Competed Grant Success Rates in US Astronomy and Astrophysics

Astronomy and Astrophysics Advisory Committee

March 15, 2016

Executive Summary:

The 2010 Astronomy and Astrophysics decadal survey, New Worlds New Horizons (*NWNH*), stressed the importance of achieving balance between funding construction and operations of observatories and maintaining a healthy core program of competed grant research. This report summarizes the strains on the core program over the last decade.

Over the last decade a number of world-leading observatories began operations or construction. The science these projects will address continues to attract a vibrant new generation of investigators whose work is critical to ensure the best scientific return from these investments and continued US leadership in astronomy and astrophysics. However, over the same period that these major projects are coming into operation, the funds available for community-wide openly competed grants have remained largely flat in both NSF/AST and NASA/APD.

Flat funding of the core program correlates with a significant decline in proposal success rates. From 2004 to 2014, the success rates in the NSF/AST AAG program declined from 30% to 17% and NASA/APD R&A proposal success declined from 30% to about 20%. Similar trends are observed in NASA Planetary (40% to 20%), NASA Heliophysics (35% to 15%), and NSF/PHY PA (45% to 39%). During the same period no significant changes occurred in the distribution of proposal merit, and in proposer demographics (seniority, gender, and institutional affiliation).

Flat funding of the core program combined with the success of the field in attracting a modest (estimated to be about 2% to 2.5% per year) influx of new investigators partly explains the decline in success rates. The decline in success rates gets exacerbated by an increase in the number of proposals submitted by the same PI on a given year and by a shorter cadence of resubmissions.

NSF and NASA should continue to work toward balance of their portfolio. In the case of NSF/AST a vigorous implementation of the divestments recommended by the Portfolio Review Committee (PRC) can increase funding for the base program, help alleviate the proposal pressure crisis, and better realize the scientific potential of the leading facilities and missions.

Given the current crisis, community based groups such as the American Astronomical Society (AAS) and the American Physical Society (APS) should study the recent and projected growth of the leading US astronomy and astrophysics research community to inform the decadal planning exercise of possible strategies for the next decade.

1. Introduction

The 2010 Astronomy and Astrophysics decadal survey, New Worlds New Horizons (*NWNH*), stressed the importance of achieving balance between funding facilities and space missions and keeping a healthy core program of PI-led research. In page 132-133, *NWNH* states[1]:

"A significant challenge for the astrophysics program is how to maintain support for individual investigators pursuing a broad range of activities in a landscape where specific, large programs provide a fluctuating level of funding for associated analysis and theory. Realizing the scientific potential of existing facilities is of primary importance, but so is placing the broad range of results in appropriate context, providing young scientists with opportunities to develop their potential, and enabling the creative thinking that lays the foundations for the future.

As in most fields, the primary mechanisms for supporting research and training are competed grants programs. NASA funds both general mission-enabling grants programs and those supporting the specific science from operating satellites, such as the guest observer programs associated with Hubble, Chandra, Spitzer, and Fermi. NSF supports a general astronomy and astrophysics grants program as well as more specialized programs such as the CAREER awards and the Astronomy and Astrophysics Postdoctoral Fellow program. DOE supports centrally administered grants programs, those administered through specific DOE laboratories, and awards for young investigators.

In recent times, funding for these essential programs has flattened or even declined at NASA and NSF, especially when considered relative to the growth of the field."

Unfortunately flat funding for basic sciences and the downward trend in the funding of the competed grants program has continued after the publication of *NWNH* in 2010 with a corresponding decrease in proposal success rates. The dynamics of such a decrease are nuanced, as the portfolio of competed grants for the US astronomy and astrophysics community is complex and agency dependent. The principal support for *NWNH* science comes from NASA Astrophysics Division (NASA/APD) and National Science Foundation Astronomical Sciences Division (NSF/AST). A productive increase in interdisciplinary interagency collaboration, notably with NSF Physics Division (PHY) and Department of Energy (DOE) High Energy Physics (HEP) Division, has helped to strengthen some areas of the program recommended by *NWNH*. NASA Planetary and Heliophysics Divisions also have strong traditional ties to the *NWNH* community in some areas of overlapping interest. The focus of this document is on the principal support of NSF/AST and NASA/APD from 2004 to 2014. Related efforts in NSF/PHY, NASA Planetary and Heliophysics are briefly discussed.

2. NSF Division of Astronomical Sciences (NSF/AST)

The Individual Investigator Program at NSF/AST includes a number of programs that individual investigators can compete for. The largest and broadest is the Astronomy and Astrophysics Research Grants (AAG) with an allocation of $43.7M in FY14, which was about 18% of the total division budget of $238.4M. Other competed programs and their FY14 budget include Astronomy and Astrophysics Postdoctoral Fellowships (AAPF) at $2.05M, Advanced Technologies and Instrumentation (ATI) $7.5M, Faculty Early Career Development Program (CAREER) at $4.76M, Enhancing Access to the Radio Spectrum (EARS) at $6.85M, Major Research Instrumentation Program (MRI) $7.23M, and other smaller programs.

Given its size, impact, and breadth, the success rate in the AAG program is the most appropriate tracer of the health of competed grants at NSF/AST. Figure 1[2] shows the funding of AAG from FY90 to FY14 and the proposal success rate during the same period. Over the FY04 to FY14 decade, AAG funding increased from $30.7M for FY04 to $43.7M for FY14 (which corresponds to $34.9M in 2004 dollars). Setting aside the American Recovery and Reinvestment Act of 2009, the growth of AAG peaked in FY10 to $49.4M ($42.7M in 2004 dollars) and has decreased from FY10 to FY14; over the same period the proposal success rate declined below historical minima.

From ~ 50% in the early 1990s to ~30% in the early 2000s, the success rate in AAG decreased significantly over the last decade reaching a value as low as ~15% in FY12 and just slightly higher at ~17% in FY14. In the absence of increased overall funding for NSF/AST and/or vigorous implementation of facility divestment as recommended by the Portfolio Review Committee, the increase in demand will drive the AAG success rate to decrease from ~15% in FY15 to below ~10% in FY19 (assuming the continuation of a 2% rise in total AAG dollar demand per year and the projected NSF/AST budget and portfolio without facility divestments out to FY19). Operations of the Large Synoptic Survey Telescope (LSST), the first priority for NSF in *NWNH*, will strain the budgets further in the next decade.

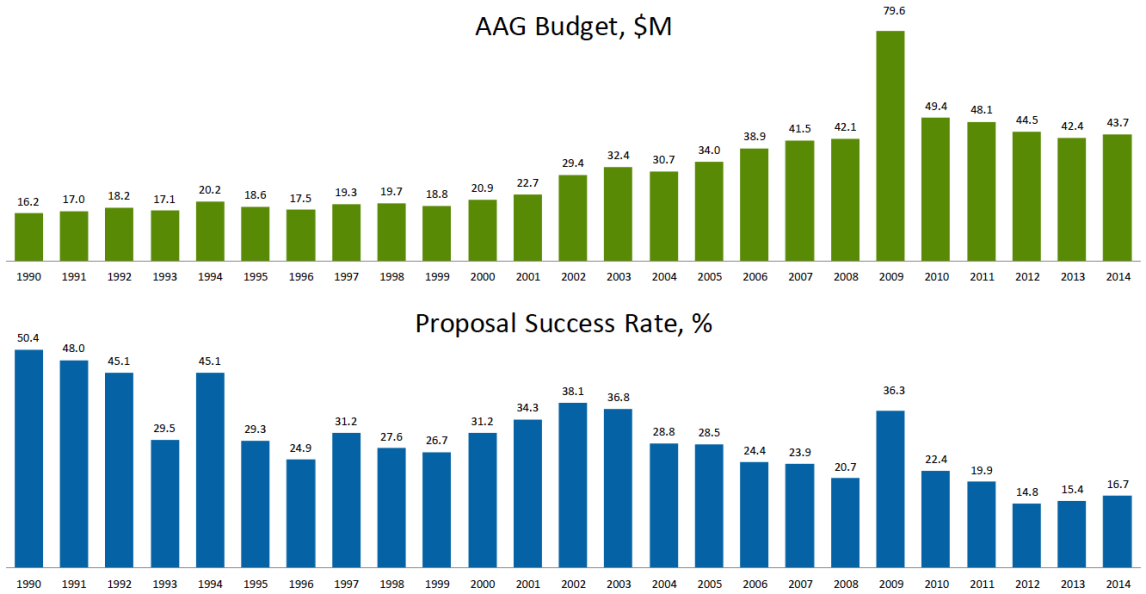

Figure 1: NSF/AST AAG Budgets and Proposal Success Rates from 1990 to 2014. The anomalous spike in FY09 is due to the one-time stimulus provided by the American Recovery and Reinvestment Act.

The low success rate is driven by a combination of flat funding and growth of number of submitted proposals. The number of submitted proposals roughly doubled from 379 in 2004 to 731 in 2014. The four fields that AAG proposals are reviewed in, Extragalactic Astronomy and Cosmology (EXC), Galactic Astronomy (GAL), Stellar Astronomy and Astrophysics (SAA), and Planetary Astronomy (PLA) all increased significantly (see figure 2). (Note that SAA and PLA assignments were restructured in 2013-14 by a move of extrasolar planet studies to PLA.)

Many aspects of the AAG statistics remained unchanged during the 2004 to 2014 period. The distribution of funding requests among budget categories (e.g., indirect costs, publications, computing, subcontracts, participant support, travel, equipment, fringe, personnel) remained nearly constant over the decade. Between FY08 and FY15, the fraction of AAG proposals that requested less than 3 months of salary per year also remained approximately flat (around 80% to 85%). The funding rate for women remained approximately equal to submission rate between FY04 and FY14 and the overall percentage of female PIs experienced a modest growth from below 20% in 2004 to about 25% in 2013. The distribution by type of institutions of proposing PIs also remained steady with 80% to 85% being PhD granting institutions.

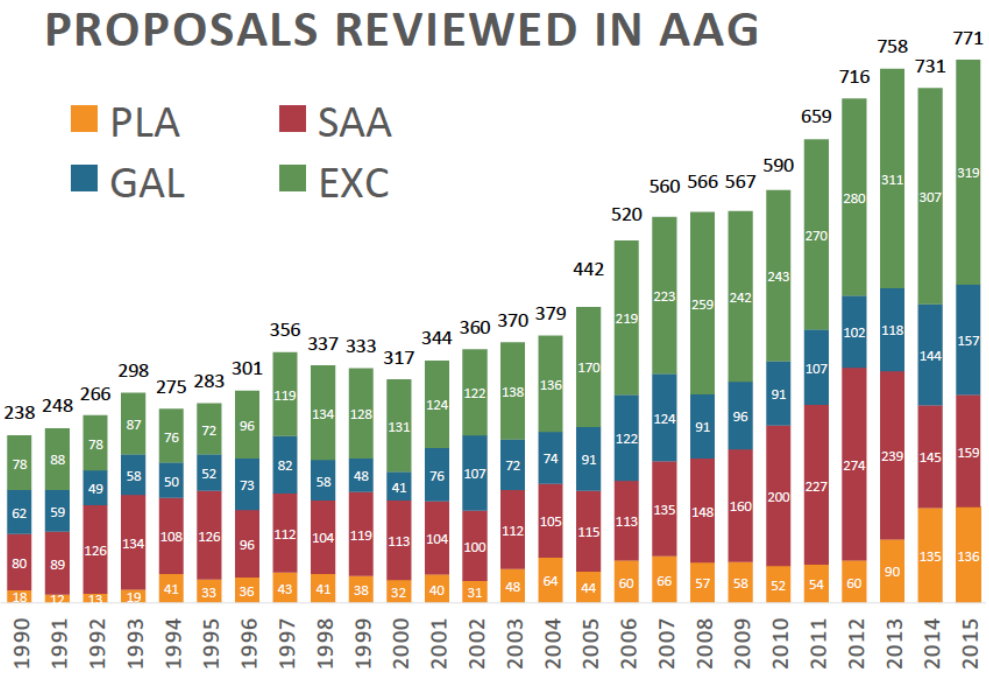

Figure 2: NSF/AST AAG Proposals divided by review sub-fields (EXC, GAL, SAA, PLA) from 1990 to 2015.

NSF/AST data indicate that proposal budgets are not growing out of line with inflation. The median proposal request for the AAG program has increased from $93k/year to $150k/year over the last 25-year period, which corresponds to a 12% reduction in constant 2015 dollars. Reducing the size of grant budgets exacerbates the proposal pressure, since a larger number of grants are required to support a viable research team, or the full salary of a key (non-academic) researcher.

The percentage of AAG proposals by PIs with 0 to 4 and 5 to 9 years after their PhD remained an approximately steady fraction of the overall distribution between 2006 and 2015 while the fraction of PIs with more than 25 years post-PhD increased from 25% to 29% from FY08 to FY15 as shown in Fig. 3. The success rate for first-time proposers has tracked the overall success rate over the years being only slightly lower: in FY14 the overall success rate was 17% while the new proposers success rate was 14.4%.

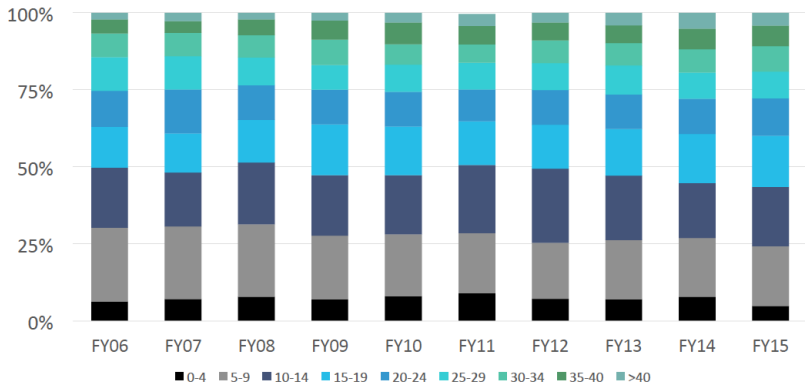

Figure 3: Distribution of submitted AAG proposal PIs versus seniority as measured by years after PhD.

The data show that there are no large trends in demographics or redistribution of proposals by subfield. The growth in submitted AAG proposals is most likely caused by the combination of new proposers joining the research effort, an increase in resubmissions of declined proposals, and an increase in the number of submitted proposals per PI.

The number of unique proposers per 3-year funding cycle has grown from 1025 during the 2008-2010 period to 1160 during 2013-2015, representing an average growth of 2.5% per year. This can be compared to the AAS full membership, which has grown from 3000 to 4500 over the years from 1990 to 2014, representing an average growth of 2.1% per year. Another indicator of new proposers is the growth in Astronomy faculty members of about 2.3% per year from 2006 to 2014, which was compiled by AIP[3].

From 2008 to 2015, the number of AAG proposals grew from 566 to 771 representing a 36% growth or an average ~5% growth per year. The character of this growth is sporadic with large fluctuations. To get a sense of the many factors involved one can assume the growth of the community to be about 2 to 2.5% per year on average, thus there is an additional factor of 2.5 to 3% per year that has affected the growth in number of proposals.

The number of single proposals submitted per PI in AAG has grown by about ~2.8% per year from 2008 to 2015. Multiple proposals submitted by the same PI to AAG on a given year can explain an additional average yearly growth of about ~2% from 2008 to 2015 on the total number of proposal. The contributions from multiple proposals nearly doubled from 56 in 2008 to 106 in 2015 with large fluctuations. In principle, this effect could be effectively controlled if NSF/AST limits the number of proposals submitted by individual PIs to AAG each year. Currently, NSF/AST strongly suggests that researchers voluntarily limit themselves in a "Note about FY16 AAG Proposals".[4] While this limit is one option to lessen the burden on proposers and reviewers, one award may be insufficient to support the personnel and other resources needed for the success of a given project.

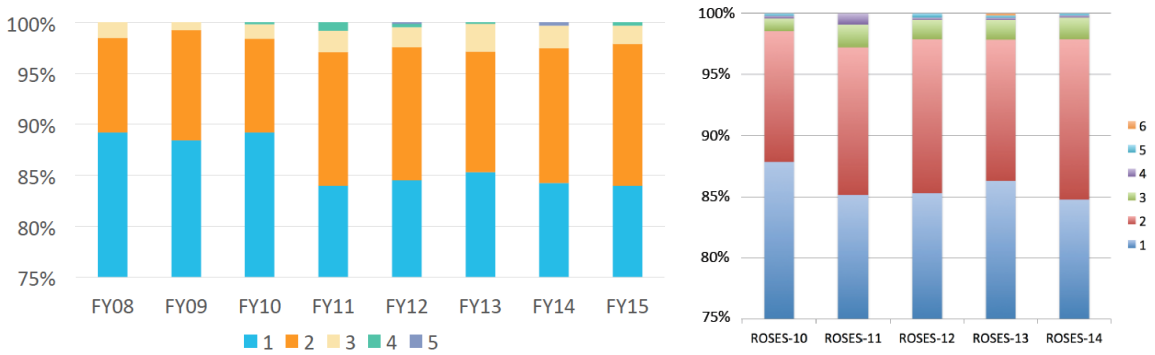

Figure 4: percent of PIs that submit multiple proposals to NSF/AST AAG from FY08 to FY15 (left[5]) and NASA/APD ADAP, APRA, and ATP from 2010 to 2014. Numbers next to each color represent the percent of PIs submitting 1, 2, 3, 4, and 5 proposals per year. (These numbers include only PIs, not Co-Is.)

As the success rate decreases it is likely that the number of resubmissions in subsequent years tends to increase. The typical AAG award is for 3 years, thus when success rates were higher, a larger fraction of investigators were likely to submit funding proposals once every 3 years. Agencies do not keep track of resubmissions following a failed proposal from the year before, but a study that compares the similarity

of the text of a given proposal with any proposal submitted in the prior year[6] is consistent with the hypothesis that AAG PIs are resubmitting proposals more often in FY12 to FY14 then in FY08 and FY09.

Summarizing the findings in the case of NSF/AST AAG, a combination of a number of small effects over the decade have conspired to create an extreme ~50% growth in number of proposals during a decade of flat funding. Flat budgets combined with the ~2% annual growth of new researchers, the effect of multiple proposals per PI per year, and a faster cadence of annual resubmissions, produce a ~5% annual increase in the number of proposals. To alleviate this situation an increase in the NSF/AST budget combined with a vigorous implementation of the Portfolio Review recommendations can alleviate the stressed AAG program, avoid even lower success rates, and realize the scientific potential of leading facilities operating and under constructions in this decade. In addition, the impact of proposed changes designed to mitigate this situation should be studied by the upcoming AAS/APS survey.

3. NASA Astrophysics Division (NASA/APD)

Over the last decade, the funding for openly competed Research and Analysis (R&A) at the NASA Astrophysics Division (NASA/APD) through the Research Opportunities in Space and Earth Sciences (ROSES) programs has stayed approximately flat. The R&A program includes the Astrophysics Research and Analysis (APRA) program, Astrophysics Data Analysis Program (ADAP), Astrophysics Theory Program (ATP), Exoplanet Research Program (XRP), Nancy Grace Roman Technology Fellowships (RTF), and others. R&A was funded at $82M in FY05, suffered a 15% cut in FY07, and only reached $82M again in FY12. By FY15 it grew back to $90M (which is still below the inflation corrected value of FY05). In addition, the guest investigator programs associated with operating missions fluctuated from $68.9M in FY05 to $56.2M in FY15 with peak funding in FY07 of $78.4M. On a positive note, the funding available for named fellowships (Hubble, Einstein, and Sagan) grew steadily from $5M in FY05 to $13.6M in FY15.

The number of submitted proposals to the NASA/APD R&A program has increased from around 500 in FY04-05 to past 800 in FY15.[7] With some fluctuations, the number of selected proposals and the funding levels for selected proposals in NASA/APD have remained approximately constant, so the success rate for proposals has decreased from ~30% to ~20% over the decade. Including the NASA Astrophysics Guest Observer programs increases the overall success rate to approximately 25%.

NASA Astrophysics has tracked proposal scores for many years and has reasonable confidence in the stability of the ranking scale. The proportion of all submitted proposals that are rated Very Good to Excellent (VG, VG/E, E) has remained roughly constant, with some evidence for at most a ~10% decrease. Also stable across all programs are the success rates for proposals with VG/E and E ratings at >75% and >90%, respectively. However, the success rate of proposals in the VG category has fallen from 45% in 2007-2008 to 25% in 2012.[8] Thus, while the quality of submitted proposals appears to remain high, a greatly increasing fraction of meritorious proposals can no longer be funded.

While not as comprehensive as the available data from NSF/AST, data of the NASA APD competed grants programs show similar trends to NSF/AST. In 2014 there were 573 proposals from 476 unique PIs applying to NASA Astrophysics R&A programs. In 2008 and 2009, the number of proposals rose from 290 to 393. Thus we know that there were no more than 290 (393) unique PIs in 2008 (2009), compared to 476 in 2014. The pattern of increased number of PIs mirrors the situation for NSF/AST. As shown in figure 4, the number of PIs submitting only one proposal is around 80 to 85% similar to NSF/AST. The

number of PIs submitting more than one proposal also increased in NASA's ROSES program from 2010 to 2015.

4. Other Related Programs

Another funding resource for some areas in *NWNH* comes from the NSF Particle Astrophysics (PA) program in the Division of Physics (PHY). NSF PHY/PA is a smaller program that studies astronomy and astrophysics with particles: cosmic rays, high-energy photons, neutrinos, and dark matter particles. Over the past decade, their budget has been a steady percentage of the Physics budget, around 7%. While the program is small compared to NSF/AST its success rate has also decreased. From 2005 to 2014 the number of proposals more than doubled (from 30 to 70), whereas funding increased by about 34% in the same period. The average success rate from 2005 to 2007 was 45%, while from 2012 to 2014 the success rate had decreased to 39%.

The solar and space physics community relies primarily on NASA Heliophysics (125 proposals per year) and the NSF Division of Atmospheric and Geospace Sciences (25 proposals per year in Solar-Terrestrial). Overall, inflation has steadily eroded the buying power of NASA Heliophysics research funding, which has remained essentially constant in real dollars since FY04. The success rate has decreased steadily over the last 8 years, dropping from ~35% to 17%.[9] The same story is generally true for NASA's Planetary Science Division. The Planetary budget for competed grants grew from $110M (2006) to $180M (2014) and the proposal success rate went from above 30% to around 23%.

Over the last decade the NASA Heliophysics program has increasingly emphasized a few larger missions at the expense of smaller missions and the competed research program. The Solar and Space Physics survey gave specific recommendations to rebalance the portfolio in the next decade, with an emphasis on research and analysis. NSF Division of Atmospheric and Geospace Sciences (AGS) is currently conducting its own portfolio review of geospace facilities in order to address this challenge of operating new facilities versus the expense of existing facilities and the competed research programs.

Since the AAAC is concerned with interagency coordination, it would be desirable to assess the extent to which PIs are submitting proposals to multiple agencies. At this time such an analysis is not possible, since the PI names of declined proposals are not public. A future APS/AAS survey may address this point and other limitations of the analysis presented here.

5. The Cost of the Review Process

The most serious consequence of a low proposal success rate is the loss in scientific productivity of the leading research efforts in US astronomy and astrophysics. The smaller fraction of meritorious science projects that are funded by openly competed grants limits the full realization of the scientific potential of existing facilities, and the creative thinking that lays the foundations for the future. At these historically low success rates a large percentage of very good to excellent science is not being supported.

The increased proposal load also poses significant review management challenges to the funding agencies. Although agency staffing has remained relatively flat in recent years, the number of panels and the number of proposals per panel have both increased. The organization and execution of just one

panel takes 130+ hours of each NSF Program Officer's time. NSF has developed a number of tools to optimize the internal review processes, but another 30% increase in proposal volume over the next five years would not be manageable. In 2014, NASA/APD handled 832 proposals in its core R&A programs. The estimated yearly cost in NASA staff time and direct expenses for reviewer travel, meeting space, etc. to plan, execute, and document the evaluation and selection process is ~$3M.

In addition, recruitment of reviewers is another challenge. With an increase in submissions, conflict of interest disqualifies a large number of possible reviewers. In addition, reviewers are less likely to accept a task where most highly rated projects cannot be funded. Reviewer acceptance rates have been falling; currently only 20-25% of reviewers agree to serve when asked.

4. Conclusion

The last decade has witnessed the construction and operations of world-leading observatories with the potential to secure the long-term leadership of US astronomy and astrophysics. Over the same period funds available for community-wide openly competed grants have remained largely flat in both NSF/AST and NASA/APD. Balance between funding construction and operations of observatories and maintaining a healthy core program of competed grants is crucial for the future of the field as stressed by *NWNH*.

Flat funding of the core program strongly correlates with a significant decline in proposal success rates. The effect of flat funding of the core program combined with the success of the field in attracting a modest 2% to 2.5% per year rate of new investigators generates a decline in success rates. The impact of an increase in the number of proposals submitted by the same PI on a given year or in subsequent years, natural reactions to a declining success rate, exacerbates the decline.

NSF and NASA should continue to work toward balance of their portfolio including divestment and termination efforts that can increase funding for the base program, alleviate the proposal pressure crisis, and realize the scientific potential of leading new facilities and missions.

Community based groups such as the American Astronomical Society (AAS) and the American Physical Society (APS) should study the recent and projected growth of the leading US astronomy and astrophysics research community to inform the decadal planning exercise of the end of this decade. Such a study should include a measure of the impact of proposed remedies to the falling success rates.

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[1] National Research Council. New Worlds, New Horizons in Astronomy and Astrophysics. Washington, DC: The National Academies Press, 2010. doi:10.17226/12951.

[2] http://www.nsf.gov/attachments/131083/public/Dan-Evans_AST_Individual_Investigator_Programs-AAAC_Meeting.pdf
[3] numbers provided by Rachel Ivie, Director Statistical Research Center at the American Institute of Physics
[4] http://www.nsf.gov/div/index.jsp?org=AST
[5] http://www.nsf.gov/attachments/131083/public/Dan-Evans_AST_Individual_Investigator_Programs-AAAC_Meeting.pdf
[6] http://www.nsf.gov/attachments/131083/public/Dan-Evans_AST_Individual_Investigator_Programs-AAAC_Meeting.pdf
[7] http://science.nasa.gov/media/medialibrary/2015/01/07/AAS_Townhall_Hertz_Jan2015_FINAL.pdf
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[9] http://science.nasa.gov/researchers/sara/division-corner/heliophysics-division-corner/