URSSI Implementation Plan

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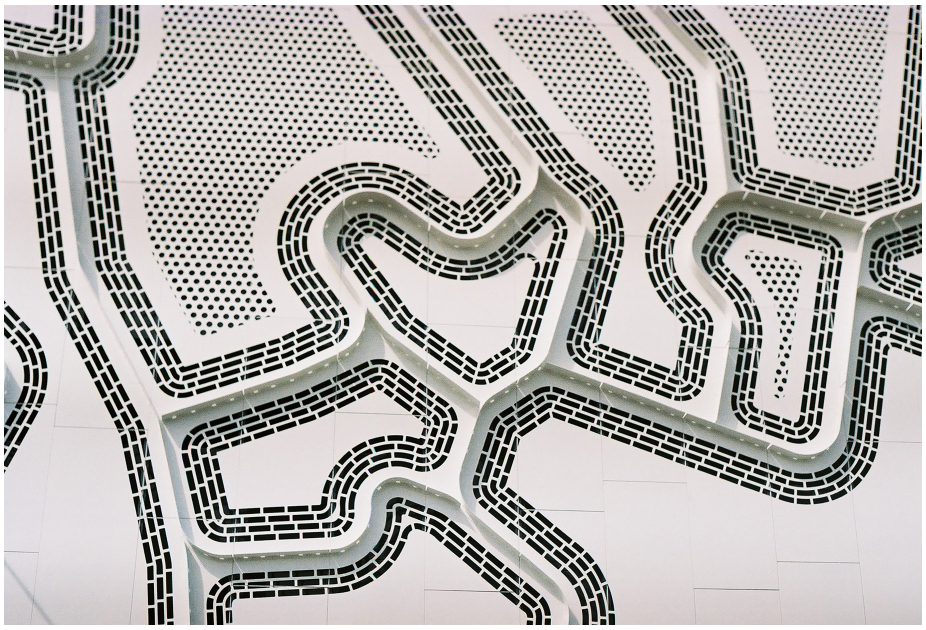


This public document is a draft of the final URSSI plan. Empty sections are under internal review before being posted here.

Chapter 1

Introduction

Software pervades all parts of modern scientific research, including data analysis and inference as well as computational science. Recent surveys in the US and UK show that 90-95% of researchers rely on research software, and 63-70% of them cannot continue their work if these software were to stop functioning (Hettrick et al., 2014). Much of this software is developed by researchers for researchers, as the contemporary scientific process demands the development of new methods in tandem with the demands of new discoveries and fields. However, despite its importance, a large proportion of research software is developed in an ad hoc manner, with little regard for the high standards that are characteristic of other research activities. As a result, the research software ecosystem is fragile and the source of numerous problems that plague modern computational science (Carver et al., 2018).

Researchers today are under intense pressure to demonstrate expertise in their chosen domains while also trying to maintain a working current knowledge of software engineering practices. This combination is unsustainable for most researchers. With little bandwidth to keep up with best practices or sufficient recognition of software development as a scholarly activity, much research software is developed in a manner that makes it wholly unsustainable, despite the obvious role that it plays in modern research, for a multitude of reasons. Academic promotion and tenure, even in institutions with liberal policies, consider peer-reviewed publications to be the primary metric of progress in most disciplines. Even when the impact of software is made clear through citation, it is usually not considered a traditional scholarly activity, making it very challenging to get credit. There is no shortage of horror stories of academics who have built demonstrably impactful software, only to be denied tenure. Even outside the tenure track, only a few academic jobs offer meaningful career progression for software work. A second reason, strongly correlated with the lack of recognition of software, is the lack of training opportunities. Many research software engineers are self taught. Others learn programming from boot-

camps and workshops rather than in traditional academic coursework. Overworked academics are unable to take advantage of such opportunities and therefore develop software using outdated practices. Lastly, even when software is recognized as having impact, funding agencies rarely fund maintenance and ongoing development of such work, leading to reinvention rather than reuse (https://chanzuckerberg.com/rfa/essential-open-source-software-for-science/).

We have spent the last two years engaged in a series of activities designed to gain a deeper understanding of why research software is so unsustainable and what can be done about it. Through numerous discussions with diverse groups of researchers, we have brainstormed challenges and solutions that can meaningfully impact the largest number of researchers. This plan discusses the problem in this chapter, describes our activities (in Chapter 2), and outlines plans (in the remaining chapters) for a new institute that will work in multiple areas to improve research software and the careers of those that produce it, with an end goal of performing better research.

1.1 Nature of the problem

One would be hard pressed to name any field of scientific endeavor that has not been substantially transformed by software. From physics to psychology, software has transformed the way we create, acquire, process, model, and draw insights from data. Much of this transformation has come from the increasing availability of open source tools, many of which have helped improve the rigor, quality, and reproducibility of research. The development of research software is often not considered scholarship, making it very difficult for academics to seek funding and find meaningful career paths, especially when research software activities make up a significant part of their contributions. Such people often lead double lives, working tirelessly to meet the traditional responsibilities of academic life, while developing open source tools that enable modern research. We are able to break the problem down into the following four areas:

Research software itself is not sustainably developed: In many fields research software is developed by academics for other academics. Because these people have spent much of their careers developing deep domain expertise, but not developing deep software expertise, software does not get the same level of care as other aspects of the research enterprise (https://www.nature.com/articles/s41592-019-0686-2). Therefore the quality of the software is highly variable, making it hard to sustain. Mounting technical debt often makes it easier to develop software from scratch than to use existing tools. Versions of software used in papers are exceedingly hard to track down, making it challenging to reproduce research findings or reuse research software. When Collberg and colleagues (Collberg et al., 2013, 2014) decided to measure the extent of the problem precisely, they investigated the availability of code and data as well as the extent to which this code would actually build with reasonable effort. The

results were dramatic: of the 515 (out of 613) potentially reproducible papers, across applied computational research, the authors managed to ultimately run only 102 (less than 20%). These low numbers only count the authors' success in running the code, not in actually validating the results.

Lack of career opportunities: Software does not count for career advancement (e.g., promotion and tenure) in academia, making it an invisible scholarly contribution. Research software is often not cited (31-43%), even in high impact journals (Howison and Bullard, 2016). Besides the negative impact on career trajectories, this lack of visibility means that incentives to produce sustainable, widely shared, and collaboratively developed software are lacking. For university staff members, the Research Software Engineer (RSE) movement has begun creating a new class of academic positions that explicitly value software work, but such positions are not very common in the United States.

Lack of training opportunities: When NSF PIs in the BIO directorate were asked about their biggest challenges in leveraging vast amounts of data currently available, lack of training was listed as the single biggest challenge (Barone et al., 2017). Although this training deficit describes the ability to use existing data science software, the skills needed to develop them are harder to come by [citation]. While programs like Software Carpentry and a handful of university courses offer training in analyzing data, very few train researchers in modern open source software development. This gap remains to be filled.

Lack of diversity in research software: Open source communities struggle to gain participation from women and more broadly from underrepresented groups. Less than 10% of contributors to open source communities identify as female (Lee and Carver, 2019) compared with approximately 25% of the overall computer science field (National Science Foundation, 2017; Vasilescu et al., 2012). Cultivating a diversity of perspectives, fields, and backgrounds is important for growing a robust research software community. There is a need to understand the sources of diversity problems and work to improve over the current state (Daniel et al., 2013). Contrary to the initial belief in open source communities, the ability to contribute to a project anonymously does not solve the gender diversity issue (Nafus, 2012) at least partially because project members are able to determine the gender of contributors, even those that use pseudonyms (Vasilescu et al., 2015). In addition, a large percentage of female contributors have either been subject to or witnessed gender-based discrimination (Powell et al., 2010) and have been discouraged from participating in these projects because of the agressive nature of the discourse and the lack of female role models (Reagle, 2012).

1.2 Valuing producers of research software

Despite the numerous barriers that prevent people from receiving recognition and career success for their research software work, some have successfully

overcome them. An exemplar is in this regard is Dr. Fernando Perez, currently an associate professor in statistics at the University of California, Berkeley. For much of his career he worked in a traditional untenured position as a research scientist in neuroscience and computational research, while collaboratively developing an open source notebook interface for the Python programming language as a side project. Over time, his software work started having much more of an impact than any of his traditional scientific contributions. The current evolution of his group's efforts, the Jupyter ecosystem (https://jupyter.org/), is considered by many to be "universally accepted by the scientific community" and has won him and his team awards such as the Association for Computer Machinery award for software. More recently, the magnitude of his software contributions and the far reaching impact of this effort (https://www.theatlantic.com/science/archive/2017/06/gravitational-waves-black-holes/528807/, https://www.theatlantic.com/science/archive/2018/04/the-scientific-paper-is-obsolete/556676/) has earned him a fast-tracked tenured position at University of California, Berkeley. This type of unconventional success in a traditional public university is a sign that the recognition of software work as scholarship is changing.

While the result of Dr. Perez' story is promising, it is very difficult to achieve. Other academics who have produced work of similar or greater magnitude in the past weren't so lucky. Travis Oliphant, for example, served as an assistant professor of Electrical and Computer Engineering at Brigham Young University in the early 2000s. Among his accomplishments during this time, he is credited as the primary creator of NumPy, the Python library for numerical arrays that is the foundation of modern data science tools, and as one of the early contributors to SciPy, the widely used library for scientific Python. These contributions were deemed insufficient for tenure. Kirk McKusick, a professor at EECS in Berkeley was denied tenure in the early 1990s because his primary work was on the BSD Software Project, which then went on to become the foundation of the modern internet. [**TODO**: Other examples would be welcome and appreciated. Are there women/people of color who have experienced similar situations that we can highlight here?]

1.3 Why we ran this conceptualization

It comes as no surprise to researchers that software is undervalued in academia. However, substantive evidence supporting this claim is scattered and mostly anecdotal, making it hard to build a convincing case that the research community and their stakeholders need to care more. In 2017 we submitted a proposal to the National Science Foundation's Software Infrastructure for Sustained Innovation (S2I2) program to gather this evidence, identify unique challenges not already being addressed, and to formulate a plan for an institute to implement solutions. The proposal was funded in December 2018, allowing us to engage in various activities over the following 24 months. Despite the awareness of these

issues and the existence of similar conceptualizations (albeit domain centric ones), the core challenges around sustainability (of people/software/practices), recognition and credit, and training/workforce development remain poorly understood and poorly addressed.

We used a wide range of approaches to understand the core social and technical challenges of developing sustainable research software. These approaches include an extensive survey, in-person unconferences, both general and topic focused, a pilot training event, and a series of ethnographic studies. We mapped out the current state of software related challenges with an extensive survey targeting researchers across the country. We also invited participants to workshops across the country to share critical challenges and brainstorm solutions in small groups. We dug deeper on a couple of core issues that arose repeatedly (credit and incubators) by organizing two focused workshops to tackle them (credit and incubators). This report captures our summary of the survey, workshops, and studies and describes a core set of activities that define the work of a future US Research Software Institute.

1.4 What we plan to do and why

The conceptualization phase with its survey, workshops, and ethnographic studies elucidated the need in the community for different components of a potential implementation of URSSI. We identified four areas for supporting the research software community - to accelerate science for diverse research domains as well as software engineering as a research area in its own right.

1. **Incubator**: Sustainability of research software has many aspects beyond good software engineering practices that overlap with diverse areas of expertise. Such areas include technology advice, project management, business planning, usability advice, license management, etc. The incubator service area would focus on providing projects with experts who have a consultancy agreement and could support a project in the different stages of their life cycle – from spinning up a project to first results and uptake of software to planning its sustainability after the funding ends.

2. **Education & Training**: Many universities offer curricula in software engineering to students but there is a lack of training to meet the community needs to go into depth for different technologies. The survey showed that there is a need to choose a format and timeframe that is suitable for people in the role of Research Software Engineers (RSEs) who lack formal or informal training. While The Carpentries, for example, does an excellent job of teaching basic programming and computational & data analytic methods to researchers in a peer-to-peer model, mostly in 2-day courses, URSSI could fill the gap in teaching more in-depth software engineering, software project management, and community development practices

in longer engagements, such as a 5-day summer- and/or winter-school. URSSI would collaborate on topics with The Carpentries and the existing software sustainability institutes, such as the Science Gateways Community Institute and the Molecular Sciences Software Institute, so that rather than replicate effort, it identifies the training in the overall research software landscape that is now missing.

3. **Policy**: Policy is an important area to improve the sustainability of research software. Policies could include guidelines for citation of software, templates for job positions, good software engineering practices as well as bad software engineering practices as counterexamples. The goal would be in collaboration with the international community and initiatives/projects such as US-RSE and the UK SSI to find a common ground on international level while considering the specific situation in the US.

4. **Community & Outreach**: Many researchers or developers in the role of an RSE work in silos and the Community & Outreach area of URSSI would connect them to peers and provide access to beneficial material, resources, and contacts to improve this situation. Community engagement would include one-way communication such as a website, blogs and newsletters, two-way communications for discussions such as webinars and online discussion forums as well as face-to-face meetings in the form of workshops. In addition, this area will include a fellows program to support work done by community members that benefits URSSI activities.

Building these different areas into URSSI would make it the focal point for the overall community of software developers as well as for a set of disciplinary communities to accelerate science that needs research software and improve the career paths of those who develop and maintain it, including RSEs.

Chapter 2

URSSI Conceptualization

The purpose of this conceptualization project was to create a roadmap for a US Research Software Sustainability Institute (URSSI). The roadmap was to be informed by and responsive to a community of potential stakeholders, including researchers, software developers and users, funders, and program / product managers. To engage this diverse group of people and institutions we completed the research described in this section including a series of workshops, community outreach and communication, a survey, set of ethnographic studies, and a pilot Winter School for early-career researchers. At the conclusion of this section we offer a summary of the challenges identified, collectively, across all of the URSSI conceptualization activities and what role we believe URSSI should play in addressing these challenges.

2.1 Workshops

Community wide workshops: In 2018 we held two community workshops with URSSI stakeholders in Berkeley (April) and Chicago (October). We invited participants based on their ability to represent diverse roles, institutions, and perspectives on research software. The general goal of the two community workshops was to determine which topics this diverse group of stakeholders consider to be well-understood, which topics still have uncertainty or a need for guidance, and what work remains to be done in supporting sustainable research software. URSSI PIs facilitated broad discussions and participated in small group breakout discussions. Additionally, participants at each workshop gave presentations about their on-going research software activities.

Thematic Workshops: Participants at the first community workshop identified two topics worthy of more focused discussion and community input. We organized the following workshops to better understand those topics:

- The **Metrics, Credit and Citation Workshop**, held in Santa Barbara, California in January 2019, focused on reseach software metrics, citation, and impact evaluatin. The 23 participants had strong expertise in the various workshop themes, including the PIs of the CodeMeta project, Zenodo, and software credit initiatives such as SourceCred.
- The **Research Incubators Workshop**, held in College Park, Maryland in February 2019, focused on methods for incubating new and existing research projects. The 20 participants had strong expertise in research software project development, including program officers from various government agencies, open-source research software developers, and organizational scholars that have studied research software processes.

URSSI Design Workshop: In April 2019 members of the Senior Personnel and Advisory Committees participated in a workshop in Chicago, IL. PIs presented preliminary results from our research (ethnographies and survey) as well as lessons learned from the four previously held URSSI workshops.

2.2 Website / Newsletter/ Blog

One of the major goals of the conceptualization project was to build awareness of the need for an institute, publicize our activities, and increase overall community interest. To achieve this goal, we used a website, nine newsletters, 36 blog posts, and a seires of public talks and webinars given by the PIs and others. We sent the newsletters to the URSSI email list, which consists of workshop attendees and other interested members of the community. We also publicized the newsletter and blog posts via the URSSI twitter account, which has over 500 followers.

2.3 Survey

We developed and disseminated a survey to compliment workshop participation. The primary goal of the survey was to gather the opinions, preferences, and self-reported activities of the research software community regarding development practices, development tools, training, funding/institutional support, career paths, credit for software work, and diversity/inclusion. For each of these topics, we asked a small number of general questions and then allowed participants to self-select to answer more detailed questions about any area of particular interest. We distributed the survey to PIs of currently funded NSF and NIH projects and to relevant mailing lists. The survey closed in May 2019 after receiving approximately 1200 responses.

The results of the survey highlighted some areas where URSSI could play a key role in advancing the sustainability of research software in the United States.

1. There was a mismatch between how respondents wanted to allocate their time and their actual allocation of time. This result provides an opportunity for URSSI to work with developers and teams to help them focus their efforts on the tasks that are most relevant.

2. The aspects of the software development process respondents viewed as being more difficult than they should be tended to be people-related activities rather than technical activities. This result suggests that URSSI could support teams and developers by providing training and/or resources related to human factors in the software development process.

3. Respondents indicated they use a number of software development practices. However, one key practice that was underutilized is peer code review. URSSI can provide training on peer code review and work with teams to ensure that the infrastructure is in place to appropriately support this activity in the research software space.

4. The respondents indicated that software development practices including *requirements*, *design*, *maintenance*, and *documentation* were not well-supported by tools.

5. In terms of version control, there is still a sizable percentage of people who use methods like *copying files to another location* and *zip file backups* as version control. This result suggests that URSSI could provide additional training and tools to help teams use modern version control systems.

6. Many of the items above relate to training, or the lack thereof. The survey results suggest a large percentage of respondents have not received training in software development. While the respondents indicated there were sufficient opportunities for training, most of them suggested they did not have sufficient time for training. URSSI could help by providing

training in different formats that work better with the demands of the research software developers' environments.

7. Many respondents also found the level of support, in terms of funding, to be inadequate to be successful. URSSI could help by advocating both at the national funding level as well as at the University level for increased funding for important research software development activities.

8. Respondents also indicated their software contributions were not significantly valued in performance reviews. URSSI could help by developing and advocating for policies that help research software developers get adequate recognition for their work.

9. Most projects lack a formal diversity plan. URSSI could help by providing template diversity plans and support for developing appropriate plans for individual projects.

2.4 Ethnography

To gain a deeper understanding of the practices and experiences of researchers who are actively engaged in software development, we have undertaken a series of ethnographic studies. These studies focused on software projects of varying size and complexity in the fields of hydrology, astronomy, and biochemistry. Using observations, semi-structured interviews, and a series of archival documents, we produced case studies of how, over time, these projects overcame challenges of recruiting contributors, building a governance model, seeking funding, and sharing credit in sustaining a software project that has demonstrable impact on a community of researchers.

We developed two of these studies, Astropy and Rosetta Commons, as full case studies. Both projects face unique sustainability challenges that they solved somewhat differently. While the main findings of this work are not novel in the sense that they will surprise anyone familiar with challenges to sustaining research software, the value of this work is in comparing the two cases. By better understanding common approaches to overcoming sustainability challenges, we believe there is a valuable opportunity to abstract these approaches into models of success that research software projects in other domains can modify or tailor. The following is a brief summary of the findings from these two case studies.

Points of comparison:

- *Distributed work coordination*: Key to the success of both Astropy and Rosetta Commons is coordination of remote collaborative work. Astropy mirrors Python's core development team in structuring contributor guidelines and supporting designated maintainers. Rosetta Commons

differs substantially in that the project employs four full-time infrastructure maintainers. This offloading of maintenance responsibilities frees up contributors (distributed labs throughout the USA) to focus on conducting research and driving innovations that extend Rosetta's key functionality.

- *Funding*: Astropy is fiscally sponsored by NumFocus, but depends upon grant funding from a variety of sources to sustain its collective work. A recent grant from Gordon and Betty Moore Foundation, "Sustaining and Growing the Astropy Project," is focused exclusively on maintenance and governance for the project's long-term viability to practicing astronomers. Rosetta Commons combines licensing and grant funding to sustain its work. Licenses for commercial use and an NIH infrastructure maintenance grant have continuously supported the project since 2005.

- *Credit*: Both projects have had a number of papers published about their development. Astropy suggests two publications to cite when acknowledging use of the software (Robitaille et al., 2013; Price-Whelan et al., 2018). These two publications, combined, have over 3000 citations. Rosetta Commons, because it has many versions, methods, and language specific implementations, has no canonical citation. Interviews with contributors to Rosetta noted that this lack of canonical citation causes confusion for authors when rushing towards publication. Many researchers have sought a centralized source they could acknowledge. Despite the lack of a canonical citation, two papers describing Rosetta and its use in predicting protein structures have, combined, over 4300 citations (Rohl et al., 2004; Salmena et al., 2011).

We observe differences in the two projects that seem marginal at first glance, but upon further analysis have important practical consequences for software development activities. For example, two substantial differences in the projects have consequences for the long-term sustainability of each project:

- Astropy, in following an open model of contribution, focuses time and attention on clearly documenting and making contributor guidelines accessible to research software engineers. The maintenance team therefore focuses their effort on ensuring contributors are supported while simultaneously keeping various packages up to date and available to the community that depends upon this code for their research. This approach is partially a result of the software ecosystem being broadly useful to a discipline (Astronomy), as compared to Rosetta Commons, which focused on specific analytic tasks within a subfield of biological engineering (Macromolecular modelling).

- Continuous annual grant funding and licensing fees allow Rosetta to centralize infrastructure tasks to a core team whose sole job is maintenance.

> This approach in turn encourages innovation and expansion of feature sets for labs that focus solely on producing new research insights. Astropy has, over time, centralized maintenance of the project's software development and maintenance. But until very recently, this maintenance has been a volunteer activity. Shifting time, attention, and energy towards organizing an open-source model of development impacts career trajectories for practicing astronomers and contributes to a more fragile ecosystem for astronomy.

We recognize that software sustainability is more than just financial support, but what these case studies make clear is that the economic realities of maintaining and contributing to software development have important downstream impacts that shape innovation and engagement. The URSSI conceptualization has studied how these challenges can be practically overcome.

2.5 Winter School

In late December 2019 we ran our first ever URSSI school on research software engineering. We began accepting applications in July and received an overwhelming response to our call for applications. For the 30 participant slots available, we received 169 applications, meaning we had a challenging time selecting the participants and had to turn away a large number of interested researchers. While the selection committee used multiple criteria to evaluate and select participants, successful applicants already had some experience with Python programming, Git, and Unix skills, which was necessary to benefit from the workshop. Our goal was not to repeat the same material covered in bootcamps and Software Carpentry style workshops, but to focus on the research software engineering skills that not formally taught in any setting. These skills include best practices for packaging code as software, testing, collaborative software development, code review, and related topics such as licensing and archiving. The school lasted 2.5 days.

Based on the demand described above, this experience made evident the strong need for the skills covered in the school. The overall feedback from the school was also positive (more on that below). Some key lessons from this pilot that impact our design of a Summer School as part of URSSI are: 1) the school needs to be longer to allow for both discussion time and focused time for students to work on their own code, applying the lessons from the lectures; and 2) the presence of additional helpers outside of the primary instructors was quite beneficial to help answer specific questions from the students.

A few example quotes from the Winter School feedback form include:

- "I really can't say enough good things about this super empowering workshop! You did an amazing job identifying the things I didn't know that I

didn't know, and teaching them at a level that was immediately actionable in my work."

- "Thank you so much to everyone for taking this amazing initiative to teach young scientists on software sustainability."
- "Thank you for putting together this winter-school, it was super useful to me and I'm looking forward to applying everything I learned to my future projects and to go deeper into the topics that were covered."

2.6 Joint Activities

During the URSSI conceptualization process, we helped start two new activities that overlapped our goals, both so that we could promote these goals and also so that we could build up these future partners of a later full URSSI institute.

2.6.1 Research Software Alliance (ReSA)

URSSI instigated (along with the UK Software Sustainability Institute and Australian Research Data Commons) a global community of organizations interested in promoting and sustaining software, called the Research Software Alliance (ReSA). ReSA has held three meetings, at RSE18, eScience2018, and RSEConUK19, with representatives from about 20 other organizations and has assembled a mailing list with about 40 such organizations and an umbrella organization under which all these groups can collaborate to strengthen all of our activities. ReSA is currently working on defining governance and other activities to formalize ReSA, and at the same time, it has started a set of task forces to 1) analyze and document the landscape of different communities and topics of interest for the research software community (e.g., preservation, RSEs, citation, productivity, sustainability), 2) collect and share evidence for the importance of research software, and 3) assemble and maintain a register of research software funding opportunities. Additionally, ReSA is currently working with other members of the scholarly community to start up a task force to define FAIR for software, likely co-organized with FORCE11 and RDA.

2.6.2 Research Software Engineering (RSE)

In a 2012 workshop sponsored by the UK SSI, a number of UK researchers who develop software realized that while they internally recognized a number of common elements to the work they did, along with others at their universities, there was no commonality to how others saw this work and these roles, and they needed to come together to build and develop a community. As stated by James Hetheringon, they decided they needed to "develop the profession of a scientific

software engineer and the career track of software developers in academia." They studied academic job descriptions in the UK, and found about 10000, of which about 400 were related to software development, with 194 different job titles. To build recognition of the common software elements of these positions, they chose the name "research software engineer". They then began publicizing this idea, building a community of people who identified with the role and encouraged them to also identify with this title, building RSE groups in UK universities, encouraging universities to change their job titles, holding workshops and then conferences for RSEs, encouraging a funding agency to provide fellowships to RSEs, and building up an association with about 2000 members, which later developed into a professional society (Hettrick, 2016).

As a number of non-UK people (including some URSSI PIs) started attending UK RSE conferences, the SSI also supported activities to grow the international community. These self-developed and SSI-supported activities have led to RSE groups in Germany, the Netherlands, the Nordic countries, the US, Canada, and South Africa, some of which have now held national workshops and conferences. The US Research Software Engineer Association (US-RSE) formed in 2018, with the support and participation of three of the five URSSI PIs, and has 340 members as of February 2020. The US-RSE Association is centered around three main goals:

- *Community*: to provide a coherent association of those who identify with the role (not necessarily title) of Research Software Engineer, and to provide the members of the community the ability to share knowledge, professional connections, and resources.
- *Advocacy*: to promote RSEs' impact on research, highlighting the increasingly critical and valuable role RSEs serve.
- *Resources*: to provide useful resources to multiple demographics, including technical and career development resources, and information and material to support the establishment and expansion of RSE positions and groups within the research ecosystem.

There are thus some overlaps between US-RSE's goals and URSSI's and a clear reason for us to work together going forward.

2.7 Synthesis of URSSI Activities

In the following section we describe common challenges and dilemmas we identified across URSSI's conceptualization activities. Where possible, we identify the role URSSI could play in helping overcome these challenges as a funded institute.

Challenge 1: Decentralized expertise

Throughout the planning activities, the community of stakeholders recognized that there already exist a number of individual efforts to help improve the development, maintenance, and overall sustainability of research software in the US. While these efforts, collectively, are comprehensive in their scope, the decentralized structure of this expertise is inefficient for both resource discovery and delivery of services. For example there are many points of expertise in research software development (e.g., SWEBOK, RSEs), education and training (e.g., academic initiatives, Carpentries), credit and metrics (e.g., CiteAs), incubation (e.g., ESIP, the UW eScience Institute) that are available to individuals at specific institutions. However, there is currently no comprehensive organization that can serve to coordinate these activities, promote centers of expertise, and ensure that effort is not duplicated– a role that is played admirably in the UK by the Software Sustainability Institute.

As a coordinating center, URSSI could help solve this challenge in the following ways:

- Broker connections between points of expertise and serve to coordinate efforts and funding such that different experts could better collaborate on sustainable development, education, and policy initiatives.
- Identify and convene experts to help fill gaps that exist between service delivery, for example, where the Carpentries see gaps in knowledge skill or acquisition in sustaining software education.
- Disseminate best practices from specific disciplines to the broader research community. By acting as a center of research software excellence URSSI could be a space where solutions from one domain could be learned and efficiently transferred to another.
- Coordinate and help to curate relevant research software packages through discovery portals, such as https://libraries.io/

Challenge 2: Pathways to sustainability for non-commercial research software

Throughout the URSSI conceptualization activities, participants voiced concern for the viability of valuable software projects that do not seek commercialization. Technology transfer programs at universities and through research funding agencies (e.g. I-Corps, SBIR/STTR) are well established and have been successful at helping entrepreneurially-focused software projects recognize and execute viable business models. This transition pathway is promoted for software that has a potential to sustain itself through fees or licensing agreements. However, there is no equivalent university guidance for software projects that would like to pursue non-commercial open source models for sustainability.

There is a need for a US-based institute, divorced from any single university, to help valuable research software projects realize a non-commercial open-source

route to sustainability. This support could include a program, such as an incubator, that would guide research software projects towards developing open-source governance, budgeting, licensing, and fiscal sponsorship in service of non-commercial sustainability. We view this route, and its guidance from an institute, as critical to promoting an ecosystem of diverse research software projects that may not be readily amenable to commercialization, or have the potential to build healthy and viable volunteer developer communities as an alternative to licensing.

Challenge 3: Coordinated advocacy and analysis for policy change

Related to the first challenge of decentralized expertise, there is a need for coordination and targeted leadership around policy for sustainable research software. Participants in URSSI workshops described a need for coordinating communities around emerging national, institutional, and even disciplinary specific policies that have a downstream impact on sustainability, such as software citation principles, tenure and promotion guidelines that recognize research software contributions, sustained funding or financial support for research software maintenance, and software management plans that explicitly document expectations around software development and archiving.

Currently, community members take on many of these policy activities as additional professional service, or as volunteer work. This secondary focus on any one policy issue, in turn, leads to slow progress, high turnover of volunteers, and does not allow any one person or institution to develop the deep expertise needed for effective sustained analysis or advocacy.

An institute that could dedicate time and attention to policy design, invest personnel time in developing needed expertise, and coordinate a sustainable lobbying network would allow advocacy work to become more manageable, effective, and result in better outcomes for research software stakeholders. Further, there is often a need to conduct advocacy work driven by empirical research that can substantiate how or why one policy decision is better than another. An institute dedicated to these activities would facilitate data-driven policy research that could lead to stronger advocacy positions, and benefit funding agencies, universities, and research institutions that seek to adopt new policy aimed at improving research software sustainability.

Challenge 4: Signals of viability

A valuable contribution of the URSSI workshop and engagement activities has been convening stakeholders with expertise in the evaluation and funding of research software. These stakeholders include current and former program officers from NSF, NIH, DoE, DoD, and IMLS, as well as philanthropic organizations like the Gordon and Betty Moore and Alfred P. Sloan foundations. These participants have a collective desire for an institute to develop stronger signals of a research software project's viability; to help evaluate a project's potential for long-term sustainability; and help communities of research software stakeholders

coalesce around strategic funding initiatives that could benefit research through software investments.

A dedicated US institute focused on software sustainability could help meet this challenge in a number of ways, but we recognize that there is no overarching or simple solution. The plan we describe below explains, in numerous places, how URSSI can and should convene different communities to address complex problems like strategic financial investment, evaluation for viability, etc.

Challenge 5: Career Advancement and Credit

Closely related to Challenges 1, 3 and 4 is a desire of URSSI stakeholders to see an institute dedicate time and resources towards promoting recognition for research software activities and helping to shape reliable career pathways for research software engineers (RSEs). At URSSI workshops, there was near-unanimous agreement that the acknowledgement of research software contributions remains difficult for career advancement and there is a lack of clear guidance for both universities and funding agencies on how to make progress on these issues.

A dedicated US-based institute for research software sustainability could play a leading role in advocating for best practices in the measurement, reward, and credit for research software activities. This activity would include dedicated research into measuring and evaluating software development activities, advancing techniques for use and user impact evaluation, and promoting formative metrics that are conducive to long-term viability. Relatedly, a dedicated US-based institute could better evaluate and promote the impact of research software engineering positions that currently exist and advocate for their creation where they do not.

In the next chapter, we describe URSSI's plan to meet each of these challenges. In particular, we focus on how a strategic investment in a US-based software sustainability institute would practically organize itself, allocate budgets, and measure progress on each of the challenges identified in the conceptualization phase.

Chapter 3

URSSI Plan

Throughout the URSSI conceptualization process, the team worked on overall planning iteratively, using slides at workshops and the URSSI website to disseminate current thoughts, using the survey and the ethnographic studies as inputs, using workshops (including slides and shared note documents) and the discuss forum (https://discuss.urssi.us) to gather and record feedback. Together, these activities plus internal discussions of the team and a focused mission and vision working group have led to most of the content of this document.

3.1 Mission and Vision

URSSI PIs began to develop mission and vision statements in late 2018. The intent of these statements was to succinctly state the purpose for URSSI's existence (mission) and based on that purpose what URSSI strives to achieve (vision). The process for developing these statements was:

- At the first two workshops, we asked participants about the goals and vision that a US research software sustainability institute should pursue.
- The URSSI PIs then identified institutions with similar goals and collected their mission and vision statements for comparison.
- Eight members of the Senior Personnel and Advisory Committee participated in a working group focused on developing URSSI's mission and vision statement.
- Each working group participant provided a written set of three mission and three vision statements based on the conceptualization proposal, workshop participant's feedback, and guidance from the URSSI PIs.

- Neil Chue Hong, director of the Software Sustainability Institute in the UK, facilitated a synthesis of the working group's feedback. This synthesis process included a teleconference with participants to discuss and refine versions of each mission and vision statement.
- The URSSI PIs then presented drafts of each statement to workshop participants at the final URSSI meeting in Chicago and refined a final version of each statement.

The mission and vision of URSSI are as follows:

Mission: Our mission is to improve the recognition, development, and use of software for a more sustainable research enterprise. We achieve this mission through collaboratively developing education, outreach, and software services that emphasize open, transparent reproducible, and cooperative practices. URSSI is an institute for software expertise as well as a social infrastructure that promotes an inclusive and diverse community of research software engineers, maintainers, contributors, and users.

Vision: Empowered people, building better software, enabling exceptional research

3.2 Planning assumptions, methods, and principles

The following assumptions are inputs to our planning process:

- We will propose an institute with a 5-year duration and a potential 5-year extension, based on NSF's current institutes and published documents.
- The budget of URSSI will be $3m-$5m per year. We take $3m as the baseline minimum funding level needed to operate an institute, below which an institute is not the right method to achieve the mission and vision, and then build higher cost and higher return activities on that baseline.
- There is demonstrated interest in supporting some URSSI goals from private foundations and potential interest from other federal agencies, so URSSI activities should be planned as a set of reinforcing (but separable) activities, potentially on different timelines.
- There is a strong need for improved software sustainability across all fields, and URSSI cannot solve this need in all fields by itself.
- There are many partners who can help URSSI achieve some of its goals, as there is overlap between these goals and the goals of those partners.

- It is not practical for URSSI to directly work with the US software development community due to the small size of URSSI and the large size of the community, so URSSI needs to work indirectly by leveraging other groups.

Given the mission and vision, and our assumptions, we plan to use a set of methods to ensure that URSSI is successful:

- URSSI must choose a set of initial targeted communities and efforts, focus on them for some period, then move on to the next set of targets
- URSSI must work closely with partners to amplify its efforts
- URSSI must be clever about using resources, attempting to achieve multiple outputs for activities whenever possible.

Guiding principles:

- Leverage existing organizations for authority, credibility, resources
- Focus on individuals (i.e., aim at people not projects)
- Leverage available resources (software, services, credit systems, training materials, etc.) where possible rather than reinvent
- Respect and learn from volunteers
- Activities should have an end or a sustainability plan beyond URSSI
- Distinguish between quality (badging/intrinsic) and impact (reuse) measures
- Sustain software by sustaining its communities (stewards, developers, maintainers, leaders, active users)
- Coordinate activities rather than start new ones when possible
- Advocate and promote a variety of solutions to challenges, recognizing that no one solution is likely to work for all stakeholders or in all situations

Some topics are partially or completely out-of-scope for URSSI:

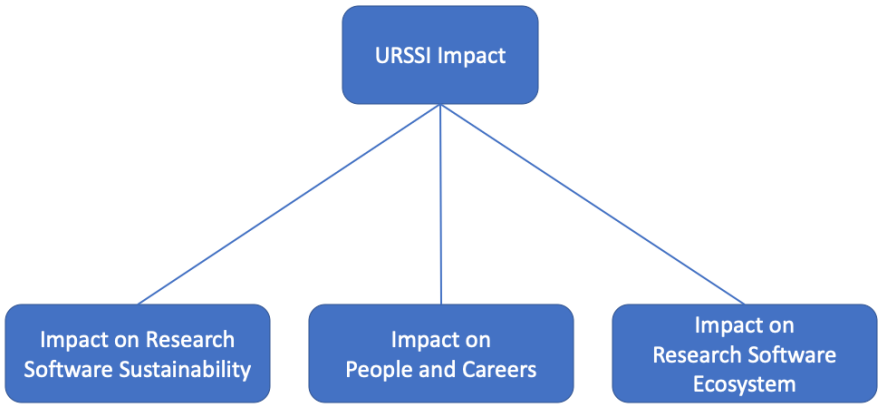
- **Software Commercialization**. As an institute, URSSI will position itself as a broker to existing bodies of knowledge or expertise, and seek to fill needed gaps where no expertise already exists. Relevant to this positioning is a route to research software sustainability through software commercialization. We view this path to sustainability as already well supported by existing programs and initiatives, some of which are already

funded by NSF. As a principle, URSSI is not opposed to or discouraging of research software commercialization. We will actively seek to learn from and collaborate with the commercial software ecosystem, including technology transfer offices that provide structured pathways to commercialization for research software in academic institutions. In this role, URSSI might guide people in deciding if commercialization is a realistic or good choice for their software project, and connect those who decide that it is to existing support programs like I-Corps. What we believe URSSI can uniquely provide, and what we find to be lacking, is support for alternative routes to sustainability through open-source or non-commercial fiscal sponsorship. While these alternative routes are obviously less straightforward, and more challenging they remain the most viable option for improving the long-term accessibility and impact of most research investments in software. A majority of even the best research software projects won't be commercially viable given the size and scope of their audience. It is this critical gap, between commercialization and open-source, that URSSI seeks to close.

- [**TODO**: what else should be out-of-scope for URSSI?]

3.3 Desired impact

URSSI's ultimate desired impact, as stated in the vision, is on scholarly research in all fields. URSSI aims to achieve this impact by enabling and encouraging the contribution of the resources and training to the research software ecosystem that will improve research software and to empower the people who create and maintain that software.



For software, URSSI aims to improve the sustainability of research software by

- Developing and sharing good-enough and best practices for software projects, including for testing, governance, codes of conduct, continuous integration
- Documenting sustainability models and providing guidance on how to choose among them
- Promoting communities and appropriate governance models for open source research software
- Building models to make best use of and support transient software contributors (e.g. students)

For people, URSSI aims to improve the careers of those who develop and maintain research software by:

- Promoting new career paths for those who develop and maintain research software
- Developing and advocating for research software usage and impact metrics to be a factor in the hiring and promotion of software developers and maintainers
- Promoting the publication of research software
- Coordinating community efforts, including by URSSI, to create and provide training for those who want to develop and maintain research software
- Encouraging a diverse set of participants to enter the research software development and maintenance field and decreasing structural and systemic barriers to productive careers for members of underrepresented groups

For the research software ecosystem, URSSI aims to improve the understanding and functioning of the ecosystem by

- Documenting the use of research software in research and providing systematic and regular analysis of the impact this software has on research
- Growing and participating in communities around the field of research software
- Promoting an increased understanding of the importance of research software in research
- Promoting software credit and citation mechanisms
- Studying and disseminating methods to catalog and promote research software
- Supporting the use of software in reproducibility

Chapter 4

Organization & Management

Coming soon.

Chapter 5

Policy

The Policy area's intent is create an enablng environment to support the people who develop and maintain research software, and to support research about research software, to ultimately increase the science & research impact of software.
The Policy area's activities are divided into two parts, research and advocacy. Research is the collecting and analyzing of data, while advocacy is the dissemination of the research results in such a way that it changes practices. The Policy area focuses on understanding and then advocating for potential initiatives (actions, mandates, incentives, directives) that decision makers can take, sometimes thought of as leverage points, including strategies and decisions to invest. Policy happens at multiple levels, including national, funding agency, institution, and research group.

The changes that the Policy area seeks to make include:

1. In funding agencies, direct funding of software maintenance and other software sustainability activities is a core part of the mission, e.g., at NSF, this includes all program officers across all directorates.

2. In universities and academic fields, positions for people developing and maintaining research software are available, recognized, and rewarded.

3. In publishing, support and recognition for software as a core part of scholarly research is the norm. (This includes the recognition that software is as valuable to the research community as the results themselves, that processes exist to evaluate software in papers, expectations for authorship for software developers are clear.)

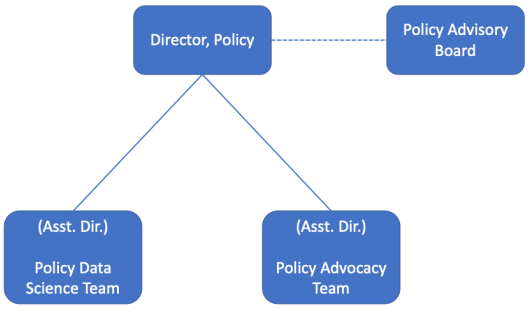
4. In industry, sharing best practices, coordinating efforts, and contributing to open source software projects is the norm.

5. Open source software is recognized as a key element of open science and reproducibility.
6. Research software is built and maintained by a diverse and inclusive group.

5.1 Resources

The policy area will require resources that include funding for people and for events and travel.

5.1.1 People



The policy area comprises:

- Director for Policy, an URSSI co-PI, leads the overall Policy area, working with the Policy Advisory Board and Policy staff to define and execute policy research and advocacy activities.
- Policy Data Science Team: performs research such as finding, collecting, and analyzing data, aimed at informing policy, but not about policy itself. For example, with regard to software usage metrics, empirical studies would be most effective, but this team would not recommend policy language based on those studies. Includes a possible assistant director, funded staff, URSSI fellows, and community volunteers.
- Policy Advocacy Team, focused on policy development (such as use cases and examples of practices that are effective for sustainability), which ultimately would be used for presenting actionable ways to support research

software to institutions, possibly integrating and building upon the data science team's findings. This team focuses more on planning advocacy that in doing it, by understanding different stakeholders, and building a roadmap for how to effectively advocate (within universities, foundations, industry, national labs, etc.) Includes a possible assistant director, funded staff, URSSI fellows, and community volunteers.

- Policy advisory board (appointed volunteers) who provide advice on potential policy area research questions and advocacy activities.

Funding for personnel:

- 3 FTEs, divided across possibly part-time Assistant Directors for Policy Data Science and Policy Advocacy, the Policy Data Science Team (potentially a postdoc), and the Policy Advocacy Team. The Director for Policy might also act as one of the Assistant Directors, depending on that person's background.

Additional team members, not funded by the policy area:

- Director for Policy, an URSSI co-PI, funded by URSSI at top level
- Policy Advisory Group (appointed volunteers)
- URSSI fellows, working in Policy Data Science Team and Policy Advocacy Team
  - (Fellows program to be run by URSSI Community area; these policy fellows might be funded by policy area if needed)
- Other community volunteers, in Policy Data Science Team and Policy Advocacy Team

5.1.2 Additional resources

Additional resources may be needed by the research group for data collection, management, analysis, etc., and by the advocacy team for dissemination of materials and community organization and support. Both teams may need additional resources for producing materials, including graphic design, copy editing, etc). Amount are **TODO** TBD

5.1.3 Events & travel

Funding for workshops: **TODO**: TBD

- Potentially including a policy conference / workshop(s) akin to Aspen Institute or CODATA - $370k. This could also could be part of an annual URSSI event.

Funding for travel/speaking: **TODO**: TBD

- As part of advocacy activities, URSSI personnel will discuss findings and recommendations.

5.1.4 Flexibility

If there is less budget available, we would cut back on workshop funding

If there is more budget available, we would:

- Expand policy program to have a summer program for undergraduate and graduate students focused on software / science policy (e.g., an NSF REU site or something like a Google Summer of Code for policy / law students)
- Hire communication staff to do outreach and engagement around policy topics (dedicated expertise in policy as opposed to general outreach)

5.2 Methods

Initial activities are planned around an initial set of challenges articulated below, where additional challenges also will be suggested. The URSSI leadership group will regularly review suggestions of new challenges, and will determine a rough desired level of activity across the challenges.

The policy team will then develop and scope activities to match these desired levels, with review from the Policy Advisory Board, which will also be able to suggest adding or removing challenges back to the leadership group.

The policy team will also maintain this listing of active, planned, and potential activities and its mapping to the challenges. Activities will be split into those that, if successful, are likely to lead to significant changes in 1-2 years, 3-5 years, and longer-term, with an initial goal of applying 50% of resources to the 1-2 year activities, 40% to the 3-5 year activities, and 10% to the longer-term activities.

5.2.1 Challenges

Initially, the policy area will work to address the following set of challenges:

1. Career paths (including titles and evaluation criteria for hiring and promotion) aren't well established.

2. It's hard to measure the impact of individuals, especially in activities that are inherently collaborative like software development.

3. The academic credit model disincentivizes individual contributions to public goods / infrastructure

4. We conflate quality and impact of software and need to disentangle them.

5. There is a lack of recognition of the value and importance of software.

6. There is a lack of funding opportunities and stable funding for maintenance of software that is important but doesn't have a generic market and/or isn't considered novel in the eyes of the average funder/reviewer, and "lumpy" project funding (projects that are competitively funded for fixed periods, often with gaps between funded project periods) means that maintenance/sustainability can't be reliably folded into project costs.

7. The development and maintenance community is much less diverse than the overall US population.

5.2.2 Partners

The Policy area will work with other NSF SI2/CSSI Institutes & Centers of Excellence (e.g. SGCI, MolSSI, IRIS-HEP), the Research Software Alliance, the Software Sustainability Institute, the US-RSE Association, the (UK) RSE Society, the Academic Data Science Alliance, the Research Data Alliance, the American Association for the Advancement of Science (AAAS) Science & Technology Policy Fellows, CaRCC, OECD, and any other projects and organizations that also seek to define and address overlapping challenges.

The Policy area needs to build relationships with the following groups and organizations, and to work closely with them, particularly in policy activities.

- Institutional and research leaders in the academic and national laboratory community, such as VCRs, CTOs/CIOs, who can help URSSI penetrate various institutions and disciplines

- Representatives from professional academic associations

- Representatives from industry (including those already invested and sold on OSS, as well as those skeptically interested)

- Representatives from Open Source communities, particularly those that are already effective and working at scale

- People working in science policy, such as in AAAS and the National Academies (in particular, AAAS policy fellows might be interested in helping on time-constrained activities that match the purpose and period of their fellowship)
- Representatives from organizations and companies serving OSS and RSE communities (e.g. NumFOCUS, Code for Science & Society, GitHub, Code Ocean)
- Representatives from organizations that represent other research support roles (e.g., librarians, data stewards, RSEs), to work together to promote all such roles
- Representatives from organizations that focus on diversity and inclusion in academia, to encourage them to include software-focused roles where possible
- People from the European Commission regarding European Open Science Cloud (EOSC), etc.
- Representatives from organizations like the Research Data Alliance and FORCE11

5.2.3 Planned Activity Pool

This is the initial list of activities that URSSI will maintain, and choose from. The specific activities that will be chosen to start depend on the funding level for URSSI. Most activities include an amount of effort (generally in person-months) that is needed to accomplish them. Note that some activities (the items below) include raising additional funds for those activities - that fund raising is part of the activity. Other activities, in the next subsection, are tracked but are beyond the scope of URSSI, and are more likely activities that others might perform, potentially in coordination with URSSI.

High-level activities include:

- Maintaining the list of potential activities and prioritizing them, including getting inputs from the overall community. These inputs will be collected and recorded by all members of the project in their interactions with the community, as well as by community members, via tagged GitHub issues. Community members will be able to see this list and react with a +1 to issues they think are important, and URSSI will use these reactions as an element of prioritization. (ongoing)
- Tracking completed activities and their consequences (ongoing)
- Collecting examples of good and bad policy, structures, and interventions from industry and from other disciplines (potential fellow project)

- Developing an advocacy roadmap for how to effectively advocate (to universities, foundations, industry, national labs) (policy person & advisory committee, spread over 3 months)

5.2.3.1 Policy Research Activities

These activities involve research, such as gathering and analyzing evidence and data.

Faculty career path policy - research actions:

- Study tenure guidance and policies, and find/document ways that software work is measured and recognized. Publish examples of successes. (ADSA is interesteded in partnerering on this; the ADSA Career Development Network is mostly faculty facing exactly these challenges. Additionally, RDA is in the processing of developing an Open Science Registry[1] as a collaborative platform to share both the intention and outcomes of pilots and other initiatives that specifically address the academic reward system, as an outcome of the European Union Open Source Policy Platform (OSPP) final report (Mendez et al., 2020).) (2 months)

Staff career path policy - research actions:

(All the actions below will be coordinated with US-RSE and other national RSE organizations. Additionally, some infomation already exists that can be mined, such as international and national RSE surveys (Philippe et al., 2019), …)

- Document existing (known successful/viable, known failures) career paths for individuals creating research software (2 months)
- Examine and document industry career paths vs. national laboratory career paths vs. academic career paths (1 month)
- Create and maintain a mailing list for those interested in career paths (mailing list to be supported by Community area) (ongoing, low level of effort)
- Create a clearinghouse of job descriptions with criteria for performance assessment; distill out design patterns or different categories for different roles. This could also include documenting salary levels for different job descriptions, and connecting the job descriptions with then learning modules necessary for these jobs (3-4 months, plus ongoing maintenance)
- Examine how salaries for RSEs compare with those of other researchers? (needs to follow clearinghouse, 1 month)

[1] This link may not yet work.

Measuring the impact of individuals policy - research actions:

- Identify factors (manual, such as evaluations, and automated, such as crawling repos) that are part of impact and publicize them. Some known factors to investigate include quantifying code contributions, code review, mentoring. Determine good practices (for formatting or housing the information on these factors) so those factors are discoverable and/or queryable. (An initial effort of 6 months will make progress and better scope additional work that could be performed.)

Incentivize contributions to public software policy - research actions:

- Gather data/examples that show when contributions to public projects increase your citation count or regular metrics (1 month)
- Gather examples of successful use of individual contributions to public goods/infrastructure to gain academic promotion (1 month over 3-6 months)
- Use regular surveys to better understand why people do and don't contribute; get data to understand the value of public goods to community (1 month over 3-6 months each year)
- Determine a way to make it easy for scientific communities to peer-review public-good software (or contributions to such software), with the idea that peer-review is considered a mark of quality. This could be done by starting a new journal or working with existing journals or conferences, or via existing community organizations or software-focused organizations (ongoing, not well-scoped)
- Research to counter the idea that publishing in the small set of "highest impact" journals is key, and expose actual impact of work instead (work with scholcom community, use what they have done, maybe adapt their work for software - maybe 2 months to start)

Disentangle quality and impact of software policy - research actions:

- Create checklists/review guidelines for different levels of peer-review for software; can be tiered, could issue stars or use another rating system; leverage information already available from journals and other resources. (1 week)

Recognize the value and importance of software policy - research actions:

- Find science/discovery cases where software was particularly fundamental, particularly digging into software that is not so generally well-known (2 months over 6 months)
- Research and deliver case studies in sustainable software value, e.g., NetCDF, HDF5, DS9 image viewer, GCM model(s). How much money was invested in these projects and how did these projects return value to the community? Examples of value could include: number of research projects taking advantage of these solutions, amount saved by not having to reinvent these technologies. (6-to-12-month fellow project)
- Quantify the money that has implicitly funded maintenance and sustainability, and has been saved or lost in the shift to open source (e.g., where have funds been spent on one-off software rather than maintaining existing open source software, and where has an investment in software maintenance saved funds from being spent on one-off software) (6-month fellow project)
- Calculate bus factor for a bunch of key software in disciplines (partner with CHAOSS, or perhaps 6-month fellow project)
- Document maintenance and funding for critical packages for several disciplines, e.g. IRAF in astronomy (6-month fellow project)

Funding opportunities for software maintenance policy - research actions:

- Review the landscape of funding opportunities for software maintenance (and gather data about them) and provide a public summary, then keep the summary up-to-date. (jointly done with ReSA? Or CZI EOSS?) (1 month and some ongoing work)
- Gather case studies of successful commercialization of open source projects and encourage the research community to understand and make use of them (2 months)
- Review the scope of maintenance needs by various research disciplines. Determine the order of magnitude of the maintenance backlog for research software (with CHAOSS and others, unscoped)

Diversity and inclusion policy - research actions:

- Survey US research software projects to examine diversity of leadership and contributors (3 months)
- Study/survey contributors who make a single contribution and those who make ongoing contributions vs membership in underrepresented groups (3 months)

- Contribute to DISCOVER event cookbook, working with NumFOCUS's DISC
- Other items with CS&S and NumFOCUS's DISC, for example, creating a cookbook aimed at projects

5.2.3.2 Policy Advocacy Activities

These activities focus on advocacy. They generally depend on policy research or previously gathered evidence and data.

General advocacy actions (not mapped to specific goals):

- Work with REU[2] programs? – set up a network of software-focused REUs? Or focus on software aspects of more REUs? (provide training, guidance, language for proposals, …) (2 month to start + ongoing)
- Foster competition between universities (and their administrations), as has been done by the SSI in the UK to create RSE groups, by:
  - Highlighting software work (including internal investments to sustain projects that the university sees as important and prestigious) and successes (including funded projects that focus on software) in some universities.
  - Ranking the contributions of universities to software or their structure for software developers, and publicizing the ranking (maybe with US-RSE) – via newsletter, blogs, press releases (pontentally run by or at least coordinated with the URSSI community area). This could be based in part on information submitted by the software community, e.g. Laura Noren's and Brad Stenger's Data Science Community Newsletter. These rankings and information would also be bi-directionally shared with ReSA.
- Work in citation and credit (get publishers to recognize and highlight software in research) (with FORCE11 and others) (minor support of other activities)
- Promote software management plans and software sustainability plans as part of proposals (3 months over a year, bringing together community and volunteers, work with ReSA and RDA)
- Develop a set of options for how institutions can support research software (e.g., RSE groups, RSE careers, tenure and promotion guidelines) and disseminate it (with US-RSE, starting after year 1)

[2]REU is refers to both NSF's Research Experience for Undergradautes program, as well as being a generic term for summer and other programs that provide undergraduates with research experience.

- Create and operate a professional award program (working with other established organizations) e.g., ESA URSSI software award. The URSSI software contribution to research awards: URSSI/ESA (e.g. John Chambers software award from stats association). $10k funding available from URSSI (eventually domain societies would be asked to partially fund the awards). URSSI would need to define the categories, criteria/heuristics, etc. for awards beforehand. And find people (either staff or community volunteers) to run awards processes (accept nominations, make decisions) (2 weeks/year starting in year 2)
- Work with NumFOCUS to provide guidance to projects on how to work with (including obtaining funding from) industry (sharing material with incubator area)
- Offer training for software development proposals (or point to others who do)
  - Develop and disseminate best practices for software development proposals (with NumFOCUS or the Capentries)
  - Training/materials could be asynchronous, or in-person with NSF program officers as well, if they were willing to do so
- Licensing (in partnership with OSI, Creative Commons, others)
  - Provide (pointers to) guidance on licenses and copyright for research software (little work, partner with OSI and point to existing best practices)

Faculty career path policy - advocacy actions:

- Promote best practices in recognizing and measuring software work in hiring practices and tenure letters via sample guidance documents for committees, for faculty, and for letter-of-reference authors. (needs focused workshop and follow-through, ~3 months over a year)
- Commission a NAS report (similar to the one on Open Source Software Policy Options for NASA Earth and Space Sciences) on career pathways/progression in academia (for scope see last item in next set of bullets)

Staff career path policy - advocacy actions:

- Help start organizational "chapters" of research software developers (perhaps called URSSI chapters?) at existing universities / societies / organizations; create handbook, tools, best practices to support local organizers; assign an URSSI "coordinator" / community manager. These chapters could: talk about training, do consulting for problems, host hacky hours,

study groups, software days, and come together in a larger event, perhaps a regional workshop or an URSSI-wide conference. Overall, this helps / grows / establishes the community (and make connections that could help chapter members meet the right person for their next career moves).

  - Done with URSSI Community area; Policy part (1 month) is creating some materials, e.g., guidance on how to set up a chapter, how to align it to local activities, and how to run it.
  - Also to be coordinated with US-RSE, as regional US-RSE groups might overlap regional URSSI chapters.

- Work to promote and support the establishment of RSE capabilities at universities around the US. Provide advice on how to talk to university administrators (and which ones) about this, etc. (1 month, jointly with US-RSE)

- Provide examples of language to universities they can use in HR/job ads for RSE positions (1 month, jointly with US-RSE)

- Commission a NAS report (similar to the one on Open Source Software Policy Options for NASA Earth and Space Sciences) on {career pathways/progression in academia, recognition of software, evaluation of software developers, inclusion of software in hiring and promotion} Would need to define, then raise funds from outside URSSI (~$1m), then work with NAS to define a charge and to contract for the study. (4 months over 2.5 years)

Measuring the impact of individuals policy - advocacy actions:

- Create champions (e.g. librarians) to promote and educate individuals and projects of these good practices, working with the best practices activity in Community area.

- Help individuals understand how they can best promote themselves (e.g., claim software works on ORCID), working with the best practices activity in Community area.

Incentivize contributions to public software policy - advocacy actions:

- Work to persuade high-profile individuals to make public contributions to public projects

- Share examples of successful use of individual contributions to public goods/infrastructure to gain academic promotion, produce templates, advocacy toolkits and examples to help others to make their case. Similarly, work to persuade people that contributing to projects will increase their

products within their normally accepted reward system (e.g., get more collaborators and papers; increase opportunities to meet/work with new/old collaborators; will build social connections/network)

- Show how you can participate in public goods / infrastructure projects (e.g., how to structure an issue, how to write your first PR), collaboratively with best practices activity in URSSI Community area (low initial effort, low ongoing effort to maintain)
- Produce templates based on successful use of individual contributions to public goods/infrastructure to gain academic promotion, advocacy toolkits, and examples to help others to make their case (1 month)
- Reframe contributions as first class research products / objects (i.e., explain how building the best software is itself science, as it's both discovery and creation). In order to do this, amplify existing efforts to build a taxonomy of such contributions to make it clear what those contributions are, and encourage people to claim/talk about/take pride in these contributions; work with publishers to highlight these contributions and the people who make them. Also advocate (materials, webinars, ambassadors, etc.) within academic communities (deans, faculty, science societies, review panels, funders) that public software contributions are research (also could be done by cross-disciplinary respected groups, such as the national academies)
- Work to revise funder policies to ensure reviewers prioritize grant proposals that reuse, build-upon and contribute back to maintenance of public infrastructure
- Create high-profile equivalent of "highest impact" journal for software and data work - where publication is seen as an accomplishment indicating the significance of the software

Recognize the value and importance of software policy - advocacy actions:

- Publicize science/discovery cases where software was particularly fundamental, focusing on demonstrating impact of software (1 week/year, ongoing)
- Raise awareness that software needs to be maintained (low level, ongoing)

Funding opportunities for software maintenance policy - advocacy actions:

- Encourage funding agencies to require software management/maintenance plans (SMPs). Use them to couple the idea of maintenance to the idea

of development, to make it clear that just doing development without maintenance doesn't work. Note that this leads to questions about when maintenance should be stopped, and it's also unclear how long-term maintenance would be supported (since grants are by definition time-limited). (1-2 months/year ongoing, work with ReSA)

- Advocate for funding agencies to provide a funding pool for short-term maintenance grants for existing projects (e.g. CZI's EOSS program). (1-2 months/year)

- Advocate for universities to support maintenance of software developed by their university as part of research impact (or possibly technology transfer), in part by including how software we highlight in the success stories campaign was paid for, including university and RSE contributions, then using this collectively to demonstrate the impact of specific university-funded activities, to encourage other unviersities to step up. (2 months/year over multiple years)

- Encourage companies to provide funds and channel these funds into maintaining research software projects, perhaps via a review process with reviewers from both academic software projects and the companies. This could be done jointly with NumFOCUS or a similar organization, similar to Tidelift (1-2 months/year)

Diversity and inclusion - advocacy actions:

- Advertise DISCOVER event cookbook, working with NumFOCUS's DISC

- Other items with CS&S and NumFOCUS's DISC, such as advertising the cookbook aimed at projects

- Reach out to projects to encourage them to mentor Outreachy interns and those from other programs (e.g., Linux Foundation diversity programs, https://opensourcediversity.org/#programs), and to work with Google Summer of Code, maybe include some matchmaking. Consider URSSI as an organization that applies to a set of these programs on behalf of a set of software projects.

- Build community mentoring program focused on diversity

- Work with RLadies, Women in Data Science, etc.

5.2.3.3 Unplanned Activity Pool

The activities listed here are those that would support URSSI but are beyond the scope of URSSI. They are listed here to provide ideas to others, and URSSI

would potentially be willing to encourage and support them, but likely without resources.

Staff career path policy - research actions:

- Comparative study of research success at universities with core RSE groups vs those without. (potential research topic, not to be started by URSSI)

Disentangle quality and impact of software policy - research actions:

- Define what software quality means.
- Define what software impact means and how to measure it. Impact can be looked at in many ways: scientific, economic, societal, etc.
- Define how you know what software will be impactful (signals of high impact)
- Capture the difference between quality and impact in written resources (blog post, paper, etc.)
- Conduct a Delphi study or multiple Delphi studies across or between disciplines to determine a consensus on key indicators of software impact and related questions, such as: Does improving the quality of software improve its impact?
- Perform randomized experiments of software impact where the treatment is improved software practices
- Perform a retrospective study of software quality as related to "impact" of that software.

Recognize the value and importance of software policy - research actions:

- Study whether higher-quality software produces higher-impact science or more reliable science results

General advocacy actions:

- Talk about problems with current software licenses/models and suggest alternatives
- Create peer-review and publishing systems that are software appropriate, and not just a version of article appropriate system. For instance, find a software ecosystem-native way to peer-review software inside a code management system, or "publish" software by giving a specific version of code a DOI

Incentivize contributions to public software policy - advocacy actions:

- Run a help desk once a week on-line for people who are running into difficulties in making contributions and need help

Funding opportunities for software maintenance policy - advocacy actions:

- Provide a system to match open source maintenance needs and open source programmers (e.g., classified ads), to be funded by URSSI, or URSSI could support proposals for such maintenance work (both morally and by providing guidance to the proposer)
- Provide fellowships for programmers to "do good stuff" related to maintenance
- Attach money for maintenance to some of the to-be-created awards for good software development, jointly named and funded with other communities

5.3 Work with other parts of URSSI

- Education & Training – use to learn about problems, use training events to disseminate products and advocacy
- Community – provide topics for fellows, work with on newsletter and dissemination, host champions, contribute to and disseminate best practices
- Incubator – develop both general and specific guidance for projects

5.4 Metrics/Milestones

- Amount of funding provided by US public and private funding agencies for research software development and maintenance
- Number and fraction of US universities with RSE-like positions, and number of such positions at each university
- Number and fraction of US university faculty who successfully use software work as an important part of their tenure packages
- Number of participants in policy events, and their satisfaction based on exit surveys

- Collect “thank yous” and anecdotes where URSSI is recognized for helping do something
- Number of requests from universities for talks from URSSI staff
- Number of talks by others where URSSI is discussed
- Number of views and citations of URSSI policy documents and web sites
- **TODO**: more needed

Chapter 6

Education & Training

Researchers often view software development skills as separate from, but complementary to their disciplinary training. This perspective introduces a dilemma for researchers, particularly for early-career researchers, who need to master their discipline and simultaneously acquire sufficiently-good software engineering skills. When forced to choose, they typically make sacrifices or take shortcuts in software engineering, as they view their disciplinary skills and knowledge as more important to their careers, and more rewarded by current incentive systems. Further, many researchers do not aspire to become software engineering experts, but approach the acquisition of software skills as a means to a research end. As a result of this approach, there are valuable skills such as packaging, testing, releasing, archiving, and even designing research software that are dramatically underdeveloped in the overall research ecosystem.

Previous studies demonstrate that researchers are rarely purposely trained to develop software. A
2017 survey of US National Postdoctoral Association members regarding postdocs' use of software in research and their training regarding software development found that 95% of respondents use research software. However, 54% (n = 104) of the respondents to this survey reported that they have not received any training in software development (Nangia and Katz, 2017). A similar survey of software use and training from the UK repeats this finding: In 2014, Heatrick et al. asked researchers at randomly selected researchers in 15 Russell Group universities about their software use and training. Of the 417 responses, 45% report having no training in software development. Of the 55% of respondents that reported having received some training in software development 40% had received some form of formal training in a software development course, and 15% were self-taught. In further analyzing these results, Hettrick et al. report that 21% of respondents who develop their own software had no training in software development (Hettrick, 2018, 2014). A 2016 survey of 704 PIs from the Biological Sciences Directorate of the US NSF found the most pressing unmet

needs are training in data integration, data management, and scaling analyses for HPC (Barone et al., 2017). And a 2018 survey of almost 1600 scientist-developers found that 82% of respondents felt that they were spending "more time" or "much more time" developing software than they did 10 years ago (Pinto et al., 2018).

Not only is there a gap in software development training in general, there's also an additional gap across gender. When analyzed by gender (self reported binary of men and women) the first two surveys show that only 39% of female respondents in the UK and 32% in the USA report have received some form of software development training, compared to 63% of male respondents in the UK and 64% in the USA.

This lack of training is not new, nor is it newly discovered. Greg Wilson has written (Wilson, 2016; Software Carpentry, n d) about the history of Software Carpentry:

> In 1995–96, [Wilson] organized a series of articles in IEEE Computational Science & Engineering titled, "What Should Computer Scientists Teach to Physical Scientists and Engineers?". These grew out of the frustration he had working with scientists who wanted to run before they could walk, i.e., to parallelize complex programs that were not broken down into self-contained functions, that did not have any automated tests, and that were not under version control.
>
> In response, John Reynders (then director of the Advanced Computing Laboratory at Los Alamos National Laboratory) invited [Wilson] and Brent Gorda (now at Intel) to teach a week-long course to LANL staff. This course ran for the first time in July 1998, and was repeated nine times over the next four years. It eventually wound down as Gorda and [Wilson] moved on to other projects, but two valuable lessons were learned:
>
> 1. There is tremendous pent-up demand for training in basic skills.
> 2. Textbook software engineering is not the right thing to teach most scientists.

This led to the Software Carpentry organization, which built a successful train-the-trainer model for collaborative lesson development and delivery, and which was used as a model to build Data Carpentry, which then merged with Software Carpentry into The Carpentries, and now also includes Library Carpentry. The Carpentries has developed highly impactful training content and events that meet an intermediate need for training researchers to better develop software. Many computing centers, including those funded by NSF and DOE, have also long had user training in some types of development (similar to that of Los Alamos), for example, joint activities run by TeraGrid and now XSEDE,

and Argonne's ATPESC. Given the success of the Carpentries, these computing center training events often either include or contribute to Carpentries lessons, or complement them In addition, other NSF-funded software institutes (e.g., MolSSI, SGCI, and IRIS-HEP) are also developing training resources for their target communities, similarly making use of, contributing to, and complementing the Carpentries.

We believe that there is an important role that a US-based research software institute can play to expand the breadth and depth of the training available, and to further coordinate and facilitate the acquisition of software engineering expertise by researchers engaged in various development activities. Rather than reinventing content, we anticipate collaborating with and pointing to relevant resources developed through other related efforts.

The Education & Training thrust of the URSSI institute complements and builds upon existing efforts through the following activities. We plan to:

1. Develop and annually run a summer school on practices for sustainable software development for research software
2. Develop a Research Project Carpentry lesson program that teaches people how to turn code into a formal project
3. Plan a review service for software project plans (and note that the implementation of this plan is likely out of scope of URSSI by itself)
4. Evaluate and document successes and failures of industrial software development practices in research software
5. Compile and maintain a body of knowledge of best practices for research software development (This URSSI activity will seek to aggregate both existing practices, and serve as an outlet for emerging practices from other domain-specific software institute, e.g., MolSSI, SGCI, IRIS-HEP)

6.1 Resources

This area requires the following staff:

- Training Lead - who will coordinate all training activities and assessment of those activities [~1 FTE]
- Assessment Coordinator - who will coordinate the assessment efforts (this position could be shared with other parts of the project) [~.5 FTE]
- Research Coordinator who will lead the effort to gather experiences from research software projects [.25-.5 FTE]

6.2 Methods

This section provides more details on how we plan to design and execute each of these activities within URSSI.

6.2.1 Develop and annually run a summer school on practices for sustainable software development for research software

Overview: During the conceptualization phase, we identified a need for additional, focused training opportunities on sustainable software development practices for researchers who were not in a domain covered by an existing institute. One of the primary reasons for this need is that it is generally difficult for professors to make room for this type of content. We plan to meet this need with a summer school, which is a proven method for providing hand-on training to transfer these skills to students, in this case on sustainable software development practices for research software development. We conducted a Pilot Winter School as part of the conceptualization process. The details of that activity appear in Chapter 2. The plan described here builds on the key lessons learned, including: (1) the school needs to be longer to allow for both discussion time and focused time for students to work on their own code, applying the lessons from the lectures and (2) the presence of additional helpers outside of the primary instructors was quite beneficial to help answer specific questions from the students.

Content: Based on the needs identified during our survey, workshops, and other discussions, we identified the following topics as candidates for inclusion in such a school: (1) software design (including modularity), (2) software testing, (3) packaging and distributing code, (4) collaborative software development with modern version control (i.e., git/GitHub), (5) peer code review, (6) open science principles, and (7) software citation.

Format: The summer school will be a 1-week in-person event. We plan to follow the successful PNAS hackweek model (Huppenkothen et al., 2018) where we lecture in the morning and provide time in the afternoons for hacking and putting concepts into practice. We will invite instructors with expertise in the different topic areas (see above) to participate and deliver the lectures in the mornings. To facilitate the afternoon "hacking" time, we will ask school participants to bring a code project they wish to work on during the school. The afternoon "hacking sessions" will allow ample time for the participants to have hands-on time applying the concepts learned to their own code projects. These sessions also provide time for code reviews and other ad hoc topics that arise during the school. The instructors will be available during this afternoon time to help the participants as needed. By the end of the school, the participants should have substantial intellectual knowledge and experiential knowledge. Because

researchers often do not have sufficient time for training or to attend events like this one, as an alternative to the face-to-face summer school events, we also plan to package the content into Carpentries-style lessons that can be used either in shorter training sessions, webinars, or asynchronously.

6.2.2 Develop a Research Project Carpentry lesson program that teaches people how to turn code into a formal project

Overview: One challenge faced by many research software developers is how to convert a small (individual) coding effort into a more formal project. This situation occurs frequently as researchers develop small units of code to accomplish tasks important in their own work. When other researchers are exposed to these code units, they often want either to use the code, add to the code, or both. This is the point when the researcher needs to convert that code into a more formal project, both to ensure quality as others use it and to allow the community to contribute to it. Therefore, we propose to develop a Research Project Carpentry lesson plan, along similar lines as Software Carpentry, that will help researchers make this transition from an individual coding effort to a community-focused project.

Content: The goal of this effort will be to help projects develop a good project plan. As such, the Research Project Carpentries lesson program will focus on helping researchers understand what content a good plan needs to contain. It will also provide information researchers need for making choices about which of the various practices are most relevant to their particular project. The topics to be covered in Research Project Carpentry include: (1) Requirements elicitation, (2) Issue tracking, (3) Source control, (4) Testing, (5) Documentation, (6) Packaging and Distribution, (7) Pair programming, (8) Code review, and (9) Metrics. Note that there is some overlap between the focus of Research Project Carpentry and the Summer School described above. We anticipate reusing relevant content between these efforts.

Format: We will develop modules on the topics above as carpentries-style modules. This approach will allow the Research Projects Carpentries materials to be used either in a face-to-face training course, like the Summer School, or as stand-alone units. This flexibility will allow researchers to access the content in a mechanism that is most relevant to them.

Note: While this activity is relevant to the URSSI effort, we believe that it will have appeal beyond URSSI. Therefore, even though we include it here in the plan, we will seek funding to support it from organizations outside of NSF. We also plan to solicit other organizations and individuals to contribute to this activity. Therefore, while URSSI will drive it and encourage external participation, URSSI will not have the bandwidth to perform all of the work.

6.2.3 Plan a review service for software project plans

Building on the work done for Research Project Carpentries, URSSI has identified the need for a service where experts review and comment on proposed project plans. Researchers who are interested in this service would submit a project plan in a specified format. Then, experts would review the plan to ensure both that it is (1) complete with respect to the content necessary for the type of project and its current stage as well as (2) the choices made for each aspect of the project plan are consistent with best practices. Once the review is completed, the reviewer would work with the project team to help resolve any deficiencies identified in the original project plan.

This activity is likely beyond the scope of URSSI, so we will create an initial plan for it, then seek to partner with other organizations who are pursuing similar efforts and explore external funding sources. In addition to the operating service, URSSI and partners will need to develop and make available the following resources: (1) templates for project plans, (2) checklists for researchers to follow when developing the plan, and (3) guidance on how to choose from various alternatives for each section of the plan.

6.2.4 Evaluate and document successes and failures of the use of industrial software development practices in research software

Industrial software engineering has developed and refined a number of best practices for software engineering and software development. It is not always clear which of these practices are relevant for use in developing research software. It is also not always clear which aspects of the research software domain motivate the need to develop new software engineering or software development practices to handle the unique contexts within which research software exists. To accomplish this activity, URSSI will need to perform the following steps.

First, URSSI will gather experience reports describing the successful and unsuccessful use of industrial software engineering and software development practices in research software projects. Gathering these experiences will involve conducting surveys and interviews of developers of research software to document important information. In addition to the successes and failures with specific practices, the experience reports will also document cases where developers of research software encountered a situation or a problem for which they were unable to find software engineering or software development practices that were relevant. Cases where there is a lack of relevant practices suggest opportunities for creation of new practices.

Second, URSSI will analyze the experience reports to systematize the successes and failures and develop a series of evidence-based lessons learned. Because this

information will be based upon real experiences from research projects, they will have great value to other research software projects.

The results of these efforts will feed into Activity 5 by providing concrete experiences that we can document into best practices. These experiences will be beneficial because we will draw them from experiences on real projects, with knowledge about the context within which the practice works. This context will help provide a description of the limitations on the practice, which is equally important to document.

6.2.5 Compile and maintain a body of knowledge of best practices for research software development

Based on the outcomes of the above activities, URSSI will develop a portal to provide living information about best practices for research software development. In addition to including content developed from our own activities, URSSI will also actively find, through various means that include workshops and surveys, and curate information from other sites related to the development of research or scientific software. We will specifically ensure that information produced by the Carpentries is included, as relevant.

We will curate the following types of information:

1. Checklists for sustainable software - much of the content here will overlap with ideas discussed in earlier activities.
2. Templates for use in developing software, including templates for project plans, templates for documenting requirements, templates for test planning, and templates for community guidelines and policies.
3. Badging efforts that provide recognition for various qualities of research software and research software projects.

In addition to best practices, the URSSI clearinghouse will also curate information about training resources. In addition to providing links to the URSSI-developed training (described above), we will also link to other relevant training resources developed through other efforts like MoLSSI, SGCI, and IRIS-HEP. To help individual researchers and teams better understand how to make use of the various training options, we will develop roadmaps that guide people to the most relevant training for their current situation.

6.3 Cross-cutting Activities

To support the five activities described above, URSSI will also need to perform a number of cross-cutting activities as follows:

1. *Curriculum Development and Coordination* To achieve the goals stated above, URSSI will need to support the development of new training materials. We anticipate providing support to experts in the research software community who can take their existing knowledge and package it in a Carpentries-style format that is most amenable to be used in the various types of training activities URSSI will support. Importantly, the training proposed above is meant to build upon, and provide a compliment to existing educational outreach efforts. This training will provide follow on, more advanced content than the Carpentries and will be longer in duration.

2. *Instructor Training* To help deliver all of the developed content to a wide range of audiences in various locations, URSSI will need to provide support for training instructors. These instructors will be integral to the success of the Summer School and the Research Projects Carpentry.

3. *Piloting Workshops* As we develop content, we will conduct smaller workshops to pilot the content to ensure its sufficiency before deploying it to a larger audience. Because we will be asking people to participate in content development by providing feedback, we will need to have resources to support the travel for instructors and participants.

4. *Gathering Experiences Successes and Failures of Software Practices* URSSI will support a team of researchers, who are experienced in survey and interview methods, to gather experiences. URSSI will need to provide support for the time required to gather these experiences as well as the travel for the team to meet with members of research projects.

5. *Conducting Workshops* URSSI will provide support for the Summer School and Research Project Carpentries instructors to travel to the workshops. URSSI will also provide small fellowships for the instructors to compensate for the time required to participate. In addition, to increase participation from a diverse community, URSSI will provide travel support for a small number of workshop participants, determined based on need in individual cases.

6.4 Metrics/Milestones

To ensure that the training activities are providing sufficient content, URSSI will conduct numerous assessment activities. These activities will occur both concurrently with the training activities, i.e., as entry and exit surveys, as well as longitudinally after training. The benefit of conducting assessment longitudinally is that it provides insight into whether the content learned during training is viewed as useful over time as real projects evolve.

Some of the specific measures that we will gather include:

- Post event evaluations - for workshops and training courses, we will conduct follow-up surveys to evaluate the value of the content. We will conduct evaluations immediately at the end of each event while the information is fresh in the attendees' minds. We will then conduct a follow-up survey 6 months, 1 year, and 3 years later to evaluate the applicability of the content to the attendees' work.
- Demand - we will measure demand for the content by the number of people who apply to attend various training events and workshops.
- Use of material - we will measure downloads and use of the information that we produce.

Chapter 7

Incubator

The Incubator area's intent is to support software projects seeking to grow, transition to an open-source model of development, or improve software engineering practices. It does this by providing mentorship, a small amount of funding, and guided activities focused on improving governance, documentation, financial planning, and evaluating development practices. The following sections describe the motivation for an Incubator program focused on research software.

7.1 Background

Common tasks solved by research software often include the generation, analysis, visualization, and processing of data. These software solutions are, just as often, generalizable beyond the immediate needs of an individual researcher, research group, or a particular research effort. However, there are few institutional and personal incentives to develop generalizable research software, package this software for reuse, create meaningful documentation, and share software in open repositories. Each of these activities requires substantial investments of time, money, and effort. For researchers the return on this investment may be minimal - software is rarely cited in scholarly literature (Howison and Bullard, 2016; Hwang et al., 2017; Hsu et al., 2019; Park and Wolfram, 2019), tenure and promotion committees rarely consider software contributions (Moher et al., 2018), and grant funding often acknowledges software development as a byproduct of rather than a substantive contribution to a research project (Broman et al., 2017; Siepel, 2019).

These challenges are despite increasing evidence of the value of software sharing and reuse in addressing research challenges that require fast and efficient community response. For example, the Medical Research Center in the UK is

currently using a 13 year old pandemic simulation codebase to model control measures for COVID-19. In doing so, they've attracted collaborators from Microsoft, the Abdul Latif Jameel Institute for Disease and Emergency Analytics, and the WHO Collaborating Centre for Infectious Disease Modelling to document, refactor, and extend this code. While the original author of the simulation code acknowledged its numerous imperfections [1], the ability to start from an existing working model saved time, money, and effort in combating a global pandemic.

Contemporary research is littered with similar examples - imperfect software that is valuable for one purpose can be made more broadly useful by being shared, properly documented, and made available for sustainable reuse. Finding ways to encourage and support research software so that it remains accessible for future improvements and uses is a primary goal of URSSI. But, there currently exists little guidance for how a single research software project can transition from the individual efforts of a small set of researchers to a distributed open model of development that attracts and retains valuable communities of contributors (Howison, 2015).

Open source models are a helpful, but not the only, reference for the forms of cooperative community organizing that we believe will be valuable to developing a more sustainable research software ecosystem. An open-source model has some basic features for community development that are necessary for sustainable research software: code is openly licensed for reuse, members are distributed across time and space, and the organization of development efforts depend, in part, upon loosely connected individuals making small contributions (or peer-production) [2]. These types of models for collaboratively organizing a software project are substantially different from how most researchers are trained and learn to develop software. Most research software development is currently focused on solving immediate short-term individual needs rather than collaboratively building generalizable solutions or performing necessary maintenance of this software [3]. These are obviously beneficial and valuable modes of collaborative software development that can and should play a more prominent role in the research software ecosystem. In the following section we further justify some of our working assumptions about why open models of software development can lead to more sustainable research software, and then propose the design and implementation of a research software incubator program that would help foster a transition to open-source, or similar, forms of research software development.

[1] See Sean Furguson's tweet for an extended commentary
[2] See the Open Source guide on building community
[3] Rene Gassmoeller has made this argument succintly in a recent blog post

7.2 Evidence base

There currently exist several detailed taxonomies of successful open source community models, including the Apache Project Maturity Model and Mozilla's Open Source Archetypes. The features that differentiate one open source model from another are often subtle, but important, in project organization, credit distribution, and methods for reaching consensus on strategic decisions. Decades of empirical research into open-source provides the following key findings relevant for the likely success of distributed research software development:

- **Governance** in open source often includes a framework for organizing distributed work, establishing formal and informal roles for participants, managing access to resources, and distributing credit for work performed (O'Mahony, 2007,). Many previous studies of open-source success (measured as the long-term usefulness or accessibility of a codebase) have shown that vertical authority structures (such as how decisions are made and responsibilities are delegated) and horizontal coordination (open contributions) are key governance features that frameworks can help to make explicit and transparent (Stewart, 2016). As contributors and maintenance responsibilities grow in scope, software governance research has also emphasized the importance of designing coordination processes so that contributors can be empowered to self-select tasks that lead to positive outcomes for a software project over time (Shaikh and Henfridsson, 2017).
- **Documentation** plays a key role in open-source projects - it eases the onboarding of new contributors and plays an important role in the effective reuse or repurposing of a software package (Aversano et al., 2017). Documentation is also an important, but often underdeveloped, aspect of software development in research settings (Geiger et al., 2018). Underdeveloped documentation is true of all software development [4], but the tedious and time consuming tasks related to creating useful documentation are arguably more difficult in research settings where the development activities focus on solving practical problems in analyzing or interpreting data (Ram et al., 2018).
- **Maintenance** is also a key element of open-source development activities. Maintenance includes solving problems introduced by operating system changes, code defects, and evolving software to meet emerging user requirements (Bourque and Fairley, 2004). Open-source projects often face practical challenges in attracting and retaining maintainers. Previous empirical studies show that many projects on GitHub, for example, have only 1 maintainer (Eghbal, 2016). Recent surveys of developers report that up to 86% of projects have no maintainer (Coelho and Valente, 2017).

[4] In GitHub's annual developers survey documentation was noted as the biggest barrier to engaging with open-source software https://opensourcesurvey.org/2017/

- **Licensing** is a key feature defining an open-source model of software development. But, developers often have a difficult time making licensing decisions without consultation of legal experts. A recent survey makes this point clear - up to 38% (n=375) of experienced developers were not able to select an appropriate license given a scenario in which they were asked to identify an appropriate license for a given software library (Almeida et al., 2017). Developers' understanding of how to interpret licensing restrictions also significantly decreased in scenarios where multiple licenses were required.

For software projects that have the potential to broadly impact research communities, we believe that, at minimum, there should be greater support for making decisions about governance and licensing, and assistance in creating useful documentation that can attract new contributors or ease maintenance tasks. Rather than simply creating a guidebook or articulating best practices for adopting open-source models of software development, a meaningful intervention for URSSI could include close interaction with and service to research software development projects that seek a route towards sustainability through community engagement and collaboration.

7.3 Incubators Background

Incubators or business accelerators are a common way for venture capitalists to support entrepreneurs and "start-up" companies attempting to break into a new market. These types of incubator programs often provide mentorship as well as fiscal support for a founder or product owner to identify market fit, build out or expand software features, and develop a network of interested stakeholders. Successful graduation or exit from a start-up incubator is viewed as securing funding or launching a new product (often with a culminating event where the founder / product owner "pitches" the product to potential investors). Successful start-up incubators like Tech stars or Y Combinator have designed processes for attracting, evaluating, and helping promising software-based projects achieve financial success. Y combinator for example has successfully graduated over 2000 companies that collectively have a market valuation over $155 billion.

Open source incubators are less common. The most successful and long running is the Apache Software Foundation incubator, which provides a well documented process for software projects wishing to become part of the Apache Foundation. Similar to a start-up incubator, the Apache model of incubation includes a project mentor and dedicated resources (infrastructure) for projects to develop releases of their software that comply with the Apache Foundation's standards. Success, or graduation, in the Apache incubator is thus dependent upon making two consecutive software releases that are evaluated, and ultimately accepted by Apache developers.

Through conceptualization activities, notably community workshops, we began to formulate a plan for *incubating* research software projects that would focus specifically on providing project developers time and support to improve the sustainability of their software projects. A research software incubator would help projects identify and make strategic decisions about governance, assist research projects in creating valuable documentation, and strategically plan for transitions from individual or small teams to fostering a community of contributors and maintainers.

We believe that a research software incubator should have features similar to start-up and existing open-source incubators, but also should differ in appreciable ways. First, we do not intend successful graduation or exit to be based solely on funding or code acceptance into a particular foundation structure. Start-up incubators in particular focus on software development as a means to a company being acquired or receiving a large investment for future development. Instead of focusing solely on growth for funding, we see a research software incubator model as providing the necessary time, mentorship, and financial support that will help a promising software project make decisions about how to improve the sustainability of their software and their project organization. Second, and importantly, start-up incubators often provide financial support for founders to dedicate all of their time and attention to a project's successful graduation. This level of financial support is likely infeasible for URSSI. Additionally, most researchers would have a very difficult time in dropping all other responsibilities at their institution to focus solely on a single software project that doesn't have the potential for a significant financial return on their investment of time and effort. Therefore, we believe it is important to design a research software sustainability incubator in which a researcher can complete it with a small amount of effort and mentorship from the URSSI community. We do not not expect that URSSI Incubator activities can or should be a project team's only focus.

7.4 URSSI Incubator

Our plan addresses problems related to credit, reward, and acknowledgement of research software development activities in its Policy area. The URSSI Incubator proposal aims to provide multiple alternative pathways to sustainability through mentorship, project development advice or guidance, and strategic planning for governance. We seek to help projects that show promise in solving general research problems mature, both the code and the project itself, in ways that are valuable to a broad community of potential users. In doing so, we believe there is an opportunity to increase the sustainability of research software.

The broad goals of the URSSI Incubator program are:

1. Provide the social and technical infrastructure to help research software projects become more sustainable. For projects that are growing, support

will focus on how to achieve this growth in manageable ways. For projects that are already at a community level of contribution and development, support will help to identify and eliminate technical debt.

2. Provide research software projects, at various points in the development lifecycle, the opportunity to improve their development and organizational practices so as to mature, or develop, in ways that are broadly valuable to scholarship.

3. Provide an alternative to academic technology transfer offices for scholarly research software that is focused not on commercialization but on a transition to open-source community models. Technology transfer programs at universities and through research funding agencies (e.g. I-Corps, SBIR/STTR) are well established and have been successful at helping entrepreneurially-focused software projects recognize and execute viable business models. This transition pathway is promoted for software that has a potential to sustain itself through fees or licensing agreements. However, there is no equivalent university guidance for software projects that would like to pursue non-commercial open source models for sustainability.

4. Provide guidance and mentorship in best practices for development, licensing, project coordination, and advice for funding to projects wishing to grow into community software projects. This component of the Incubator will draw upon expertise and guidance that is developed in URSSI's Education and Policy areas.

7.5 Resources

Personnel

- 0.5 FTE Program Director shared with Education + Teaching, Policy, or Communications
- 1 FTE Program Lead. This individual would be in charge of coordinating the application and selection process, administering incubated projects, tracking success, coordinating an Incubator Advisory Board (described in detail below), and acting as the URSSI Incubator project manager.
- Advisory Board (Volunteers). A group of senior researchers and software engineers who can offer strategic guidance to the Incubator program for meeting targeted goals.
- Project Mentors (Volunteers + Graduated projects). Provide intensive, one on one mentoring to research software projects based on existing expertise in a discipline, software language, stage of development, or other criteria of compatibility.

Additional Resources that may be valuable for an incubator program to succeed:

- Annual Incubator showcase, or a "demo day", for projects that have successfully graduated or exited the URSSI's program. This activity could be part of a larger URSSI annual event that coordinates the community dedicated to software sustainability. Invitations to this event would be extended to public and private funders who may see an overlap with their own programs during pitches. This can result in matchmaking between projects and funders.
- Incubated project funding: Monetary (or in-kind service) award for projects that will be given a budget to advance goals during a period of "incubation". Each project should receive a similar allocation of money. This money would be similar to how the SSI currently funds research fellows at a standard rate across their period of engagement. The money could be discretionary to the project so that it could be used for travel, advocacy, website development, assistance in writing documentation, etc.

7.6 Methods

URSSI's Incubator program will include a process for soliciting applications (or call for participation), selecting participants, a cycle of activities, and a standard for successfully exiting or graduating from the Incubator. The incubator will run on a semi-annual schedule so that new project cohorts can enter the Incubator in either January or July of each year. In the following subsections we describe the intended processes for running each stage of the Incubator.

7.6.1 Project Solicitation and Selection:

The URSSI Incubator will solicit proposals for projects three months in advance of the formation of a new incubator cohort. A cohort will consist of a minimum of five projects that will go through the incubator activities (described below) at the same time. The cohort model enables a network effect and should allow URSSI to scale incubator activities appropriate to the personnel and resources available.

The incubator application will ask a project to identify its goals for developing, growing, improving development practices, and/or maturing a software product in some targeted way, as well as a description of the limitations preventing the project from making the software useful beyond a small community. The application will ask project leaders to clearly articulate the problem the software is trying to solve and provide evidence of the need for a generalizable solution that will serve a broad community of users and the potential to attract new contributors. The project lead (defined below) should also clearly state how or if the project is seeking to transition to a new model of development. Acceptance into

the URSSI Incubator will not require the project to be seeking a transition or an attempt at growth per se. We are designing the incubator to be accomodating to software projects that seek either a shift or change in development models or to solidify and establish best practices within an existing model of development.

In short, the Incubator will select projects based on their potential to:

- Address a demonstrated or emerging need in scholarship
- Organize development in an open-source or equivalent model
- Attract and sustain a developer community
- Benefit from a network of URSSI mentors

The URSSI Incubator Selection Committee will select projects on a semi-annual basis. In the Apache incubator model this committee is the Incubator Project Management Committee. This committee will include a mix of URSSI staff including the Program Lead (described above), URSSI steering committee / senior personnel members, and selected external URSSI community members such as recognized leaders in open-source research software as well as previous incubator participants. Selection committee members will serve a two year term, with some initial members serving either a 1 or 3 year term to guarantee continuity. In this way, no more than 50% of the committee will change in a given year. The advisory board will also conduct incubator project evaluations (described below).

Over time, there may be an opportunity to build cohorts around a particular theme, a point in development, a particular software language, or even sponsorship by a particular funding agency. For example, URSSI might be contracted by the Alfred P. Sloan Foundation to run a cohort of projects that have been funded and are potentially in need of guidance. For the initial cohorts we plan to simply run an open call for applications and select, as stated above, at least five projects per year.

7.6.2 Project Entry

Selection as a participant in an URSSI incubator cohort will require at minimum:

1. A project lead who is responsible for completing incubator activities in a timely manner and managing any funding allocated to the project. The project lead would be the equivalent of the PI on a funded grant. The project lead is further responsible for coordinating activities and communicating with the URSSI incubator program administrator.

- Importantly, URSSI will not be prescriptive as to who can play the role of a project lead. A project lead could be anyone - a senior student who worked on the code and wants to make the project more sustainable, a PI

or co-PI of grant (but not assuming the PI will stop being a researcher to be a software developer), or a dedicated contributor to a project that seeks a more permanent leadership role. This model could resemble the NSF's I-Corps program, which focuses on transitioning promising technologies to commercialization, but instead be focused on a transition to sustainable open-source. We see the project lead as beneficial to the individual: recognition of making it into the URSSI Incubator program can then be their badge of merit to helping to secure promotion or preparing the lead for future positions of leadership.

2. An identified and dedicated mentor (from the URSSI community) who will strategically offer advice and guidance through the set of activities described below. A mentor should not be seen as administrative support, but instead a trusted person for whom the project team can consult when making decisions. In the Apache incubation model, this mentor role is often described as critical to a project's ultimate success in graduating from incubation.

3. A code repository that is openly accessible. The repository should be a central hub where documentation (e.g., contributor guidance, governance, licensing, etc.), code, reviews, and issue tracking can take place.

7.6.3 Incubator Activities

After projects join an Incubator cohort, URSSI will match them with a project mentor. The mentor will help guide the project through the Incubator activities described in this subsection. The mentor will further evaluate and offer feedback on the successful completion of each activity.

URSSI Incubator activities will likely be consistent across each cohort. In preparation for a new cohort entering the incubator, the Program Lead will publish an URSSI Incubator Cookbook (similar to the Apache Model) that describes the activities, expectations for project leaders, and evaluation metrics.

Below are activities that we imagine to be consistent across each cohort. These activities are not chronologically organized - a project can work on any of these activities at any time in their period of incubation.

Project Roles
The project lead will, under the guidance of the mentor and program lead, establish a formal definition of roles that a project member is to play. If a project already has a set of predefined roles then those roles will be reviewed for improvement, and formally documented.

- Roles will likely be similar across projects, but can and should leave some room for interpretation depending on the maturity of the project and the project's stated goals.

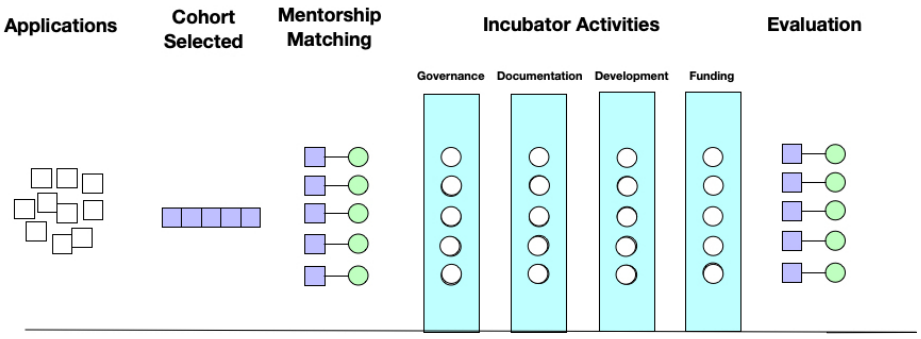


Figure 7.1: A general depiction of how the URSSI Incuabtor may be organized

- Formally defining roles within the project is meant to ensure transparency, encourage participation, and efficacy in onboarding new or explaining the expectations for contributing to a project. As an example, Node.JS defines three roles for a project's governance:
  - A *Contributor* is any individual creating or commenting on an issue or pull request
  - A *Committer* is a subset of contributors who have been given write access to the repository
  - A *TC (Technical Committee)* is a group of committers representing the required technical expertise to resolve rare disputes

Project Governance
In addition to defining roles, the project lead will, under the guidance of the mentor and Program Lead, establish a model of governing the project that is clear about expectations in how decisions are made, establishing a roadmap or release schedule, and adjudicating disputes that may arise. (Note: URSSI does not have to develop this guidance from scratch, but can modify and adapt existing guides for research software.

In addition, a governance model should also include:

- Code of conduct - which can follow existing best practice recommendations
- Process and expectation for citing software, acknowledging use, and authoring papers related to the project, including how credit should be given to different project contributors. (Jupyter has a very good model for this governance documentation)

A key component of the governance model will be selecting a license which dictates the proper uses of the intellectual property of the project.

Establishing best (or good enough) software engineering practices
This components of the incubator will be provided by the URSSI Education & Training area, and include, but not limited to activities such as:

- Version control management
- Test coverage and code integration
- Code reviews
- Issue templates and tracking
- Software design
- Release management

Documentation
Incubator activities around creating or improving documentation related to a software project will include guidance for creating helpful ReadMe files (e.g. WriteTheDocs' recommendations) on readable readme documentation], project descriptions, creating style guides for documentation, and review of documentation with a technical writer.

Project Funding & Financial Planning
The project team should develop a policy for accepting donations, managing funds, seeking grants, etc. After a project lead formalizes this policy, it should be added to the governance documentation.

Project Evaluation
Projects would, under the guidance of the program lead and mentors, establish appropriate metrics to track (e.g. following guidance from the open source handbook on metrics). Guidance on this work will be informed by the metrics work URSSI is engaged in through its Policy area. These metrics could include a number of potential evaluations:

- Discovery - CodeMeta or appropriate metadata is created for the repository to be discovered and reused
- Usage - formal citations, stars or forks on GitHub, etc.
- Contribution / Maintenance
- Retention of contributors or maintainers

7.6.4 Project Graduation or Exit

Upon completion of the activities described above, a project will go through an Exit Evaluation. This evaluation will include four components:

1. The project will publish a software paper in JOSS or similar domain journal.
2. The project mentor will then provide structured feedback to the project lead, and allow the project lead to reply or address any concerns raised in the feedback
3. The Project Lead will provide a very short recorded presentation to review the progress made on goals stated in the project proposal, activities completed, and demonstrate working software products for evaluation.

4. The URSSI Incubator Selection Committee (described above in the Selection subsection) will convene annually to review each cohort's materials - including the JOSS publication, the mentor review, and the project lead's presentation. The committee will vote on whether or not the project should graduate from the Incubator.

Graduation from the Incubator should send a positive signal about the sustainability of the project, but should not be a formal credentialing mechanism or certification of guaranteed sustainability. Similar to other incubator programs (e.g. YC, or Apache) graduation should be viewed as a significant achievement in itself.

7.6.5 Relationship to Funding and External Awards

An incubated project could have a relationship to external funding or funders in a variety of ways. Most significantly, we view the incubator as a potential matchmaker between promising research software projects and potential funders. Thus, funders will be invited and are an important participant in the Incubator showcase or graduate events. Successfully graduating from the incubator program should act as an informal signal to funders that the project has the potential for further investment. In this scenario, completing the URSSI Incubator would act as an informal quality check. Funders would have greater assurance about the potential for a project to succeed, for funding new directions of the project, or potentially funding an institution or group around the project so as to better support sustainability.

7.7 Metrics/Milestones

For Incubated projects there will be two periods of evaluation.

Short-term evaluation (1-2 years):

- Increase in the number of mentions in research projects on GitHub, publications, and software dependencies compared to other research software of similar age.
- Increase in the number of GitHub stars, forks, downloads (from package managers) relative to other projects of similar age that have not gone through the incubation process.
- Improvement in codebase, documentation, governance, licensing, or strategic planning. This improvement can be defined with project mentors that set specific targets or goals for individual projects.

Long-term evaluation (3-5 years):

- Number of projects that attract follow-on funding
- Persistence - This could be measured by the number of projects that continue to exist 5 years from incubator graduation, software that has regular contributions or updates to the repository, and active maintainers that have been identified as part of the project for different stages of development.

- Attracted contributors - This could be measured over a portion of time that looks at commit history of different individuals contributing to a repository.

For the Incubator program evaluation may include any of the following:

- In years 1-3 URSSI will select at least 15 projects for incubation. The program should be evaluated based on the success of projects' graduating from the Incubator, and whether or not those projects meet both short and long term milestones (as described above).

- Funders participation (i.e., that the program attracts funded projects to enter and exit URSSI Incubator)

Chapter 8

Community and Outreach

Researchers in academia and national labs are incentivized to become experts in one or more specialized domains. While research software plays a critical role in achieving such mastery, skills to develop such software are rarely taught in formal settings. These skills are often picked up from secondary special interest communities and online resources. We plan to formalize such community resources and associated activities in our institute plans.

The institute's Community area will build a thriving community of like-minded peers for researchers to seek advice, learn about training opportunities and funding announcements. A community manager will curate state of the art information on best practices for research software development. The Community area will also administer a competitive fellowship program for early career researchers. These fellowships will provide funding, training, and prestige to pursue a career that promotes the development and use of research software. The thriving community will also provide venues and annual conference focused on software across disciplines where researchers can share their work, learn about new software, and software development techniques.

Many of the current challenges around sustainability of software, and those who produce it, are mostly social and cultural and not limited by any unassailable technical challenges. While other areas of the institute such as Policy and Education & Training lay down the guidelines and training necessary to grow the research software enterprise, a strong community strategy will be key to maintaining it. URSSI will act as the hub for all types of researchers interested in using and developing research software. The institute will provide necessary resources to address shared challenges and help catalyze collaborations to tackle emerging problems. URSSI's Community & Outreach area will achieve this mission through the set of activities described below.

8.1 Resources

Managing communications (website with regular posts, mailing list), producing high quality newsletters and acting as a community liaison will require 2-3 FTEs. This could involve a Director of Community (could be part of a PI's time), with the remaining part of the area's workforce split over two positions: a community manager and fellowship coordinator (split with the Incubator Area), reporting to the Director of Community. Besides the budget for the 2-3 positions, the Community & Outreach area of the institute will also require budget for:

- Technical infrastructure (including: website, mailing list, archiving of resources)
- One URSSI fellow (as part of a cohort of 4-5 fellows/year)
- Participant support for fellows to attend annual meetings
- Base costs for an annual URSSI conference (with the rest to be supported by registration and sponsorships)

8.2 Methods

8.2.1 In-person events

Create new community events: Building upon the work of small workshops such as WSSSPE, there is an opportunity for URSSI to host an annual in-person conference for scientists, developers, and students to connect and discuss research software development and their applications. The conference will initially be small (with a limit of 300 participants) and grow depending on the interest. Talks and workshops will span the entire continuum from applied computational research to software development. The event will also feature a "demo day" for URSSI incubated projects. The costs for such an event will be supplemented by a mix of registration fees and sponsorships.

8.2.2 Online community events

Promote existing activities: One of URSSI's strengths will lie in amplifying the work of existing initiatives. We will achieve this by showcasing projects in our weekly newsletter, by inviting projects to present their work on monthly community calls (aka webinars), and by highlighting/crossposting news via partner organizations such as the Carpentries, rOpenSci, Workshop on Sustainable Software for Science (WSSSPE), Mozilla, and others.

Community calls: Modeled after the successful series organized by Mozilla and rOpenSci, a monthly webinar series will expose researchers to the latest best

practices and new trends in research software, and will provide them an opportunity to interact with prominent research software engineers. This free and open series will provide additional opportunity for the community to participate, especially for those that are constrained by travel. Past calls, including videos, code, and Q&A will be archived and made searchable by a dedicated community coordinator.

Curating and disseminating best practices {#Ch-Comm-Best-Practices}

URSSI fellows will convene ad hoc panels of experts to curate information on state of the art practices for scientific computing. The topics will cover many foundations of research software engineering including but not limited to collaborative software developing with modern version control, software testing, code review, packaging and distribution, and overall software design. The materials will also provide strong guidance on open science practices to increase impact of such work. These include guidance on licensing, properly archiving research software, and citation.

8.2.3 Newsletter and social media

There is a huge opportunity for URSSI to produce and disseminate a high quality newsletter to keep the community informed about research software news, notable research papers, critical software, events and job openings. The data science community already benefits from such a newsletter that is maintained by Laura Noren and Brad Stegner and financially supported by the Academic Data Science Alliance. The community manager will curate news, jobs, software releases, conferences, and activities of other organizations (by crossposting). For community calls, we will invite speakers from related communities such as SSI, BSSw, US-RSE, and also solicit presentations from the larger community. All material will be stored in public GitHub repositories under a permissive license to allow people to use and remix the content while contributing back to the original source.

The four major channels of communication will be a website, a newsletter, mailing list, and accounts on social media such as Twitter and Slack.

8.2.4 Other activities

Besides the activities described above, the institute will feature these ongoing activities:

- URSSI will serve as a broker for software expertise and connect developers to scientific projects [TODO: Flesh out details of this program]
- Promote training events from URSSI and other communities

- Develop an ambassador program for early career researchers to promote sustainable software and current issues to their local communities. [TODO: Flesh out details of this program]
- Hosting a blog, with a series of staff and guest blog posts, including cross-posting relevant blog posts from others

8.3 Metrics of success

Goals:

- Steadily grow the number of subscribers and participants each year
- Grow the diversity of participants, instructors, and speakers each year. Self reported data on affiliations and domains of expertise will also provide a measurable metric of impact across domains.
- Grow the number of applications we receive for the fellowship program every year
- Grow the rate of paper and poster submissions every year
- Improve the careers of those who participate in URSSI

Metrics:

- Number of subscribers to the newsletter, visitors to the website, and social media followers over time
- Number of subscribers to the newsletter, visitors to the website, and social media followers over time
- Quantify instructors, presenters, lesson developers, and participants by demographic and geographic breakdown
-
- Count citations of software that have participated in URSSI
- Tracking career paths of fellows will also act as a measure of success for the program

Chapter 9

Budget

in progress

Chapter 10

Metrics and Evaluation

in progress

Chapter 11

Final Words

We have finished a nice book.

Glossary

in progress

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