Impact of Declining Proposal Success Rates on Scientific Productivity

Version: 2015 July 08 - PC

AAAC Proposal Pressures Study Group Keivan G. Stassun, Ted von Hippel, James Lowenthal, others...

Recent years have witnessed an overall decline in the fraction of proposals for basic research in astronomy and astrophysics which are successful in obtaining funding. There are an increasing number of proposals per funding opportunity, while the agency budgets are flat or declining in inflation-adjusted dollars. While this basic trend is incontrovertible, the fundamental cause(s) and therefore the appropriate response(s) have been less clear. What is the appropriate between, on the one hand, a healthily competitive funding environment, and on the other hand, a funding environment in which proposal writing prevents more science from being done than the sought-after funding would have enabled. In other words, what quantitative proposal success rate threshold should be considered "too low"?

This brief report from the AAAC Proposal Pressures Study Group presents the interim results of an ongoing analysis of funding agency statistics, together with findings from recent literature on the impact of proposal writing. Our purpose is to assess how declining success rates affect the health of astronomy and astrophysics research. This is a direct response to the 2014 AAAC report¹ 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." The 2015 AAAC report² included preliminary findings from the newly-formed Study Group, many of which are included here. In this short report, we also put the effect of falling success rates in context, by examining results from "A Survey Analysis of Grant Writing Costs and Benefits."³*

Executive Summary: By 2014 proposal success rates in NASA Astrophysics had dropped to roughly 25% (including mission Guest Observer programs). In the NSF Division of Astronomical Sciences proposal success rates dipped to 15% and in the absence of facilities divestment, are projected to drop to 10% by 2018. Data across agencies show that this is not principally the result of a decline in proposal merit (the proportion of proposals receiving high rankings is largely unchanged), nor of a shift in proposer demographics (seniority, gender, and institutional affiliation have all remained unchanged), nor of an increase (beyond inflation) in the average requested funding per proposal, nor of an increase in the number of proposals per investigator in any one year. Rather, the statistics are consistent with a scenario in which the overall population of investigators has grown, and a larger proportion of these investigators are resubmitting meritorious but unfunded proposals, likely in response to the decreased success rates. Recent research on the time cost of proposal writing versus that of producing publishable results suggests that a funding rate of ~6% represents the tipping point below which proposal writing prevents more papers than grants produce. However, we suggest a more useful benchmark threshold is ~20%: At this threshold, the opportunity cost is still significant (2-3 papers per successful proposal), and the average investigator submitting a "very good" to "excellent" proposal can expect only a ~50% chance of funding after three attempts. In addition, at this average funding rate of 20%, new investigators and those who have gone unfunded in recent years experience an effective funding rate of ~10%. close to the tipping point mentioned above. We emphasize that this does not represent an optimally healthy success rate for meritorious science; rather it is a recommended absolute minimum for the viability of the field. An aspirational funding rate of 30-35% would be healthy and yet still competitive.

1

Priscilla Cushman 7/9/2015 9:53 AM Comment [1]: Which opportunity? ROSES? Individual research grants?

¹ http://www.nsf.gov/mps/ast/aaac/reports/annual/aaac 2014 report.pdf

² http://www.nsf.gov/mps/ast/aaac/reports/annual/aaac_2015_report.pdf

³ http://journals.plos.org/plosone/article?id=10.1371/journal.pone.0118494

1. Proposal success rates and demographics trends

The data clearly indicate that the number of proposals submitted to NASA and NSF in the fields of Astronomy and Astrophysics is increasing faster than the funding available, causing a corresponding drop in success rate. The number of individual investigator awards available is also constrained by existing or proposed commitments to space-based missions or ground-based facilities operations. In the face of constrained federal budgets, this portfolio balance becomes one of the few knobs that can be used to adjust the proportion of individual research grants which are funded. Another adjustable knob could be the size of the average grant budget, but data indicate that proposal budgets are not growing out of line with inflation. The data show that the PIs submitting these proposals have remained a stable demographic entity in terms of race, gender, number of years since PhD, type of institution, and number of proposals submitted per opportunity. However, as discussed below, the data do indicate that proposers are now more likely to resubmit their meritorious but unfunded proposals. The data therefore suggest that researchers consequently spend more time re-submitting their proposals, often to no avail. We consider the impact on scientific productivity in Section 2.

1.1 Proposal funding rates

At present, the grants budgets for basic astronomy and astrophysics research in NSF and NASA are **\$xxxM** and **\$yyyM** per year, respectively. Over the last decade, there has been a steady decline in the rate of successful proposal funding for individual investigator grants and mid-scale grants in the fields of Astronomy and Astrophysics, across all of the basic funding programs at NSF and NASA. As an example, the number of proposals submitted to the NSF/AST AAG program from FY05 to FY15 has increased by 84% resulting in success rates which have plunged to 15% from roughly 30% in 2005, as shown in Figure 1. In the absence of any portfolio readjustment, the proposal success rate would fall even lower to ~10% in FY19. Indeed, NSF/AST is moving forward rapidly to divest those optical and radio telescopes recommended by the Portfolio Review to prevent this scenario. If divestment proceeds as planned, if the budget continues to be flat, and if modest trimming of proposal budgets is maintained at the levels practiced by NSF/AST in recent years, then success rates can be stabilized at ~15%. This is still lower than the recommended minimum of 20% (see below). Note that the NSF AST funding rate was a much healthier 30-35% in the early 2000's, such that the average investigator could expect a manageable risk of ~25% of no funding after three attempts as Shown in section 2.



Figure 1. Historical NSF/AST (AAG) proposal success rate⁴ through 2014, and projected success rate in the absence of facility divestment. The anomalous spike in FY09 is due to the one-time stimulus provided by the American Recovery and Reinvestment Act.

⁴ http://www.nsf.gov/attachments/131083/public/Dan-Evans_AST_Individual_Investigator_Programs-AAAC_Meeting.pdf

2

Keivan Stassun 7/9/2015 9:53 AM

Comment [2]: Prisca, add in the current budget amounts, as per David Lang's question.

Priscilla Cushman 7/9/2015 9:53 AM Comment [3]: Need help here – is this ROSES? Is this ?? what actual compendium of grants will we quote?

1.2 Proposal quality

NASA/APD has tracked scores for many years and has some confidence in the stability of the scale. Using NASA selection data from all Science Mission Directorate ROSES programs⁵ from 2007 to 2012, a pattern emerges. First, the proportion of submitted proposals that are rated Very Good to Excellent is roughly constant, with some evidence for at most a ~10% decrease in the proportion of such highly rated proposals. Second, while the success rate for VG/E and E remain stable at >75% and >90% respectively over all programs, the number of funded proposals in the VG category is rapidly falling from 45% in 2007-2008 to 25% in 2012. Thus, the proportion of proposals rated as meritorious (Very Good to Excellent) has not changed significantly and remains high, but the majority of these proposals can no longer be funded.

1.3 Proposer demographics

NSF data from the Astronomy and Astrophysics Grants (AAG) program show that the rise in proposals is driven largely by an increase in the number of investigators participating in a given year, each submitting on average one proposal. The proportion of individuals submitting two or more proposals has only experienced a modest rise from 16% to 21%. Data from NASA and DOE do not have as straightforward a breakdown, but the same story emerges. For example, for NASA Astrophysics programs (ADAP, ATP, WPS and XRP) in 2014, there were 573 proposals from 476 unique Pls⁶. In 2008 and 2009, the number of proposals rom 290 to 393. Thus we know that there were no more than 290 (393) unique Pls in 2008 (2009), compared to 476 in 2014. Note that this does not address whether Pls are submitting a larger number of similar proposals to multiple agencies without disclosure.

By tracking the growth of PIs who are members of the Astronomy and Astrophysics community, we can see that the population growth is not dominated by an influx of PIs from other fields. While the total membership of AAS has increased substantially, it has grown mostly by conscious recruitment of graduate students and postdocs. Comparing the number of PIs to the number of full AAS members is a fairer measure. In 1990 ~7% of the 3000 AAS full members were PIs, whereas in 2014 it has grown to ~13% of the 4500 full members.

The possibility that funding opportunities and fellowships targeting postdocs have created an additional population, just now moving into the ranks of PI, is also not borne out by the statistics. Indeed, the proportion of submitting PIs who are less than 15 years since PhD has actually declined somewhat in NSF AST, from ~50% in FY06 to ~45% in FY15. In NSF Particle Astrophysics, the fraction of younger PIs was very small⁷ when the division was created in 2000, so the uptick in younger researchers since then has simply brought it into the same balance observed by NSF/AST over the last decade.

There is also no significant change in the proportion of institution types submitting proposals⁴, nor in the average salary-months requested by PIs⁴, nor in the average requested inflation-adjusted budgets⁴, nor in the relative success rates by gender and ethnicity⁴. The data do not directly speak to possible changes in the proportion of "soft money" investigators driving up proposal pressure, however to be consistent with the above findings, such soft money investigators would have to comprise a mix of junior and senior investigators in such a way as to leave the overall demographics unchanged. It is thus clear that, while the number of proposers has been rising steadily, the demographic pool from which they are drawn has not significantly changed. The mix of junior and senior investigators is largely unchanged, and the number of investigators submitting multiple proposals has increased only modestly.

1.4 Proposal resubmissions

In Figure 2 note that the average number of unique proposers over a typical 3-year grant cycle (number in the right panel divided by 3) is less than the number proposing each year. These data (and anecdotal evidence) indicate that senior investigators are reapplying in the next year(s) when their 3-year proposals are not funded. This has the effect of driving up the number of proposals each year, and driving down the success rates even further. While we do not have direct access to how many of the proposals are new and how many are resubmissions, we can come up with quantitative models under

⁵ <u>http://science.nasa.gov/researchers/sara/grant-stats/a-plot-of-grades-vs-who-gets-selected/</u>

⁶ http://science.nasa.gov/media/medialibrary/2014/04/09/2014.03.27_ApS_RA_final-2.pdf

⁷ NSF/PHY Program in Particle Astrophysics data. Provided by J. Whitmore.



Priscilla Cushman 7/9/2015 9:55 AM Comment [4]: Still do not know where this

comes from . Joel Parriott says try Marc Postman or Jim Ulvestad some general assumptions. For example, if we assume that the number of new proposals is **not** rising each year, and that the falling success rates of Figure 1 are applied each year equally to the mix of new and repeat proposals, then the resubmission rate can be obtained. A simple fit under these conditions to the each-year and 3-year submission rate data in Figure 2 yields a 70% resubmission rate. As an example, if the number of new proposals and resubmitted proposals had been equal in 2008, then by 2014 the number of new proposals would be only 40% of all submitted proposals. Thus resubmission has a secondary effect of driving up the number of proposals and driving down the success rates even further. Previously a larger fraction of investigators could submit funding proposals roughly every 3 years, whereas now they increasingly (re)propose in consecutive years, for some (as yet unknown) number of years. We revisit the issue of repeat submissions and success rates below.



Figure 2. Trending plots showing the number of unique individuals submitting to NSF/AST AAG program as PI each year, as well as the sum over 3 years corresponding to a typical grant cycle. Declined proposals can be re-submitted the next year, but PIs with accepted proposals will not resubmit for the same project until after (typically) 3 years.

2. What should be the minimally acceptable funding rate for meritorious science?

Having established that the steady declines in proposal success rates are not being driven principally by changes in proposer demographics, nor in the merit of the science proposed, we consider the question: What should be adopted as the minimal acceptable funding rate? To answer this question, we draw upon and extend recent research that uses empirical data to develop a statistical model of astronomy grant proposers and success rates³.

2.1 Probabilities of funding success

Table 1 uses the statistical model of von Hippel & von Hippel (2015) to consider various hypothetical scenarios of funding and resubmission rates, assuming that the typical investigator submits a single proposal to a given opportunity (consistent with real behavior as illustrated in Section 1). Scenarios corresponding to NSF Astronomy funding rates in FY2003, and those projected for FY2018 in the absence of any facility divestment (see Figure 1), are highlighted as green and red, respectively. Highlighted in orange is the minimum benchmark for sustainable scientific productivity, defined as the point at which the time it takes to write potentially unfunded proposal "costs" more in terms of scientific output than the papers facilitated by a successful proposal (see Section 3). Note that the historically much higher success rate of 30-35% in FY2003 still represented a healthily competitive environment, in which the average investigator faced a manageable level of risk (~25%) of no funding after three attempts.

Importantly, von Hippel & von Hippel (2015) show that, due to reviewers rating currently-funded investigators more highly (a well-known rater bias known as the Matthew Effect), the average funding rate is always an over-estimate of the true rate for new researchers. For example, for an average funding rate of 20%, a researcher with current funding has a 50% probability of being funded in the next cycle compared to only 7% for new researchers. This is also true for researchers who have not been successfully funded in recent years.. For a 20% average funding rate, presently unfunded and new investigators compete with one another for an effective funding rate of only 12%. Using these conditional probabilities for three consecutive attempts, one-eighth of the presently funded researchers (1 - 0.5)³ plus

4

two-thirds of the presently unfunded or new researchers $(1 - 0.12)^3$, or a total of ~80% of proposers, will be unable to secure grants for their research in a three-year funding cycle.

In this scenario, for a funding rate around 20%, even successful investigators may find themselves in a "meta-stable" situation, in which they experience a reasonably good funding rate for some number of years before the probabilities catch up with them and they "phase transition" into the unsuccessful group and therefore drop into the long-unfunded category.

PROPOSAL SUCCESS RATE	P (no funding) 1 try	P (no funding) 2 tries	P (no funding) 3 tries	P (no funding) 4 tries	P (no funding) 5 tries
10%	90%	81%	73%	66%	59%
15%	85%	72%	61%	52%	44%
20%	80%	64%	51%	41%	33%
25%	75%	56%	42%	32%	24%
30%	70%	49%	34%	24%	17%
35%	65%	42%	27%	18%	12%

Table 1. Probabilities of unfunded proposals for different hypothetical funding rates and number of proposal attempts. The green shaded cell represents the state of the field circa 2003 (see Fig. 1). The red shaded cell represents the impending situation expected by FY2018 in the absence of portfolio rebalancing. The orange shaded cell is the nominal "absolute minimum" benchmark recommended here.

2.2 The cost of time and scientific productivity

Three quarters of the proposers in the von Hippel study were at large research universities. The survey found that principle investigators spend 116 hours on average per proposal, and co-investigators spend 55 hours, corresponding to 10-15 research hours per week. This translates into more than 8 PI calendar-weeks and 3.8 Co-I calendar-weeks per proposal. In effect, writing a typical proposal costs these investigators an average of 0.41-0.67 research papers. If the funding rate averages only 20%, the cost per successful proposal becomes 2.1-3.3 (on average) papers. On the other hand, the number of papers facilitated by grants in astronomy is approximately 7.9 papers per grant. If astronomy funding rates were to drop to ~6%, time spent on proposal writing would exceed that spent on the research papers that the subsequent grants produce.

3. Concluding Remarks

An average funding rate of ~6% in astronomy would represent an unsustainably low rate for the health of the field. Yet, as discussed above, this is close to the effective funding rate for new investigators or investigators who have recently transitioned into unfunded status even for an average success rate of 20%, and the current average is already below this in NSF/AST. Such a low success rate costs our field an immense amount of scientifically productive time and may push investigators away from grant-supported research. We should strive for a funding success rate similar to that seen a decade ago in order to prevent proposal writing costs from overtaking scientific productivity, and to encourage bold new ideas. A success rate of 35% on average, when combined with the Matthew Effect, allows ?? % of new researchers to successfully compete with established programs after ?? tries on average.

The capabilities provided by new facilities and missions are exciting for the field and provide tools for the next breakthrough discovery, however direct support for investigators is just as important, in order to realize those capabilities. As the data and analysis discussed above show, funding rates as low as the current ~15% in NSF/AST clearly indicate the need to address the balance between grants and facilities in the agency portfolio. The situation in NASA Astrophysics is somewhat better at present, and there is the hope of increasing funding through upcoming GO opportunities (e.g., in connection with JWST). Even though the currently high portfolio fraction devoted to ground-based facilities operations has been seen before (i.e. <u>~60% in the 1980s</u>), the funding rates then were a factor of 2-3 higher than today. Thus, both the low overall funding and the ever-increasing number of meritorious proposals (and scientists they

Priscilla Cushman 7/9/2015 9:53 AM Comment [5]: Resubmitted proposals are already included in the success rates, so they do not add additionally to the opportunity cost on average.

Priscilla Cushman 7/9/2015 9:56 AM

Comment [6]: Can you calculate these numbers for 30%...what does Matthew effect give for the aspirational number? Keivan says it is only calculated for 20% - why?

Keivan Stassun 7/9/2015 9:53 AM

Comment [7]: Check this.

Keivan Stassun 7/9/2015 9:53 AM Comment [8]: Check this.

5

represent) represent a crucial qualitative difference today. It warrants a fresh look at steps to rebalance the portfolio, seriously protect the grants programs, and understand how to address the practical problems associated with increased proposal pressures on both the researchers and the funding agencies as they cope with this stress, such that once again we can provide the capacity to enable the best science.

6