the areas of support. AST should evaluate the needs for AI in astrophysics in the context of current and planned experiments and assess how these needs can be met. DOE and NASA are making considerable investments in AI/ML as well both at their centers, and with targeted solicitations. Coordination across the agencies to ensure that methodological developments in AI and ML broadly enhance astrophysics research could significantly increase the science returns from current and future missions and experiments.

Many of the advanced statistical approaches have in addition ethical and societal implications. As we train a workforce that will work in academia and industry - training in ethics is essential and should be integrated within educational programs

Recommendation: The AAAC recommends that the agencies continue the development of AI and ML initiatives across astrophysics including the potential creation of institutes focused on AI in the context of astrophysics.

5 Ensuring a diverse and inclusive community

As with any other endeavor, the astronomical sciences in the United States cannot meet their charge or their potential without drawing from the full spectrum of talent and creative potential in the nation. Multiple events in 2020 brought to the fore the systematic biases that pervade federal, state, and local governments and agencies. Astronomy as a field is not immune from these biases, and as a result, does not reflect the diversity of the country in its ranks. In recent months, the agencies have begun new initiatives around DEI, both at agency-wide and divisional levels. For example, NASA established internal Anti-Racism Action and DEIA Working Groups. Additionally, a National Academies Study is now underway to identify barriers to next generation mission proposal investigators. Furthermore, NASA has begun to employ dual-

anonymous proposal reviews across its research portfolio to help mitigate implicit bias. Similar efforts are being explored at NSF and DOE, but with varying degrees of scope. The AAAC feels that these efforts must continue to mitigate the implicit biases known to pervade the field.

Finding: The AAAC supports the expansion of dual anonymous reviews at NASA.

Recommendation: The AAAC recommends continuation of the expansion of dual anonymous reviews within NASA, and requests that NSF and DOE develop and adopt similar reviews or other practices that provide the committee with sufficient evidence of bias mitigation in their review processes.

Although the efforts to date emerge from a desire to further DEI initiatives, they lack a critical input to both direct their evolution, and to test their effectiveness: robust demographic data. For example, dual anonymous effectiveness is currently measured by comparing past and previous results based on only *inferred* proposer demographics (e.g. gender). Multiple reasons exist for the lack of demographic data availability. In some cases, the data exists, but is not generally available due to restrictions placed on the agencies by OMB and/or Congress. In other cases, the biases have been deemed, incorrectly, not to exist, leading to a lack of data collection at all. Even when the data exists and is available, it is often incomplete. The tragic events in 2020 that led to a renewed national focus on DEI issues demand that the situation surrounding availability of demographic data, both within the agency workforces, and within the researcher populations funded by agency grants, change immediately, so that progress can be properly gauged going forward.

The Biden-Harris Administration has already signaled a desire to increase access to demographic data within the federal system. For example, a recent Executive Order (EO) states in part:

Sec. 9. Establishing an Equitable Data Working Group. Many Federal datasets are not disaggregated by race, ethnicity, gender, disability, income, veteran status, or other key demographic variables. This lack of data has cascading effects and impedes efforts to measure and advance equity. A first step to promoting equity in Government action is to gather the data necessary to inform that effort.

The AAAC agrees with the initiative outlined in the EO to record and collect relevant data in order to conduct a proper census of the DEI in all the activities of the agencies. Moreover, the data must be made available for analysis to be useful. For example, NASA is currently collecting opt-in data for everyone who uses their NSPIRES grant submission system. Presently, these data are collected and currently held at the Office of Chief Scientist (OCS) and analysis of the data for effective use by individual divisions such as the Astrophysics Division is hampered by the lack of access to the data and ease of availability.

Finding: The current lack of public access to demographic data for federally funded research in the astronomical sciences severely hampers the ability for review of efficacy of diversity, equity, and inclusion initiatives at NASA, NSF, and the DOE Office of Science.

Recommendation: The AAAC recommends that the NASA Office of the Chief Scientist share its demographic data or at a minimum provide the results of analysis of the data to the directors within NASA's Science Mission Directorate so that the divisions can evaluate the effectiveness of their processes and policies for DEI.

Recommendation: The AAAC requests that the NSF and DOE collect and disseminate demographic data for astronomy and astrophysics awardees of funds from those agencies.

In addition, fine-grained data is needed. For instance, the data collected by NASA's NSPIRES lacks additional nuances such as sexual orientation, the non-binarity of gender orientation, and the lumping of all Asian Americans into one category. More detailed data that captures diversity along multiple dimensions is needed to understand the extent to which DEI is a problem, the kinds of interventions that might be needed and the implementation of these interventions. While additional guidance and directives on these matters is expected from the Astro2020 Decadal Report, AAAC strongly advises the agencies to set up structures to collect and share these demographic data. In addition, since astrophysics is very international in terms of the origin of its workforce, it is also important to distill the differences between US-residents and US-citizens and foreign collaborators in these demographics.

Recommendation: AAAC recommends that NASA, NSF, and DOE work with OMB to collect the needed fine-grained demographic data to understand the proposal pool and the awardee pool for its entire portfolio of grants.

Recommendation: The AAAC requests that NASA, NSF, and DOE provide regular updates to the committee on demographic data and DEI initiatives.

6 Implementation of NWNH Recommendations

Given the impending release of the Astro2020 report, we only will devote a short space to the review of the agency responses to NWNH recommendations, with a focus on issues resulting from the FY2022 budget request, and those of particular interest to the AAAC.

6.1 Ground-based projects

6.1.1. The MSIP funding line within NSF

In response to the 2010 decadal survey, the NSF astronomy division initiated the Mid-Scale Innovations Program (MSIP) specifically to fund mid-scale astronomy projects with budgets larger than the foundation-wide MRI program limits but not large enough to be funded through the Major Research Equipment and. Facilities Construction (MREFC) program. Although highly variable in total funds allocated, the MSIP program has consistently been over-subscribed and proved to be an important avenue for funding the current generation of astronomy surveys, instruments and projects. The newly introduced NSF-wide Mid-Scale Research Infrastructure (MSRI) is also a source of funding for projects of this scale.

Finding: Although constrained by the resources available, the MSIP program has consistently been over-subscribed and variably funded. MSIP has proven to be an important avenue for funding the current generation of astronomy surveys, instruments and projects, and for realizing the science goals put forward by the Decadal Surveys.

Recommendation: We recommend that NSF continue to offer the MSIP program within the AST division in parallel with, but separate from the NSF-wide MRI and MSRI calls. We further recommend that NSF strive to stabilize, and ideally increase the MSIP funding level cycle-over-cycle.

Currently, the committee is not able to robustly assess the success of proposal programs available to the astronomical community by NSF, including, but not limited to MSIP. Although the data often exist, it can be made more easily discoverable for committee discussion.

Recommendation: NSF should provide to the AAAC data summarizing the proposal success statistics for MRI, MSIP, and MSRI awards to better gauge the impact of these programs. Furthermore, NSF should provide a summary of any significant astronomy focused infrastructure awards outside the MRI, MSIP, and MSRI programs along with the source of those funds, namely whether they come from within the AST budget or outside of it.

6.1.2 The Vera C. Rubin Observatory

The 2020-2021 timeframe was notionally to be a very significant one for the actions needed to complete the Vera C. Rubin observatory and begin its ten year Legacy Survey of Space and Time. COVID-19 significantly impacted the construction efforts in Chile, effectively stopping the completion of the telescope dome enclosure, and the arrival and integration of key telescope components. Additionally work was slowed on completion of the main workhorse camera. Given the pace of COVID-19 infections in Chile at the time of writing, new delays may come to impact the construction activities, but the pace of vaccination in the mainland United States brings optimism for assembly, integration, and test activities there, along with the implementation of new data processing infrastructure.

In addition to construction efforts and delays, a new process of international in-kind contributions to the project was established, along with a new data rights policy for member institutions and the wider community. As of writing, continued efforts are being made at optimizing the LSST cadence for science yield, along with an analysis of survey changes that may need to be made to mitigate satellite megaconstellation impacts.

Finally, as with previous years' findings, the AAAC remains concerned that the operations costs for the Rubin observatory will have a significant impact on budget portfolio balance within NSF AST.

Finding: The AAAC is gratified to see continued, significant progress by the NSF and DOE toward completion of the highest priority decadal ground-based facility, the Vera C. Rubin Observatory, which is advancing toward the start of survey science operations in 2023.

Finding: Operations of the Rubin Observatory may place significant strain on the ability for NSF and DOE/Cosmic Frontier to maintain a balanced portfolio of facilities and other funding.

Recommendation: The AAAC urges NSF and DOE to put in place a long-term operations plan that will, while maintaining a balanced overall portfolio, ensure that the US science community can capitalize on the substantial investment in the Rubin Observatory.

6.1.3 Arecibo Observatory

The Arecibo Observatory (AO), located in Arecibo, Puerto Rico, suffered a series of cable failures between August - November 2020 that ultimately led to the collapse of the 305-m reflector telescope on December 1, 2020. With human safety as the highest priority, it is a testament to all management organizations, site personnel and contractors that such a catastrophic event did not result in any injuries or loss of life. NSF and its contractors are conducting a forensic analysis to determine the causes of the collapse, and in parallel with that effort NSF has requested an independent study of the cable failures by the National Academies of Science, Engineering, and Medicine. Site restoration, environmental mitigation, and historical and cultural preservation activities are also ongoing. The collapse of the 305-m represents a significant loss to the scientific community as well as the residents of Puerto Rico. AO continues to support scientific research using some of the remaining facilities on site, but the long-term plan for restoring the unique capabilities afforded by the 305-m remains unclear. One challenge with relying on the Decadal Survey for guidance in terms of how to prioritize AO among other ground-based facilities is that AO serves multiple scientific communities (astrophysics, solar/space physics, planetary), each of which is on a separate decadal survey schedule. In Spring 2021 NSF plans to sponsor a community workshop for the various stakeholders and in parallel with that, explore ways that they can strengthen ties between the AO and the Puerto Rican community.

Finding: The collapse of the 305-m reflector telescope at Arecibo Observatory represents a significant loss to both the astronomical community and the people of Puerto Rico.

Recommendation: The AAAC strongly supports the proposed discussions among the various stakeholders to ensure that they will all continue to have a voice in the ultimate fate of Arecibo Observatory.

6.2 The Facility Operation Transition Activity

Of significant concern to the committee and beyond is the continued tension with the NSF AST division between the facilities operations and the research and instrumentation funding. Currently, facilities operations represent the majority of the AST division budget. While significant effort has been made within AST to help address the issue and budget tensions, including the portfolio review of previous years, more funding is needed to bring appropriate balance.

In the FY 2020 budget for NSF, a small pilot program, the Facility Operation Transition activity, was launched to help lessen the budgetary pressure of operations and maintenance, and to help transition some facilities into divestment. This pilot program, however, was only assigned $10 million, a level far below what is needed to appropriately balance the AST division budget portfolio, particularly in the light of significant operations costs attached to ALMA, DKIST, and the upcoming Rubin Observatory. Given the support from Congress for the program, the AAAC hopes to see

this or a similar initiative obtain the finding it needs to provide a stable, long-term solution to the operations and maintenance costs currently within AST.

Finding: The AAAC strongly supports the goals of the Facility Operation Transition activity, but expresses concern that the funds allocated to this activity, even as a pilot, are insufficient.

Recommendation: Congress should provide sufficient appropriations to NSF to ensure that NSF's strategic commitments to operations and maintenance of its major facilities can be met, but not at the expense of the research and instrumentation funding portfolio within NSF-AST. The AAAC recommends a significant augmentation of the Facility Operation Transition activity.

6.3 Space-based Projects

6.3.1 The Nancy Grace Roman Space Telescope

In February of 2020, the WFIRST mission, the top-ranked space mission in the 2010 Decadal Survey, successfully passed the KDP-C review and entered Phase C of the mission, establishing a mission budget and schedule. In May of 2020, the mission was renamed to the Nancy Grace Roman Space Telescope. The mission is slated to launch in the mid 2020s. In multiple years, mission funding was not requested in the Trump administration's budget request, but then later appropriated by Congress.

Finding: The AAAC strongly endorses the renaming of WFIRST to the Nancy Grace Roman Space Telescope.

2021 will serve to be a very important year for the Roman Telescope, with a ROSES 2021 call to reconstitute science teams, and with multiple construction and review activities. The impacts of COVID-19 on the Roman timeline and budget are currently not well-characterized, but are very likely to represent a budget increase and schedule slip. Nevertheless, the AAAC applauds NASA's efforts to continue mission development within a highly uncertain environment. As in past years, the AAAC continues to endorse inter-agency cooperations between survey efforts to best maximize the science yield of Roman and major ground-based surveys

Recommendation: The AAAC encourages inter-agency initiatives to maximize the scientific yields of the Vera C. Rubin Observatory and Nancy Grace Roman Space Telescope by considering survey designs that maximize the synergy between these two facilities.

6.3.2 The Explorers program

The NASA Astrophysics Division continues to have a pipeline for focused Explorer Missions and Missions of Opportunity. Over the past decade, the division has maintained a pace of a mission selection every 2-3 years (~4/decade). Two SMEx missions missions are in the study phase, with a downselect expected for the Fall of 2021. Similarly, there are two Missions of Opportunity being

studied. The Division plans to continue developing these missions at the current pace to provide a complement to the larger missions, consistent with the 2010 Decadal Survey recommendations.

6.3.3 CubeSats, SmallSats and the Pioneers program

The NASA Astrophysics Division is ramping up its support for SmallSat, CubeSat and RideShare missions. This responds to a need in the community for rapid-turnaround missions that are even more focused and less expensive than Explorer class missions. This has been very popular, with 24 proposals for smallsat Pioneer missions received in the 2020 Call, as well 32 proposals for CubSat astrophysics studies. The Division budgets for roughly one CubeSat start per year (each has a total cost cap of 5 million dollars), and anticipates maintaining that pace going forward. In the last call, four smallsats (with a lifetime cap of 20 million dollars) were selected for development studies. The Division anticipates continuing the program going forward.

Finding: The AAAC is encouraged by the popularity of the Pioneers program, and the success in bringing the first CubeSat projects to fruition. We are also encouraged that the program is serving as a way for first-time PIs to gain experience with NASA missions that will help with future missions. We are particularly encouraged that 100% of both the CubeSat and Pioneer programs have first-time PIs, with diversity across multiple axes.

Recommendation: The AAAC recommends that NASA Astrophysics continue to maintain the Pioneers program at least at its current level, and continue its efforts to recruit new mission PIs that move into leadership positions for the larger missions of the 2020s and 2030s.

6.3.4 The James Webb Space Telescope

JWST has undergone significant testing in the recent year, completing the full spacecraft integration, the last of the sunshield deployment tests, and the final rounds of environmental testing. As of writing, only a small number of deployment tests remain. The observatory is slated to be packaged for shipping to French Guiana, where it will be launched on an Arianne rocket in late 2021.

In addition to observatory preparation, the astronomical community submitted proposals for Cycle 1 of JWST observations. Over 1,100 proposals were received. The Time Allocation Committee met in February and March of 2021, and final Cycle 1 selections are to be announced in the coming weeks.

Finding: NASA has made significant positive progress towards the completion of the JWST mission activities leading to a late 2021 launch. As of this writing the expected launch date remains as scheduled to be October 2021.

6.3.5 SOFIA

COVD-19 significantly impacted SOFIA operations, with no flights between March and August 2020, and the deployment to New Zealand cancelled. As in previous years, the AAAC remains concerned about the scientific output of SOFIA, irrespective of the impacts of COVID-19 on flight

operations. The committee thus continues to recommend that SOFIA be considered in the NASA Senior Review of operating missions.

Recommendation: The AAAC recommends that SOFIA undergo senior review including a decision on mission extension, in line with normal NASA review procedures.

7 Astro2020 and other major strategic surveys

The Astronomy and Astrophysics Decadal Survey (Astro2020) will develop a comprehensive research strategy and vision for a decade of transformative science at the frontiers of astronomy and astrophysics. This exercise, undertaken every 10 years, is instrumental in setting the priorities for missions and initiatives, new directions for research and guidance for current activities with specific recommendations for NASA, NSF and DOE. As reported by the Co-Chairs of the Astro2020 Decadal Committee to the AAAC, they continue to make steady progress despite COVID-19. The Steering Committee has been holding all of its meetings virtually and has been engaging in a vigorous schedule of weekly telecons and multi-day meetings to continue its deliberative work. The goal remains to deliver the report in Spring 2021, and the recommendations are eagerly awaited. Recommendations are expected in the realm of science questions, ranking of submitted legacy space missions and ground-based facilities, as well as on the state of the profession, including articulation of EDI priorities and goals.

Finding: The Astro2020 Steering Committee has made significant progress towards completing and delivering the survey to the community in spite of the significant challenges of the COVID-19 pandemic.

At the start of the Astro2020 process, the agencies advocated for an ambitious survey that would yield transformative science for the next decade and well beyond. In support of the process, the agencies commissioned a number of large space mission concept studies, probe class space mission studies, and similar efforts on major ground-based facilities across the electromagnetic spectrum. Along with highlighting the significant science gains these new capabilities would bring, these studies presented a significant advance over previous exercises in exploring the technological developments, needed, the risks, the budgets, and the schedules. The AAAC endorses and applauds these efforts. Nevertheless, the budget profiles, particularly for NASA and NSF, are likely to be unable to bring many of the new capabilities to fruition in the coming decades without augmentation and particular attention paid to budget phasing, including technology development.

Astro2020 comes at a particularly crucial time for the astronomical sciences in the United States. The nation's leadership in astronomy and astrophysics is significantly threatened by the combination of under-investment in the priorities set out by the community in the Decadal Surveys and other strategic surveys and rising competition by other nations or international consortia. Unlike the United States, where funding is determined annually, consortia such as ESO have significantly enhanced financial stability, allowing for more secure and realizable long-term planning. Furthermore, the agencies must be able to effectively plan for the implementation of Decadal priorities, further underscoring the need for budget growth predictability.

Finding: Leadership by the United States in the astronomical sciences is significantly threatened by budget uncertainty, lack of growth, and increasing international competition.

Finding: Absent appropriate and robust planning, resources, and resource phasing, the agencies will be unable to effectively implement an ambitious and transformative set of recommendations from Astro2020.

The Planetary Science and Astrobiology Decadal Survey is also currently underway and will focus on 2023-2032 to assess key scientific questions in planetary science and astrobiology, identify priority medium- and large-class missions and other initiatives, and present a comprehensive research strategy for the 2023-2032 timeframe. Given the natural overlap with many of the astrophysics missions and facilities considered by Astro2020 and the astrobiology components of this survey, our concerns about implementation of this survey's recommendations are similar to those above.

Finally, the High Energy/Particle physics community conducts an independent, analogous "Snowmass" process led by APS/DPF to identify science questions, funding priorities and directions for the coming decade. The Snowmass Deliberation process started in summer 2019 and will culminate in a workshop in summer 2022 (moved out a year due to covid-19 to ensure broad engagement and the fullest possible participation of the HEP community).

8. Additional Matters of Note

8.1 Agency budget delivery

Given the AAAC's charge, particularly the focus on interagency coordination and collaboration, it is essential that the Committee have the most relevant and timely information available from the agencies. It is difficult for the Committee to properly evaluate agency efforts if adopted budgets, even at moderate levels of specificity, are not provided in a manner that allows for joint analysis. For example, the NSF budget implementation is described to the AAAC effectively a year after that from other agencies.

Finding: The policies surrounding reporting of proposed and implemented fiscal year budgets are not uniform across the agencies the AAAC is charged with advising. In particular, the NSF budget reporting cycle lags by a year that of the other agencies, significantly hampering the AAAC's ability to meet its charge.

Recommendation: NSF should report their budget forecasts and implementations to the AAAC so as best to overlap with the other agency report timelines.

8.2 AAAC report timing

The statutory date for report submission by the AAAC is March 15 (although this year, the delivery date was delayed due to the impacts of the COVID-19 pandemic). This date requires that the Committee and agency representatives meet, the Committee formulate recommendations, and the report be drafted and submitted within approximately one month of the notional delivery date of the President's annual budget request to Congress. Given rapidly shifting and uncertain budget scenarios, it is often the case that the report of the AAAC is not fully informed by important budget developments. The AAAC wishes to judiciously fulfill its charter and provide timely and meaningful recommendations. In order to do so, a change to the statutory due date would be

extremely helpful. Generally, a due date of, for example, 45-60 days following the submission of the President's budget, would provide sufficient time for the AAAC to fully interact with the funding agencies and formulate its recommendations.

Finding: The statutory deadline, March 15th, for the submission of the AAAC annual report does not allow sufficient time for the committee to react to budget developments that typically occur in the first two months of each calendar year.

Recommendation: the AAAC recommends that the annual report deadline be changed from a fixed date to a deadline 45-60 days following the submission of the President's budget, so as to enable sufficient opportunity for the committee to interact with the funding agencies, understand the impact of the President's budget, and formulate recommendations. The AAAC would endeavor to still meet the current deadline of March 15th when possible.

Appendix A: Explanation of Abbreviations

AAAC	**Astronomy and Astrophysics Advisory Committee**
AAS	**American Astronomical Society**
ALMA	**Atacama Large Millimeter/submillimeter Array**
CMB	**Cosmic Microwave Background Radiation**
DESI	**Dark Energy Spectroscopic Instrument**
DKIST	**Daniel K. Inouye Solar Telescope**
DOE	**Department of Energy**
EM	**Electro Magnetic**
FACA	**Federal Advisory Committee Act**
FY	**Fiscal Year**
HEP	**High Energy Physics**
HST	**Hubble Space Telescope**
JWST	**James Webb Space Telescope**
KPNO	**Kitt Peak National Observatory**
LIGO	**Laser Interferometer Gravitational-Wave Observatory**
LSST	**Legacy Survey of Space and Time**
MPS	**Mathematical & Physical Sciences (NSF Directorate for …)**
MREFC	**Major Research Equipment and Facilities Construction**
MRI	**Major Research Instrumentation**
MSIP	**Mid-Scale Innovation Program**
NASA	**National Aeronautics and Space Administration**
NASA/APD	**National Aeronautics and Space Administration Astrophysics Division**
NEID	**NN-explore Exoplanet Investigations with Doppler spectroscopy**
NOAO	**National Optical Astronomy Observatory**
NRC	**National Research Council**
NSF	**National Science Foundation**
NSF/AST	**National Science Foundation Division of Astronomical Sciences**
NSF/OPP	**National Science Foundation Office of Polar Programs**
NSF/PHY	**National Science Foundation Division of Physics**
NWNH	**The 2010 NRC decadal survey report "*New Worlds, New Horizons in Astronomy and Astrophysics*"**

NWNH-AMA	**The 2016 NRC mid term assessment report, "*New Worlds, New Horizons in Astronomy and Astrophysics, A Midterm Assessment*"**
OIR	**Optical InfraRed**
OMB	**Office of Management and Budget**
P5	**Particle Physics Project Prioritization Panel**
R&D	**Research and Development**
SMD	**Science Mission Directorate, NASA**
SOFIA	**Stratospheric Observatory for Infrared Astronomy**
TESS	**Transiting Exoplanet Survey Satellite**
WFIRST	**Wide-Field Infrared Survey Telescope**