investments and provides agencies with specific guidance. *On the order of $40 million per year spread across the National Aeronautics and Space Administration (NASA), National Science Foundation (NSF), and Department of Energy (DOE) would be required to address the highest priorities*. Ideally, this funding would not come at the expense of current research grant funding but would be supplementary. Not all issues can be addressed immediately. Where appropriate, the panel identified methods to be implemented rapidly and others that require more time.

As this report was written in mid-2020, the United States was in the midst of profound self-examination of social and economic inequalities resulting from historic and systemic racism, discriminatory police brutality highlighted by the Black Lives Matter movement,[2] sexual harassment and inequalities highlighted by the #MeToo movement, and the starkly inequitable and severe health and economic impacts of the COVID-19 pandemic on people of color. This background of social ferment and introspection makes all the more timely and more urgent a frank assessment of the ties between the equity and well-being of the Profession, including issues of race, ethnicity, gender, and workplace climate.

N.2 THE LANDSCAPE OF THE ASTRONOMY PROFESSION

This section gives a snapshot of the state of the Astronomy Profession as of mid-2020, the forces that have shaped it over the past decade, and those likely to shape it going forward. This discussion is not comprehensive, but outlines themes and conditions of the Profession that ground the panel's suggestions.

N.2.1 What Does the Panel Mean by "the Profession"?

Historically, astronomers have conceived the Profession (Box N.1) as a relatively dehumanized scientific enterprise, pursuing observatories and data with secondary regard to the humans who use them and the values that animate their work. As a result, progress toward an equitable and inclusive profession that is representative of the population has been slow. Astronomers have often failed to ethically engage with communities who are impacted by the facilities that they build. Barriers to equitable access and advancement are ingrained in both educational and professional astronomy contexts. Identity-based discrimination and sexual harassment continue within the Profession. These wrongs undermine the professional integrity and the scientific excellence of the Profession.

The panel asserts that people and organizations are integral to the discovery process. The panel is concerned with the full scope of resources that enables scientific advancement. This includes the Profession that *does* the science, their knowledge and skills (i.e., human capital), and equity in the organizations where the work is carried out. In this report, the panel considers "the Profession" to be the community of scientists, engineers, technicians, and nontechnical people engaged in the production, dissemination, and instruction of astronomical knowledge, as well as learners on the path to joining their ranks. More than half (54 percent) of full-time employed U.S. American Astronomical Society (AAS) members with Ph.D.s work at institutions of higher education; 33 percent work at government labs, research institutes, or observatories.[3] Also relevant are the broader set of communities with whom the Profession interacts, including amateur astronomers, editors, journalists, and educators who enable, support, communicate, and inspire the work of astronomy.

Astronomy is a quest to understand the universe and humanity's place within it. Its discoveries resonate deeply with the public. Many in the Profession depend on a small number of shared resources:

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documentation. The specific resources used in making individual suggestions are provided in footnotes. The final implementation of suggestions made here will necessarily reflect more formal and thorough analysis of cost, schedule and most effective programmatic practices.

[2] See Box N.2, "Black Lives Matter."

[3] J. Pold and R. Ivie, 2019, "Workforce Survey of 2018 US AAS Members Summary of Results," https://aas.org/sites/default/files/2019-10/AAS-Members-Workforce-Survey-final.pdf, accessed 26 August 2020.

observatories and supporting infrastructure. While most astronomy funding comes from NASA and NSF, astronomy is one of many priorities for these agencies.[4] Still larger societal forces profoundly shape the Profession. Yet, as a small field, astronomy can be nimble and experimental, and grass-roots efforts of a few individuals through policy change can have a greater impact on the whole of the Profession. For example, NASA rapidly switched guest observer programs to dual-anonymous proposal review to reduce implicit bias from the review process.[5] Owing to astronomy's outsized visibility and influence in public opinion, its move toward equitable and inclusive practices may influence other professions to move in the same direction.

With these core qualities of the Profession in mind, the next section considers the central role of investments and the impacts they have on the Profession. Then, the panel provides a summary of the Profession's demographics at different points in the pathway from college to and through career and in both academic institutions and research labs.

N.2.2 Investments and Their Impacts

Funding affects everything from technology and infrastructure to academic opportunities and human capital development. Therefore, funding decisions influence which members participate, advance, and feel they belong. Overall funding for astronomy in the past decade has been increasing, with growing investment in facilities. But support of astronomers performing research and funding to train future researchers has been flat or declining during this same period.

N.2.2.1 Federal Agencies

Funding from federal agencies for astronomy has grown 40 percent in the past decade; however, this falls far short of the doubling in federal investment in astronomy that was envisioned in the 2010 decadal survey. Furthermore, funding for individual investigators and proposal success rates have been flat or declining. The Astronomy and Astrophysics Advisory Committee (AAAC) reports why this is happening and the impact on science and scientists of the declining proposal success rates.[6] The NSF Division of Astronomical Sciences (AST) allocates only 17.5 percent of its total division budget to its primary individual investigator grants program, the Astronomy and Astrophysics Research Grants (AAG). The largest share of the division's budget has historically been directed toward facility operation. Meanwhile, the grant success rate for NSF AST fell from 50 percent in 1990 to close to 15 percent in 2015 and has remained under 20 percent since. NSF AST undertook a mid-decade review to identify opportunities for divestments. This led to the elimination of NSF's Partnerships in Astronomy and Astrophysics Research (PAARE), their sole program to develop human capital at undergraduate and graduate levels through partnerships with minority-serving institutions. NASA Science Mission Directorate (SMD) proposal funding rates were a healthy 30–35 percent in the early 2000s, but since then they have steadily declined.

[4] For example, in the fiscal year 2020 NASA budget, the $1.729 billion spent on astrophysics was 7.6 percent of the total budget, and 24 percent of the NASA Science budget. The NSF Division of Astronomical Sciences budget was $287 million out of the NSF's $8.578 billion budget. DOE's Cosmic Frontier budget was $94.9 million out of DOE's $38.586 billion budget.

[5] A. Witze, 2019, NASA changes how it divvies up telescope time to reduce gender bias, *Nature* 571:156.

[6] P. Cushman, et al., 2015, "Impact of Declining Proposal Success Rates on Scientific Productivity," https://arxiv.org/ftp/arxiv/papers/1510/1510.01647.pdf.

N.2.2.2 Private Foundations

Private philanthropy has been an important source of funding for astronomy for over a century.[7] For instance, the Carnegie Institute funded the development of the Mt. Wilson Observatory in 1904, and construction of the Hale Telescope on Palomar Mountain was funded by the Rockefeller Foundation in 19282The Sloan Digital Sky Survey, supported by the Sloan Foundation, has transformed how astronomical research is conducted. The Heising-Simons Foundation recently funded the PI Launchpad to increase the number of space mission proposals led by principal investigators (PIs) with historically marginalized identities. A growing number of private foundations and individual philanthropists fund ground-based optical telescopes, individual researchers through fellowships and award programs, university participation in observatories, and an increasing role supporting postdoctoral researchers.[8]

N.2.2.3 Impacts of Trends in Investment

Scarcity of funding threatens capacities for creativity and risk-taking that are essential to bold scientific advancement. It also negatively affects the culture of workplaces and the training of the next generation. Scarcity increases the likelihood that both everyday and scientific decisions will be driven less by an ethical vision of scientific conduct than by urgency and pressure.

In this environment, the panel sees at least three promising directions that would enable progress. First, the field can communicate funding priorities to federal agencies to increase direct support to astronomers as researchers, mentors, and communicators, relative to agencies' funding of facilities. Second, private foundation support could grow significantly to play a bigger role in the Profession's future. Of the $2.3 billion in private funds distributed to science in 2017, 87 percent went to life sciences, with 11 percent ($250 million) going to physical sciences.[9] Third, the Profession can associate more closely with industry and related fields with strong growth and investment, such as data science and advanced computation, to better support a variety of career paths.[10] There are many applied areas where astronomy is positioned to contribute to the training of the scientific workforce.

N.3 DEMOGRAPHIC LANDSCAPE

The past decade has witnessed a substantial growth in the desire of Americans to participate in the excitement of astronomical discovery. The number of astronomy B.S. and Ph.D. degrees shows continued growth (Figure N.1). As nearly daily coverage of astronomical discoveries in the popular media reveals, the field is effectively communicating with the public. While there has been a steady increase in the numbers of women and Hispanic American degree recipients (Figures N.1 and N.2), the number of African American students earning Ph.D. degrees remains low and unchanged over three decades (Figure N.2).

[7] This section was informed by data collected by the Astro2020 Panel on an Enabling Foundation for Research.

[8] See https://www.hsfoundation.org/programs/science/51-pegasi-b-fellowship/.

[9] This information was provided by Marc Kastner, president, Science Philanthropy Alliance, in a presentation to the Enabling Foundation for Research Panel, 22 October 2019.

[10] The need for academic institutions to do a better job informing students about alternative career options was one of the recommendations of the Astro2010 decadal report.