Report of the Astronomy and Astrophysics Advisory Committee

March 15, 2014

UNIVERSITY OF CALIFORNIA, DAVIS

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March 15, 2014

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Office of the Administrator
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Dr. Ernest Moniz, Secretary of Energy
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The Honorable John D. Rockefeller, IV, Chairman
Committee on Commerce, Science and Transportation
United States Senate
Washington, DC 20510

The Honorable Ron Wyden, Chairman
Committee on Energy & Natural Resources
United States Senate
Washington, DC 20510

The Honorable Lamar Smith, Chairman
Committee on Science, Space and Technology
United States House of Representatives
Washington, DC 20515

Dear Dr. Marrett, Mr. Bolden, Secretary Moniz, Chairman Rockefeller, Chairman Wyden, and Chairman Smith:

I am pleased to transmit to you the annual report of the Astronomy and Astrophysics Advisory Committee for 2013–2014.

The Astronomy and Astrophysics Advisory Committee was established under the National Science Foundation Authorization Act of 2002 Public Law 107-368 to:

(1) assess, and make recommendations regarding, the coordination of astronomy and astrophysics programs of the Foundation and the National Aeronautics and Space Administration, and the Department of Energy;
(2) assess, and make recommendations regarding, the status of the activities of the Foundation and the National Aeronautics and Space Administration, and the Department of Energy as they relate to the recommendations contained in the National Research Council's 2010 report entitled *New Worlds, New Horizons in Astronomy and Astrophysics*, and the recommendations contained in subsequent National Research Council reports of a similar nature;
(3) not later than March 15 of each year, transmit a report to the Director, the Administrator of the National Aeronautics and Space Administration, the Secretary of Energy, the Committee on Commerce, Science and Transportation of the United States Senate, the Committee on Energy and Natural Resources of the United States Senate, and the Committee on Science, Space, and Technology of the United States House of Representatives, on the Advisory Committee's findings and recommendations under paragraphs (1) and (2).

The attached document is the eleventh such report. The executive summary is followed by the report, with findings and recommendations for NSF, NASA and DOE regarding their support of the nation's astronomy and astrophysics research enterprise, along with detailed recommendations concerning specific projects and programs.

I would be glad to provide you with a personal briefing if you so desire.

Sincerely yours, on behalf of the Committee,

Andreas Albrecht
Chair, Astronomy and Astrophysics Advisory Committee

cc: Senator John Thune, Ranking Member, Committee on Commerce, Science and Transportation, United States Senate
Senator Lisa Murkowski, Ranking Member, Committee on Energy & Natural Resources United States Senate
Representative Eddie Bernice Johnson, Ranking Member, Committee on Science, Space, and Technology, United States House of Representatives
Senator Bill Nelson, Chairman, Subcommittee on Science and Space, Committee on Commerce, Science and Transportation, United States Senate
Senator Ted Cruz, Ranking Member, Subcommittee on Science and Space, Committee on Commerce, Science and Transportation, United States Senate
Senator Barbara Mikulski, Chairwoman, Subcommittee on Commerce, Justice, Science, and Related Agencies, Committee on Appropriations, United States Senate
Senator Richard Shelby, Ranking Member, Subcommittee on Commerce, Justice, Science, and Related Agencies, Committee on Appropriations, United States Senate

Senator Dianne Feinstein, Chairwoman, Subcommittee on Energy and Water Development, Committee on Appropriations, United States Senate
Senator Lamar Alexander, Ranking Member, Subcommittee on Energy and Water Development, Committee on Appropriations, United States Senate
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Representative Daniel Lipinski, Ranking Member, Subcommittee on Research and Technology, Committee on Science, Space and Technology, United States House of Representatives
Representative Mike Simpson, Chairman, Subcommittee on Energy and Water Development and Related Agencies, Committee on Appropriations, United States House of Representatives
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Representative Chaka Fattah, Ranking Member, Subcommittee on Commerce, Justice, Science and Related Agencies, Committee on Appropriations, United States House of Representatives
Representative Steven Palazzo, Chairman, Subcommittee on Space, Committee on Science, Space, and Technology, United States House of Representatives
Representative Donna Edwards, Ranking Member, Subcommittee on Space, Committee on Science, Space, and Technology, United States House of Representatives
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Dr. Maria Womack, Program Director, Division of Astronomical Sciences, National Science Foundation

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Dr. Stefi Baum, Rochester Institute of Technology
Dr. James Buckley, Washington University St. Louis
Dr. William Cochran, University of Texas at Austin
Dr. Priscilla Cushman, University of Minnesota
Dr. Craig Hogan, University of Chicago
Dr. Mordecai-Mark Mac Low, American Museum of Natural History, Vice Chair
Dr. Geoffrey Marcy, University of California, Berkeley
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Dr. Angela Olinto, University of Chicago
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Dr. Angela Speck, University of Missouri
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Executive Summary

Astronomy and astrophysics have a long tradition of advancing the scope of human knowledge through astonishing discoveries and steady progress in our quest to understand the universe around us. Over the years the US has invested strongly in astronomy and astrophysics. The outcomes of this investment have captivated the public, inspired our children to study scientific and technical fields, and directly resulted in two of the last ten Nobel Prizes in Physics.

This report reviews the accomplishments over the last year of the astronomy and astrophysics community and the agencies that support us. We give particular scrutiny to the extent to which the priorities of the National Research Council Astronomy and Astrophysics Decadal surveys are being achieved, and the degree to which the different agencies are working well together on projects that are supported jointly by more than one agency. We emphasize the 2010 decadal survey, *New Worlds, New Horizons in Astronomy and Astrophysics* (*NWNH*), but also discuss projects endorsed by earlier decadal surveys when appropriate. Our report tells a story of impressive accomplishments by agencies and scientists in the context of a challenging budget environment.

In this report we recommend *Principles for Access to Large Astrophysics Projects and Facilities* in order to enable agreements among the funding agencies and between the agencies and third parties that provide competitive access to important facilities and open access to data. Such "open skies" policies are crucial to maximizing scientific productivity.

Our findings and recommendations, collected below, summarize the essential points of our report.

Collected Findings and Recommendations

***FINDING*: Thanks to a long history of strong planned and coordinated US investment in Astronomy and Astrophysics, the US program has achieved numerous advances and breakthroughs over the past year.**

***FINDING*: Competitive access to important facilities and open access to data are widely regarded as key elements of best practices in the allocation of scientific resources. Their implementation can greatly enhance the impact of a given scientific investment. These best practices already guide the work of US funding agencies**

***RECOMMENDATION*: We recommend the Principles for Access to Large Astrophysics Projects and Facilities be used in negotiating agreements regarding access to large astrophysics projects and**

facilities. We hope this recommendation will advance a culture of transparency and openness about our scientific process as we continue to promote best practices.

Principles for Access to Large Federally Funded Astrophysics Projects and Facilities

In its 2013 annual report[1], the Astronomy and Astrophysics Advisory Committee (AAAC) recommended that "Negotiations towards the coordination of projects or the development of partnerships should proceed on the basis of the principles of reciprocal participation and mutually agreed sharing of costs and responsibilities." In the current environment of complex partnerships there is a need to articulate the principles that enable the best science within constrained resources in order to realize large astrophysics projects and facilities for the benefit of the global astrophysics community. The resulting document specifies the advantages of global coordination, open data, and open access. It defines how such principles can be implemented via participation, opportunity and reciprocity. The document itself can be found in section 3 of the report, as well as in the form of a standalone document on the AAAC web site[2]

The AAAC believes that addressing these principles will lead to the most productive scientific use of current and future generations of large astrophysics projects and facilities. We understand that there may be grounds for justifiable deviations from these principles, such as treaty obligations or statutory restrictions. However, by formulating these principles, and recommending that any rationale for deviation must be explicitly articulated, we hope to create a climate in which the best possible science can be achieved.

Thus, the AAAC recommends the following for large astrophysics projects and facilities; that the Office of Science and Technology Policy (OSTP) Division of Science, the National Aeronautics and Space Administration (NASA) Astrophysics Division, the National Science Foundation (NSF) Division of Astronomical Sciences, and the Department of Energy (DOE) Office of High Energy Physics:

- apply the following principles to all projects and facilities that are funded by these organizations
- apply these principles to international collaborations, to collaborations among Federal agencies, and to collaborations with other public and private entities within and outside the United States,
- assess all proposed projects and facilities against these principles before deciding to undertake them, and
- discuss these principles with their partners in current and future projects and facilities.

These organizations should attempt to reach a common understanding with their partners on application of these principles to all large partnership projects and facilities in astrophysics. Deviations from these principles should be justified and any rationale for deviation should be publicly articulated.

FINDING: The agencies and the community as a whole have done an impressive job of moving forward with the NWNH priorities (and priorities from previous Decadal Surveys) as well as possible, given the disappointing budget environment. However budget realities have slowed the progress of new discoveries in astronomy and astrophysics.

[1] http://www.nsf.gov/mps/ast/aaac/reports/annual/aaac_2013_130308finalreport.pdf
[2] http://www.nsf.gov/mps/ast/aaac.jsp

***RECOMMENDATION**: Should the budget situation improve, we recommend more aggressive progress be made on the NWNH priorities, to move us closer to the bold vision endorsed in NWNH.*

***FINDING**: The NSF Portfolio Review Committee (PRC) has done a good job in a difficult situation, recommending tough choices that must be made in our challenging budget environment in order to make significant headway on NWNH priorities.*

***RECOMMENDATION**: We recommend that the divestments recommended by the PRC be pursued in the most expedient possible manner in order to make headway on the top NWNH priorities.*

***FINDING**: The facilities recommended for divestment by the PRC are valuable facilities doing excellent and unique science.*

***RECOMMENDATION**: Where possible without creating significant delays, the NSF should leverage the value of the facilities being divested to negotiate agreements for the new stewards to make some access available to the astronomy community on a competitive basis, according to the "Principles of Access" presented in this report.*

***FINDING**: In recent years US spending on astronomy and astrophysics has fallen below even the most pessimistic scenarios considered in the NWNH report.*

***FINDING**: In the FY 2015 President's Budget R&D funding is up 1.2%, but funding for basic research is down 1%, and overall funding for astronomy and astrophysics is down 2.7%.*

***RECCOMMENDATION**: We urge Congress and the Executive Branch to recognize the important role of basic research to the future of our country, including the special contributions astronomy and astrophysics can offer, and prevent the disturbing decline we see in the FY15 budget from becoming a trend.*

***FINDING**: Individual investigator grants and mid-scale programs play a crucial role as a source of important new ideas (some of which become the next big initiatives or facilities) and as a means for training young scientists.*

***FINDING**: Proposal success rates for individual investigator grants at NSF and NASA have dropped below 20% and even below 15% in recent years. It is widely believed, among both researchers and program administrators, that such low rates make the grant application and review process unreasonably inefficient.*

***FINDING**: There are many concerns and questions in the community and among agency staff about the implications of declining proposal success rates for the overall health of our field (factoring in both the crucial role of these grants and our wish to use our efforts efficiently). However, so far too many questions are unanswered to reach clear conclusions and recommend concrete improvements.*

***RECOMMENDATION**: The AAAC and the agencies should work together to clarify and quantify the questions related to individual investigator grants and mid-scale programs raised in this report. Other*

groups such as the American Astronomical Society and the National Research Council's Committee on Astronomy and Astrophysics should be involved as appropriate. The goal should be a clearer factual base on which to assess the health of the current individual investigator grants programs and make recommendations for future improvements.

FINDING: Interagency coordination and cooperation has for the most part been extremely successful.

FINDING: The unpredictable funding environment has presented challenges; in some cases extraordinary ones. In the case of the LSST, recent funding issues (including the 2013 sequester) have caused major schedule disruptions. Costly delays were averted only through supreme efforts on the part of the agencies to create a new plan (certainly a most impressive example of interagency coordination and cooperation). In the case of some Antarctic programs, the programmatic disruptions from the Federal government shutdown proved insurmountable causing an entire year of long duration balloon flights to be lost.

RECOMMENDATION: Congress, OMB and OSTP should do their best to stabilize the funding environment in order to avoid costly loses. The existing talent for interagency coordination and cooperation could then be directed toward advancing our programs rather than saving them from major disruption.

1) Introduction

Astronomy and astrophysics have a long tradition of advancing the scope of human knowledge. Both astonishing new discoveries and steady progress have been instrumental in our quest to understand our origins and the fundamental physical laws governing the universe around us. Much as measurements of the planets motivated Newton's formulation of his laws of motion, modern astronomical studies are driving and even revolutionizing progress in fundamental physics. Along the way, our discoveries have captivated the public with amazing astrophysical phenomena and gorgeous images of the cosmos and the wide array of beautiful and bizarre objects within it. The US investment in astronomy and astrophysics has inspired our children to study the scientific and technical fields, and has resulted directly in two of the last ten Nobel Prizes in Physics. Fully half of the last ten Physics Nobel Prizes have deep scientific ties with our field. As perhaps the most accessible of sciences, astronomy and astrophysics play a key role in nurturing the pioneering spirit of adventure and discovery that is so much part of our national identity and which drives a great many of our nation's achievements and endeavors.

In this 2014 Annual AAAC report, we note the impressive achievements over that last year which have resulted from our national investments in astronomy and astrophysics, and make recommendations intended to enhance our success in the future. A highlight of the AAAC work this year is the recommendation of *Principles for Access* (presented in Section 3). These principles are meant to guide the negotiation of astronomy and astrophysics partnerships with international and private partners, in order to implement the practice of "open access" and "open skies" which are crucial to maximizing US investments in science.

In recent years our nation has endured challenging economic times, impacting every sphere of life. The US astronomy and astrophysics research community has shared in this burden. In this report we recognize the impressive job which the community and the agencies have done to support the best possible science with limited resources, but we also identify how our progress has been slowed by economic circumstances. While this slowing is understandable in the broader economic context, more worrying are the numbers in the President's 2015 budget request. As discussed in Section 5, this request proposes to increase the overall research and development budget by 1.2 percent in FY 2015, yet funding for basic research is dropped by 1%, and astronomy and astrophysics was decreased by 2.7%. We urge the agencies and Congress to reverse the decline we see in the FY15 budget, recognizing the important role of basic research to the future of our country, including the special contributions astronomy and astrophysics offer due to their accessibility and their power to astonish and inspire. In this report we point out opportunities to more fully realize the bold scientific vision endorsed by US advisory groups, especially the 2010 National Research Council astronomy and astrophysics Decadal Survey (*New Worlds, New Horizons* or *NWNH*), should a more positive funding climate become possible.

The AAAC advises the Department of Energy (DOE), the National Aeronautics and Space Administration (NASA) and the National Science Foundation (NSF) on issues within the field of astronomy and astrophysics that are of mutual interest and concern. Established by the NSF Authorization Act of 2002, the AAAC is chartered[3] to assess and make recommendations regarding the coordination of the agencies' astronomy programs, to assess the status and make recommendations regarding agency activities as they relate to the National Research Council (NRC) astronomy and astrophysics decadal surveys, and to report the committee's assessments and recommendations annually 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 current committee and includes an examination of interagency coordination, particularly in the context of the 2010 NRC decadal survey report "New Worlds, New Horizons in Astronomy and Astrophysics" (*NWNH*) and its predecessors.

Since March 15, 2013, the AAAC has had two face-to-face meetings and two teleconferences. Representatives of the three agencies have given briefings and provided input on the status of their programs. A representative of the Office of Science and Technology Policy (OSTP) attended the face-to-face meetings. At the time of the writing of this report, the FY14 agency spending plans have not yet been approved by Congress, and the FY15 President's budget request has only recently been released. Because of these limitations this report is less substantive in terms of a detailed budgetary assessment than it would be under different circumstances.

2) Science Highlights

Here we list some of the most highly acclaimed Astrophysics breakthroughs in the last year. We expand further on these in Appendix A. These topics represent just a small fraction of the extensive advances in astronomy and astrophysics breakthroughs in the last year.

A1. The discovery of 715 new extrasolar planets by NASA's Kepler Mission is clearly destined to be named one of the top breakthroughs of 2014, and has been transformative to the field of exoplanet science. Other research in this field has shown that Earth-like planets are commonplace in the Universe, with one in five Sun-like stars hosting a planet similar to ours.

A2. The BICEP2 experiment at the South Pole Telescope (SPT) recently announced the discovery of primordial B-mode polarization in the cosmic microwave background, stirring intense excitement in the entire community. Last year, their first measurement of the more detectable B-modes from gravitational lensing made the Physics World top 10 list for 2013.

A3. An image of "space wind" from the newly inaugurated Atacama Large Millimeter Array (ALMA) was selected by Nature magazine as one of the most striking scientific images of 2013.

[3] The AAAC charter can be found here: http://www.nsf.gov/mps/ast/aaac/charter.pdf

A4. Science magazine named the Fermi Gamma-ray Space Telescope (FGST) confirmation that cosmic rays are produced by supernovae as one of the top 10 science breakthroughs of 2013.

A5. The Planck satellite revealed the highest resolution full sky map of the early universe, making both Science News and Nature magazines' top 10 for 2013.

A6. Physics World 2013 breakthrough of the year went to the IceCube South Pole Neutrino Observatory's detection of neutrinos from beyond the solar system.

A7. Nature magazine lauded the newest dark matter exclusion limit achieved by the Large Underground Xenon as one of the top scientific breakthroughs of 2013

We note that numerous results have achieved "top breakthrough" status in reviews that cover many fields of science, not just astronomy and astrophysics.

***FINDING*: Thanks to a long history of strong planned and coordinated US investment in Astronomy and Astrophysics, the US program has achieved numerous advances and breakthroughs over the past year.**

3) Principles for Access

Competitive access to important facilities and open access to data are widely regarded as key elements of best practices in the allocation of scientific resources that can greatly enhance the impact of a given scientific investment. The 2013 AAAC report made these recommendations regarding open access and reciprocal partnerships in astronomy and astrophysics projects:

> ***Recommendation* (from 2013):** *The agencies should implement a flexible open skies policy that both affirms the ideal of open access and permits negotiation on access to federally-funded facilities and data sets as required to establish a level of parity in access to foreign and non-federally-funded facilities and data sets.*
>
> ***Recommendation* (from 2013):** *Negotiations toward the coordination of projects or the development of partnerships should proceed on the basis of the principles of reciprocal participation and mutually agreed sharing of costs and responsibilities. Responsible federal agencies should coordinate early in the project development to enable the maximum scientific return to the nation from the federal investment in facilities, simulations, and analysis.*

In response to these recommendations, staff from DOE, NASA, NSF and OSTP drafted a document spelling out the relevant principles, and presented it to the AAAC for consideration in fall 2013. AAAC members discussed general elements of these principles with their colleagues in the community, and

then conducted a public discussion of the draft principles at the AAAC meeting on November 13-14, 2013. The National Research Council's Committee on Astronomy and Astrophysics also provided an opportunity for a community discussion of such principles at an open Town Hall meeting in the January 2014 American Astronomical Society meeting, and AAAC members listened with interest. The AAAC then concluded deliberations on the principles in its meeting on February 3-4, 2014. Thus, the AAAC has formulated the following recommendations and principles for the agencies, written as a stand-alone document[4]. Our recommendations are directed toward large projects and facilities. We understand that implementation of these recommendations may be complicated by special circumstances and context, which is why we state these as principles, not rules. It is why we discuss the possibility of deviations and recommend how they should be handled. We hope these principles will be a useful guide for building future partnerships and agreements for access to facilities and data.

***FINDING*: Competitive access to important facilities and open access to data are widely regarded as key elements of best practices in the allocation of scientific resources. Their implementation can greatly enhance the impact of a given scientific investment. These best practices already guide the work of US funding agencies**

***RECOMMENDATION*: We recommend the following principles be used in negotiating agreements regarding access to large astrophysics projects and facilities. We hope this recommendation will advance a culture of transparency and openness about our scientific process as we continue to promote best practices.**

2014 Astronomy and Astrophysics Advisory Committee recommendations on Principles for Access to Large Federally Funded Astrophysics Projects and Facilities

In its 2013 annual report[5], the Astronomy and Astrophysics Advisory Committee (AAAC) recommended that "Negotiations towards the coordination of projects or the development of partnerships should proceed on the basis of the principles of reciprocal participation and mutually agreed sharing of costs and responsibilities." In the current environment of complex partnerships there is a need to articulate the principles that enable the best science within constrained resources in order to realize large astrophysics projects and facilities for the benefit of the global astrophysics community.

The AAAC recommends that the Office of Science and Technology Policy (OSTP) Division of Science, the NASA Astrophysics Division, NSF Division of Astronomical Sciences, and DOE Office of High Energy Physics, in regards to large astrophysics projects and facilities:

- apply the following principles to all projects and facilities that are funded by these organizations
- apply these principles to international collaborations, to collaborations among Federal agencies, and to collaborations with other public and private entities within and outside the United States,

[4] Available at http://www.nsf.gov/mps/ast/aaac.jsp
[5] http://www.nsf.gov/mps/ast/aaac/reports/annual/aaac_2013_130308finalreport.pdf

- assess all proposed projects and facilities against these principles before deciding to undertake them, and
- discuss these principles with their partners in current and future projects and facilities.

These organizations should attempt to reach a common understanding with their partners on application of these principles to all large partnership projects and facilities in astrophysics. Deviations from these principles should be justified and any rationale for deviation should be publicly articulated.

PRINCIPLES FOR ACCESS TO LARGE ASTROPHYSICS PROJECTS AND FACILITIES

1. THE PRIMARY GOAL OF THE ASTROPHYSICS COMMUNITY IS TO PRODUCE THE BEST UNDERSTANDING OF OUR UNIVERSE. Implementation of large astrophysics projects and facilities should be organized so as to enable the best use of their resources. A balance must be struck between preserving the opportunity for the implementing consortium and the funding partners to reap the benefits of the resulting data, and participation by the wider community, to ensure the best science possible.

2. GLOBAL COORDINATION: Nations and funding partners will achieve greater advances in astrophysics when community-wide coordination and collaboration allow resources to be used efficiently, effectively, and without unnecessary duplication. Coordination could mean jointly developing an astrophysics project as a partnership, or choosing unique astrophysics projects that are complementary.

3. OPEN DATA: The best science occurs when an open data policy enables the global astrophysics community, the broader science community, and the public to extend the science outcomes of projects. A period of limited access to data for the implementing consortium or the funding partners to reap the benefits of their investment is reasonable. However, policies and funding should ensure that large projects make standard data products and analysis tools publicly available in a timely and useable manner.

4. OPEN ACCESS: The best science relies upon selecting the most compelling astrophysics investigations. Access to a large astrophysics project or facility should be allocated through an open, merit-based process, recognizing that some level of preferred access may be reasonable for the implementing consortium and the funding partners to reap the benefits of their investments. Calls for proposals extending beyond the implementing consortium should be open to the global astrophysics community.

5. OPPORTUNITY TO CONTRIBUTE: The best science is fostered by including the most-qualified scientists in the implementing consortium. Opportunities to participate in the implementing consortium of an astrophysics project or facility should be based upon openly advertised criteria and processes that are equally applied, regardless of institutional or national affiliation. The criteria and processes should be based on merit and/or consortium sponsorship.

6. RECIPROCITY: The best science occurs when nations and other funding partners of large astrophysics projects and facilities practice reciprocity with the wider scientific community. Nations and funding partners whose communities expect access to external resources (for example, funding, data, observing time, or consortium membership) should offer access to their own resources.

The AAAC believes that addressing these principles will lead to the most productive scientific use of the current and coming generations of large astrophysics projects and facilities. We understand that there may be grounds for justifiable deviations from these principles, such as treaty obligations or statutory restrictions. However, by formulating these principles, and recommending that any rationale for deviation must be explicitly articulated, we hope to create a climate in which the best possible science can be achieved.

4) Status of Decadal Survey Programs and Recommendations

Overview

A key part of the AAAC charge is to report on progress on the Decadal Survey programs and recommendations. Although the focus of our report is on the most recent survey (*NWNH*), we also comment on several large projects from prior surveys, that either are still under construction or whose ongoing operations constitute a large and ongoing financial commitment that influences the implementation of NWNH.

Major Programs Recommended by Previous Decadal Surveys Currently Under Construction

A number of top priority projects recommended by previous decadal surveys are still under construction. These are discussed below.

ALMA: As noted in Section 2, the Atacama Large Millimeter/submillimeter Array (ALMA) was inaugurated in March 2013 and continued its transition from the construction phase to full operations. It has already made important science impacts.

JWST: The James Webb Space Telescope (JWST), the top priority large space mission from the 2000 Decadal Survey (*Astronomy and Astrophysics for the New Millennium*, or *AANM*), remains on track for a 2018 launch. This next generation space telescope will open up windows on a wide array of exciting astrophysics, from studying the first bright objects formed in the early universe to the study of planetary systems and the origins of life. The 2010 JWST replan is being successfully followed and the project is within budget and on schedule. We commend the White House and Congress for holding to the funding plan (and for holding to the plan in the FY15 President's Budget Request), and NASA for maintaining the cost and schedule (NASA was able to absorb the impacts of the 2013 government shutdown, in part by using up some of the contingencies built into the schedule, so as not to impact the October 2018 launch date). FY 2014 is the peak funding year for JWST, with many critical activities, and the project has

entered its long and challenging Integration and Test activities. Several aspects of the technical progress are worth highlighting:

- Instruments are delivered and are in their integration and test phase
- All optics are complete and delivered to Goddard Space Flight Center
- Telescope wings, backplane support fixture, and center section are all complete
- Spacecraft completed Critical Design Review in January 2014

DKIST/ATST: The Advanced Technology Solar Telescope (ATST), endorsed by the 1990 decadal survey, was renamed the Daniel K. Inouye Solar Telescope (DKIST) on December 15, 2013, in honor of the late senator. Construction is progressing on track for operational status in mid-2019. The DKIST will make extremely high resolution images of the Sun that will allow scientists to advance our fundamental understanding of the Sun and also provide monitoring that is of major importance to space weather forecasting. This forecasting is critical for protecting the nation's satellites and power grid.

SOFIA: The Stratospheric Observatory for Infrared Astronomy (SOFIA, a joint program of NASA and the German Aerospace Center) was scheduled to start sustained science operations in 2014 with four commissioned instruments. A period of alternating science flights and further development of hardware, software and instruments on the observatory is currently underway. Endorsed by the 1990 decadal survey, SOFIA operates a 2.5 meter diameter telescope in a Boeing 747 aircraft that can be flown at altitudes as high as 40,000 feet. This provides access to wavelengths from 0.3 microns (the visible) to 1.6 millimeters, including a large portion of the far infrared spectrum not visible from the ground. Two additional SOFIA instruments were scheduled for commissioning in 2014. Cuts to the NASA astrophysics budget in the President's FY 2015 budget request have resulted in plans to mothball SOFIA until funds can be found to continue operations at a future date. This would be a significant blow to the realization of the decadal survey goals, precipitated by the unfavorable budget environment.

NWNH priorities and recommendations

The 2010 NRC decadal survey report "New Worlds, New Horizons in Astronomy and Astrophysics" (*NWNH*) identified three broad scientific objectives aimed at understanding our origins by (1) exploring how the first stars, galaxies and black holes came to be, (2) by looking for new worlds, or nearby habitable planets beyond our solar system, and (3) using astronomical measurements to unravel the mysteries of gravity and fundamental physics beyond the reach of Earth-based experiments. This survey identified a number of priorities for both ground and space-based experiments to address these broad goals, as well as providing guidance for the technology development programs and theoretical studies that move beyond the current decade to future experiments. The recommendations of *NWNH* serve as critical guidance for NASA/Astrophysics Division and the NSF/Astronomy division, but also impact other agencies. In particular, these recommendations impact the NSF/Physics division and the High Energy Physics (HEP) division of the Department of Energy (DOE).

NWNH identified a number of the highest priority projects. In order of priority, the large space-based projects included:
(1) The *Wide-Field Infrared Survey Telescope* (WFIRST)—an observatory designed to settle essential

questions in both exoplanet and dark energy research, advancing topics ranging from galaxy evolution to the study of objects within our own galaxy.
(2) *The Explorer Program*—augmenting a program that delivers a high level of scientific return on relatively moderate investment and that provides the capability to respond rapidly to new scientific and technical breakthroughs.
(3) the *Laser Interferometer Space Antenna* (LISA)—a low- frequency gravitational wave observatory that will open an entirely new window on the cosmos by measuring ripples in space-time caused by many new sources, including nearby white dwarf stars and black holes.
(4) the *International X-ray Observatory* (IXO)—a powerful X-ray telescope that will transform our understanding of hot gas associated with stars and galaxies in all evolutionary stages.

For large-scale ground-based projects, *NWNH* identified the following four priorities:
(1) *Large Synoptic Survey Telescope* (LSST)—a wide-field optical survey telescope that will transform observations of the variable universe and will address broad questions that range from indicating the nature of dark energy to determining whether there are objects that may collide with Earth.
(2) The *Mid-Scale Innovations Program augmentation*— a competed program that will provide the capability to respond rapidly to scientific discovery and technical advances with new telescopes and instruments.
(3) The *Giant Segmented Mirror Telescope* (GSMT)—a large optical and near-infrared telescope that will revolutionize astronomy and provide a spectroscopic complement to the James Webb Space Telescope (JWST), the Atacama Large Millimeter Array (ALMA), and LSST.
(4) *Atmospheric Čerenkov Telescope Array* (ACTA)—participation in an international telescope to study very high energy gamma rays.

Throughout, the *NWNH* emphasized the importance for funding medium-scale projects aimed at laying the technical and scientific foundations for the main scientific objectives of the *NWNH* report, and covering other developments that did not fit into the budget envelope assumed for the prioritization exercise. In subsequent years it became clear that budget constraints made it difficult for the agencies to achieve even their highest priorities. In this environment, the value of these mid-scale programs has become increasingly apparent. And unfortunately, in this environment, NSF participation in GSMT and NSF and DOE participation in ACTA have slowed to very low levels.

Budget realities have been significantly harsher than anticipated in the *NWNH* report, and have fallen well below even the most conservative budget scenarios considered there. Within this context, the AAAC finds that NASA, NSF and DOE are all making good efforts to address these priorities even though they are not able to fully fund these efforts. They have accomplished this by identifying areas where international collaboration might help to achieve the same goals (e.g., LIGO demonstration, X-ray experiments), by midscale programs that might be able to support initial studies or technology development for future large projects (e.g., the development of the Astrophysics Focused Telescope Assets concept for WFIRST), or where a combination of mid-scale support and international participation may allow the U.S. to continue to play a leading role in science (e.g., the NSF/AST Mid-Scale Innovation Program, or MSIP, program providing support for ACTA).

Specifically, the AAAC commends the agencies on the following progress and initiatives to address NWHH:

LSST: The AAAC applauds the NSF, DOE, the Office of Science and Technology Policy (OSTP) , the Office of Management and Budget (OMB) and the LSST team for their accomplishments in moving the LSST forward as the top priority *NWNH* ground-based project. NSF and DOE have carefully defined the agency responsibilities and scope of work through a high-level Memorandum of Understanding signed in 2012; the NSF will be responsible for delivery of the telescope, site, and data management system, while the DOE will be responsible for delivery of the advanced 3-gigapixel camera. The agencies have a joint oversight group, and regularly meet with OSTP and OMB. We note that:

- The LSST Major Research Equipment and Facilities Construction (MREFC) start is in the 2014 president's budget request for NSF, and also appears in the recently released 2015 budget request as well as the 2014 NSF plan that was submitted to Congress.
- NSF, DOE, and the LSST Project rescheduled the entire project in response to the budgetary restriction that prevented initiation of DOE camera construction in FY 2013, minimizing the cost increase and disruption to schedule that was caused by this funding delay.
- The NSF moved aggressively to reschedule the LSST Final Design Review (the original schedule for this had to be changed due to the government shutdown) to minimize delay to the overall process.
- The LSST Final Design Review (FDR) took place in December 2013, and went extremely well. The FDR report states: "We have no hesitation in our assessment that the project will be ready for start of construction on July 1, 2014".
- The LSST camera, a DOE responsibility, has been approved as a Major Item of Equipment (MIE) fabrication start in the FY14 budget.
- NSF program staff and the LSST scientists are carefully preparing for the National Science Board (NSB) to hear an action item for approving an LSST construction award at the May 2014 NSB meeting.
- The Primary-Tertiary mirror is on track to complete final polishing in 2014, thanks to crucial private funding.
- The bidding process is in progress or complete for certain items key to the construction start.

WFIRST: NASA has initiated a number of studies to reformulate the highest priority space mission in the *NWNH* report (the WFIRST mission). One concept is called WFIRST/AFTA. WFIRST/AFTA work would make use of one of two 2.4 meter satellite telescopes made available to NASA by the National Reconnaissance Office to develop a new mission concept called the Astrophysics Focused Telescope Assets (AFTA) which would follow JWST as the next large space telescope. Through supporting technology development of a coronagraph for the mission, NASA could extend the capabilities of WFIRST/AFTA to address the *NWNH* goals in exoplanet science.

DES: The Dark Energy Survey (DES) is a major DOE/NSF astrophysics collaboration that went into full operation at the end of August 2013 and completed its first season in February 2014. DES data will yield impressive advances in our understanding of dark energy using four different probes. In addition to producing great science, DES serves as a forerunner to a similar but much larger collaboration on LSST, teaching us much about the processes as well. We congratulate all involved in moving this project successfully forward.

Explorer Program: NASA has augmented the Explorer program, planning funding increases ramping up

to $140M/yr in FY16 and beyond, supporting Announcements of Opportunity (AOs) every three years starting in 2014.

LISA: By partnering with the European Space Agency (ESA), NASA is supporting the development of a LISA pathfinder and is discussing partnership in ESA's L3 gravity wave detector.

IXO: By supporting US participation in ESA's L2 X-ray observatory, NASA might address many of the scientific goals of the IXO mission.

Other Surveys: NSF Astrophysics and DOE Cosmic Frontier support a number of mid-scale cosmic-survey instruments. They also fund enhancements to ground-based CMB measurements by multi-pixel upgrades to the South Pole Telescope (SPT) and the Atacama Cosmology Telescope. Through these efforts, combined with the LSST, the agencies are making good progress in addressing the third key scientific objective of *NWNH*. Together, these wide-field optical and CMB surveys will provide unique information about cosmology and new physics including inflation, dark matter, dark energy, and understanding of neutrino properties.

MSIP: The NSF/AST Mid-Scale Innovation Program (MSIP) may provide an avenue for supporting many possible projects, including several called out explicitly as *NWNH* high priority ground-based experiments (for example studies of CMB polarization, the epoch of reionization and advanced adaptive optics). This program is in the FY 2014 budget and a solicitation of proposals was issued, pre-proposals have been evaluated, full proposals have been invited with a deadline in mid-March. This is impressive progress in the space of one year. It addresses the second *NWNH* priority: a mid-scale innovations program. Depending on the outcome of the High Energy Physics planning process (see section 8) DOE and NSF/Physics might be able to provide the additional support needed to allow the U.S. to play a major role in the ACTA project

***FINDING*: The agencies and the community as a whole have done an impressive job of moving forward with the NWNH priorities (and priorities from previous Decadal Surveys) as well as possible, given the disappointing budget environment. However budget realities have slowed the progress of new discoveries in astronomy and astrophysics.**

***RECCMMENDATION*: Should the budget situation improve, we recommend more aggressive progress be made on the NWNH priorities, to move us closer to the bold vision endorsed in NWNH.**

NSF Portfolio Review

Following the recommendation of the *NWNH* decadal survey (pp. 32, 173), the NSF Division of Astronomical Sciences (NSF/AST) convened a Portfolio Review Committee (PRC) in 2011-2012. The PRC reported in August of 2012. The budget scenarios considered by the PRC for the AST division corresponded to 65% and 50% of the *NWNH* projections by 2022. Both scenarios require significant divestment of some facilities. The recommendations for the 50% projection do not provide any public access to 20-30 meter diameter optical/infrared (OIR) or wide-area submillimeter telescopes in 2020. Funds for instrument upgrades are reduced and individual investigator grants and midscale programs are also significantly decreased.

Given the constrained budget scenarios of the recent past and the outlook for the next year, implementation of the PRC recommendations is imperative to secure a vibrant and innovative future for US astronomy. NSF/AST has released a "Dear Colleague Letter'' to the community outlining the steps for every telescope that was the subject of a divestment-related recommendation in the PRC report. The implementation strategy has been to find new stewardship and to prepare the path for divestment of some telescopes. NSF is in close coordination with NASA and DOE in studying alternatives for new stewardship of some NSF astronomical facilities. The AAAC commends NSF/AST for beginning the implementation of the difficult but necessary divestments. It is important to prepare a budget that will accommodate the first NSF priority in the *NWNH* (the Large Synoptic Survey Telescope or LSST), and the second priority of *NWNH* (the midscale program). The AAAC notes that the current federal budgetary environment coupled with the finite time required to divest the NSF/AST portfolio of the recommended facilities, has resulted in pressures on the mid-scale program and on the individual investigator grants program. Completing the divestments will be a critical step in allowing those programs to flourish.

***FINDING:* The NSF Portfolio Review Committee (PRC) has done a good job in a difficult situation, recommending tough choices that must be made in our challenging budget environment in order to make significant headway on NWNH priorities.**

***RECOMMENDATION*: We recommend that the divestments recommended by the PRC be pursued in the most expedient possible manner in order to make headway on the top NWNH priorities.**

We note however that the PRC choices were difficult ones, as the telescopes planned for divestment are valuable facilities doing good science that is in many cases unique. They are not simply being superseded by the newer facilities. The telescopes scheduled for divestment exist due to previous US investments in astronomy and astrophysics infrastructure, and we recommend that NSF leverage the value of the facilities being divested to negotiate agreements for the new stewards to make some access available to the astronomy community on a competitive basis, according to the *Principles of Access* presented in this report.

FINDING: The facilities recommended for divestment by the PRC are valuable facilities doing excellent and unique science.

***RECOMMENDATION*: Where possible without creating significant delays, the NSF should leverage the value of the facilities being divested to negotiate agreements for the new stewards to make some access available to the astronomy community on a competitive basis, according to the "Principles of Access" presented in this report**

5) Budgets

Recent years have seen lower levels of federal spending on many programs of importance to the nation. Astronomy and astrophysics shared in these difficulties, although we note that we have done better than a number of other federal programs. We appreciate this recognition of the value of our contributions. Nonetheless, astronomy and astrophysics budgets still lie below even the most pessimistic projections of the most recent long-term strategic planning exercises, such as the two most

recent Decadal Surveys, *NWNH* and *AANM*. In part to adapt to this shortfall, agencies have significantly delayed even the highest priority projects and planned the divestment of valuable astronomical facilities. The top priority decadal strategic project, WFIRST, will not launch until well into the next decade, and the second priority strategic project, a space based gravitational wave detector, which responds to the *NWNH* LISA recommendation, will likely be led by the European agency, ESA, with a launch date at least twenty years from now. In addition, most individual investigator grants programs are seeing falling success rates (see the discussion in the next section).

Although the lower funding levels can be attributed at least in part to our nation's recent economic challenges, we have other concerns about numbers in the recently released President's Budget for 2015. While showing an increase in R&D funding of 1.2%, the basic science budget decreases by 1% from 2014[6]. Astronomy and astrophysics was hit particularly hard: This budget shows a decrease of 2.7%[7] for astronomy and astrophysics. We urge the agencies and Congress to reverse the decline we see in the FY15 budget, recognizing the important role of basic research to the future of our country, including the special contributions astronomy and astrophysics offer due to their accessibility and their power to astonish and inspire.

We note that the substantial delays in the implementation of the *NWNH* program mean there are exciting research opportunities in the queue which can be implemented, should funding levels improve in the future. Such an additional investment would yield a more aggressive rate of advances and breakthroughs, more training of young scientists, and bring us closer to the bold vision for US astronomy and astrophysics endorsed in the *NWNH* report.

We also note that the impacts of the 2013 US government shutdown on astronomy and astrophysics were significant, and we document these in *Appendix B*.

***FINDING*: In recent years US spending on astronomy and astrophysics has fallen below even the most pessimistic scenarios considered in the NWNH report.**

***FINDING*: In the FY 2015 President's Budget R&D funding is up 1.2%, but funding for basic research is down 1%, and overall funding for astronomy and astrophysics is down 2.7%.**

***RECOMENDATION*: We urge Congress and the Executive Branch to recognize the important role of basic research to the future of our country, including the special contributions astronomy and astrophysics can offer, and prevent the disturbing decline we see in the FY15 budget from becoming a trend.**

6) Individual Investigator Grants and Mid-Scale Programs

The AAAC has had extensive discussions of the individual investigator grants programs in astronomy and astrophysics. These grants have a major role in nurturing innovative projects driven by individual

[6] http://www.aaas.org/news/white-house-modest-2015-rd-budget-proposal-twist
[7] The methods for calculating this number are presented in *Appendix C*

initiative. Research funded by individual investigator grants is widely regarded as a major source of important new ideas and advances in the field, and is key to making the most of the large facilities and projects prioritized in the decadal surveys. Research funded by these individual investigator grants provides much of the groundwork for future major initiatives and facilities. These small grants typically support students and postdocs and are thus essential for training the next generation of science leaders.

Both NASA and NSF presented statistics showing proposal success rates dropping below 20% and even below 15% in recent years for many individual investigator grant programs (rates are higher at DOE, due to how the program is structured). Even as NSF has worked commendably to share the budget challenges fairly among the grants program and facilities, NSF/AST grant success rate has decreased almost monotonically from 2002 (38%) through 2013 (15%). At the same time, the number of proposals has doubled. In NSF funding, these grants are squeezed by reduced total funding at the same time that facilities commitments are growing, so even a flat total budget will reduce the amount of grant funding.

Concern was expressed by AAAC members and NASA and NSF staff that such low rates lead to significant inefficiencies, given the amount of proposal preparation and reviewing effort that ultimately produces such a low overall rate of funding. A number of ideas were floated such as introducing a pre-proposal phase, running the selection process every two years rather than annually, and limiting the total number of applications per PI. However, since it is not obvious whether such measures would significantly improve the ability of individual scientists to pursue innovative new research activities, the AAAC is committed to collecting the information necessary to make fact-based recommendations in the next annual report.

AAAC members also expressed concerns that the individual investigator grant programs were especially vulnerable to budget cuts since it is easier to cut a few grants than it is to delay the carefully-structured schedule of a major project. However, long term statistics presented by the agencies show decreasing success rates even during times when the funding of investigator grants programs as a whole is increasing. Thus it appears that the increasing number of proposals contribute significantly to the decreasing grant success rates.

Ultimately, the AAAC realized that we have an insufficiently clear understanding of these matters to make specific recommendations. Important questions are unanswered such as: Are some researchers just applying for more grants, even though well-funded? Are strong researchers being insufficiently funded? Has the total number of strong astronomy and astrophysics faculty increased significantly? How do the statistics look when inflation is carefully taken into account? The astronomy and astrophysics community, including researchers and funding agencies, needs to come to a clearer understanding of these and related questions. It is not yet completely clear that we have even identified the most revealing questions to try to answer.

Also, if major changes are made to the process of reviewing and awarding individual investigator grants (such as moving to every two years), it is essential that the community be on board, or at minimum understand the intended impact and reasoning behind such a change. When addressing these issues, it

is critical that the careers of young scientists are given special consideration, since they often have a window of only a few years in which to establish a successful record of extramural funding.

Similar comments apply to flexible mid-scale programs, which also provide valuable training and incubate new ideas in larger consortia of investigators. The impact of budget cuts on these programs will become clearer in the next year, as we anticipate a similar low success rate and contraction of many important initiatives.

In our next recommendation, we outline steps that should be taken to clarify and addresses the important issues discussed here.

***FINDING*: Individual investigator grants and mid-scale programs play a crucial role as a source of important new ideas (some of which become the next big initiatives or facilities) and as a means for training young scientists.**

***FINDING*: Proposal success rates for individual investigator grants at NSF and NASA have dropped below 20% and even below 15% in recent years. It is widely believed, both among researchers and program administrators, that such low rates make the grant application and review process unreasonably inefficient.**

***FINDING*: There are many concerns and questions in the community and among agency staff about the implications of declining proposal success rates for the overall health of our field (factoring in both the crucial role of these grants and our wish to use our efforts efficiently). However, so far too many questions are unanswered to reach clear conclusions and recommend concrete improvements.**

***RECOMMENDATION*: The AAAC and the agencies should work together to clarify and quantify the questions related to individual investigator grants and mid-scale programs raised in this report. Other groups such as the American Astronomical Society and the National Research Council's Committee on Astronomy and Astrophysics should be involved as appropriate. The goal should be a clearer factual base on which to assess the health of the current individual investigator grants programs and make recommendations for future improvements.**

7) Interagency Coordination and Cooperation

The 2013 AAAC report set out the following criteria for evaluating the value of cooperative programs among the agencies*:*

Interagency cooperation is advantageous if the joint program

1) *Enables additional, better or faster science productivity;*
2) *Offers the opportunity for increased cost effectiveness or cost saving in terms of the science return;*
3) *Taps unique expertise at each of the multiple agencies involved;*

4) *Avoids duplication of effort.*

Indeed, these criteria are met, and advantages are achieved in many instances of cooperative programs in the field astronomy and astrophysics. The 2013 AAAC report documented more than twenty of these. Without reproducing a complete list here, we reinforce the message that cooperation among agencies has been very successful and productive and has contributed significantly to the excellence of the US astronomy and astrophysics program. The FGST (featured in our *Science Highlights* above) and the LSST (discussed in the Status of *Decadal Survey Programs and Recommendations* section) are prime examples, as is the Dark Energy Survey (discussed in section 4). Some other joint programs are also discussed in Appendix A.

The 2013 AAAC report also issued the following recommendation:

> *Recommendation (from 2013): When funding major cooperative interagency programs, the Congress, the Office of Management and Budget (OMB) and the Office of Science and Technology Policy (OSTP) should ensure that funding is provided on a coordinated schedule consistent with the multiagency partnership*

In a number of important cases, this worthy goal has proven extremely difficult to achieve in the recent challenging political and economic environment. For example, the FY13 President's Budget Request had called for a 2013 start for the LSST-camera as a Major Item of Equipment (MIE), a DOE part of the project which determines the Critical Path of the overall project. However due to continuing resolution-type budget restrictions such a start was not possible. In FY2014, after the budget was passed by Congress, a fabrication start for the MIE was approved. Due to the LSST-camera start-of-fabrication delay until FY14, the LSST project was completely re-planned as an integrated whole between the DOE and NSF portions to minimize total cost and delay. Part of this re-plan included commissioning the camera with a partially populated focal plane, so that integration and test of the telescope/camera could go forward before the camera was fully populated with sensors. This reduced the potential delays and costs toward the end of the construction project. It is estimated that this innovative re-plan saved the agencies millions of dollars as compared to accepting a simple one-year delay. This is an impressive example of interagency cooperation, and the AAAC congratulates everyone involved in achieving this successful outcome.

Budget problems created insurmountable problems for certain South Pole-based Astronomy programs. Reduction of NSF infrastructure support at the Antarctic McMurdo Station, caused by the 2013 government shutdown, was especially badly timed with respect to the NASA long duration balloon schedule. This program is only viable during a narrow window, due to the Antarctic weather patterns. Thus the impact of the shutdown at NSF forced NASA cancellation of the entire long duration balloon campaign for 2013.

Our overall assessment is that interagency cooperation is very healthy, in terms of the ability of the agencies to work well together. Accomplishments resulting from strong interagency cooperation are discussed in Appendix A (on science highlights). Our recent budget problems have presented some

extraordinary challenges. In the case of the LSST, the agencies were able to react successfully and develop a work-around, but in the case of the balloon program no workaround was possible, resulting in a year of balloon-based astronomy lost.

***FINDING*: Interagency coordination and cooperation has for the most part been extremely successful.**

***FINDING*: The unpredictable funding environment has presented challenges; in some cases extraordinary ones. In the case of the LSST, recent funding issues (including the 2013 sequester) have caused major schedule disruptions. Costly delays were averted only through supreme efforts on the part of the agencies to create a new plan (certainly a most impressive example of interagency coordination and cooperation). In the case of some Antarctic programs the programmatic disruptions from the Federal government shutdown proved insurmountable causing an entire year of long duration balloon flights to be lost.**

***RECOMMENDATION*: Congress, OMB and OSTP should do their best to stabilize the funding environment in order to avoid costly loses. The existing talent for interagency coordination and cooperation could then be directed toward advancing our programs forward rather than saving them from major disruption.**

8) Other Planning Processes

As discussed above, the *NWNH* decadal survey identified three broad scientific objectives aimed at understanding our origins by (1) exploring how the first stars, galaxies and black holes came to be, (2) looking for new worlds, or nearby habitable planets beyond our solar system, (3) using astronomical measurements to unravel the mysteries of gravity and fundamental physics beyond the reach of Earth-based experiments. This survey identified a number of priorities for both ground and space-based experiments to address these broad goals, as well as providing guidance for the technology development programs and theoretical studies that address these goals and move beyond the current decade to future experiments. The recommendations of *NWNH* serve as critical guidance for NASA/Astrophysics, the NSF/AST, and the DOE Cosmic Frontier programs. In addition, these recommendations impact the Particle Astrophysics program in the NSF Physics Division and the High Energy Physics (HEP) program of the Department of Energy (DOE).

It is therefore important to integrate our findings with a similar decadal exercise (a.k.a. Snowmass) directed by the American Physical Society, Division of Particles and Fields (DPF). This year-long process gathered community input, generated targeted studies, and produced an extensive account of new opportunities for the field[8]. This community planning exercise provides scientific input to the HEP Advisory Panel (HEPAP) which makes recommendations directly to HEP-related divisions in NSF and DOE. A subcommittee of HEPAP (the Particle Physics Project Prioritization Panel, or P5) is directly charged with prioritizing the various research efforts described in the Snowmass report under various budget scenarios. This P5 report is expected to be released in May 2014. The AAAC heard a

[8] http://www.usparticlephysics.org/p5/

presentation from the P5 Chair at our February 2014 meeting. P5 is clearly doing a thorough job of consultation and outreach along their way to making their final recommendations

The DOE has identified three broadly-defined categories within HEP: the Intensity Frontier (encompassing accelerator and reactor-based neutrino experiments and precision measurements), the Energy Frontier (particle accelerators) and the Cosmic Frontier (probing the fundamental physics of cosmological or astrophysical processes). All three frontiers are under the purview of HEPAP, but only the Cosmic Frontier overlaps with the projects prioritized in *NWNH* and assessed by the AAAC.

While the current Snowmass/P5 process looks to the future, we note that the report of the previous P5 process (released in 2008) has played a key role in DOE planning (including in astrophysical areas) , while the report of the Particle Astrophysics Scientific Assessment Group (PASAG) which came out in 2009 has provided recommendations specific to particle astrophysics.

We also note the road-mapping process undertaken by NASA in 2013, which produced the *Enduring Quests Daring Visions* report[9], looking out toward a 30-year time frame.

Although the planning aspects of the AAAC charge related most directly to the implementation of the Decadal Surveys, we recognize the importance of these other planning processes to the progress of astronomy and astrophysics as a whole. We expect results of these planning processes will factor in to work of future decadal surveys (as the *NWNH* report factored into these). Overall this staggered planning process appears to work well, in that different communities can use the recommendations of the other group as a solid reference point for their work.

Appendix A: Advances in Science and development of new projects

A1. The search for planets outside our solar system ("exoplanets") has generated deep fascination from scientists and the public alike, and has even been the subject of a congressional hearing[10]. An historic breakthrough was made in 2013[11], with the discovery that Earth-like planets are commonplace in the Universe around us. The discovery team used data from NASA's Kepler Mission to detect Earth-size planets and, using NSF funding to perform further analysis, showed that 22% of Sun-like stars have an Earth-size planet that receives about the same incident flux of starlight as the Earth. The paper won the Cozzarelli Prize[12] from the National Academy of Sciences for the best paper in all physical sciences published in the Proceedings of the National Academy of Sciences during 2013. We note success of the joint NSF-NASA support in achieving this result.

[9] http://science.nasa.gov/astrophysics/documents
[10] http://science.house.gov/sites/republicans.science.house.gov/files/documents/HHRG-113-SY16-20130509-SD001%20.pdf.
[11] http://www.pnas.org/content/110/48/19273.full
[12] http://www.pnas.org/site/misc/cozzarelliprize.xhtml

A2. The BICEP2 experiment at the South Pole Telescope (funded primarily by the NSF Division of Polar Programs with contributions from NSF/AST and DOE) observed the first measurement of a special signature in the CMB ("B-mode polarization"), positioning this signature to be an important tool for future studies of our cosmos. The SPT result made the *Physics World* top 10 list for 2013[13]. We note that the NSF and NASA funded BICEP: Background Imaging of Cosmic Extragalactic Polarization. This same collaboration just announced the discovery of primordial B-modes, produced during the Inflation period of Universe (10^{-35} seconds after the Big Bang). If confirmed, this Nobel Prize-worthy result ushers in a new era in understanding the physics of inflation and even quantum gravity.

A3. On March 13, 2013 the Atacama Large Millimeter/submillimeter Array (ALMA)[14] was inaugurated and continued its transition from the construction phase to full operations as an astronomical observatory. Its science impact has already been felt around the world. **Figure 1** shows an image of "space wind" flowing from the Sculptor Galaxy 9 (aka NGC 253) produced from ALMA data. Although ejected in a cool dilute form, a mass equivalent to 9 times that of the Sun is emitted from the galaxy each year. Data like these are transforming our understanding of star formation in the universe, and Fig. 1 was selected by *Nature* magazine as one of the most striking scientific images of 2013.

A4. The Fermi Gamma-ray Space Telescope (FGST, a joint project of NASA, DOE and international partners launched in 2008) continues its record of scientific breakthroughs. The origin of cosmic rays (high energy protons and particles from outer space) has long been a mystery. This year the FGST discovered key gamma ray signatures that, taken together with measurement by ground-based gamma-ray instruments, indicate that cosmic rays are produced by supernovae. Some of the data are shown in **Error! Reference source not found.** *Science* magazine named these FGST results one of the top 10 science breakthroughs of 2013[15]. For this report, it is noteworthy that both space and ground-based instruments contributed to this discovery and that in both cases these experiments resulted from successful interagency cooperation. The Fermi project was not only jointly funded by NASA and DOE, but also benefited from the close cooperation of disparate scientific communities, with experimental high-energy physicists working closely with NASA astrophysicists. The ground-based Very Energetic Radiation Imaging Telescope Array System (VERITAS) experiment has also made key observations that contribute to this story. VERITAS (and other European-led experiments like the High Energy Stereoscopic System and Major Atmospheric Gamma-ray Imaging Cherenkov Telescopes) has provided high-angular-resolution images of these same Supernova remnants, and provide key data showing that the energy spectrum of these sources continues up to trillion-electron volt energies with the expected spectrum. (VERITAS is a U.S. led interagency experiment supported by DOE HEP, NSF/AST and NSF/Phy as well as the Smithsonian Astrophysical observatory, featured in previous AAAC reports).

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[13] http://physicsworld.com/cws/article/news/2013/dec/13/cosmic-neutrinos-named-physics-world-2013-breakthrough-of-the-year

[14] ALMA is a next-generation array of radio telescopes built and operated as a partnership between Europe, North America and East Asia in cooperation with the Republic of Chile. US involvement is funded through the NSF. http://www.almaobservatory.org/

[15] http://news.sciencemag.org/2013/12/sciences-top-10-breakthroughs-2013

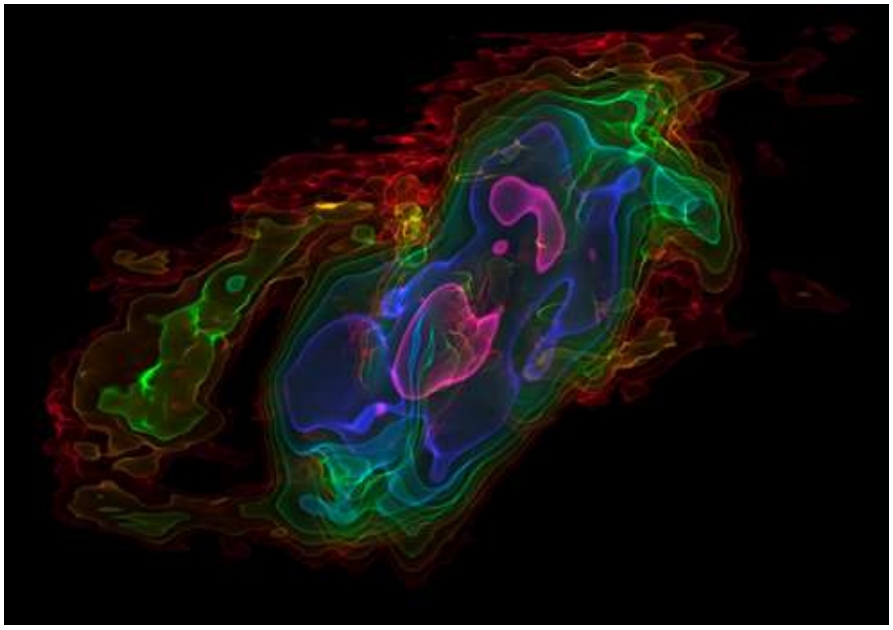

Figure 1 Space wind ejects nine solar masses of cold gas per year from the Sculptor Galaxy. This image is from the new ALMA radio telescope and was named one of the most striking scientific images of 2013 by *Nature* Magazine. (From ALMA press release: http://www.almaobservatory.org/en/press-room/press-releases/621-starburst-to-star-bust-alma-sheds-light-on-mystery-of-missing-massive-galaxies)

A5. Last year was notable for studies of the Cosmic Microwave Background (CMB), radiation that reaches us from the very earliest phases of cosmic evolution. The Planck satellite (a European Space Agency mission with significant NASA participation) revealed the highest resolution full sky map of the early universe, confirming certain aspects of our fundamental understanding of the universe and reinforcing other puzzles hinted at by earlier data. This result made *Nature* magazine's top 10 for 2013 list[16], and was 3rd on the list from *Science News* as well[17].

[16] http://www.nature.com/news/365-days-2013-in-review-1.14366
[17] https://www.sciencenews.org/article/top-25-science-stories-2013-microbes-meteorites

Figure 2 Composite image of a supernova remnant. The FGST has detected telltale gamma rays which trace the origins of cosmic rays to supernovae such as this one, a *Science* magazine breakthrough of the year for 2013. (From NASA press release: http://www.nasa.gov/mission_pages/GLAST/news/supernova-cosmic-rays.html)

A6. The IceCube South Pole Neutrino Observatory, a kilometer square particle detector built into the Antarctic ice (funded primarily through NSF with significant contributions from the DOE and European partners) announced the detection of neutrinos that originate far beyond the solar system, launching the field of "neutrino astronomy", where neutrinos are the messengers that bring us information from the distant cosmos. This discovery was lauded as 2013 breakthrough of the year by *Physics World*[8]. We note that IceCube and SPT derive significant support from the NSF Polar Program, and ground-based neutrino and gamma-ray experiments typically derive support from NSF Physics. While the AAAC charge is focused on interagency cooperation between NSF/AST, DOE/HEP and NASA/Astrophysics the NSF Polar program and NSF/Physics cooperation form a critical component of many of the experiments under our review.

A7. While searches for dark matter particles interacting directly with terrestrial detectors is not specifically included in the AAAC charge, it is part of DOE HEP Cosmic Frontier program and NSF Physics, and is a significant part of the overall planning process. It is also a vital part of the larger search for dark matter in the cosmos which IS under the AAAC umbrella. We therefore note that the Large Underground Xenon dark matter experiment (LUX), situated a mile underground in the Sanford Underground Research Facility, had its first run last year, After just a three month initial run, they were able to place the tightest constraints yet on the mass of dark matter particles above 10 GeV/c^2 and the strength of their interactions with ordinary matter. Their results[18] were hailed by *Nature* magazine as one of the top scientific breakthroughs of 2013[19]. Recently, the SuperCDMS experiment at the Soudan Underground Lab was able to set even stricter limits yet on lower mass dark matter particles, thus extending the

[18] LUX press release: http://sanfordlab.org/news/press_release/first-results-lux-experiment-south-dakota
[19] http://www.nature.com/news/365-days-2013-in-review-1.14366

search for terrestrial dark matter interactions across all mass ranges. Direct detection of dark matter particles on earth provides constraints on astrophysical signals that might be interpreted as indirect evidence for dark matter interactions in our galaxy.

Appendix B: Impacts of the 2013 US government shutdown

The US federal government entered a shutdown from October 1 through 16, 2013 after Congress failed to appropriate funds for fiscal year 2014 or to enact a continuing resolution. The US astronomy and astrophysics program experienced significant impacts from this shutdown. We list below the impacts to our program organized by agency. We commend all the agencies for their efforts to minimize these impacts and to recover as quickly as possible to keep most core programs on track. These accomplishments are all the more impressive given the widespread morale issue which naturally impact government employees during a government shutdown.

NSF

- Reduction of NSF infrastructure support at the Antarctic McMurdo Station caused NASA cancellation of the entire Long Duration Balloon (LDB) campaign for this year.
- LSST Final Design Review postponed from Oct to Dec; delay causes disconnect with Feb NSB meeting, and significantly complicated the overall approval process for LSST.
- NRAO North America shut down due to lack of 2014 funds
- Several other National Facilities on the brink of furloughs and/or closures if shutdown had continued a few days longer
- Staff demoralization at national facilities funded by NSF, including resignations caused by uncertainty in current and future funding
- Midscale Innovation Program schedule delayed by about 1 month
- Plans for CAA O/IR study delayed by several months

NASA

- JWST testing affected: cryogenic thermal vacuum of Integrated Science Instrument Module (ISIM), center section of telescope backplane. This resulted in loss of three weeks of funded schedule margin on the critical path, now down from 14 months to 13.25 months.
- 2013-2014 Antarctic Long Duration Balloon program cancelled:
    - Shutdown came at a critical time, with insufficient resources and time to prepare the Arctic McMurdo station and the payloads for launch.
    - Three astrophysics LDB flights cancelled: Spider (an experiment that measures the CMB); BACCUS (studying cosmic-ray astrophysics); Super Pressure Balloon 100 day test flight (testing new balloon technology)
- SOFIA cancelled 9 science flights with U.S. instruments;
    - First Light Infrared Test Experiment Camera commissioning delayed full Operational Capability (FOC) milestone by 1 month
- Stand down in Astro-H Mission soft x-ray spectrometer (SXS) integration and test resulted in ~5 week delivery delay to the Japan Aerospace Exploration Agency (JAXA) ; SXS is near Astro-H critical path, so impacted Astro-H integration and test schedule; Delay increased U.S. cost to complete SXS

- Other development projects had schedule hits including 1 month on International Space Station Cosmic Ray Energetics and Mass (ISS- CREAM) payload
- Operating missions continued most activities, some delay in science data processing
- Research funding disbursement delayed

DOE

- Critical Design Review 1 (CD-1) for the Dark Energy Spectroscopic Instrument (DESI) camera delayed from January to February
- Other shutdown impacts are difficult to separate from the impact of the sequester. An example of these combined impacts is given in the LSST discussion in Section 7.

Appendix C: FY 2015 budgets

Program	**2014**	**2015**	**% Change 14-15**
NSF MREFC: DKIST	14.92	25.12	68.4%
NSF MREFC: LSST	36.88	79.64	115.9%
NSF MREFC: ALMA	0	0	
NSF MREFC: LIGO	27.5	0	-100.0%
Total MREFC	79.3	104.76	32.1%
NSF/AST	239.06	236.24	-1.2%
NASA: JWST	658.2	645.4	-1.9%
NASA: Astro	668	607.3	-9.1%
DOE: Cosmic	89.786	93.67	4.3%
Total	**1734.346**	**1687.37**	**-2.7%**

Table 1: Calculation of budget numbers used in the text.

These numbers and other numbers in this report quoting overall changes in R&D and Basic Research funding come from the following sources:

1) AAAS reporting on the FY15 President's Budget http://www.aaas.org/news/white-house-modest-2015-rd-budget-proposal-twist
2) Agency presentations at the Feb 3, 2014 AAAC meeting http://www.nsf.gov/events/event_summ.jsp?cntn_id=129940&org=AST

3) NSF (http://www.nsf.gov/about/budget/fy2015/index.jsp) and DOE(http://www.energy.gov/cfo/downloads/fy-2015-budget-justification) postings about the FY15 President's Budget Request
4) Presentations from the agencies at the Committee on Astronomy and Astrophysics meeting March 3-5, 2014: http://sites.nationalacademies.org/BPA/BPA_048755#pastpresentations

We acknowledge that there is some natural variation in the funding profiles of large projects which adds complexity to such discussions, but the impacts of the decline for FY 2015 will be felt in real terms (see for example the discussion of SOFIA in section 4).

Appendix D: Explanation of Acronyms

AAAC	Astronomy and Astrophysics Advisory Committee
AANM	The 2000 NRC report "Astronomy and Astrophysics for the New Millennium"
ACTA	Atmospheric Čerenkov Telescope Array
AFTA	Astrophysics Focused Telescope Assets
ALMA	Atacama Large Millimeter Array
ATST	Advanced Technology Solar Telescope
CAA	The National Research Council's Committee on Astronomy and Astrophysics
CD	Critical Design review
CMB	Cosmic Microwave Background Radiation
DES	Dark Energy Survey
DESI	Dark Energy Spectroscopic Instrument
DKIST	Daniel K. Inouye Solar Telescope
DOE	Department of Energy
DPF	Division of Particles and Fields (of the American Physical Society)
ESA	European Space Agency
FDR	Final Design Review
FOC	Full Operational Capability
FGST	Fermi Gamma-ray Space Telescope

FY	Fiscal Year
GSMT	Giant Segmented Mirror Telescope
HEP	High Energy Physics
HEPAP	High Energy Physics Advisory Panel
ISIM	Integrated Science Instrument Module
ISS-CREAM	International Space Station Cosmic Ray Energetics and Mass
IXO	International X-ray Observatory
JAXA	Japan Aerospace Exploration Agency
JWST	James Webb Space Telescope
LSB	Long Duration Balloon
LISA	Laser Interferometer Space Antenna
LSST	Large Synoptic Survey Telescope
MIE	Major Item of Equipment
MREFC	Major Research Equipment and Facilities
MSIP	Mid-Scale Innovation Program
NASA	National Aeronautics and Space Administration
NSB	National Science Board
NRC	National Research Council
NSF	National Science Foundation
NSF/AST	National Science Foundation Astronomy Division
NSF/PHY	National Science Foundation Physics Division
NWNH	The 2010 NRC decadal survey report “New Worlds, New Horizons in Astronomy and Astrophysics”
OMB	Office of Management and Budget
OSTP	Office of Science and Technology Policy
SPT	South Pole Telescope

SXS	Soft X-ray Spectrometer
PASAG	Particle Astrophysics Scientific Assessment Group
PRC	National Science Foundation Portfolio Review Committee
R&D	Research and Development
SOFIA	Stratospheric Observatory for Infrared Astronomy
VERITAS	Very Energetic Radiation Imaging Telescope Array System
WFIRST	Wide-Field Infrared Survey Telescope