

For the Public Good: Connecting, Retaining, and Recognizing Current and Future RSEs at U.S. National Research Laboratories and Agencies

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Abstract—US national research laboratories and agencies play an integral role in advancing science and technology for the public good. The authors of this article, as Research Software Engineers (RSEs) and allies from eight unique national organizations, came together to explore RSE needs from the perspective of national research and development institutions. We identified three key areas of improvement for future RSEs to pursue science in the national interest: community establishment, hiring and retention, and recognition. To retain and cultivate this essential talent, US national institutions must evolve to support appropriate career pathways for RSEs and to recognize and reward RSE work.

■ **US NATIONAL RESEARCH LABORATORIES AND AGENCIES** are federally-funded research institutions that work alongside industry and academia to drive innovation, being both mission-focused and able to tackle challenges with long time horizons – such as in health, energy, and national security. Playing this role requires a seasoned, diverse, and multi-disciplinary workforce

able to tackle the scientific challenges of national interest.

Today, with computing being central for scientific discovery and the demand for high-quality software capabilities continuing to rise, it is imperative that national institutions recruit and retain research software engineers (RSEs). Persistent organizational and cultural challenges are de-

laying progress. While national laboratories and agencies are not unique in needing to evolve to better support RSEs, existing policies and structures for hiring, training, and retaining software engineering talent are increasingly out of step with both academia and industry. As a result, RSEs are less likely to pursue a career at government research institutions and more likely to exit early [1].

The authors of this article – RSEs and allies representing eight national organizations – firmly believe that government research institutions can and must be leaders in software engineering excellence. To achieve this objective, we must integrate RSEs into the community, create pathways for their career advancement, and demonstrate that RSEs are valued and recognized for their contributions. To that end, we articulate the challenges we have experienced in seeking these changes, and we explore strategies for mitigating those challenges. We hope that our work helps to inspire our fellow RSEs, organizational leadership, and policy-makers to take action on these fronts.

We discuss the necessity for inter- and intra-organization networking for RSEs and the necessity for the uniting term “research software engineer,” as well as what a community of these individuals would look like in practice. We explore the realm of hiring and retention. While certainly not a unique issue to national organizations, procedural changes can improve the state and trajectory of RSE careers. We examine the potential avenues for RSEs to effect meaningful contributions, to foster unique professional development opportunities, and the necessity for career progression that accommodates the profile of RSE work. Finally, we evaluate the state of recognition for RSEs within national organizations. In this category, we elucidate the necessity of having internal, dedicated RSE groups and networks, providing external collaboration opportunities, and building trust in RSE expertise.

1. Community Building

Community building is a key factor not just in software success, but also employee productivity and happiness [2], [3]. Historically, national labs have been successful at building inter- and intra-lab communities around software. Recent

examples include the Exascale Computing Project (ECP)¹, a collaborative effort between six core national laboratories and eleven additional participating labs and universities; the Tri-lab Advanced Simulation & Computing Sustainable Scientific Software Conference², a conference for SNL, LANL, and LLNL; and the Energy Exascale Earth System Model (E3SM) Project³, the next generation climate modeling project that includes eight different lab participants. This list is hardly exhaustive; national agencies are known for identifying strategic collaboration opportunities to better serve the national interest. These efforts exist between labs and national institutes as well; for example, SNL, ORNL, NIH, and NIST joined forces to develop methods for studying viruses like HIV⁴.

With such strong ties and an emphasis on cooperative software development and discussions, the importance of RSEs in national laboratories and agencies has never been greater. However, for many years, software development was seen as a side activity of domain scientists, who based their professional identity on their domain science role. As software became more ubiquitous and more complex, large software projects grew to include contributors whom we would now call RSEs.

There are many variations in the RSE role and how it is institutionalized across the national laboratories. For example, some laboratories, including ORNL and SNL, have created specific organizations to house and support RSEs [4] and actively recruit for this role. Others, such as LANL, LLNL, NIH, and NIST, have strong communities of research software professionals who play RSE-like roles but have not widely adopted RSE terminology or created dedicated RSE organizations. At all of these laboratories, some individuals in RSE roles work more independently within general science and engineering organizations rather than in research software-focused organizations. These varying organizational contexts for RSE work create a wide variety of potential career paths and different levels of support for RSEs [5]. RSE community-building efforts can address these variations to help ad-

¹<https://www.exascaleproject.org>

²<https://s3c.sandia.gov>

³<https://e3sm.org>

⁴https://newsreleases.sandia.gov/hiv_protein

vance common understanding and support of the RSE role across laboratories.

While recognition of the professional designation and participation in RSE associations has skyrocketed since 2018⁵, participation by national laboratory and government sectors has not scaled with that growth [6]. As these strategic efforts continue to evolve and grow, so should the awareness of the RSE role and efforts to be inclusive both within and external to national institutions. This means that institutional leadership must rethink how they engage with RSEs, both internally and throughout the wider community, to maximize their participation and effectiveness. While these organizations excel at creating synergistic ties to benefit certain technical or strategic directions, there is a demand for community-building to benefit those people who identify with the RSE term. Using a common designation of RSE can provide a focal point to build valuable networks and communities.

1.1. Uniting Under a Common Banner

A statement many members of national laboratories have heard is, “I don’t know what the labs do.” There is a tendency to silo and segregate work to particular sub-communities due to, for example, funding restrictions, niche research areas, security concerns, etc., resulting in low inter-community communication. The authors have all experienced a lack of understanding of the overarching portfolio of tasks and problems their unique organizations try to address. This means that, regardless of whether a single “software person” on a larger team identifies with the RSE role, they tend to be isolated from other groups and the larger community. Even when there are multiple RSEs working as a team, effective interactions between researchers and that team can be difficult to achieve. Frequently this is attributed to a misalignment of values as scientific researchers tend to focus on the resulting science more-so than the software, whereas RSEs place emphasis on craftsmanship and quality in the software itself. Along with the personal implications of feeling isolated as a software professional, the lack of communication and community creates redundancy in work. Where RSEs are separated

by institutional divides, they miss opportunities to learn from one another and to feel connected and supported; RSEs can experience a loss of professional identity and feel that they are “outsiders” in their institutions. A recent study of RSEs by Dr. Benjamin Sims of Los Alamos National Laboratory echoes this, explaining how maintaining a professional identity as an RSE can help reduce feelings of marginalization [5]:

Some who identify as RSEs, particularly in academic settings, previously felt marginalized in the scientific enterprise, without a distinct or valued role, which in turn led them to doubt their own career choices. The role of RSE may resonate strongly with these people specifically because it allows them to articulate a positive identity and a sense of group belonging.

Community-building efforts can address these issues in various ways – from creating spaces for RSEs and their own professional and personal development to helping shape their understanding of their value within these organizations to providing them with resources and strategies for more effective teaming with researchers.

Because public research institutions are frequently called to address the nation’s most pressing challenges, it is essential that these efforts not be waylaid by inflexible and poor-quality software. Strengthening the RSE community and bridging the divides would improve the state of software engineering practice and enable RSEs to do their best work. There are ample opportunities to minimize rework, converge on solutions to common problems, and promote dialogue between RSEs and the research communities they serve.

1.2. Towards a Community of Practice

National laboratories and agencies excel at creating strategic links. This expertise can be adapted and applied towards building a community for RSEs to increase the overall happiness and productivity. There is a rich body of literature supporting the creation of communities of practice (CoP). CoPs require three defining elements: a domain, a community, and a practice [7]. In practice, CoPs have positive implications for personal growth, helping define organizational

⁵<https://us-rse.org/join>

direction, and cultivating a sense of belonging. An RSE community, focused both on human factors as well as strategic direction, would cultivate talent and benefit existing and novel strategic efforts to address crucial problems RSEs face in cutting-edge research by more efficiently connecting people across a wide range of domains and software expertise.

Organizations could schedule regular meetings between RSEs from multiple national organizations with a specific, well-defined agenda on challenges surrounding RSEs and their work. An example of one of these types of meetings might be a “hackathon” – a co-located, focused opportunity to explore a particular domain or concern and potential solutions. Not only do these events bring energy and enthusiasm to their participants, they also deliver actionable results that can be brought back to individual institutions and create opportunities for future collaborative efforts.

Regardless of meeting format, the objectives are layered. From a strategic perspective, various teams together can discuss broad-based strategy or goals and set aside time to advance more ambitious projects or programs. From a human perspective, these gatherings would connect people and provide a space for camaraderie and innovation. These networks of connected peers may also contribute to a larger sense of belonging among RSEs in addition to helping with recruitment and retention.

2. Hiring and Retention

In software engineering, Beecham et al. [2] demonstrate that having a sense of belonging and community is one of the primary factors that leads to overall motivation and satisfaction. As the authors note, this has a direct impact on hiring and retention:

The majority of the studies cited retention as the major outcome of motivated or de-motivated software engineers. Twelve studies showed that motivated engineers tend to stay in their jobs longer than de-motivated engineers.

The enduring institutional memory and experience of national research organizations is vital to innovation. If we intend to make software engineering a first-class concern in these organizations, we must consider how to retain RSE

talent in the long-term. To draw an analogy, the success of the US State Department relies on its seasoned workforce to resolve conflicts in a peaceful, diplomatic, and secure manner. With the emergence of the COVID-19 pandemic and the ongoing climate crisis, it has become apparent that research infrastructure needs the same maturity and adaptability. A large part of this infrastructure relies on the longevity of the workforce and the retention of institutional wisdom, knowledge, and expertise. The scale and scope of challenges addressed by the national laboratories and agencies require flexibility and agility, which are enabled by the flexibility and agility of software development.

There is a common misunderstanding that software engineering skill sets are interchangeable and that software development talent is relatively easy to replace; this is far from true. The role of RSEs in scientific software development is to act as a bridge between conventional software engineering and the domains of science and engineering [8], a specialized composition of knowledge and experience that can take years to replicate. Complicating matters further, high turnover can cause software to not only stall, but regress, and can lead to downstream failures in reproducing results or discovering new approaches. For the mission-critical work of national research institutes, this is an unacceptable outcome.

We recognize that competitive industry salaries may be a significant driver of turnover. Research institute salaries cannot compete with top Silicon Valley tech giants. According to a recent study by Chaudhry et al. [9], however, compensation is ranked *fifth* in factors that motivate research computing professionals to change jobs. National organizations are well-positioned to address the top three factors.

- *Making a Difference*. The work completed at national laboratories and agencies directly impacts the national interest. As the 2020 *State of the Laboratories* report details [10], US national laboratories tackle problems from energy to climate science to nuclear deterrence to international pandemics. There is no shortage of opportunities to explore challenging, meaningful problems with direct, real-world impact. Additionally, due to the frequently changing

state of the world and the breadth of available domains, RSEs can pivot their work at any point in their careers.

- *Career-long Professional Development Opportunities*. National institutions regularly and strategically invest in their workforce. Because of their overall size and influence, they can (and regularly do) bring in outside organizations to provide training on both technical and social topics (e.g., Python for Engineers or Leadership Summits). Many organizations also have dedicated funding sources for exactly these activities. While opportunities may be abundant, frequently RSEs' time is limited due to fragmentation across multiple projects, and they are unable to take advantage of chances for improvement. RSEs need to be allotted time and space across all federally-funded facilities for their unique professional development needs.
- *A Culture of Innovation*. National laboratories and agencies specifically exist to explore cutting-edge areas of research previously unexplored and to improve areas where performance makes a true difference. ECP and E3SM are examples in which national institutions aim to change the future of the nation and our approach to scientific software development and climate change. Innovation in the national interest is the ultimate goal of these institutions. National laboratories and agencies are mission-focused on specific problems (similar to industry), but they also are capable of working on problems over longer time scales (similar to academia). Their multi-disciplinary workforce is able to tackle a wide variety of problems across the spectrum of research to application.

While congressional intervention would be required to address the compensation mismatch, national organizations are well-equipped to provide attractive opportunities to current and future RSEs in these three primary areas.

3. Recognition

3.1. RSEs Enable Cutting-edge Computing and Research

As Woolston's recent article in *Nature* states, the modern scientific enterprise is inextricably

bound to software and those who create it [11]:

Software runs through the entire research process, but professors tend to get most of the recognition and prestige. Pieces of software can have just as much impact as certain research papers, some of them much more so. If RSEs can get the recognition and rewards that they deserve, then the career path will be that much more visible and attractive.

While the article is geared towards RSEs in academia, the same holds true within our national laboratories and agencies. Science and engineering has significantly evolved over the past 40 years thanks to public investments in computing technologies. As we enter into the era of exascale supercomputing, we see how scientific research is launched into new, cutting-edge areas that can be explored at dizzying speeds. The hardware, however, is only made useful by the expertise to effectively create, optimize, and use the software that runs on it [12]. Within public research institutions, this expertise often comes from RSEs working in concert with researchers.

A primary driver of retention is recognition [2]. When software engineers feel seen and valued by their organization, they are motivated to stay with that organization. Unfortunately, RSE work is not accorded the same credit as that of computational scientists and experimentalists. The economy of science is centered around producing numerous, high-profile publications, which RSEs are not in a position to write because they are seen as acting in a "supporting" role. The status afforded to RSEs is juxtaposed by the amount of time and resources needed to produce an RSE able to do the work. That is, RSEs spend years at national research organizations becoming adept at delivering technical solutions within the mission space, but in our experience, they are given few paths to recognition and promotion in order to continue to cultivate and reward those skills. The career progression opportunities that are available to RSEs, save for becoming prolific researchers, often involve migrating to leadership or managerial roles and away from technical work. This standard is often enshrined in institutional promotion requirements to have a

high publication volume or to lead major projects. We want to note that this problem is not unique to RSEs – technicians and laboratory assistants also encounter similar barriers to advancement. However, given their highly-specialized skills and knowledge to craft high-quality software, RSEs and their work should be given the same regard as leadership or research ability.

Because both the term RSE itself and practitioners being hired under that designation are relatively new, it is rare for people who have previously worked in RSE roles to be in managerial positions, especially in the upper echelons of public research institutes. This can lead to a situation where RSEs struggle to make their voices heard to higher-level administration or receive feedback on the technical direction of their work. In the worst cases, this can result in RSEs feeling that they are not trusted to help guide management, to be promoted, or to act on their professional best judgment without managerial approval. These perceptions can cause RSEs to feel devalued as compared to their research peers.

3.2. Recognizing RSE Contributions

The question remains: how can RSE work be adequately and appropriately recognized? This is a matter of importance to all RSEs, and a full treatment of this subject deserves its own, separate article. We can, however, touch upon the ways in which RSEs positively impact specific projects, national laboratories and agencies overall, and the wider scientific and engineering community, and how to feed this impact back into the recognition and reward structure of national organizations.

There are important activities and milestones in RSE practice that can and should be considered for career progression, including technical presentations, releases of scientific software, open-source contributions, or hosting and maintaining databases for scientific data collection. RSEs frequently perform extensive “invisible” labor of significant value to science, such as testing framework improvements, but there is no reward structure in place for these contributions. We recognize there are significant institutional hurdles to creating systemic change. A paradigm shift in the long-established process for promotions and the resulting leadership culture will not happen

overnight, but it can and must be done. RSEs at these institutions deserve credit and respect commensurate with the instrumental work they perform in the national interest.

Explicit recognition through career advancement is a necessary step towards equity for RSEs, but we note that there are numerous ways in which US national laboratories and agencies can go beyond this in giving credit to RSEs and their work:

- *Supporting Dedicated RSE Groups:* A common grievance in many national organizations is the feeling of isolation and disconnect from others doing similar work. Some laboratories are fortunate to have already established departments around RSEs (see [4]), which have effected great improvements in productivity both of RSEs and of the teams and overall organization that they support. Following this model is feasible in other organizations. If nothing else, avenues should be created to connect “floating” RSEs within a single institution to each other to foster teaming for great results and technical excellence.
- *Facilitating External Collaborations:* In lieu of a dedicated RSE group, organizations can prioritize and encourage RSE engagement with external RSE collaborators and associations. This paper, in fact, can be attributed to the existence of the US Research Software Engineer Association. These external connections can boost retention and recognition by enabling exposure to new ideas and problems while bringing that expertise directly back into the institution’s areas of interest. This engagement with the broader community also increases external exposure to laboratory and agency missions and initiatives.
- *Fostering Trust in RSEs:* One of the struggles many RSEs face is a feeling of being lesser than their scientific research peers. This perceived lack can be addressed in several concrete ways. First, leadership should empower individual RSEs to act by recognizing and acknowledging when RSEs bring a problem to their attention, and be willing to advocate for the implementation of a solution. Leadership should also recognize when RSE individuals or teams make contributions that make new

discoveries and innovations possible, rather than focus only on the research outcome. This would empower individual RSEs to feel their contributions are being heard and valued. Second, leadership should provide avenues for RSEs to exert organizational influence by inviting RSEs into strategic conversations as they relate to the direction of the organizational mission. In a localized scope, RSEs should be approached for feedback regarding their home institutions and immediate projects. At a higher level, RSEs should be included in workshops, such as the Advanced Research Directions on AI for Science and Security workshop⁶, which result in congressional reports that dictate the direction of research and development across all publicly funded research institutions.

4. Conclusion

The practice of science and engineering increasingly depends on having a sustainable ecosystem of high-quality software; indeed, the science is only as good as the software that underpins it. For that reason, our national scientific institutions need more professionals who can combine domain-specific expertise with software engineering best practices to meet emerging national needs. In this article, members of eight unique national laboratories and agencies identified challenges that face RSEs within national organizations and provided actionable suggestions for changes that would benefit current and future RSEs and their home institutions.

In the realm of community building, there is an essential need for both inter- and intra-organizational networks of RSEs. Though there is not an inherent need for the job title “research software engineer” to exist across all institutions, RSE is a useful unifying term to categorize critical work and the people undertaking it. In practice, community building can bridge RSEs across a variety of organizational and domain boundaries, providing them the social and technical resources to tackle an array of research and institutional challenges. This can take the form of events such as “hackathons”, formal teams, or informal social groups.

⁶<https://www.anl.gov/cels/advanced-research-directions-on-ai-for-science-and-security>

With regards to hiring and retention, it is no secret that the public sector cannot compete with industry compensation packages. However, the top three motivating factors for software engineers to stay in research computing organizations are the ability to meaningfully contribute, access to professional development opportunities, and the presence of a culture of innovation to which they can contribute. As leaders in the pursuit of scientific discovery, national research organizations can and do compete with industry for talented and passionate software professionals. With respect to professional development, allocating dedicated time and resources for RSEs and their unique development needs could help meet hiring and retention challenges.

To bolster retention, we highlighted the importance of recognition for RSEs and their work. Though not exclusive to national laboratories and agencies, there is a well-recognized issue with promotion structures for software engineers. Research organizations emphasize leadership and researcher roles but not those who implement technical solutions. We argued for the need for more sustainable technical career paths as an explicit form of recognition. Following this, we discussed how stronger communities – either through local, dedicated RSE groups or external collaborations – foster better teaming, happiness, and productivity. Along similar lines, we call for more trust in RSEs, to empower them to exercise their professional best judgment and to ensure they have a seat at the table in strategic conversations around software.

The nation requires a robust scientific engine to meet the incredibly complex demands of the modern challenges that we face. A strong workforce is the fuel in this engine. RSEs represent a critical component of this workforce as they enable the future of scientific achievement. As such, it is our duty as civil servants to pave clear, achievable pathways for the next generation of RSEs who serve in the national interest.

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