Software Deposit: Guidance for Researchers

Michael Jackson (ed.), The Software Sustainability Institute

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Introduction

Research software is an integral part of the modern research ecosystem. Taken together, research software, alongside data, facilities, equipment and an overarching research question can be viewed as a research activity or experiment, worthy to be published. Conversely, a publication can be considered as a narrative that describes how the research objects are used together to reply to the research question.

Depositing research software into a digital repository can offer significant benefits. By depositing not just papers, but software, and data sets, as well, researchers can store a more complete record of this ecosystem for future use to both the researchers who undertook the research and also the wider research community. Making research software available allows other researchers to inspect, replicate, reproduce and reuse the research, as manifested in the software, in the short term and to inspect, for the historical record, in the long term. It allows research software to remain available beyond the lifetime of any current project, or a researcher's current employment at a specific institution. Digital repositories can also provide unique persistent digital identifiers for software which can be cited and help researchers to get attribution and credit for their research software when it is used by others.

The Software Sustainability Institute [1], funded by Jisc [2] have developed a set of complementary guides covering the main aspects of depositing software into digital repositories. These guides are intended for researchers, principal investigators and research leaders and research data and digital repository managers. This document provides an overview of the content covered by the guides.

What is research software?

The Software Sustainability Institute takes the view that research software is any software used in research and does not differentiate between what are often termed scripts, written in scripting languages such as bash shell or Python or R, and programs, written in "traditional" programming languages such as C, C++, Fortran or Java. In the view of the Institute a 50 line bash shell script for manipulating and filtering files, a collection of 50 line R scripts for running a bioinformatics analysis, 10,000 lines of Java for medical image analysis or 100,000 lines of Fortran using MPI for computational fluid dynamics are all examples of research software and may be suitable candidates for deposit into a digital repository. It is this view of research software that is assumed throughout the guides.

Guiding principles

The guiding principles that motivated the form and content of the guides were as follows.

Mandate little, recommend lots, focus not on "best practice" but "good enough, or better than at present, practice". This was motivated by Beals et al. (2018) in particular the observation that "Incremental progress is still progress."

Emphasise the importance of deposits to allow others to inspect, replicate, reproduce and reuse in the short term and inspect, for the historical record, in the long term. This was motivated by Brown (2017)'s argument that "[I]t is at least plausible to argue that we don't really care about our ability to exactly re-run a decade old computational analysis. What we do care about is our ability to figure out what was run and what the important decisions were - something that Yolanda Gil refers to as 'inspectability.' ... exact repeatability has a short shelf-life.".

Take no position on whether or not to deposit binaries, containers or virtual machines. Whether these provide solutions to issues around replicability, reproducibility and reuse of research software or spawn a different set of problems is very much an open question (compare, for example, Haines and Jay (2016) versus Brown (2017)). The guides do not mandate or suggest depositing such artefacts but nor do they preclude them.

Provide lists of key points or things to do, only a few pages long, with minimal rationale. Direct researchers to other resources for further information. This was motivated by a recommendation in Brown et al. (2018) that guidance "for stakeholders e.g. researchers, research data managers, institutions and publishers, needs to speak their respective languages, not require significant time or effort to apply and be free of developer jargon."

Consider deposits of software as attachments or ancillary files submitted alongside publications to publishers to be out-of-scope. Instead, software is considered as a first class research object, worthy of deposit as an object in its own right. However, much of the guidance in these guides (especially what to deposit and how to describe such deposits) would apply to depositing software in this scenario too.

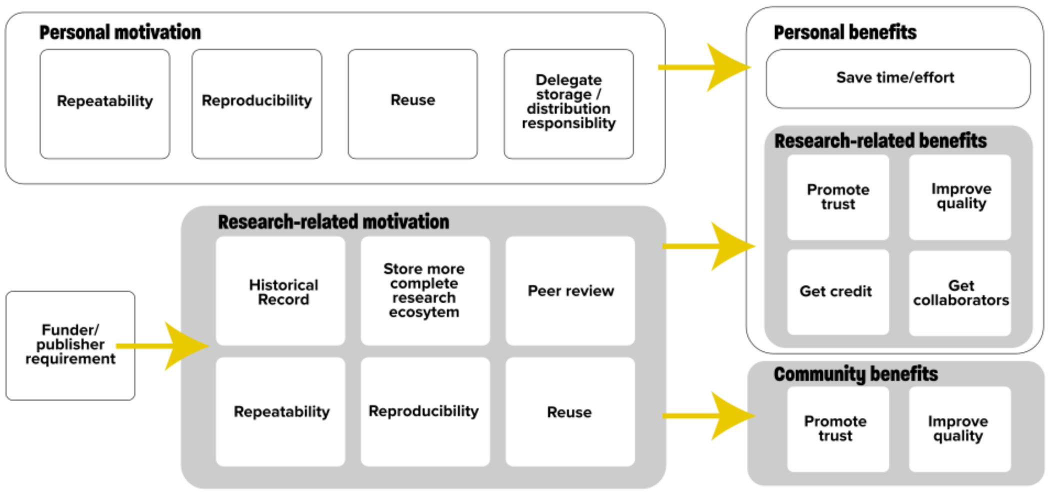
Guides for software deposit

The guides and their target audiences are shown in the following table. Each guide, plus this overview document, has been published via Zenodo [3] and the DOIs are shown below. The guides are also available online [4] and this online resource will also, in time, host resources that complement the guides including links to examples of what are considered to be good software deposits and good research software generally supported with commentary on why these are considered to be good.

Guide	Researchers	Principal Investigators	Research Data Managers	DOI
Why deposit software	✔	✔		10.5281/zenodo.1327333
When to deposit software	✔	✔		10.5281/zenodo.1327331
Where to deposit software	✔	✔		10.5281/zenodo.1327329
How to deposit software	✔			10.5281/zenodo.1327327
What to deposit	✔		✔	10.5281/zenodo.1327325
What not to deposit	✔		✔	10.5281/zenodo.1327323
How to describe a software deposit	✔		✔	10.5281/zenodo.1327321
How to choose a software licence	✔	✔		10.5281/zenodo.1327316
How to review a software deposit	✔		✔	10.5281/zenodo.1327314

A summary of the content of each guide now follows.

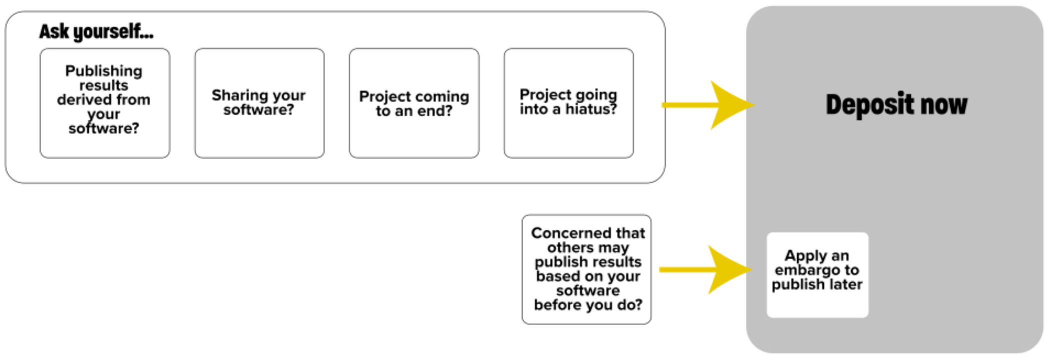
Why deposit software



Why deposit software

Why bother depositing research software into a digital repository? Why go to all that time and effort? What are the benefits to researchers for doing so? "Why deposit software" describes some of the significant benefits that depositing research software delivers, both to individual researchers and to the research community and also addresses concerns that they may have about sharing their software with others.

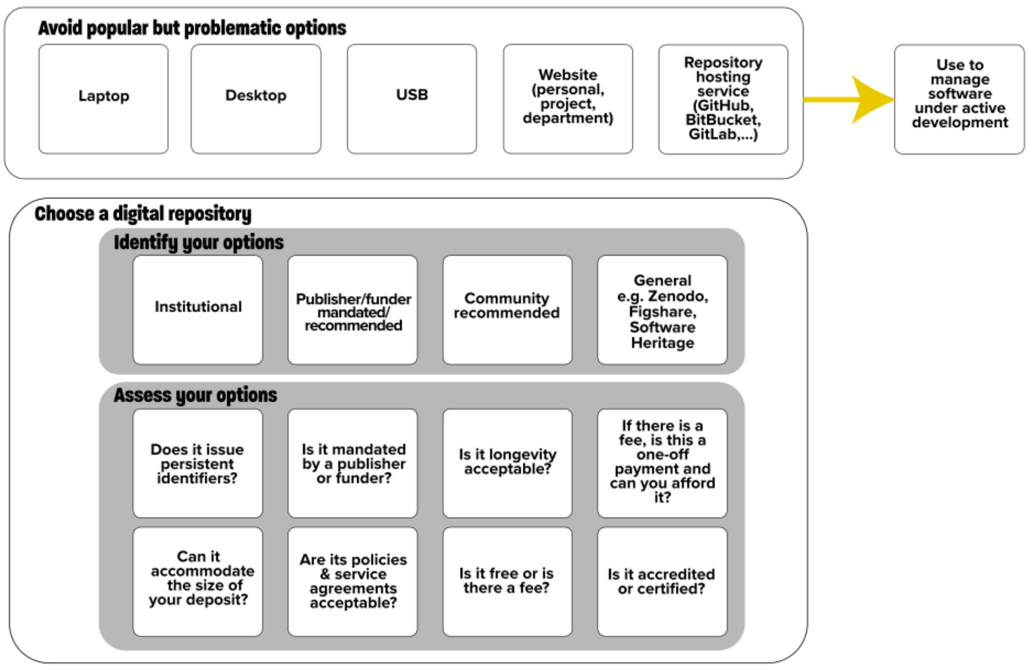
When to deposit software


Ask yourself...
Publishing results derived from your software?
Sharing your software?
Project coming to an end?
Project going into a hiatus?
Deposit now
Concerned that others may publish results based on your software before you do?
Apply an embargo to publish later

When to deposit software

A researcher may be convinced of the importance and benefits of depositing research software within a digital repository, so that the exact versions of their software upon which they have published their research results are retained and remain available for future inspection and use, both by themselves and by other researchers. But, the researcher may ask, when is the best time for them to deposit their software? "When to deposit software" poses a series of questions for researchers to ask themselves. If the answer to any of these questions is "yes", then that is the time for them to deposit their software.

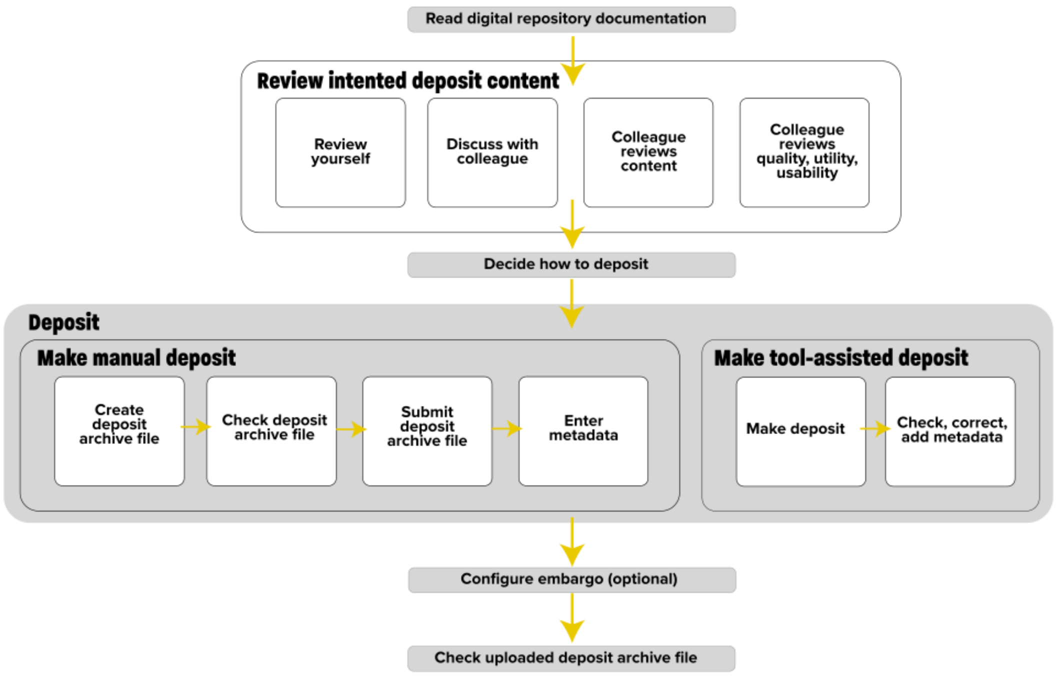
Where to deposit software


Avoid popular but problematic options
Laptop
Desktop
USB
Website (personal, project, department)
Repository hosting service (GitHub, BitBucket, GitLab,...)
Use to manage software under active development
Choose a digital repository
Identify your options
Institutional
Publisher/funder mandated/ recommended
Community recommended
General e.g. Zenodo, Figshare, Software Heritage
Assess your options
Does it issue persistent identifiers?
Is it mandated by a publisher or funder?
Is it longevity acceptable?
If there is a fee, is this a one-off payment and can you afford it?
Can it accommodate the size of your deposit?
Are its policies & service agreements acceptable?
Is it free or is there a fee?
Is it accredited or certified?

Where to deposit software

There are myriad digital repositories where researchers can deposit their research software so that the exact versions of their software upon which they have published their research results are retained and remain available for future inspection and use, both by themselves and by other researchers. These digital repositories may be provided by their institutions, recommended, or mandated, by funders or publishers, or provided as a service to research communities by third-party organisations. "Where to deposit software" provides advice to researchers on choosing where to deposit their software.

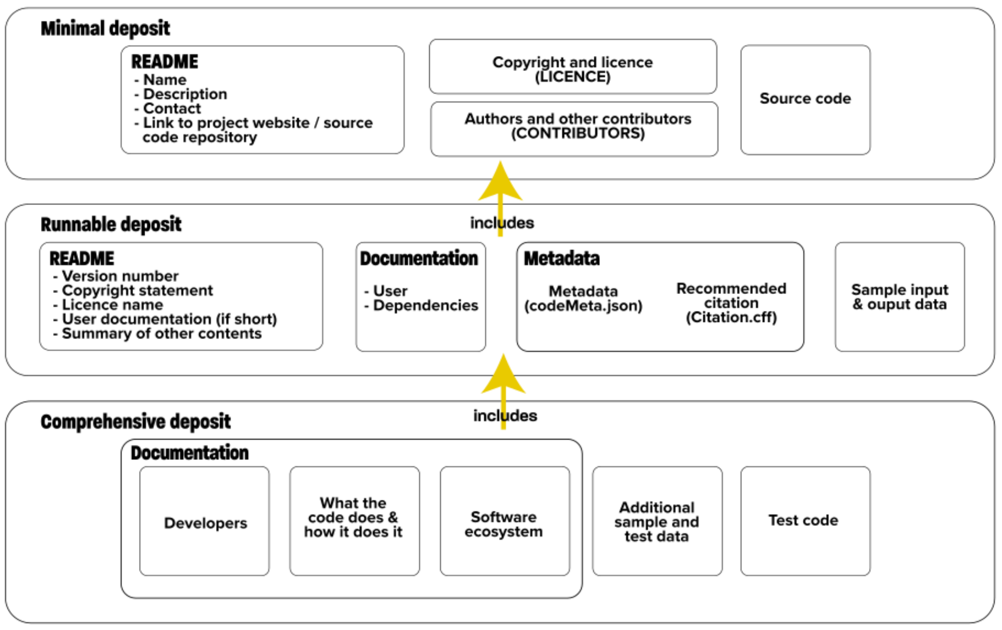
How to deposit software


Read digital repository documentation
Review intented deposit content
Review yourself
Discuss with colleague
Colleague reviews content
Colleague reviews quality, utility, usability
Decide how to deposit
Deposit
Make manual deposit
Create deposit archive file
Check deposit archive file
Submit deposit archive file
Enter metadata
Make tool-assisted deposit
Make deposit
Check, correct, add metadata
Configure embargo (optional)
Check uploaded deposit archive file

How to deposit software

Different digital repositories have different means of submission and different requirements as to the deposits they will accept, the metadata associated with these deposits and how deposits are done. However, regardless of the digital repository that a researcher will use, there are some common tasks that a researcher should do before, during and after they deposit their software. "How to deposit software" describes these tasks.

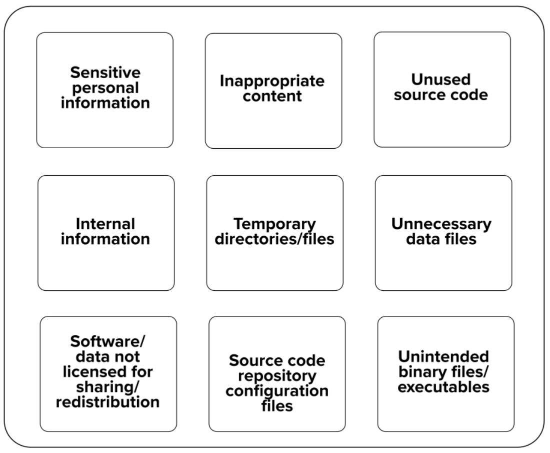
What to deposit


Minimal deposit
README
- Name
- Description
- Contact
- Link to project website / source code repository
Copyright and licence (LICENCE)
Authors and other contributors (CONTRIBUTORS)
Source code
includes
Runnable deposit
README
- Version number
- Copyright statement
- Licence name
- User documentation (if short)
- Summary of other contents
Documentation
- User
- Dependencies
Metadata
Metadata (codeMeta.json)
Recommended citation (Citation.cff)
Sample input & ouput data
includes
Comprehensive deposit
Documentation
Developers
What the code does & how it does it
Software ecosystem
Additional sample and test data
Test code

What to deposit

What do we mean by a "software deposit"? What does a software deposit need to contain to enable it to allow other researchers to inspect, replicate, reproduce and reuse the research, as manifested in the software, in the short term and inspect the software, for the historical record, in the long term. "What to deposit" describes what a software deposit should include, in terms of three types of deposit: a minimal deposit (with a README, source code, copyright, licence and contributors information), a runnable deposit (with additional user documentation and sample data) and a comprehensive deposit (providing a rich set of code, data and documentation relating to the software).

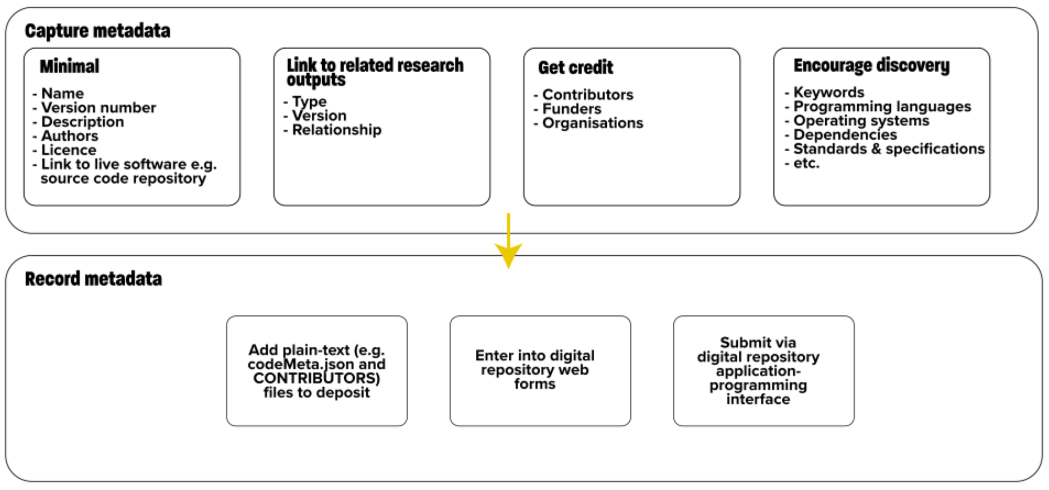
What not to deposit


Sensitive personal information
Inappropriate content
Unused source code
Internal information
Temporary directories/files
Unnecessary data files
Software/ data not licensed for sharing/ redistribution
Source code repository configuration files
Unintended binary files/ executables

What not to deposit

A software deposit lodged within a digital repository can contain myriad content. But there is certain content that should not be included within a software deposit. Some of this content may be innocuous and only result in a deposit being more bloated than it otherwise needs to be. Some of this content may compromise a researcher's security. And, in the worst case, some of this content may result in a researcher inadvertently breaking local laws relating to data protection. "What not to deposit" summarises the content should not be deposited with a researcher's software.

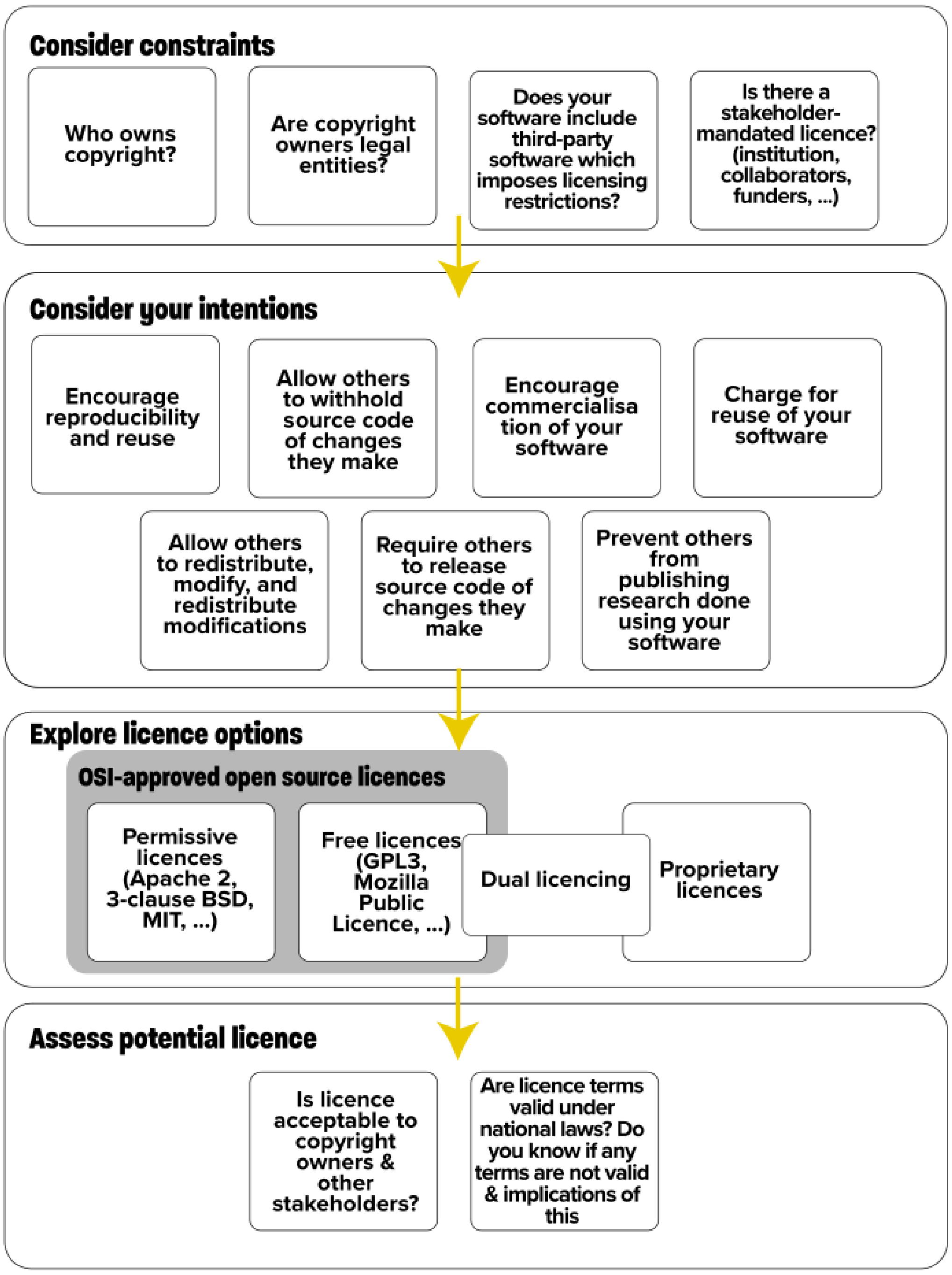
How to describe a software deposit


Capture metadata
Minimal
- Name
- Version number
- Description
- Authors
- Licence
- Link to live software e.g. source code repository
Link to related research outputs
- Type
- Version
- Relationship
Get credit
- Contributors
- Funders
- Organisations
Encourage discovery
- Keywords
- Programming languages
- Operating systems
- Dependencies
- Standards & specifications
- etc.
Record metadata
Add plain-text (e.g. codeMeta.json and CONTRIBUTORS) files to deposit
Enter into digital repository web forms
Submit via digital repository application-programming interface

How to describe a software deposit

Papers have titles, authors, abstracts, subject categories and keywords, all of which are metadata, data which describes the paper. These metadata help others to categorise and index papers and find papers of interest to them. Metadata can serve a similar purpose for software deposits, providing a description of a software deposit. This metadata can help a researcher get credit for their software, help digital repository managers categorise and index their software deposit and help other researchers find this software according to criteria of relevance to them. Researchers will need this metadata when depositing their software into a digital repository. "How to describe a software deposit" summarises the metadata researchers can, and should, capture.

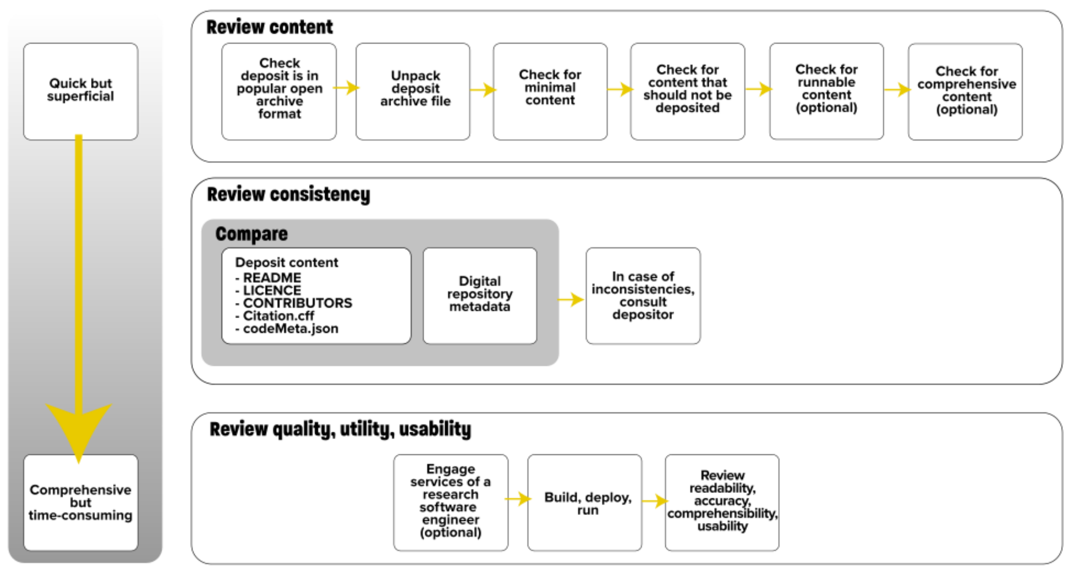
How to choose a software licence


Consider constraints
Who owns copyright?
Are copyright owners legal entities?
Does your software include third-party software which imposes licensing restrictions?
Is there a stakeholder-mandated licence? (institution, collaborators, funders, ...)
Consider your intentions
Encourage reproducibility and reuse
Allow others to withhold source code of changes they make
Encourage commercialisation of your software
Charge for reuse of your software
Allow others to redistribute, modify, and redistribute modifications
Require others to release source code of changes they make
Prevent others from publishing research done using your software
Explore licence options
OSI-approved open source licences
Permissive licences (Apache 2, 3-clause BSD, MIT, ...)
Free licences (GPL3, Mozilla Public Licence, ...)
Dual licencing
Proprietary licences
Assess potential licence
Is licence acceptable to copyright owners & other stakeholders?
Are licence terms valid under national laws? Do you know if any terms are not valid & implications of this

How to choose a software licence

By depositing software into a digital repository, a researcher is implicitly stating that, at some point in time, they expect, or hope, someone will download it, with the aim of inspecting, replicating, reproducing or reusing their research. A software licence is an explicit, and legally-binding, statement of what others can, and cannot, do with a researcher's software and any obligations upon them. "How to choose a software licence" provides an overview of the licensing options available - specifically open source licences, proprietary licences and dual licencing - and the key qualities of each in respect to allowing others to inspect, use and reuse research software.

How to review a software deposit


Quick but superficial
Comprehensive but time-consuming
Review content
Check deposit is in popular open archive format
Unpack deposit archive file
Check for minimal content
Check for content that should not be deposited
Check for runnable content (optional)
Check for comprehensive content (optional)
Review consistency
Compare
Deposit content
- README
- LICENCE
- CONTRIBUTORS
- Citation.cff
- codeMeta.json
Digital repository metadata
In case of inconsistencies, consult depositor
Review quality, utility, usability
Engage services of a research software engineer (optional)
Build, deploy, run
Review readability, accuracy, comprehensibility, usability

How to review a software deposit

Digital repositories can differ in the deposits that they accept, the metadata requested from researchers, how researchers make their deposits and how these deposits are processed. This includes how deposits are reviewed post-deposit and pre-publication and the criteria that are used in these reviews. Despite the differences between individual digital repositories, there are some common checks that can be done for any software deposit. The nature and degree to which a software deposit can be reviewed depends upon the time, effort and expertise available. "How to review a software deposit" describes three approaches to reviewing a deposit: a quick content review, a more detailed consistency review and a comprehensive review of quality, utility and usability.

Glossary

The following terms are used throughout the guides.

Digital preservation system: a repository, archive or service that also hosts digital artefacts, including research outputs, but also implements strategies to afford long term access to the digital artefacts, in the face of technological changes. For example, Archivematica [5]. Preservica [6] or Arkivum Perpetua [7].

Digital repository: a repository, archive or service that hosts digital artefacts, including research outputs such as papers, presentations, data sets and software. For example, Zenodo [8], figshare [9], DSpace [10] or Samvera [11].

Inspect: read source code, supporting narratives and papers to understand what was run, the environment in which it was run, important decisions that were made, how results were produced and to identify any flaws.

Repeat: the same lab runs the same experiment with the same set up to try and get the same result.

Replicate: an independent lab runs the same experiment with the same set up.

Reproduce: an independent lab varies the experiment or set up to try and get similar results.

Repository hosting service: a service that hosts source code repositories within an institution, within a community, or for myriad individuals and communities. For example, GitHub [12], BitBucket [13], GitLab [14], CCPForge [15] or Microsoft Visual Studio Team Services [16].

Rerun: the same or independent labs running the same or different experiments with the same or different set ups.

Research software: any collection of scripts or code written for, or used within, a research context. For example, a 50 line bash shell script for manipulating and filtering files, a collection of 50 line R scripts for running a bioinformatics analysis, 10,000 lines of Java for medical image analysis or 100,000 lines of Fortran using MPI for computational fluid dynamics are all examples of research software and may be suitable candidates for deposit into a digital repository.

Reuse: an independent lab runs a different experiment.

Source code repository: a version control tool, revision control system, source code management tool or source code repository i.e. any tool that manages versions of source code and related files. For example, Git, Mercurial, Subversion or Microsoft Team Foundation Version Control.

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Selina Aragon, The Software Sustainability Institute, formatted the images.

References

In addition to material referenced in the "Find out more" and footnotes in the individual guides, the material in the guides has been drawn from the following papers, reports, blog posts and presentations.

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1. The Software Sustainability Institute, http://www.software.ac.uk.↩
2. Jisc, http://www.jisc.ac.uk.↩
3. Zenodo, https://zenodo.org.↩
4. Software Deposit Guidance for Researchers, https://softwaresaved.github.io/software-deposit-guidance.↩
5. Archivematica, https://www.archivematica.org/.↩

6. Preservica, https://preservica.com/.↩
7. Arkivum Perpetua, https://arkivum.com/perpetua/.↩
8. Zenodo, https://zenodo.org.↩
9. figshare, https://figshare.com.↩
10. DSpace, http://www.dspace.org.↩
11. Samvera, https://samvera.org.↩
12. GitHub, https://github.com.↩
13. BitBucket, https://bitbucket.com.↩
14. GitLab, https://gitlab.com.↩
15. CCPForge, https://ccpforge.cse.rl.ac.uk/gf/.↩
16. Microsoft Visual Studio Team Services, https://www.visualstudio.com/team-services/.↩