Research software is essential for research data, so how should governments respond?

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Research software is becoming increasingly valued in the research ecosystem, and international and national policy practices are evolving to reflect this. Studies have shown that 33 percent of international research produces new code (see Figure 3.4), 90 percent of UK researchers acknowledge software as important for their research, while 95 percent of US postdoctoral students use research software.

Several governments are now expanding their focus on research software, in line with increasing international recognition of the crucial role that research software plays in research outcomes. Key international bodies, such as the Organisation for Economic Co-operation and Development (OECD) and the United Nations Educational, Scientific and Cultural Organisation (UNESCO), have recently incorporated research software into their recommendations. Going beyond the requirements of the UNESCO and OECD, the vision of the Research Software Alliance (ReSA) and its collaborators is that research software and those who develop and maintain it are recognised and valued as fundamental and vital to research worldwide.

This blog post provides an overview of the current state of international adoption of research software policies and how different countries address these, in order to lay out concrete advice and examples for national governments wishing to update their policies.

International adoption

On 20 January 2021, the OECD Council adopted a revised Council Recommendation on Access to Research Data from Public Funding. This legal instrument was revised for the first time to include software, meaning that OECD members (which include most research-intensive countries) will have to create policy and law to implement it.

This recommendation, which is known as a “soft law” legal instrument, has been updated to address new technologies and policy developments. It provides policy guidance in seven areas with an expanded scope to cover not only research data, but also related metadata as well as bespoke algorithms, workflows, models, and software (including code), which are essential for their interpretation.

The OECD Council recommends fostering (and requiring where appropriate) the adoption of good practice for research data and software management across the research system, promoting data and software citation in academic practice (including the development of

citation standards), training a cadre of research software engineers and enabling recognition and reward of software development skills as high value added to publicly funded research and innovation.

In the same vein, the UNESCO Recommendation on Open Science was unanimously adopted by member states in November 2021. This recommendation defines open scientific knowledge as:

> open access to scientific publications, research data, metadata, open educational resources, software, and source code and hardware that are available in the public domain or under copyright and licensed under an open licence.

In particular, the recommendation argues for users to gain free access to open source software and source code in a timely and user-friendly manner, in human- and machine-readable and modifiable format, under an open licence. The source code must be included in the software release and made available on openly accessible repositories, and the chosen licence must allow modifications, derivative works and sharing under equal or compatible open terms and conditions.

The Research Software Alliance's vision

In 2018, the Research Software Alliance (ReSA) was formed as a backbone organisation fortop global research infrastructure organisations to deliver collective impact. ReSa's vision is that research software be recognised and valued as a fundamental and vital component of research worldwide.

By bringing research software communities together to collaborate on the advancement of the research software ecosystem, ReSA plays a key role in highlighting research software in international dialogue and has coordinated the community development of guidelines for policy makers, funders, publishers, and the research community responding to COVID-19.

ReSA's activities influencing policy development emphasise three key recommendations that comprise an international shared vision:

1. Research software must be recognised as a key element of research.
2. The development and maintenance of research software must be supported.
3. Research software must be as open and/or as Findable, Accessible, Interoperable and Reusable (FAIR) as other components, so that the research it enables can be trusted and replicated.

National landscape analysis

While these changes in international policy are valuable steps forward, policy at other levels must also keep step. But how can national policy be improved, and which countries are

leading this work? Already in 2021, there has been a range of important national policy initiatives and programs supporting research software:

Australia

The Australian Research Data Commons (ARDC) is a nationally funded digital research infrastructure initiative whose stated purpose is to provide Australian researchers with competitive advantage through data. In 2020 the ARDC recognised that research software was an essential element to a research data commons and began to increase its investment in this area.

In 2021, a draft national research software agenda, which undertook an extensive program of consultation, was released. This resulted in a detailed implementation plan that commenced in the latter half of 2021 and will continue in 2022 and 2023. ARDC staff also contributed to the development of the FAIR for Research Software (FAIR4RS) Principles, and a plan for how to apply these principles to all of the activities of the ARDC is currently being developed ahead of internal implementation. This self-adoption approach will enable the ARDC to both test and advocate for the application of these principles nationally.

Canada

Canada's activities in the open science context are emerging from a number of key national actors, including funders and federal research agencies. The Office of the Chief Science Advisor released the Open Science Roadmap in February 2020, and, while it is focused on federal science, it provides a useful process and model for others in the Canadian research community.

The Digital Research Alliance of Canada (the "Alliance", formerly NDRIO), a new national organisation funded to support research data management, research software, and advanced research computing in a more cohesive and integrated way, is working on a policy framework that will include key elements of an open science approach, starting with its initial funding opportunities, and including alignment with principles such as FAIR, FAIR4RS, and CARE (Collective benefit, Authority to control, Responsibility, Ethics). The Alliance's Research Software Position Paper and Strategic Plan (both to be released soon) will include support for open science through a number of initiatives that have emerged from a comprehensive needs assessment, including:

1. Support the development of tools and underlying infrastructure for the evaluation of the adoption of open science practices within research communities.
2. Promote the impact and value of research software to facilitate culture change in the adoption of open science practices.

European Union

The European Open Science Cloud (EOSC) has convened a Task Force on Infrastructure for Quality Research Software. The main objectives of this task force are to:

1. Foster the development and deployment of tools and services that allow researchers to properly archive, reference, describe with proper metadata, share and reuse research software.
2. Improve the quality of research software, both from the technical and organisational point of view for research software in general and in particular the software used in the services offered through EOSC.
3. Increase recognition to software developers and maintainers of research software as a valuable research result, on a par with publications and data, in the open science landscape.

France

The Second French Plan for Open Science, as summarised by Roberto Di Cosmo (Director, Software Heritage), squarely puts software on a par with publications and data in research and open science, and announces a number of measures designed to open research software and better recognise software development in research. This includes:

- A clear recommendation to make research software available under an open source licence, unless there are clear strong reasons not to do so.
- The creation of a high level expert group dedicated to research software in the National Committee for Open Science.
- The objective to achieve better recognition of software development in career evaluation for researchers and engineers.
- A renewed and strengthened official support of Software Heritage, with a recommendation to archive in it all research software produced in France.

Netherlands

Key organisations in the Netherlands recognise the crucial importance of software to the research ecosystem. The 2021 National Roadmap for Large-Scale Research Facilities published by the Dutch Research Council (NWO) has made FAIR, sustainable software and a software management plan conditional to receiving funding. Software is central to the funding the NWO has made available for developing 'digital competence centres' as part of the national roadmap, and the NWO has set up an open science team to push this agenda.

Established in 2012 by the NWO and SURF (the nationally funded ICT service provider) as a national research organisation specifically mandated to pioneer software in direct collaboration with researchers, the Netherlands eScience Center takes a pivotal position in raising awareness about research software in the Netherlands. Among other things, the eScience Center has been involved in the development of the FAIR4RS Principles and the GitHub software citation tool, setting up the recommendations for the FAIR software website, and initiating and supporting the NL-Research Software Engineering (RSE) network. It establishes clear requirements regarding open science, software sustainability and institutional commitment to software in all its collaborations with research partners.

United Kingdom

Software is seen as a key strength of the UK's research portfolio, and the development, support and sharing of it essential to making advances in computational research. The Government Office for Science's report on Large-scale computing: the case for greater UK coordination recognises that "high-quality software is fundamental to realising the benefits of investments in computing" and recommends "software development must keep pace with advances in hardware" noting that:

> In academia, testing, sharing, and archiving of software should become an essential part of the research process, ensuring that scientific results can be replicated. New computing architectures will necessitate considerable reengineering of software.

Recent reviews commissioned by individual research funders have echoed this. UKRI-BBSRC's Review of Data Intensive Bioscience recommends that UKRI-BBSRC should

> take specific actions to increase the UK capacity in mathematical and computational skills within the biosciences" and "significantly increase its investment in provision of high-quality software and data resources for the research community.

While the UK Research and Innovation/Meteorological Office ExCALIBUR Research Software Engineer Knowledge Integration Landscape Review notes that:

> [a] software programme should ensure that it encompasses a variety of different types of software activity and ensure they are contributing to developing the RSE community with High Performance Computing skills in the UK.

USA

While there haven't been any completely new funding programs in the US in 2021, it appears that awareness of research software as a valued product continues to increase. Some cases have followed the lead of private US philanthropies such as the Alfred P. Sloan Foundation's Better Software for Science program and the Chan Zuckerberg Initiative's Essential Open Source Software for Science program. Others have continued and grown existing federal programs, such as the NSF's Cyberinfrastructure for Sustained Scientific Innovation (CSSI) program, which has added a new type of award in its 2021 cycle called transition to sustainability, and the Department of Energy's (DoE) support for the Interoperable Design of Extreme-scale Application Software (IDEAS) projects, as well as other significant software investments in its Exascale Computing Project.

On the policy side, the new National Academies report on Next Generation Earth Systems Science at the National Science Foundation publicises the need for research software and RSEs:

> Computing in Earth systems science is changing rapidly. Increased complexity and new programming methods and models mean many research teams need a research

> software engineer, yet NSF computing resources are already stretched thin. NSF should expand computing resources such as hardware, software, data analytics, and a skilled workforce to harness the computational revolution for the benefit of Earth systems science.

The Department of Energy also has recently issued a Request for Information:

> seeking feedback from industry, academia, research laboratories, government agencies, and other stakeholders on issues related to the stewardship of software for scientific and high-performance computing. Scientific software stewardship is multi-faceted, potentially including but not limited to training and workforce support, infrastructure and curation, and shared engineering resources and project support.

Key recommendations from ReSA

These national strategies show that some national government policies align with the OECD and UNESCO recommendations. Furthermore, these countries are aligning with a clear, common support for the first of ReSA's three key recommendations: that research software must be recognised as a key element of research.

There is also strong consensus that the development of research software must be supported; however, ReSA's second recommendation also calls for support of maintenance. The importance of maintenance is sometimes addressed through an emphasis on software sustainability, but it could benefit from being more clearly stated (and supported) in national policies. Championing of the third recommendation is less comprehensive, with only some countries emphasising that research software must be as open and as FAIR as other components, so that the research it enables can be trusted and replicated.

To advance this agenda across the research community as a whole requires both policy development and implementation. While there are clear recommendations on how national research software policies need to develop, and examples of how some countries are implementing increased recognition of the importance of research software and those who maintain it, different countries are at different stages of development.

ReSA aims to establish collaborations that support this work, including the Research Software Funders Forum. This collaboration of organisations that are committed to supporting research software, and those who develop it, will convene in early 2022 with investment from the Alfred P. Sloan Foundation. The Forum will create a formal mechanism to share funding practices, learn from each other, and propose methods to better tackle common challenges such as resourcing for maintenance of research software investments.

ReSA encourages national governments to review their policies and implementation strategies in light of OECD, UNESCO, and ReSA recommendations. To support the work of individual countries, a more detailed analysis of how a range of countries are progressing

should also be undertaken, based on a framework such as the maturity matrix that Science Europe uses to assess the sustainability of the research data initiatives. This could provide organisations such as OECD and UNESCO with evidence of how government policies are implementing their recommendations and identify geographic regions needing additional support.