



The U.S. Department of Energy Computational Science Graduate Fellowship, 1991-2021: Follow-Up Study Shows Major Impact on Recipients and the Scientific Workforce

Since 1991, the U.S. Department of Energy Computational Science Graduate Fellowship (DOE CSGF) has addressed DOE National Laboratory needs as well as demands in the national workforce for trained professionals in computational science and engineering.

Sponsored by the Department of Energy's Office of Science and the National Nuclear Security Administration, the DOE CSGF supports doctoral students in the pursuit of novel scientific or engineering discoveries using high-performance computing (HPC) resources. To meet the program's core requirements, recipients participate in multidisciplinary studies, carry out at least one 12-week DOE laboratory research practicum, and contribute to an annual program review where the fellows present their research for sponsor review.

The Krell Institute, which has managed the fellowship on behalf of the DOE since 1997, has commissioned several follow-up studies to examine the DOE CSGF program's outcomes. This study, conducted in 2021 by Westat, builds on previous reports and includes an analysis of DOE CSGF recipients' characteristics, fellows' outcomes and professional accomplishments, alumni's career paths and achievements, and recipients' impact on national priorities through research and education.

The study included the following methods:

- A survey of all DOE CSGF recipients, both current and past, dating back to the program's 1991 inception, with an overall response rate of 56 percent;
- Interviews with a sample of alumni who completed the program between 2011 and 2018 and a sample of current fellows; and
- An analysis of curricula vitae (CV) data collected from alumni, which included CV data for 292 of the 422 total alumni for whom contact information was available.

Characteristics of DOE CSGF Recipients

The DOE CSGF has provided 565 fellowships since 1991, which includes 107 current fellows. Recipients have been increasingly diverse over time with regard to gender and the specific fields of study in which they pursued a degree.

While 72 percent of fellowship recipients have been men, women have increasingly made up a larger proportion of awardees and have comprised 40 percent of those who received the fellowship since 2013. The 565 recipients have pursued degrees in a wide variety of fields of study, with the most common being engineering and physical science disciplines, followed by computer science/mathematics and biology/bioengineering. The proportion of recipients within each of these major fields of study has shifted somewhat over time, with the proportion of recipients in the physical sciences and computer science/mathematics having increased in recent years and having become the most represented areas.

The DOE CSGF program includes a mathematics and computer science (Math/CS) track, which is designed to:

- Address the increasing workforce demand for those skilled to support and sustain emerging, next-generation computing systems;
- Provide opportunities for students focused on the application and use of applied mathematics and computer science in high-performance computing and data-intensive science; and
- Allow students in applied mathematics, statistics, or computer science to focus on issues in high-performance computing as a broad enabling technology as opposed to any particular science or engineering application.

The DOE CSGF has drawn a large number of highly qualified applicants, and those who have received the fellowship typically attend the nation's most prestigious universities.

Alumni and current fellows collectively represent 76 universities across 33 states and the District of Columbia. Nearly all fellows have attended R1 doctoral universities, according to the Carnegie Classification of Institutions of Higher Education (i.e., those with the highest level of research activity). Of the 76 institutions (about half of which are private and the other half public), 6 universities account for nearly half of all recipients: Massachusetts Institute of Technology; Stanford University; the University of California, Berkeley; Harvard University; the University of Illinois Urbana-Champaign; and California Institute of Technology.

Recruitment and Entry into the DOE CSGF Program

Recipients cited the unique combination of benefits and support as a factor in their decision to pursue the fellowship, with many fellows choosing the DOE CSGF over other programs.

When asked whether they had applied to other fellowships, nearly three-quarters of fellows overall indicated they had, and among those, just over half were accepted to at least one other program. In the survey, two reasons for why they decided to accept the DOE CSGF were cited by at least half of fellows. First, two-thirds indicated that the program offered generous financial benefits, with many also noting in the interviews that the DOE CSGF offered more financial support relative to other fellowships and 4 full years of funding. Second, just over half of survey respondents cited the program's prestige. As for other important factors, 40 percent cited the ability to conduct a practicum at a specific laboratory, while 36 percent viewed the program as a stepping stone for their career. In the interviews, fellows were most likely to cite these same factors but also described how the fellowship was consistent with their interests in computer science and engineering (CSE) and working on supercomputers or in HPC.

Experiences in the DOE CSGF Program

DOE CSGF recipients reported very positive experiences in each of the four key components of the fellowship: research practicum, program review meetings, HPC, and mentoring. For the research practicum, both alumni and fellows reported high levels of satisfaction with the various support provided to them at their practicum site. Recipients were most satisfied with the opportunity to generate ideas about their research, obtain specialized equipment for their research, gain a better understanding of continued opportunities for collaboration, and receive direction during their research activities.

Interview responses of recipients on the research practicum component:

"I really enjoyed the group I got to work with. My practicum advisor was excellent, and he really made sure that I was getting out of it what I was interested in, as well as having me talk to other people at the lab, getting exposure to different groups ... I got to work on an interesting research project. I got to explore the different skill sets that I was interested in learning."

"It was certainly valuable, and I liked it for several reasons. It gave me an opportunity to explore a scientific area that was not really part of my dissertation work but was something I was very interested in. And there weren't very many people at my institution who really worked in that area, so it was a really good opportunity to explore that area, to learn more about it, and to satisfy my own curiosity."

With regard to the program review, virtually all recipients indicated in the survey that they found various elements of this component useful, particularly the opportunities for intellectual stimulation and exchange, interaction with researchers in other fields, presenting their research, and networking, as well as gaining insight into current and/or future big-picture problems. Some current fellows reported adverse effects of COVID-19 and the shift to a virtual setting on the extent to which recent program review meetings were useful and engaging; however, this subset of respondents generally felt the fellowship had done what it could within the limitations of meeting in a virtual environment.

Interview responses of recipients on the program review component:

"The annual program reviews were terrific. I looked forward to them every year and to the interactions that came from those. I just always came away learning so much. Not only from current fellows but from former fellows, and from people within the Department of Energy who would come to meet with us and talk with us."

"Those were great opportunities. They were some of the best run conferences that I had gone to. Organizationally, they were run really well, and they did really great thinking about what would be good opportunities, what are good training experiences that you can make out of these conferences. For example, practicing talks, practicing giving posters in the right way, that was great. Also the fact that alumni came, that was fantastic, and [DOE] laboratory employees came, that was good. I thought they were fantastic conferences."

When asked about HPC, more than 8 out of 10 alumni and current fellows indicated they had used it during their time as a fellow, with large majorities of each group reporting that they had benefited from those experiences.

Interview responses of recipients on the HPC component:

"It provided me with experience and also insight into how those kinds of machines are programmed. My experience helped inform my understanding of the whole process of what went on at the computing facility, what kinds of applications were run, what their challenges were, and so on, and it also provided me with some skills and experience that I was then able to apply to other problems that I was working on as part of my dissertation work. Even though we'd never ran those on supercomputers as such, we did end up looking at larger problems and employing some of the same techniques that you use on supercomputers across multiple areas that I learned more about during my practicum."

"I started off in cosmology and planetary science groups in which, essentially, nobody did high-performance computing, so I was able to bring that expertise and sort of change what we at [university name] were able to do in the planetary science community, which was pretty cool. I don't think, without the CSGF and the experiences I had, I would've been able to come in and do that as well."

On the mentoring component, nearly all recipients indicated that they had received high levels of support and that the specific opportunities provided to them were valuable. Current fellows were asked in the survey about which specific aspects of mentoring that were most useful, and they most often cited opportunities to network with others in fields related to CSE, opportunities to collaborate on research in fields related to CSE, and psychological or emotional support. The interview responses of alumni and fellows around each of the four key program components were largely consistent with the survey findings, with respondents consistently describing their experience with each element as not only useful to their development as a scientist but also enjoyable and rewarding.

Interview responses of recipients on the mentoring component:

"I thought my mentorship was very strong. It was actually much stronger than in an academic setting, no question. Everybody had much more time to work with you, and you work much more closely with them."

"The biggest impact in terms of mentoring that the fellowship had for me was with my practicum advisor. He did a really wonderful job about asking me about what my career plans are and what I wanted to get out of the practicum but then also following up with me later as I was starting to graduate and trying to figure out what I wanted to do in terms of postdoc or lab work."

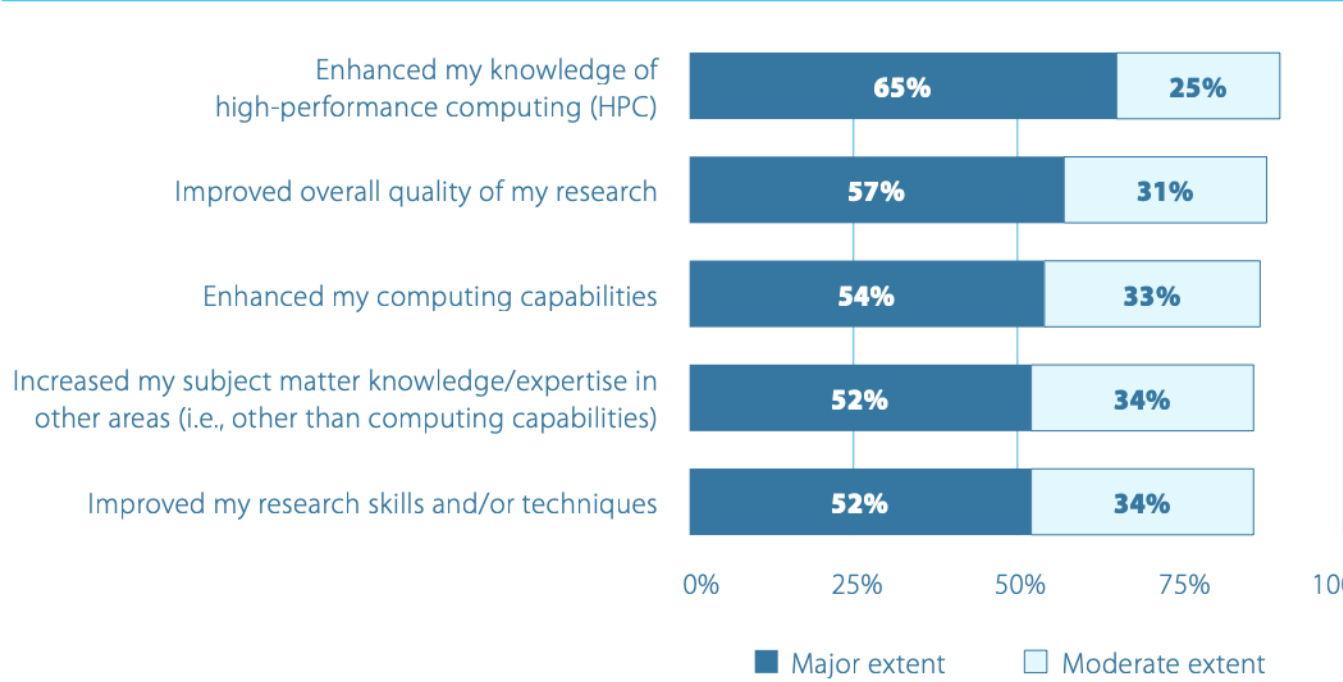
Survey data indicate that most recipients contributed to the advancement of computing activities and that their participation in the DOE CSGF resulted in their first exposure to dedicated time on a DOE supercomputer.

The survey asked both alumni and fellows about whether they had contributed to the development of scientific codes or software and the extent to which they took advantage of dedicated time on DOE supercomputers. Nearly 9 out of 10 alumni reported that they had contributed to and/or led the development of scientific codes both during the fellowship and since, while about half of alumni contributed to and/or led the development of scientific software suites and open-source scientific software. Regarding supercomputers, while relatively small percentages of alumni and current fellows reported having had dedicated time on a DOE

supercomputer prior to entering the program, over half of both alumni and fellows had utilized these resources during their fellowship, while nearly half of alumni had done so since completing the DOE CSGF.

Both alumni and fellows expressed high levels of satisfaction with the fellowship overall and cited a range of positive impacts because of their participation. In the survey, more than three-quarters of respondents indicated being satisfied with the access to facilities, equipment, and other resources that the program provided. Similar proportions were also satisfied with the networking opportunities and research training that they had been exposed to through the program. As shown in Figure 1, large majorities of recipients reported in the survey that the DOE CSGF had benefited them in several ways.

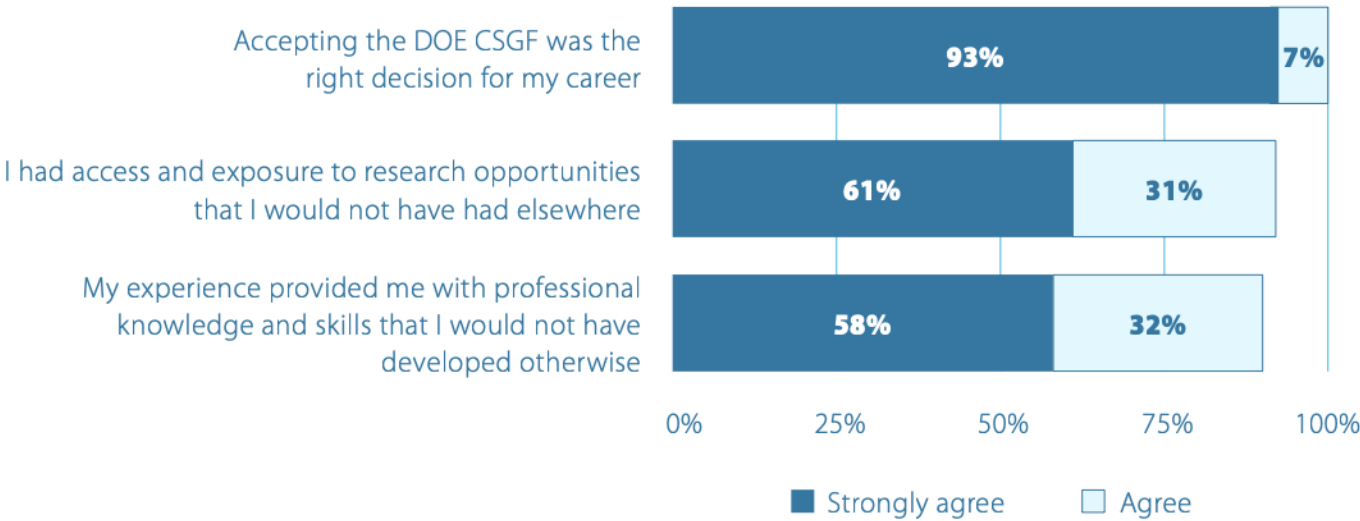
Figure 1. | Percentage of alumni reporting benefits from participation in the DOE CSGF program



As for the impacts of their participation, alumni described in the interviews how the DOE CSGF influenced their career goals and direction, including the desire to work at a National Laboratory. They also described how they experienced professional growth in their skills and content expertise, greater flexibility in pursuing research, and how the program led to the establishment of research networks that resulted in increased collaboration on research efforts among alumni. As shown in Figure 2, large majorities of recipients reported in the survey that the DOE CSGF had important impacts on their careers.

An additional area of impact that alumni were asked about in the interviews was the extent to which the program, based on their perceptions, has been successful in meeting the DOE’s workforce needs in the areas of CSE. Many of the alumni felt that the program had been effective in this respect by making fellows aware of the opportunities within DOE, attracting individuals to seek National Laboratory employment, and preparing them to excel in this setting.

Figure 2. | Percentage of alumni reporting on the impacts of their participation in the DOE CSGF program



Interview responses of recipients on the program's impact on meeting DOE's workforce needs:

"I work with other CSGF fellows at [a DOE National Laboratory], and I think it's pretty universal that we feel the fellowship prepared us very well for what the Department of Energy workforce needs are. I think a lot of us have said, 'The fellowship really helped us to hit the ground running when we got to the labs.'"

"The program has been very successful. It's been pretty effective, especially through practicums and other aspects of the fellowship, in retaining a fairly substantial portion of the graduates of the fellowship within the DOE scientific community. And then others have gone on to do other really important work for the national scientific enterprise. It's had a substantial impact, in my anecdotal experience, in that I know a number of people who are leaders in the DOE scientific community who are former fellows."

Regarding diversity and inclusion, an overwhelming majority of both alumni and current fellows reported they felt comfortable and included as a member of the DOE CSGF community and that the program creates a diverse and inclusive climate that is welcoming to individuals of all backgrounds.

More than 9 out of 10 alumni and fellows agreed that they felt comfortable and included, while at least two-thirds of each group agreed that the program has actively taken steps to ensure those feelings. In their responses to the interview questions on this topic, both alumni and current fellows generally felt that the DOE CSGF community was diverse, with many alumni observing that although diversity was somewhat more limited in the initial years of the

program, recipients had increasingly varied (i.e., along several dimensions, including gender, race, and disability) over time.

Data from the survey and interviews suggest that there is an active DOE CSGF community, with most alumni indicating that they had maintained relationships and had recommended the program to others. In addition, many alumni described the community as one of the best aspects of the fellowship.

Over 60 percent of recipients reported that they had stayed in touch with other DOE CSGF fellows, and over 40 percent reported that they had maintained contact with their practicum supervisor. In the interviews, alumni described how the fellowship's strong community component allowed them to make important connections with others in the field and to collaborate with a broad range of individuals, neither of which would have occurred if not for their participation in the program.

Interview responses of recipients on the DOE CSGF community:

"The community is the best feature. It was an excellent opportunity to network with other people in the field. I have had grants with other DOE CSGF fellows, so it's an excellent networking opportunity to get to know other people that are also working on similar things at a high level."

"I had a really positive experience, and I got a lot more than I was anticipating [as a result of the] community aspect. That's really been a part that's special about the program and very different. There's a lot of other prestigious fellowship programs, and they'll provide funding and support but the CSGF is very, very different. They provide a lot of those resources but then there is this community building and network infrastructure. You're part of this big group of multigenerational community of scientists."

Career Activities and Accomplishments Since Participating in the DOE CSGF Program

Since completing their fellowship, nearly all alumni have been employed in a range of professional settings including academia, industry, and DOE laboratories. Most alumni felt that their DOE CSGF participation was an important influence on their ability to obtain their first professional position. Of the 213 alumni who completed a survey, 91 percent reported that they have been employed since finishing their fellowship, with 40 percent of these alumni indicating that their first position was in academia and close to one-third reporting that theirs was at a DOE laboratory. When asked about the extent to which being a DOE CSGF recipient influenced their employment following the fellowship, 86 percent of alumni respondents agreed that their experience in the program gave them an advantage over others with similar qualifications. In the survey, alumni also indicated that, along with contacts they initiated on their own, several elements of the fellowship were especially useful in obtaining their first position, including the area they researched while a fellow, the publications for which they received credit while a fellow, and the prestige of the DOE CSGF program.

With regard to current employment, the vast majority of all DOE CSGF alumni are currently employed in a CSE field. The most common setting in which alumni are currently employed is industry, followed by academia and DOE laboratories. Alumni also reported having made a range of professional accomplishments since completing the fellowship. Administrative data maintained by Krell were used to examine the professional setting in which alumni are currently employed, and these data show that although alumni work in a range of sectors, industry is the most common employment setting (37%), followed by academia (27%), a DOE laboratory (14%), and other DOE positions or at another Government agency (6%). Moreover, 90 percent of alumni who responded

to the survey reported that their current position was in a CSE field, and more than three-quarters reported being satisfied in their current position and nearly three-quarters reported having a leadership role within their organization. When asked in the survey about the extent to which they have engaged in specific professional activities and accomplishments, large majorities reported a wide range of activities and accomplishments. These included achieving their overall career goals, engaging in interdisciplinary research, contributing to innovative ideas in their field, addressing key knowledge gaps in their field, contributing to a scientific breakthrough in their field, and advancing within their current organization.

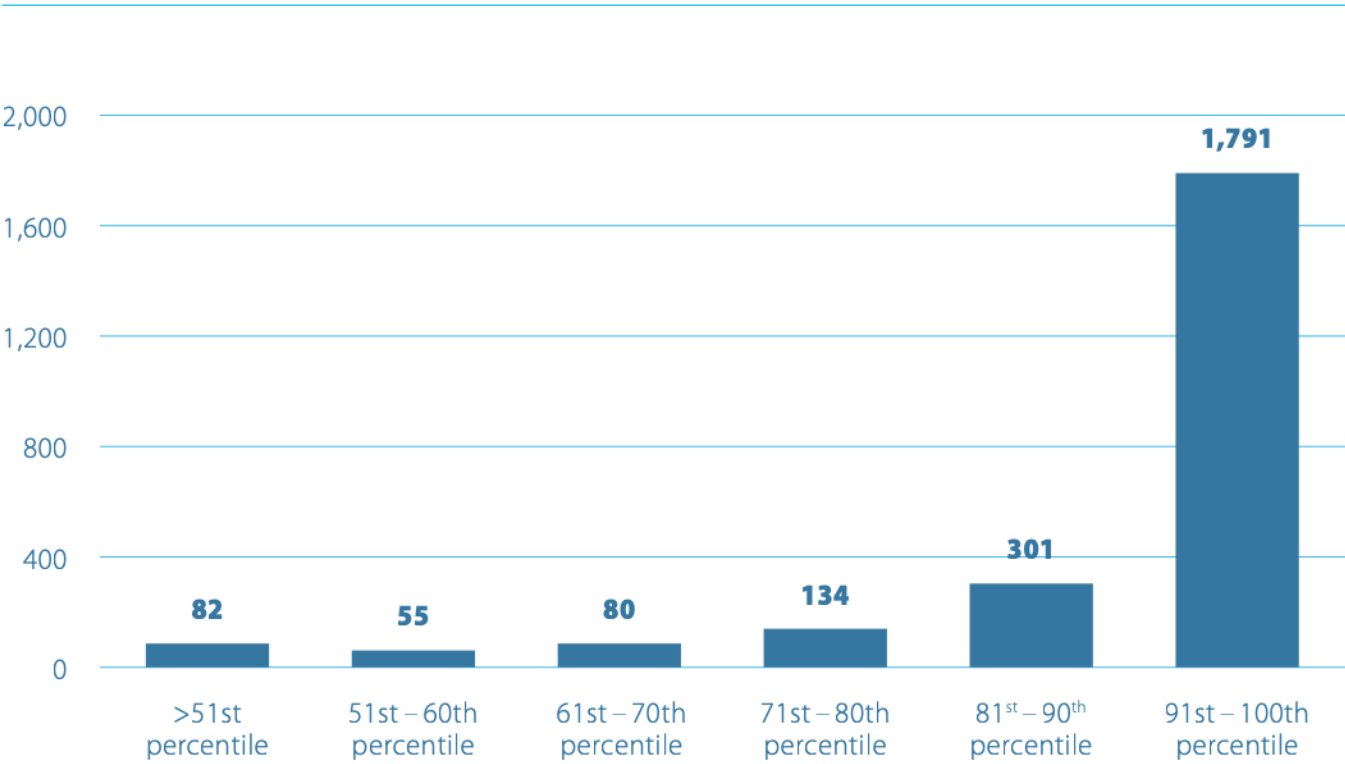
Alumni have received a large number of professional awards, grants, and patents and have published research at an impressive and steadily compounding rate. In addition to collecting information about the professional activities and accomplishments of alumni through the survey and interviews, the study included an analysis of both the publication output of the 292 alumni for whom curriculum vitae (CVs) were available, as well as the extent to which alumni received awards, grants, or patents. Among the 292 alumni who submitted a CV, 200 listed at least one award received, with an average of 3.2 per alumnus. Seventy alumni listed one or more grants or contracts, with an average of 6.8 per individual. With respect to patents, 43 alumni listed a total of 228; although nearly half of these (i.e., 95) were listed on a single CV, the average number of pending and/or issued patents per alumnus after excluding this outlier was 3.1. An analysis of the publication output of these 292 alumni showed that all listed at least one publication including journal articles, books, book chapters, reports, and conference presentations, papers, or posters. A total of 10,030 products were produced by the 292 alumni, with journal articles being the most common and comprising nearly half (i.e., 4,925) of this total. Regarding journal articles in particular, the average number per alumnus was 18.2 and, not surprisingly, the number of articles generally increased year to year as the cumulative pool of DOE CSGF alumni grew over time.

Articles produced by alumni were overwhelmingly published in highly influential journals.

In examining the research productivity of DOE CSGF alumni, this study analyzed the quantity and frequency of their publishing activity, as well as the outlets for their work. More specifically, two types of publicly available measures obtained from the Eigenfactor Project were used. These two journal-level measures, the Eigenfactor score (EF) and the Article Influence score (AI), provided insight into the prestige and influence of the journals in which alumni published their research, based in part by how frequently articles in those journals are cited by other researchers. These bibliometric data were available for 2,443 of the 4,884 journal articles produced by DOE CSGF alumni (these include articles that indicated the date of publication and were

published between 1997 and 2015, since EF and AI data are not publicly available for articles published in other years). Of these 2,443 articles, the majority (83%) were published in journals with above-average EF scores, with an average EF score of 24. This means that, on average, DOE CSGF alumni published articles between 1997 and 2015 in journals with 24 times the influence of the average journal during that time. The Eigenfactor Project also provides a percentile rank for each journal, which is useful in identifying the relative influence of journals in which DOE CSGF alumni were published each year. As Figure 3 shows, nearly three-quarters of the articles (73%) published by DOE CSGF alumni were in journals with EF scores in the top 10 percent, while another 12 percent were in journals with EF scores between the 81st and 90th percentile.

Figure 3. | Eigenfactor (EF) score percentile rankings of journal articles published by DOE CSGF alumni



Conclusions

This study of the DOE CSGF program was intended to address important questions concerning the benefits that accrue to the DOE as the sponsoring organization, the recipients themselves, and the overall research community and workforce in CSE. When considering all the data collected as part of the current study, it is clear that DOE CSGF remains a critical contributing factor in workforce development. Most notably, through a combination of survey and interview data, alumni revealed how they experienced professional growth in their skills and expertise, greater flexibility in pursuing research, and program-enabled research networks that resulted in increased research collaboration with other recipients.

The data from this study indicate the DOE CSGF is a highly sought-after fellowship that draws some of the most promising students in science, technology, engineering, and mathematics, typically from the country's leading universities. Many who enter the program choose the DOE CSGF over other fellowships based on its reputation and level of financial support relative to other programs. These data also highlight the effective outreach strategies employed by the fellowship in attracting top talent. In addition, the responses of alumni and current fellows to the survey and interview questions indicate that the program actively takes steps to include a diverse set of individuals within the relatively small number of recipients each year and works to create an environment in which those from various backgrounds feel supported and their perspectives are valued.

The fellowship also received high praise from alumni for its unique benefits. Alumni reported not only a highly satisfying experience in each key component of the program but also that it provided opportunities that were unmatched by other fellowships, through exposure to HPC, access to DOE laboratories and scientists, as well as the chance to be mentored by top researchers in the field. They described how their interests in CSE and in pursuing full-time employment at a DOE laboratory were strengthened through their exposure to these programmatic features, and many indicated that these opportunities and experiences were critical to obtaining employment. Based on the data collected as part of this study, the various opportunities provided to students by the DOE CSGF reflect a successful model that offers a broad scope of training and development.

In addition, data from this study indicate that many alumni remain involved in the program long after their fellowship support ends, by actively recruiting new fellows and providing guidance and professional development for current recipients, and by developing relationships and collaborations with fellows. The annual program review meetings serve as a forum for mentoring and career guidance and help reinforce a sense of community among current and former participants. In addition, many alumni continue to be involved in the program review and engage in other activities that extend beyond formal programmatic activities. These include the establishment of various research networks and collaborations between DOE CSGF alumni, both of which illustrate the connectedness of the computational science community that the fellowship fosters.

The inclusion of objective measures of recipients' accomplishments revealed how prolific program alumni have been in helping to advance the nation's science and technology goals into the future. The fact that alumni have received a large number of professional awards, research grants, and patents — and that they have published research in prestigious journals at an impressive and compounding rate — serves as evidence of their contributions to the broader scientific community through the generation of new knowledge and innovations.

Lastly, survey responses of DOE CSGF alumni dating back nearly three decades and interview responses from alumni who have spent up to a decade in full-time employment revealed the many long-term career benefits of program participation.

Among these were the substantial proportion of alumni who transition directly to permanent employment at DOE laboratories. Many cited choosing to work in this setting due to its stimulating environment, the research opportunities that are available, and the opportunity to make a direct contribution to the national scientific enterprise. Meanwhile, other alumni sought careers in highly specialized positions in academia, where many are directly involved in educating and training future scientists, or in industry, where they are often in leadership positions and therefore have the capacity to contribute directly or indirectly to the development of the next generation of scientists and to help spread the influence of the DOE CSGF program more broadly.

Acknowledgments

This brief describes key findings from a follow-up study of DOE CSGF recipients conducted by Westat in 2021. Westat is an employee-owned research firm serving Federal and local Government agencies, nonprofit organizations, private businesses, and other clients in a broad range of research areas, including survey research, statistical design, and program evaluation. The complete set of study results is available at:

<https://www.krellinst.org/csgf/study>