Introduction and planning

Introduction and planning

The objective here is to make a review of what has been achieved during the past 2 years from the implementation plan.
https://cds.cern.ch/record/2856044/files/CERN-OPEN-2023-007.pdf

Each tab contains the text of the current review for each OS activity.

Each editor adds:

- Actions undertaken, with if any existing KPIs for years 2023 and 2024
- Assessment of what was not done and why
- Input for new implementation plan:
    - What should be continued
    - What should be modified

This review will be discussed during the OSPF meeting in the second half of February.

General comments

General comments for next plan:

- Needs to mention the new governance (OS Office, OSPF, OSSB)
- Define better responsibilities, and evaluate resources needed (should not be a wish list)

Open Access to Publications

1. Open Access to Publications

Editor: Anne Gentil-Beccot, Kamran Naim / SIS

Policy Document Text

All CERN scientific publications are to be made immediately publicly available and reusable. The Open Access Policy for CERN Publications (2014, updated 2017 and 2021) requires that all original research publications by CERN authors are published open access, centrally supported by the CERN Open Access fund. CERN users and visiting scientists are also encouraged to publish their work under similar terms, according to the General Conditions applicable to the Execution of Experiments.
CERN scientific publications, including submissions to trusted repositories (such as arXiv), should be released under an open licence, with CC-BY as the default standard.
Publication-related metadata are made available for reuse under the CC0 waiver in line with FAIR principles (findability, accessibility, interoperability, reusability). Open access publishing support is also provided for monographs related to CERN experiments or accelerators, applied research processes or technologies, and other areas of relevance.

Implementation

Open Access (OA) Policy compliance is facilitated by the CERN Scientific Information Service (SIS) which provides central support for all CERN departments and experiments and maintains the CERN Open Access Fund. The Scientific Information Policy Board (SIPB) oversees the SIS activities, and provides input and guidance with regard to the CERN Open Access Policy and its implementation.
In accordance with the CERN Open Access Policy and the General Conditions applicable to the Execution of CERN Experiments, CERN authors are required to publish all of their peer-reviewed primary research articles Open Access (by default under a Creative Commons attribution licence, i.e. CC-BY-4.0). In order to facilitate compliance with this rule, the CERN SIS has established a number of enabling mechanisms to support authors in publishing OA:
1. Sponsoring Consortium for Open Access Publishing in Particle Physics (SCOAP3):
CERN authors should publish their physics papers in the journals covered by SCOAP3 (covering the majority of research in the discipline of high-energy physics).
2. Publisher Agreements:
Open Access publishing for the majority of research articles outside of the SCOAP3 journals is supported through dedicated transitional arrangements with publishers, which cover primary research articles with CERN corresponding authors and, in many cases, CERN experimental collaborations. Such articles are automatically detected during the submission process and are automatically published OA under the agreements.
3. Individual article support:
For articles that are not covered by either of the above arrangements, CERN authors can still be eligible for central open access funding under certain conditions:
● The article is not already covered through an agreement of any of the co-author affiliated institutions, or via an EC grant.

● Authors are required to contact the CERN SIS in advance of submission to confirm the eligibility for central payment from the CERN Open Access fund.
● Articles submitted to journals with exceptionally high article processing charges (i.e. in excess of CHF 4000) will not be funded by CERN.
● Exceptional articles to be published in high-profile journals (i.e. Nature, Nature Physics, Science Advances, etc.) and that are likely to receive a high public attention are required to be reviewed and approved by the Director of Research and Computing prior to journal submission.
● For special issues coordinated or authored by CERN resulting in high publishing costs for CERN, editors of such special issues should submit a specific justification and request for approval before organising such issues.
CERN SIS also provides proactive support to CERN authors relating to OA compliance. As well as providing authors with direct guidance on OA publishing, licences, etc., CERN SIS develops and operates
services (such as the CERN OA Author Guide) to support community compliance with the OA policy.
Beyond the above-described different routes and means to publish final OA peer-reviewed articles, submission to arXiv is a long-standing practice at CERN and a crucial part of the scholarly communication process. To support the interoperability of arXiv with CERN processes and tools, and to contribute to the sustainable funding of the arXiv initiative, CERN (through the Scientific Information Service) collaborates with Cornell University as the operating entity of arXiv on governance, funding and technology aspects.
The topics and level of collaboration vary depending on the current needs of arXiv, but CERN is committed to continue this collaboration in the long term.
CERN, through the central Open Access Fund managed by SIS, provides CERN authors support for the publication of open access books and monographs. Such support includes the coverage of book publishing charges if the title is deemed of importance for the CERN community, as well as advice on licensing and copyright questions. Authors are encouraged to contact the CERN SIS as early as possible on any upcoming book publishing project.

Review of the plan (AGB):

- In 2023 and 2024, +96% of CERN articles published in Open Access (add results)
    - SIS Activity report 2023 + 2024
- SCOAP3:
    - 10 years anniversary.
    - Implementation of Phase 4 to start in 2025
        - Including new Open Science elements in the contracts with the publishers
        - More than 72,000 articles published
- Continued support to other collective models: S2O, PRAB, SciPost
- 10 “transformative agreements” with publishers:
    - Started in 2020
    - Second “round” agreements, with adaptations to be closer to CERN needs
- Use of CC-BY is largely spread (98% in 2023, to be calculated for 2024), with some exceptions - promotion of this license to the community
- Support line for the community
- Books: SCOAP3 books program + continued support on book publishing
    - Collaboration increased with OAPEN

- Participation to discussions regarding Diamond Open Access

For future plan:

- Review impact/efficiency of Transformative agreements at CERN
    - Develop strategy for next years
- Continue discussions on Diamond Open Access
- Maintain/increase level of support to authors, develop focused training

Open Data and Reuse

2. Open Data and Reuse

Editor:Jamie Boyd

Policy Document Text

CERN experimental collaborations are committed to making their research data publicly available. The CERN Open Data Policy for LHC Experiments (2020) aims to support CERN experiments' consistent approach towards the openness and preservation of experimental data to maximise their long-term value. All data are released with persistent identifiers. Data and associated data services apply open and FAIR principles. For experimental data releases, CC0 waivers are applied as standard. Researchers and experiments are expected to develop data management plans for their research activities.

Implementation

A detailed implementation plan was developed by the Open Data Working Group. Broadly speaking, the LHC experiments have committed to making Level 1 (additional documentation) and Level 2 (education and outreach) data available as needed. Each experiment has laid out a plan to release Level 3 (reconstructed) data regularly some time after data taking has been completed, with the aim of releasing all Level 3 data by the end of the collaborations. Only representative Level 4 data (raw detector data) will be made available for specific use-cases, at the discretion of the experiments.
Work on open data, experiment software (chapter 3) and reproducible analysis workflows (chapter 5) are tightly linked together. Enabling reusability and reproducibility of an analysis requires a holistic approach including preservation and access to data, software, workflows connecting the analysis steps, documentation and metadata. This challenge is particularly addressed in chapter 5.
In addition to the above, processes for requesting, checking and approving data management plans need to be developed within the next two years. This includes the definition of respective roles and responsibilities.

Jamie to add text here on what has happened since 2020 (focus 23/24) with both successes and challenges. (to be done week 27 Feb). Full draft to be discussed at OSPF on Feb 21st. (circulate draft to ODWG for comments before 21/2)

Bullet point summary:

- Open Data WG setup in Feb 2020 to define OD policy for large LHC experiments, includes public policy document (broad aims) and internal implementation document (per experiment details of whats released when)
- After lots of discussion policy was endorsed by CBs of 4 large LH experiments at end of 2020
- Implementation needed to start within 5 years
- In discussion with DRC, IT department head in 2021 IT decided to provide storage resources for first 5 years of policy (until end of 2025)

- In 2022 IT employed 1 new person to work on tape integration of OD storage (will save money on storage resources in long term)
- Over last years large LHC experiments have released data in a way consistent with policy:
    - CMS: lots of data released even before the policy. continue regular large releases including full Run 1 pp dataset (12/22), Run2 pp data (4/24), and Run 1 HI data (9/23)
    - LHCb: big data release on 12/22 and (full Run 1) 12/23
    - ATLAS: big release on 7/24 (2015+2016 pp data), first HI release (2015 PbPb data, 12/24)
    - ALICE: waiting for current status (previously first large release imminent)
- Progress and issues monitored/discussed at annual ODWG meetings
- In parallel to above, asked by DRC to expand effort to include small LHC experiments. Discussed individually with them and by 3/23 all of these (TOTEM, LHCf, MEoDAL, FASER, SND) endorsed existing policy (but no implementation policy produced). Given 5 year period, still time for this to happen.
- Following that, was asked by DRC to investigate OD policy for ALL experiments at CERN. More difficult task. Meeting with management of non-LHC experiments in XX, clear that one policy can't fit all. Break down by facility:
    - ISOLDE: have written their own policy (similar to LHC policy, but targeted to ISOLDE community)
    - Suggest to have dedicated policy for AD experiments and nTOF (need to followup on this)
    - SPS experiments can likely sign up to LHC policy, but needs more discussion. Concerns about human resources for the implementation of that. I need to followup on this during Q1 2025.
- Discussions started/ongoing within the ODWG and within the CERN OS group on defining OD monitoring metrics / KPIs etc…
- LHCb have developed the ntuple wizard (to be publicly released in 2025) to allow more efficient storage / use of their data without huge storage requirements on the portal
- Important to clarify where storage resources for OD in the period 2026 onwards will come from (current agreement with IT until end of 2025)
- There has also been some discussion about other experiments Open Data - e.g. JADE and LEP experiments where some of the data is or becoming open
    - There are clear lessons from the open data for old experiments, related to data preservation (e.g. related to software / operating system /hardware consistency etc..)

Open Source Software

3. Open Source Software

Editor: Giacomo Tenaglia

Policy Document Text

CERN software is made available as Open Source wherever possible, applying a licence approved by the Open Source Initiative (OSI). CERN handles its research-related software as an integral part of its research products. Analysis of the CERN experiments' physics data must be possible with Open Source software. External communities should be invited to use, contribute to, and influence the evolution of CERN's software projects. CERN's software expertise should be shared with other science disciplines.
Software development processes are expected to follow best practices2. CERN contributes to Open Source software relevant to its mission through code contributions, participation in the evolution of software, and standardisation.

Implementation

Software should be Open Source from as early in the development process as practicable. Such software includes experiments' software, such as data acquisition, detector simulation, and reconstruction software. This also includes e.g. software from other communities, including IT services, accelerators, theory. The software should be made available following the FAIR principles.
Software projects are recommended to consult a future CERN Open Source Programme Office (OSPO) and the CERN Knowledge Transfer (KT) group for topics such as licence selection. The KT group at CERN is tasked to make assessments of the potential of software for other applications, and advises on licensing matters for software with dissemination potential outside high energy physics. The OSPO is in the planning phase. It is envisioned as an easy-to-use entry point for Open Source questions in the community and as a partnership across departments. Although the concrete development of the OSPO mandate is pending, the intention is that the OSPO could facilitate and publicise CERN's contributions to society through Open Source, promote CERN as an "Open Source lab" to help recruitment, provide guidance on Open Source best practices, and provide guidance on CERN's software policies.

For software with significant current or historical investment of effort and that cannot be made publicly available, the reasons it must remain closed (such as specific security concerns) should be documented within the next two years. In addition, the OSWG will survey the experiments to identify any usage of significant software in current analysis pipelines that is not available under an OSI approved licence.
CERN should provide mechanisms and convene communities to enable the following across the
organisation:
● Fostering and dissemination of best practices for software development;
● Software preservation and archiving, including enabling citation (following recommendations e.g. from software citation working groups). This may require following up

with publishers to make sure software citations are properly edited, reviewed and taken into account in their processes;
● The harvesting of software metadata by major discovery systems (e.g. INSPIRE). For instance, following OpenAIRE Guidelines.
Open Source Software with significant current or historical investment of effort require sustainability plans which outline long term support. These plans should be made available publicly.
CERN should provide mechanisms to enable members of personnel to contribute to Open Source software projects external to CERN and related to its mission. The software development communities at CERN should report to the OSWG on their engagement with and efforts to foster collaboration with communities / bodies from other sciences and industry every two years. This reporting could be done via the future OSPO (mentioned above).

Open Source Software in 2023-4

CERN founded its OSPO in September 2023 to help open source at CERN, be it CERN teams or users. The OSPO consists of representatives from 10 departments and groups: BE, EP, HSE, IPT-KT, IR, IT, RCS-SIS, SY, TE, and TH. This covers a wide range of requirements and expectations.
On May 30th, 2023, the mandate of the CERN OSPO was officially endorsed by CERN ED. The approval of the mandate can be seen as the OSPO's first significant achievement, aligning virtually the whole Organization around open source. In particular, it defined "internal" obligations of the OSPO, geared towards facilitating best practices in the CERN community, and "external" facing objectives, focused on showcasing CERN's open source contributions to the world.
The mandate defined the CERN OSPO's two main target audiences: the internal CERN community and the broader open source ecosystem. To account for both audiences, the OSPO's inauguration was split into a public event on November 28th which hosted a number of renowned open source experts and an internal event which focused on discussions with the CERN open source community on November 29th.

During 2024, the work of the OSPO with regard to open-source software has focused on defining guidelines and best practices for publishing CERN OSS and contributing to external open-source projects. CERN's previous rules on how to open source software stem from a the Open Source License Task Force[1], whose findings were published in 2012. While much of its deliberations remain valid to this day, some of the processes have proven impractical.

To define the next generation of guidance, the OSPO took a very effective and pragmatic approach: engaging all members, the OSPO covered the whole range of areas, from best practices to license recommendations. With the involvement of virtually all key players, the OSPO could converge on a set of rules that were acceptable for the different parts, including the requirements of reliable operations for instance in BE and IT, the reality in EP with its thousands of users, the legal viewpoint, and the Knowledge Transfer perspective. The OSPO solved the friction between CERN as an international organization with its special

[1] Report at https://cds.cern.ch/record/1482206

privileges and the standard open-source licenses. Experts of the Organization's legal aspects and of the open-source aspects converged to a solution that - for the first time - enables CERN to publish its code under a default open-source license, making CERN's products compatible with the rest of the world's open-source ecosystem.

The Knowledge Transfer group was especially supportive in finding more pragmatic approaches: signing of organizational Contributor License Agreements (CLAs) is now a trivial process from the point of view of the contributor, facilitating CERN's contributions to the world's open-source projects tremendously. The fact that with the creation of the OSPO, all software is by default open-source is by itself a fantastic achievement for the Organization and a clear signal to the world. Combining this with much streamlined open-sourcing processes makes software development at CERN a technical task, not a bureaucratic one.

Overall, the new set of guidelines and recommendations[2] reduce the burden for developers of open-source hardware and software; provide clear and simple guidance to the developers' typical and recurring questions; simplify processes for both management and developers; and have the prospects of improving the quality of CERN's products through best practice recommendations.

A proof of concept of the CERN Open Source Software Catalogue (OSSCAT) has been developed and deployed, and will be open to the public during 2025. The catalogue uses the Hugo static site generator and leverages CERN Gitlab issue workflows in order to allow developers to submit their project for inclusion. Projects are regularly refreshed in order to feed the latest news into the catalogue page.

Requests to open source projects are handled by the OSPO. They are tracked internally through tickets that are assigned to members of the CERN OSPO as the main contact. During 2024, a total of 9 requests has been received, 2 of which have been resolved:

1. Licence inquiry for the SHiP software framework (FairShip[3]):
   The request covered support in choosing a license for the SHiP software framework, consultation on how the consent of the contributors can be obtained, and the copyright assignment.
2. OpenPHIGS[4] for data preservation:
   This request dealt with the compatibility of different licenses and the choice of a license of newly added source files.

A CERN community event[5] was held on 7 November 2024 with presentation by the invited guest speakers Clemens Lange (chair of the CERN Open Science Practitioners Forum) on the importance of the OSPO within the wider Open Science efforts at CERN, Anastasia Stasenko (pleias) on data commons in the context of AI, and Sophia Vargas (Google OSPO) on the challenges of sustainable open-source software.
This was followed by four open-source lightning talks that featured selected open-source projects at CERN. Axel Naumann provided an overview of the OSPO, highlighting

[2] The OSPO's recommendations are published at https://ospo.docs.cern.ch
[3] https://github.com/ShipSoft/FairShip
[4] https://github.com/CERN/OpenPHIGS
[5] https://indico.cern.ch/event/1445864/

achievements and plans for 2025. This was followed by Giacomo Tenaglia providing an update both on the software and hardware side of OSPO activities.
The event closed with an open feedback and discussion session that touched on topics such as how CERN can contribute to open-source projects, requests for stronger focus on open-source alternatives, and concerns raised on the ethical use of AI.

Open Source Software in 2025-2026

During the course of 2025, the OSPO foresees publishing the Software and Hardware Catalogues, with on-boarding of CERN open-source projects. In terms of policies and recommendations, the OSPO will finalise a workflow and tool for selecting the most appropriate license for a project. Finally, the OSPO expects to continue the collaboration with Zendis and the Sovereign Tech Agency, and to actively join the European Commission's European OSPO network.

Open Hardware

4. Open Hardware

Editor: Javier Serrano

Policy Document Text

CERN makes its technologies broadly available to society and has introduced open hardware licensing as a key mechanism to achieve this goal. Open hardware designs are made available through the Open Hardware Repository. The legal basis for the sharing of open hardware is enabled through variants of the CERN Open Hardware Licence. Hardware design releases will consider opportunities for collaboration with other research communities and industry. In cases where extensive documentation and ancillary components like software for interfacing and testing are required for projects, these should be licensed under appropriate Open Source documentation and software licences, respectively.

Implementation

Whenever a team at CERN is working on a hardware design which could be generally useful beyond the laboratory, that team should contact the CERN Knowledge Transfer (KT) group. KT will be able to recommend the best licence to use for its dissemination, including through open-sourcing that design under one of the three variants of the CERN Open Hardware License. To do so, all aspects that ultimately contribute to the impact of a hardware design outside the laboratory will be considered. This goes beyond the mere publication of the design sources. They include the fostering of active and welcoming communities around the open-sourced technologies, discussions with firms about the role they can play in these communities and ways in which they can leverage the technologies in their own commercial activity, and particular attention to the quality of the designs.

In two years, CERN should report on the CERN hardware developers' use, interest, and awareness of open-sourcing hardware. This report should also collect the developers' view on how to achieve preservation of hardware and its design.

Open Source hardware designs are made available through the Open Hardware Repository (OHWR). Long-term preservation of the designs themselves is an important part of the Open Hardware activity. For CERN designs, EDMS is used to ensure that the design files are safely stored and preserved, including versioning, and a link to the relevant location in EDMS is provided in the OHWR project corresponding to a given design.

Open Hardware at CERN in 2023 and 2024

The year 2023 saw progress on two fronts:

- The proposal to create an Open Source Program Office (OSPO) at CERN, with a launch in November. This OSPO is, compared to OSPOs in other institutes and

companies, special in that it includes Open Source Hardware (OSHW) as a "first-class citizen" along with Free and Open Source Software (FOSS).
- The rationalisation of a plan for the evolution of the Open Hardware Repository (OHR). When it was created, it played a double role: that of a "forge" in which to store and version design files and that of a catalogue. With places like github.com and gitlab.com now offering forge-like services much more efficiently, it was decided to focus the future evolution of OHR on its role as an easy-to-browse catalogue of OSHW solutions.

During 2024, with the OSPO in full operation, all OSHW-related activities were conducted in that framework. One of the first issues to tackle was that of gateware, i.e. the Hardware Description Language (HDL) code designers use to configure Field-Programmable Gate Arrays (FPGAs) and design Application-Specific Integrated Circuits (ASICs). In terms of policy, CERN draws a distinction between software (FOSS by default, with the OSPO as a default entry point for developers) and hardware (KT as an entry point for the process of discussing dissemination, be it open source or proprietary). Gateware is somehow between software and hardware, and it had been left out of the policy implementation documents. In the frame of the OSPO, it was decided that gateware is more like hardware and therefore KT should be the default entry point for designers.
There was also considerable progress in the evolution of OHR towards a catalogue website. The new site will be statically generated using the Hugo generator. Its current state of development can be seen at https://github.com/OHWR/ohwr.org with a preview of the site at https://ohwr.github.io/ohwr.org/. It should be deployed before the summer of 2025.
Another important area of activity was documentation, in particular providing guidance on best practices to open-source hardware designs. This was done in the frame of the OSPO documentation site.
Finally, the following three Key Performance Indicators (KPIs) were established to gauge progress in the implementation of the OSHW part of CERN's Open Science Policy:
- *Percentage of OSHW designs in CERN's electronics drawing office*. The drawing office is a central point for electronics design at CERN. It typically receives schematics from designers and performs layout of the Printed Circuit Board (PCB). Not all designers at CERN use the service, but most do and therefore it is a very natural place to estimate the amount of open-sourcing happening in the hardware realm. Please note that this refers to the *electronics* drawing office. There has been little progress on open-sourcing mechanical designs at CERN so far. This may be due to the lack of incentives and the less mature commercial ecosystem for OSHW in that domain. It remains a discussion to be had, maybe in 2025 (see below).
- Many OSHW designs are currently being performed using proprietary design tools. For reasons which are explained in this article, a fully open-source design should use FOSS tools. For this reason, it was decided to add a KPI representing the *percentage of designs in CERN's electronics design office using KiCad*, a FOSS tool supported by CERN IT to design PCBs.
- One big contribution of CERN to the OSHW ecosystem is the CERN Open Hardware Licence (OHL), which designers around the world use to share designs in a legally-sound way. It was decided that the *number of designs using the CERN OHL version 2 in github.com* would be a good indicator of the impact of the licence. Using the GitHub API, we can even get numbers for the use of each of the three variants of

the licence, which provides information about preferences for permissive, weakly-reciprocal or strongly-reciprocal sharing regimes.

These are the values of the KPIs for 2024:

KPI description	KPI value for 2024
Percentage of OSHW designs in CERN's electronics drawing office	15 designs out of ~200 = 7.5% (out of which 6 done in KiCad)
Percentage of KiCad designs in CERN's electronics drawing office	8 designs out of ~200 = 4% (out of which 6 released under an OSHW licence)
Use of CERN OHL v2 variants in github.com	CERN-OHL-P-2.0: 520 projects CERN-OHL-W-2.0: 286 projects CERN-OHL-S-2.0: 537 projects

Note that some of the OSHW designs are not done in KiCad and some of the KiCad designs are not OSHW. Also note that the GitHub API was used to query github.com for total number of designs using CERN OHL v2 at the end of 2024. That means that this KPI tracks the total number of designs in GitHub and not those released in 2024 or any given year. As such, it is in principle expected to grow every year, and the difference between two successive years will be a KPI on its own.

As can be seen in the table, there is quite a lot of space for improvement in the pervasiveness of open-sourcing practice at CERN in the hardware realm. The plan to get those numbers up includes better KiCad support and more widely-spread information, including public presentations, on the benefits of open-sourcing hardware in many domains and applications.

Outlook for 2025 and 2026

Sometime during the first half of 2025, the new OSHW catalogue should go live at ohwr.org. This will mark the end of the OHR as a site hosting designs, a task it has fulfilled since its first deployment in 2009. Designs will now be hosted elsewhere, and the OHR will make it easier to find them.
Another important line of action will be guidance on best practices for releasing designs as OSHW. This will include a contribution to the development of a licence chooser web application, which will provide advice of what licence to use in a given situation by asking a number of questions to the user. This chooser app will provide support for both FOSS and OSHW, including gateware. Still in the best practices realm, in collaboration with the ATS Electronics Forum, we will improve the guidelines to be followed for ensuring high-quality PCB designs. We will also create a new page describing OSHW ASIC design, using FOSS tools throughout.
Regarding the adoption of KiCad as a PCB design tool at CERN, we plan to act on four fronts: a) automating the migration of CERN component libraries to KiCad format and open-sourcing the resulting libraries, b) adding guidelines on the use of KiCad at CERN in the OSPO documentation site, c) liaising with the CERN drawing office to make sure all their

needs in terms of functionality are well covered by KiCad and d) communicating towards the community of electronics designers at CERN to raise awareness about this important tool. This last action will include interaction with the newly-created Electronic Design Automation Committee (EDAC) at CERN, whose main task is to oversee the use of EDA tools and help IT with the choices of tools to support.
This should take us to the end of 2025, in principle in a position to report on “CERN hardware developers' use, interest, and awareness of open-sourcing hardware” as requested in the implementation of the policy.
We expect that 2026 will see some of the activities above continuing, and in addition it may be the right time to tackle two areas which today are in a very preliminary state:

- A CERN-wide debate on the pertinence and possible interest to extend the reach of OSHW-related activities beyond electronics and gateware, into the realm of mechanical design.
- The implementation of support for OSHW, KiCad to begin with, in CERN’s Product Lifecycle Management (PLM) solution. This will make it easier to efficiently manage and share designs within CERN and with the outside world

Resources

A few months of work would be needed in 2025 to properly open-source the CERN KiCad libraries. Currently the CERN drawing office creates symbols and footprints for proprietary tools, and these are automatically translated into KiCad format by a script run at regular intervals. However, there are also 3D models of components which are used to render the PCB before production, generate documentation, check for mechanical compliance, etc. These 3D models are sometimes downloaded from the Web, i.e. the IP is not with CERN, so we cannot open-source that part of the library. Somebody would be needed to go through the list of 3D models and curate a selection of those which can be published, plus use automatic model generators and 3D models under appropriate licences to complement the full collection. The open-sourcing of CERN’s component libraries would be a huge contribution to the outside, and it would also make working with other institutes and companies much easier and more sound from a legal perspective.
In 2026, there could be a need for someone to work on the PLM system as described above, but it is too early to say.

Open Hardware at CERN: KPIs for 2024

Open Hardware at CERN: KPIs for 2024

Use of CERN OHL v2 in github.com

Script courtesy of Vasco Guita (BE-CEM)
CERN-OHL-P-2.0: 520 projects
CERN-OHL-W-2.0: 286 projects
CERN-OHL-S-2.0: 537 projects

Number of PCB designs using OSHW licences in CERN's drawing office

15 designs in total (6 using KiCad)
11 by BE-CEM
2 by SY-ABT
1 by HSE-RP
1 by SY-BI

Number of PCB designs using KiCad in CERN's drawing office

8 designs in total (6 of them OSHW)
4 by BE-CEM
2 by SY-ABT
1 by HSE-RP
1 by BE-GM

Total number of designs by CERN's drawing office

In order to put in perspective the number of open-sourced designs and the number of designs done using KiCad, we need the total number of designs done by CERN's drawing office in 2024. As of this writing (21 November 2024) that number is 189, with some designs in the pipeline, so for the purpose of reporting we can use 200.

Research Integrity, Reuse and Reproducibility

5. Research Integrity, Reuse and Reproducibility

Editor: Clemens Lange

Policy document Text

CERN is committed to ensuring the integrity of research. In order to facilitate the reuse of its research products, CERN provides infrastructures to accommodate the scale and complexity of its research outputs. Reuse and reproducibility are facilitated by practising comprehensive analysis preservation to capture relevant research objects, such as research data releases with supporting metadata, auxiliary data, linked software, reproducible analysis workflows, documentation, etc.

Implementation

The goal of this part of the implementation plan is to ensure reusability of physics analyses and connected research products as well as the metadata linking them together. Hence, work on research integrity and reusability is tightly linked to the work on Open Data, Open Source software and all the other elements described in this implementation plan. An analysis will only be reproducible if the data analysed (chapter 2), the analysis software used (chapter 3), the workflows connecting the analysis steps, as well as the metadata and documentation, are preserved and made openly accessible to potential users.

With this motivation and goal in mind, these are the proposed measures:
- Draft a plan on what research integrity entails for particle physics within the next two years.
- Develop analysis preservation templates within and possibly across experiments/collaborations to capture and test analysis reusability within the next two years (e.g. GitLab templates for software compilation and testing, CERN Analysis Preservation templates, software container image creation templates).
    - Sub-Task: A forum for this discussion needs to be identified. The HSF Data Analysis Working Group currently provides a natural forum for discussion of analysis preservation templates across collaborations. In addition, experimental and theoretical physicists outside the collaborations should be involved, e.g. through the LHC Reinterpretation Forum and Open Data workshops, to ensure that external reuse is actually possible.
- Facilitate discussion with experiments on needs and priorities concerning analysis preservation services. Then, recommendation and implementation of required tools and services (e.g. CERN Analysis Preservation, REANA, etc), developed in close collaboration with the experimental collaborations to make sure their needs are served. Viable technical solutions are expected to work also outside the CERN network and should — pending discussions with other communities mentioned above — consider the needs of potential users outside the collaboration.
- Design and offer training for the particle physics community on using these tools and services, and, generally, to raise awareness in the community and among service providers.
    - Training offerings need to link current research practices and open practices and work

towards an open culture where research is done “with openness as the final goal”. Research is done, preserved, documented, while having the public or the next researcher who might access the research output in mind. This is essential for reusability and training needs to include dedicated tools and services that help doing that without much overhead.

● Run automatic preservation and integrity checks regularly to ensure that time (and technological upgrade) does not break the preserved analysis: e.g. are data still in the same location, are the files corrupted, is the software accessible, is the software still running, can the research still be reproduced, etc.

● Align with global initiatives, services and best practices for FAIR data.

Activities

Activities 2023–2024

Public workshops and events

Workshop on workflow languages for HEP analysis

April 2024
Event URL: https://indico.cern.ch/event/1380367/

Took place at CERN IdeaSquare, 64 registrants, 23 in person. Supported by FAIROS-HEP and SMARTHEP initiatives for speaker travel, event dinner, and coffee breaks. Organisation by Clemens Lange (CMS), Jamie Gooding (LHCb), Lukas Alexander Heinrich (ATLAS), Matthew Feickert (ATLAS) and participation from all LHC experiments and beyond.

Led to the organisation of a Snakemake Hackathon in March 2025 (https://indico.cern.ch/event/1441041/)

The HSF data analysis working group has held a handful of meetings on various topics (https://indico.cern.ch/category/10914/).

Pre-CHEP HSF Training Workshop (https://indico.cern.ch/event/1410343/).

HSF trainings

Training on analysis preservation (https://indico.cern.ch/event/1219810/), January 2023. Online-only event, 100 registrants.

Containerization & Analysis Preservation Training Hackathon, March 2023 (https://indico.cern.ch/event/1261775/). Single-day event to improve existing documentation and training material.

Analysis pipelines training February/March 2024 (https://indico.cern.ch/event/1375507/). Online event, about 280 registrants, number of participants significantly lower.

Several other software tutorials, see https://indico.cern.ch/category/11386/ for overview.

Software development

Working with the REANA team, several patch releases have been created over the past two years (https://blog.reana.io/) that have improved the stability and user experience of REANA.

CMS released Combine software:
https://github.com/cms-analysis/HiggsAnalysis-CombinedLimit/

CMS statistical models can now be published on the new (CDS) repository: https://repository.cern/communities/cms-statistical-models/records?q=&l=list&p=1&s=10&sort=newest

Related publications

The CMS Statistical Analysis and Combination Tool: Combine (https://inspirehep.net/literature/2775812)

Other activities

A taskforce on “recommendations for best practices for open science” initiated by the chair of the ICFA Data Lifecycle panel (Kati Lassila-Perini) has been formed and has started to draft those recommendations.

Review

The goal of this part of the implementation plan is to ensure reusability of physics analyses and connected research products as well as the metadata linking them together. Hence, work on research integrity and reusability is tightly linked to the work on Open Data, Open Source software and all the other elements described in this implementation plan. An analysis will only be reproducible if the data analysed (chapter 2), the analysis software used (chapter 3), the workflows connecting the analysis steps, as well as the metadata and documentation, are preserved and made openly accessible to potential users.

This still holds true and can be kept as is.

With this motivation and goal in mind, these are the proposed measures:
● Draft a plan on what research integrity entails for particle physics within the next two years.

This plan has not been drafted. There has been significant work led by the chair of the ICFA Data Lifecycle panel (Kati Lassila-Perini) in this direction, drafting “recommendations for best practices for open science” (in particle physics). It would probably make sense to adjust the text here to point to this and reflect on what else is needed to obtain an actual plan (and not just recommendations).

● Develop analysis preservation templates within and possibly across experiments/collaborations to capture and test analysis reusability within the next two years (e.g. GitLab templates for software compilation and testing, CERN Analysis Preservation templates, software container image creation templates).
○ Sub-Task: A forum for this discussion needs to be identified. The HSF Data Analysis Working Group currently provides a natural forum for discussion of analysis preservation templates across collaborations. In addition, experimental and theoretical physicists outside the collaborations should be involved, e.g. through the LHC Reinterpretation Forum and Open Data workshops, to ensure that external reuse is actually possible.

Within CMS, significant effort has been made by a newly created Common Analysis Tools group to promote the reusability and reproducibility of analyses. Templates and services to facilitate the creation of software container images and for automated testing of analysis code have been developed. They are, however, internal to CMS. Furthermore, mechanisms to publish statistical models have been developed and the CMS collaboration board has approved the publication of such models. This publication remains voluntary, however, and 3 analyses have released their models. The models are also linked from the respective HEPData records.
Unless there are personal connections to open science proponents in the experimental collaborations or by asking experiment management directly, it is not possible to monitor/review the work/progress made.
→ Propose to require the experiments to report to e.g. the OSSB or some other body at CERN so that there is some kind of monitoring.
The HSF Data Analysis Working group (DAWG) has held six meetings over the past two years, where two (on Open Data and on HEP Statistics Serialization Standard (HS3)) are

related to analysis preservation/reusability. Analysis preservation templates as proposed in the implementation plan, however, have not been discussed.
→ Need to define a responsible person or body to establish the connection between e.g. OSPF and HSF DAWG. Also need to identify people within the experiments (→ contacts) who can provide proposals for analysis preservation templates and who follows up with them from the CERN OS side (probably CERN SIS/OS office).

> ● *Facilitate discussion with experiments on needs and priorities concerning analysis preservation services. Then, recommendation and implementation of required tools and services (e.g. CERN Analysis Preservation, REANA, etc), developed in close collaboration with the experimental collaborations to make sure their needs are served. Viable technical solutions are expected to work also outside the CERN network and should — pending discussions with other communities mentioned above — consider the needs of potential users outside the collaboration.*

As above, it is unclear here who will actually initiate/facilitate the discussions (again, probably CERN SIS/OS office). So far this has been entirely a grassroots effort of a small number of individuals (see CERN Open Science Implementation Plan Review). Probably needs a structure and also an assignment of FTEs.

> ● *Design and offer training for the particle physics community on using these tools and services, and, generally, to raise awareness in the community and among service providers.*
> ○ *Training offerings need to link current research practices and open practices and work towards an open culture where research is done "with openness as the final goal". Research is done, preserved, documented, while having the public or the next researcher who might access the research output in mind. This is essential for reusability and training needs to include dedicated tools and services that help doing that without much overhead.*

Training has been provided by the HSF training initiative as well as within the collaborations. However, internal training within the collaborations cannot be monitored from outside. There could be more (or regular) trainings on the CERN-specific tools, e.g. REANA. The frequency could be defined.

> ● *Run automatic preservation and integrity checks regularly to ensure that time (and technological upgrade) does not break the preserved analysis: e.g. are data still in the same location, are the files corrupted, is the software accessible, is the software still running, can the research still be reproduced, etc.*

This can probably be more seen as a recommendation rather than being something that is already done, at least not widely. It also requires training and documentation to do that, which so far does not exist.

> ● *Align with global initiatives, services and best practices for FAIR data.*

This is a very generic statement and it is unclear how this can be implemented in a concrete way. This could e.g. be moved to the policy part, but to remain as a recommendation, it needs to be more specific.

Infrastructure Provision for Open Science

6. Infrastructure Provision for Open Science

Editor: Jose Benito Gonzalez Lopez, Nicola Tarocco

Policy Document Text

CERN ensures that Open Science infrastructures meet trusted quality standards, comply with FAIR principles (e.g. use persistent identifiers such DOIs and ORCIDs), have long term preservation plans and are interoperable with international standards and initiatives such as the European Open Science Cloud (EOSC).

Implementation

One of the ultimate goals of Open Science at CERN is the open exchange of all the research results, e.g. publications, data and software and other required elements to enable reusability of CERN's research results.
Reaching this goal requires implementation work in the domains of digital repositories, research output management, and research output preservation. The following tasks should be completed within the next two years:

1. Define a list of core open services needed to practise reusable and open research:
○ Prepare a first list of existing services needed by the community to comply with the policy, e.g. CERN Open Data Portal, CERN Analysis Preservation, INSPIRE, REANA, CDS, Indico, Zenodo, the Open Hardware Repository and their use/adoption by the community.
○ Define quality standards for Open Science services (e.g. for trusted repositories like CoreTrustSeal or following internal review boards).
○ Explore monitoring processes and potential KPIs that will track the evolution of the core services over time (e.g. FAIR assessment tools).
○ Identify gaps and address them with new services, features and additional needs that complete the Open Science scholarly publishing workflows in a seamless manner.
○ Identify dependencies of services to enable interoperability across services.

2. Identify sustainability measures for services and resource needs for critical services:
○ All operational services will already report their resource needs. They will be compiled in the OSWG.
3. Develop a draft roadmap for critical services, with suggestions for sustainability measures; discuss results with the relevant stakeholders in the Organization.
4. Continuously review usage of core open services, resource needs and community practice.
Adjust the core services list accordingly (following quality standards)

Infrastructure Provision for Open Science v2

6. Infrastructure Provision for Open Science v2

What was done?

No concerted strategic efforts in line with the implementation plan, but many useful developments from the various infrastructures. Most notably:

- INSPIRE: new data collection
- Open Data portal: 10 years and 80k records reached
- REANA: ATLAS could successful reinterpret run 2 analyses
- CDS: new platform aiming to apply OS best practices
- Zenodo: migration to Invenio-RDM based platform, Software Heritage integration, FAIR signposting, European Open Research repository
- Digital Memory: ILC documents archived
- CERN Analysis Preservation:

What we suggest to do?

Create an Open Infrastructure Working Group to progress on the tasks of the implementation plan. This Working Group will, in collaboration with the service providers,

- Define a **non-comprehensive and very initial (pilot)** list of core open services needed to practise reusable and open research, and that allow the community to comply with the open science policy.
- These services, when it makes sense, should do a FAIR assessment, like Zenodo did https://about.zenodo.org/principles/, make it available to the service users and share it with the OS office
- Define a list of key principles to assess the openness of infrastructure services and evaluate them, in line with best practices and recommendations from the OS community, with the goal of increasing openness. These principles should help assess the quality of each service, e.g:
- *Community Governance*: how can people contribute (ensuring inclusiveness)
- *Transparency*: clear communication of policies, governance, and operations
- *Openness*: uses open source software?.
- *Sustainability*: describe long-term financial models, evaluating risks, criticality, etc.
- Define an initial set of KPIs that the services should track to assess the implementation of the policy (e.g. % of datasets that have been published openly, % of publications with PIDs, % of authors with ORCIDs, % of research outputs that were long-term preserved).

🆕 Identify if all services have long term preservation plans. Complying with OC3, future retention policies, etc.

- Recommend solutions to identified gaps within services as well as interoperable solutions between services.

Output and effort needed for this plan

- will produce a short document with the assessments and implemented actions.
- team meeting 2h/month till next plan.

Open Infrastructure Indicators and stories

Open Infrastructure Indicators and stories

https://codimd.web.cern.ch/WpknBRiaS3au8ld6u7f1mQ

Research Assessment and Evaluation

7. Research Assessment and Evaluation

Editor: Alex Kohls, Antonia Winkler

Policy Document Text

CERN is committed to collaborating with its Member and Associate Member States to incentivise quality-assured and reusable Open Science practices for research and career assessments. As part of this effort, CERN strives to support strategic discussions and implementation of community-specific rewards systems, such as responsible metrics covering the full diversity of the community's research outputs.

Implementation

After due diligence, CERN has signed the Agreement on Reforming Research Assessment as one of the 51 early signatories. CERN is closely collaborating with other research organisations, funding agencies and universities across CERN Member and Associate Member States through the Coalition for Advancing Research Assessment (CoARA), an initiative started by the European Commission, to develop and align plans towards a fair and transparent assessment of researchers and research projects. Such assessment will be based on acknowledging the diversity of research activities, including quality-assured Open Science practices, and at the same time, abandoning the inappropriate use of journal-based metrics or other rankings.

As part of this commitment, and with the direct involvement of researchers, CERN has developed a 5-year action plan to review existing practices and implement a revised research assessment framework for research projects and researchers adapted to their context of application. As a first deliverable, a review of central CERN guidelines will be undertaken in the course of 2025 and information material will be developed to create awareness among hiring managers and promotion committee members.

This is particularly applicable but not limited to recruitment processes as well as CERN's internal promotion guidelines. All measures will be regularly discussed and aligned with similar efforts of the other coalition members and the action plan will be reviewed and amended annually.

Future processes for promotion, candidate selection, award of indefinite contracts etc. will have to: (a) be explicit about the criteria used to evaluate scientific productivity, and clearly highlight that the scientific content of a paper is more important than publication metrics of the journal in which it is published or whether a paper is published at all; and (b) recognise the value and impact of all research outputs (for example datasets and software) in addition to research publications; and (c) consider other types of contributions, such as training early-career researchers, or influencing policy and practice.

These practices shall be reflected in job advertisements and other documents setting criteria for all assessment processes. This will be coordinated by HR for central CERN policies, as well as by all departments for their individual hiring and promotion principles.
Journal-level metrics shall not be relied upon as a proxy for excellence (e.g., assuming one paper is better than another because it is published in a journal with a higher journal impact factor). Together with the collaboration partners, CERN works on actively supporting this aspiration by providing respective tools and following best practices in particular in INSPIRE, the leading scientific information platform for particle physics.

INSPIRE, a collaboration of CERN with DESY, Fermilab, IHEP, IN2P3 and SLAC, signed the San Francisco Declaration on Research Assessment (DORA) and supports a fair and transparent assessment of research quality and the individual researchers and their careers.

Training, Education and Outreach

8. Training, Education and Outreach

Editor: Adelina Lintuluoto

Policy Document Text

CERN is committed to developing training courses to facilitate the adoption of Open Science and equip researchers and supporting personnel at all levels with the necessary skills and expertise to conduct research in an open and reusable (FAIR) way. Furthermore, CERN commits to facilitating the use of open educational material in teaching/education at schools and universities. CERN encourages the preparation of resources to engage pupils and teachers, both inside and outside the classroom setting, in interactive learning exercises with open datasets and software products. Wherever possible, CERN links Open Data, Software, Hardware, and additional resources to published research articles so that they can be used in university courses to practise research and corresponding methodologies (e.g. statistics, machine learning).

Definitions (in this context):
Training: within CERN, refers to activities that promote the building of capacity on Open Science related activities/practices.
Education: beyond CERN (especially focusing on school and university students), refers to activities that promote the conceptual understanding of CERN's scientific domains (e.g. physics and engineering) and how the nature of science (e.g. "science is a social endeavour") is facilitated by Open Science practices.
Outreach: beyond CERN (especially focusing on the general public), refers to activities that promote awareness of CERN's field of research and research methods emphasising Open Science activities/practices.

Implementation

Embedding Open Science in CERN's Training, Education and Outreach efforts means providing training courses on the principles of Open Science (e.g. Open Data) and the tools used for practising Open Science within the CERN community. Beyond the CERN community, this also means making the Education and Outreach material used openly available. CERN aims to embody UNESCO's definition of an Open Science organisation "aiming to make multilingual scientific knowledge openly available, accessible and reusable for everyone" (UNESCO 2021), through the following Open Science goals for (1) training, (2) education, and (3) outreach. To elaborate these further in a coherent, comprehensive and scalable manner, a roundtable will be convened with those responsible for Training, Education and Outreach across CERN (e.g. representatives from Learning and Development; Academic Training Lectures; and the Accelerator, Physics, and Computing Schools) to discuss the first measures presented below and to assure that all their respective areas are represented appropriately.

(1) Open Science Training aims:

● establish training courses on the principles of Open Science covering FAIR data.

● establish training courses on the practicalities of Data Management Plans, reusable analysis and analysis preservation services.
● establish training courses on the practicalities of Open Access and Open Data publishing.

(2) Open Science Education aims:
● host education programmes (e.g. hands-on workshops) for teachers, school and university students covering the open nature of science.
● offer online education material about modern physics for teachers, school and university students, and interested individuals.
● conduct physics education research promoting the conceptual understanding of CERN's scientific domains and the open nature of science.
● publish new or already existing educational material, and education research findings according to the Open Science standards (see #3 below).
● act as publishing house for an Open Access Science Education Journal - PriSE (Progress in Science Education) - the only multilingual international journal in this area.
● make material from the CERN schools (physics, accelerator, computing), Summer student programmes, and the Academic Training series (presentations, videos) available according to Open Science standards (see #3 below).

(3) Open Science Outreach aims:
● host outreach events (e.g. physics masterclasses) in the local area and in the Member and Associate Member States based on CERN's Open Data sets.
● develop exhibitions for visitors (on- and off-site) on the theme of Open Science and the importance of open data practices for wider society (e.g. data driven decision making).
● publish outreach material according to the Open Science standards (see #3 below).

To implement and reach the aims described above, the following tasks should be completed within the next year:
1) Agree on a definition of "CERN's Training, Education and Outreach material relevant for Open Science".
2) Based on this definition, compile a list of recommended CERN's Training, Education and Outreach material and external training offers and material relevant for Open Science, including whether it is already openly available online on a CERN website and has a clear licence, and if not, document whether it can or cannot be published openly.
3) The material identified as suitable should be gradually made available openly on a CERN website and ultimately under an open licence (i.e. CC-BY for text, CC0 for data).
4)Those responsible for CERN's Training, Education and Outreach efforts should continuously update the OSWG on additional material to be added to the list.
5) Those responsible for CERN's Training, Education and Outreach efforts are recommended to consult the future CERN Open Science Policy Office. They will facilitate and publicise CERN's contributions to society through openly available Training, Education and Outreach material and promote CERN as an "Open Science lab" to provide implementation guidance for the Training, Education and Outreach part of CERN's Open Science Policy.

Activities 2023–2024

Open Science Training

The implementation plan aimed to establish training courses on Open Science principles, including FAIR data, Data Management Plans, and Open Access publishing. However, as of April 2025, no formal training had been put in place, with the exception of the scientific writing course containing one session on Open Science and Open Access.

Open Science Education

Several education initiatives were successfully carried out and are listed below. Where specific statistics for 2023 and 2024 are available, they are indicated, otherwise, stable numbers are assumed. The activities listed were identified through discussions with various stakeholders and a review of available resources, however, this may not represent an exhaustive list of all relevant initiatives.

A. Hosting Education Programmes

- Hands-on workshops in the Science Gateway engaged about 5,200 people in 2023[6] and over 25,000 in 2024.
    - There were four workshops designed for 16-19-year-olds, covering topics such as superconductivity and electron beams. Additionally, six workshops for ages 5 to 15 explored subjects like programming, how to observe the invisible and magnets.
    - Workshops open to the public were highly appreciated, receiving a Net Promoter Score of over 80%.
- Interactive science shows in the Science Gateway attracted over 2,500 attendees in 2023[1] and 40,000 in 2024.
    - The shows covered topics such as detectors and the structure of matter.
- Close to 183,000 people took part in guided tours in 2023[1] (stable numbers assumed for 2024).
- 27 teacher programs in 2023[1] and about 40 in 2024 welcomed 801 teachers in 2023[1] and over 1,000 in 2024.
- The CERN Solvay education programme received over 600 student applications[1], with about 100 high school students attending one of the week-long summer camps.
- The Beamline for Schools competition saw an increase from 379 proposals in 2023 to 461 in 2024, with participation growing from about 2,500 to 3,000 students.
    - In 2023, 8 high school students from the USA and 10 from Pakistan were selected to pursue their projects at CERN. In 2024, 5 students from Estonia and 5 from Japan were chosen.

B. Offer Online Materials

- Over 100 virtual tours reaching nearly 4,000 participants in 2023[1] (assuming stable numbers for 2024).

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[6] CERN Annual Report 2023

- A pilot version of “A Particle Physics Course for High-School Students” launched in late 2024[7], including 16 chapters of videos and quizzes.
- 12 new education videos published as part of the Solvay programme in 2023 reached approximately 2 million online views[1].
- Launched in 2024, CERN’s educational resources platform serves as a hub for promoting CERN-produced educational materials to students and teachers. Resources created by the IR-ECO-TSP section are hosted directly on the site under an open license, while other resources are linked externally, often without a clearly defined license.
    - Teachers frequently express their gratitude for these materials, with many implementing e.g. cloud chambers at their schools using the provided manual. Since the resources are freely available, an exact usage count is not available.
- The IT department and LHC experiments maintain their own databases of resources, though these could benefit from a more streamlined and coordinated approach.

C. Conduct Physics Education Research

- In 2023, 11 scientific papers were published on this topic and 1 student finished their doctorate degree. In 2024, 3 scientific papers were published and 1 student finished their doctorate degree.
    - The research explores various themes, including approaches to improving physics teaching and student engagement, the integration of particle detectors into classrooms and the development of learning materials for advanced physics.
    - No research was conducted to promote the conceptual understanding of the open nature of science.

D. Offer Academic Training

- In 2023, CERN organised 2 physics schools, 3 accelerator schools and 4 computing schools. These numbers grew to 2, 4 and 5 in 2024.
    - The schools host public Indico pages that provide the lecture slides.
    - In some cases, student outreach presentations are recorded and uploaded.
    - Proceedings are published as CERN Yellow Reports.
- About 30 academic lectures were made public in 2023 and 10 in 2024[4].
- Around 70 summer student lectures per year were also made public[5].

Open Science Outreach

A. Host Outreach Events using Open Data

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[7] cern.ch/PPC
[3] educational-resources.web.cern.ch
[4] indico.cern.ch/category/72
[5] indico.cern.ch/category/97

- International Masterclasses organised by IPPOG involving LHC Open Data reached approximately 10,000 high school students in 2023 (assuming stable numbers for 2024).
- Independent initiatives, such as those led by German schools, have organised about 70 Masterclasses in 2023 and 2024, reaching around 1,500 high school students.
    - A similar, though less centralised, initiative exists in the UK, but no official participation numbers are available.
- On the International Day of Women and Girls in Science, around 500 students participated in 2023 and 700 in 2024.
- On World Wide Data Day, nearly 50 schools participated in 2023, reaching about 1,000 students (assuming stable numbers in 2024).

B. Develop Exhibitions

- Exhibitions developed at the Science Gateway include about 50 hands-on experiments, over 120 CERN videos, nearly 50 real objects, and 4 art commissions[1].
- A Science Gateway Inspiration Book was created in 2024 to inspire and assist science centers, museums, and institutions in developing exhibitions and events.

Review

Open Science training courses were not launched as planned. Communication with key stakeholders suggested revisiting the plan in early 2025 to assess resource requirements and implementation steps. However, as training is a cross-cutting challenge that spans multiple areas, it may not be best addressed in this chapter.

While extensive educational activities were undertaken, it remains unclear whether the open nature of science was adequately incorporated into these programs. This issue relates to the first Open Science Education aim: "host education programmes (e.g. hands-on workshops) for teachers, school and university students **covering the open nature of science**". The existence of the programs outlined above may already be considered a contribution to Open Science, although they don't directly cover the topic of Open Science. Additionally, this concern ties into the second Open Science Outreach aim: "develop exhibitions for visitors (on- and off-site) **on the theme of Open Science and the importance of open data practices for wider society** (e.g. data driven decision making)". In the next chapter it will be described how part of the exhibition can be used to serve as a unique example for public engagement through Citizen Science.

The current approach to publishing educational and outreach materials lacks a unified strategy. Many online materials are without an open license. Discussions are currently ongoing with stakeholders on how to best archive CERN-produced education and outreach resources, and how to best associate them with an appropriate license. Moving forward, a standardised approach to licensing CERN's education, and outreach materials should be established, aligning with Open Science principles such as CC-BY for text and CC0 for data.

For the updated implementation plan we suggest:

- Removing training from this chapter and instead allowing each chapter to cover its respective training efforts.
- Removing the requirement to explicitly cover the topic of Open Science in hosted education programmes and the exhibitions.
- Continue efforts to make CERN-produced education and outreach resources publicly available under an open license.

Citizen Science

9. Citizen Science

Editor: Annabella Zamora, Karolos Potamianos, Merten Dahlkemper

Policy Document Text
CERN encourages meaningful public participation in citizen science programmes that contribute to advancing the Organization's mission or responding to societal challenges. Working with Member and Associate Member States and other relevant stakeholders, CERN aims to support a diverse range of practices to open up science and innovation to citizens, in particular the younger generations.

Definitions (in this context):
Citizen Science: For the purposes of this document, citizen science is understood broadly as any activity involving a high level of public participation in scientific processes, ranging from data collection to the co-creation of research.

Citizens: Refers inclusively to members of the public from any nationality or background.

Public Participation: Encompasses a wide spectrum of activities, such as crowdsourced data collection, collaborative prototype development (e.g. hackathons), and joint project design and implementation.

Implementation
While no central strategy or coordinated effort has been undertaken in the past two years regarding citizen science at CERN, several ongoing and completed projects demonstrate an active engagement with the public. These initiatives reflect CERN's long-standing commitment to citizen science and its potential for inclusive scientific practices.

Activities 2023-2024

Volunteer Computing

LHC@Home
Operating since 2004, LHC@home, CERN's volunteer computing initiative, enables citizens to contribute computing resources for particle physics simulations. It delivers an average of 80 TFlops—comparable to a Tier-2 Grid site—across multiple LHC experiments. The project utilizes BOINC, the Berkeley Open Infrastructure for Network Computing which provides infrastructure for similar projects in various fields. The project relies on the BOINC infrastructure and continues to evolve through community engagement, including the 2024 BOINC workshop co-organised by CERN.

Data Analysis and Classification Platforms

Zooniverse's New Particle Search - CERN & Oxford
In collaboration with the University of Oxford, this initiative invites citizens to participate in the classification of collision data, furthering discovery potential through distributed visual pattern recognition.
ATLAS Citizen Science
ATLAS has piloted multiple initiatives inviting public participation in data interpretation and classification tasks related to particle collision events.

The REINFORCE Project
As part of the EU-funded REINFORCE project, CERN collaborated on a demonstrator involving the CMS and ATLAS experiments, engaging citizens in gravitational wave and neutrino detection data tasks.

Educational and Research Engagement

Citizen-Cyberlab & **Crowd4SDG**
Jointly operated with UniGE, UNITAR and CERN, this initiative explores public involvement in solving sustainability challenges from SDGs, fostering both innovation and education.

Particle Physics Playground
Educational resources and environments, including data analysis toolkits, encourage young learners to explore physics and computing.

CMS Open Data and Masterclasses
Open access to CMS data has been leveraged for education and outreach, including global Masterclasses enabling students to engage with real particle physics data.

Hackathons and Innovation Challenges

THE Port
THE Port Humanitarian Hackathons[8] running at CERN in Autumn since 2014 are curated hackathons organised in-person in IdeaSquare (until 2019) and online (during the COVID pandemic), with the final presentation held or streamed from the Globe of Science and Innovation.
These hackathons combine creative minds from CERN and non-profit organisations in interdisciplinary teams to work on humanitarian technology-related benefits to society. Interdisciplinary teams of hand-selected innovators work together on topics such as infrastructure, health, communication, and education. Since 2014, 54 projects have been tackled by over 500 participants during 10 hackathons.

The unique concept of curated hackathons starts with a discussion with partner organisations to define challenges that can be tackled during a 3-day hackathon preceded by a 6-week-long team building and hackathon preparation. Once a challenge is determined,

[8] Using HEP Expertise for Social & Humanitarian Impact, PoS ICHEP2018 (2019) 564

a rigorous application process begins, where participants apply to the event, sharing their motivation to take part and presenting their background. THE Port hand-picks the members of each team, bringing together participants from various backgrounds. Six weeks before the start of the event, team members meet with two coaches from THE Port, members of the challenge-setting organisation, and other actors facing the same challenge in the field. They then meet online as needed until the day of the event to define their work plan for the hackathon and gather as much information and material they can to fulfil their objective of coming up with a working prototype addressing their humanitarian challenge.

The availability of CERN's IdeaSquare and Globe to host this series of events has been instrumental in attracting participants and enabling them to tackle their challenges in optimal conditions.

CERN Webfest

The CERN Webfest, held annually in Summer between 2012 and 2023, brings together bright minds to work on creative projects. Participants work in small teams, often designing web and mobile applications that can be of benefit to society. Webfest isn't just for those who can code: everyone is welcome to join in and contribute with their unique set of skills. Though most of the participants in the on-site iterations were from CERN and the Geneva area, the intake was truly global during the COVID pandemic, as there was no requirement to travel to CERN.

The main question that every project has to answer is how a certain technology developed at CERN can help enhance an aspect of educational and scientific activity. The goal for the projects is to be based on CERN's technological infrastructure to enhance the learning and research process, and, in that way, directly or indirectly help improve science.

Experimental Involvement

ELISA (Experimental LInac for Surface Analysis)

Housed in the CERN Science Gateway, ELISA—a 2 MeV proton accelerator—offers a promising platform for direct public engagement. In 2024, Solvay students participated in a hands-on surface analysis activity using PIXE techniques. The accelerator holds potential for expanding citizen-led research, such as mapping environmental samples across Member States.

Review

Citizen science at CERN has primarily manifested in volunteer computing, educational programmes and thematic hackathons. However, as computing becomes increasingly centralized and personal computing is switching increasingly to mobile devices where battery life matters, there may be reduced public engagement with volunteer computing. Simultaneously, participatory formats such as hackathons and small-scale experimental collaborations are gaining traction.

This signals an opportunity to renew CERN's strategic engagement with citizen science, aligning it with broader trends in open science and public engagement.

Generally, for the updated implementation plan, we suggest:

- Establish a Coordination Mechanism
    - Appoint a focal point within the Open Science Office to coordinate citizen science efforts.
    - Initiate discussions through the OSPF on CERN's strategic approach to citizen science within the next two years.
    - Encourage collaboration between experiment teams, outreach groups, and the Open Science Office.

- Define Citizen Science Typologies
    - Map and differentiate citizen science activities at CERN by their methodology, public engagement level, and scientific output.

- Foster Institutional Support and Visibility
    - Depending on the discussion in the OSPF, e.g., include Citizen Science projects in CERN's communication strategy
    - Assess resource needs for citizen science projects

- Evaluate and Monitor Impact
    - Develop Key Performance Indicators (KPIs), such as:
        - Number and type of citizen science projects
        - Number of participants and retention rates
        - Participant satisfaction
        - Impact on public understanding of science and perception of scientists
    - This evaluation should include resource allocation for research-based assessment of long-term effects on participants and scientific outputs.

Hackathons as Strategic Elements for Citizen Science at CERN

Hackathons at CERN represent a powerful manifestation of the principles outlined in CERN's Open Science Policy, particularly in fostering "meaningful public participation in citizen science programmes." Events like THE Port Humanitarian Hackathons and the CERN

Webfest serve as unique bridges between CERN's scientific expertise and societal challenges, embodying true bidirectional knowledge exchange. These events transcend traditional citizen science models by not merely inviting citizens to contribute to predefined scientific tasks, but by encouraging them to co-create solutions to humanitarian and social challenges using CERN's technological infrastructure and expertise.

THE Port series demonstrates a particularly effective approach through its curated methodology, where careful selection of diverse participants and extended preparation periods create interdisciplinary communities blending scientific rigor with real-world problem-solving. Meanwhile, the CERN Webfest shows how accessible formats can engage broader audiences in applying CERN technologies to educational and scientific activities. These complementary models align with the UNESCO Recommendation on Open Science, emphasizing "open engagement of societal actors" and "collective intelligence for problem solving."

Moving forward, CERN should continue supporting hackathons as one of several strategic approaches to citizen science by: 1) developing formal mechanisms to track and support promising prototypes beyond the hackathon phase; 2) creating educational resources based on hackathon methodologies for broader dissemination; and 3) establishing metrics to evaluate their impact on both scientific advancement and societal benefit. This would position CERN's hackathon model as an innovative template for research institutions worldwide seeking to make science more inclusive, responsive, and relevant to society's needs.

CERN Science Gateway – ELISA Proton Accelerator: A Platform for Public Participation

ELISA (Experimental LInac for Surface Analysis) is a 2 MeV proton accelerator designed for surface analysis using techniques such as PIXE (Proton-Induced X-ray Emission). These methods have applications across multiple fields, including materials science, cultural heritage preservation, and environmental monitoring.

In 2024, a small group of students from the Solvay Programme participated in a hands-on session where they performed material analysis alongside a CERN physicist. They were able to analyse the resulting data independently on their own laptops. This pilot activity demonstrated the potential of ELISA for future public engagement.

The project is now part of a broader discussion on how to incorporate citizen science into the activities of the upcoming Science Gateway. In particular, it opens up opportunities for collaborative research projects—for example, creating sample-based environmental or mappings across different Member States based on the origin of analysed materials.

Moving forward, CERN should support this project as one of several strategic approaches to citizen science by: 1) establishing collaboration between the scientific team, the education and outreach team, and members of the public; 2) bringing together the necessary expertise to define the types of research that can be carried out and the appropriate levels of public involvement; and 3) allocating sufficient resources to support all aspects of the project, including participant coordination, accelerator operation, experiment execution, collaborative data analysis, results communication, and project evaluation.

Final draft with all chapters

Review of the Open Science implementation plan

List of editors:

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Introduction and methodology

In October 2022, the CERN Directorate approved the CERN Open Science Policy, formalizing the Organization's longstanding commitment to open knowledge dissemination and public engagement. The policy outlines the following domains of open science practice at CERN: open access to publications; open data; open source software and hardware; research integrity; reuse and reproducibility; infrastructure provision for open science; research assessment and evaluation; education and training; and citizen science. The Open Science Policy is accompanied by an implementation plan that describes how CERN intends to reach its open science goals, and is regularly updated.

In 2024, efforts began to develop a comprehensive, global monitoring framework for open science that will include clearly defined key performance indicators (KPIs) to evaluate progress and impact. While this review references some preliminary elements of the framework, it is important to note that the initiative is still in its early stages. The framework's development and refinement will continue over the coming years, and further details and results are expected in subsequent phases.

This review was conducted in close collaboration with editors of the policy document and the associated implementation plan, as well as members of the Open Science Practitioners Forum involved in different open science activities at CERN.

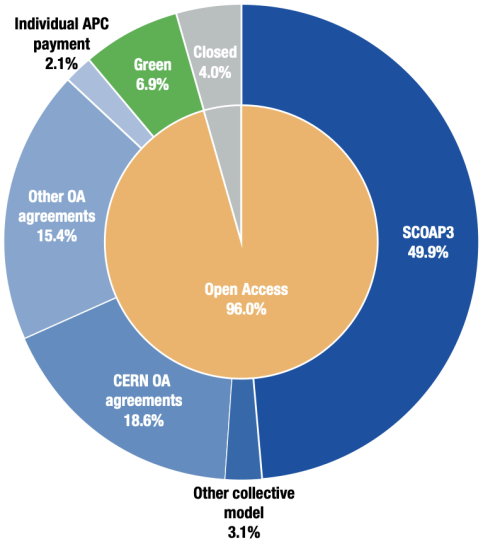
This CERN internal document examines progress made in 2023 and 2024 in various open science activities in light of the implementation plan issued in 2023. The Outlook sections outline goals for 2025 and 2026 for each activity within the Organization. These outlooks will form the basis for the implementation plan for 2025 and 2026 after the Open Science Steering Board discusses and approves them.

A summarized public version of this review will be made available as the inaugural CERN Open Science report (planned for release in Q3 of 2025).

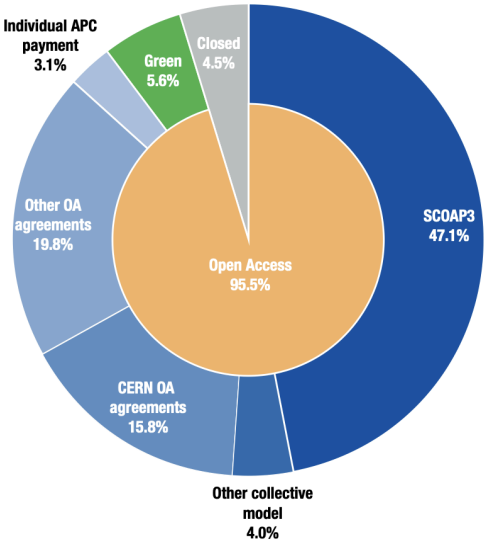
Open Access to Publications

Review for 2023/2024

In 2023 and 2024, CERN continued to make significant strides in achieving its policy goal of ensuring that all peer-reviewed publications emerging from the Organization should be published fully Open Access (OA). With over 96% of CERN's published articles compliant with this policy objective,, the Organization continues to lead in promoting the dissemination of scientific knowledge.



CERN Publications in 2023



CERN publications in 2024

SCOAP3

SCOAP3 continues to serve as the primary Open Access mechanism for CERN publications, covering approximately half of all CERN research outputs and providing authors with a transparent Open Access option beyond CERN's immediate scope. In 2024, SCOAP3 celebrated its 10th anniversary with various events hosted by national partners representing the global diversity of the collaboration. During 2023-2024, preparations were

made for Phase 4 (commencing in 2025), including the development of an innovative new contract structure with participating publishers. These updated contracts now incentivizeOpen Science practice, including data/software availability requirements and enriched metadata provision.

Other Collective Models

CERN prioritizes collectively funded and equitable models for the dissemination of scientific research. The organization currently provides financial support to several initiatives, including:

- Physical Review Accelerators and Beams (Sponsorship model)
- Annual Reviews (Subscribe2Open)
- SciPost (Sponsorship model)

While these outlets do not cover a large portion of CERN publications, the organization remains committed to supporting similarly equitable and cost effective open access models for content relevant to the CERN community. CERN also supports an equivalent model for books, through its participation in the Direct to Open progam by MIT press.

CERN Open Access Agreements

As of 2024, CERN maintains twelve Read & Publish agreements with publishers. The cost of these agreements combines a Read" component (access to paywalled content), and the "Publish" component, which ensures that CERN authored papers are published open access. These agreements are negotiated by the SIS and CERN procurement team and are made publicly available on the ESAC registry[9].
Tailored to CERN's specific needs in terms of volume and subject area, these agreements facilitate semi-automatic Open Access publication for CERN-affiliated authors, though SIS must verify author eligibility.
Several challenges exist with these arrangements:

- They consume a significant portion of our budget, particularly with major publishers
- Benefits are limited to CERN-affiliated authors (not equitable)
- Eligibility determination based solely on corresponding authors' affiliations creates occasional problems for certain author groups.

Individual APC Payments

In accordance with policy, if an author submits a paper to a journal not covered by an agreement, the central Open Access fund managed by CERN SIS can cover the costs. While the number of such articles varies annually, it remains relatively small. Though this mechanism is administratively time-consuming, it is essential for maintaining a wide selection of publication options for authors.

Green Open Access

[9] https://esac-initiative.org/about/transformative-agreements/agreement-registry/

A small percentage of articles are available only through Green Open Access, meaning that only the preprint or accepted manuscript is openly accessible. This approach does not fully align with the Open Access policy.
These articles are typically not published in full open access because they are not automatically covered by Read and Publish agreements (due to lack of a CERN-affiliated corresponding author and the corresponding author's institution doesn't have an agreement with the publisher). Those articles would be in most cases eligible to be covered centrally by CERN SIS (with individual APC payment, but the CERN author does not contact CERN SIS for central funding in advance for the submission, and the article gets published in closed access. It is worth noting that such articles would generate direct costs for the Open Access fund if published with full Open Access.

Closed Access

The proportion of articles published under closed access remains small but is difficult to further reduce. This primarily concerns articles in fields where "preprint culture" is not established (i.e. where preprints are not shared on arXiv). While outreach efforts are made to understand authors' reasons for non-Open Access publication, resource constraints have prevented systematic follow-up.

Creative Commons Licensing

In 2023-2024, over 98% of articles published through CERN's agreements were made available under the CC-BY license, maximizing research reusability. Promotion of the CC-BY license continues within the community, with support provided to help authors understand its benefits for broader dissemination and reuse of their work.

Outreach Activities

CERN SIS has maintained a dedicated support line for inquiries from CERN authors on matters relating to Open Access to publications (Average of 125 tickets per year, without counting direct interactions). In addition, members of the SIS team delivered specialized presentations on open access publishing, provided documentation for the CERN collaborations, and addressed questions of specific groups in multiple fora. Information on the CERN Open Access and Open Science Policies was presented in onboarding sessions for all newcomers to raise general awareness, and Open Science modules were integrated in the Scientific Writing Course held at CERN (held 1 or 2 times per year).

Open Access to books

CERN supports Open Access book publishing through the SCOAP3 Books program, which since its launch in 2022 expanded the scope of program beyond journals into the realm of scientific monographs and text books in high-energy physics and adjascent fields. At the end of 2024, 95 Open Access books have been published under the auspices of this project[10].

Participation in conversations on Diamond Open Access

[10] https://scoap3.org/scoap3-books/

https://cds.cern.ch/record/2919182

In 2024, the the Diamond Open Access movement (encompassing initiatives that offers free access to both authors and readers, funded through means such as institutional support or grants) gained in global traction.. Diamond OA is closely aligned with CERN's SCOAP3 approach and the support of the collective models. Several members of the SIS team participated in the 2nd Diamond OA conference in Cape Town in December.

Outlook

- Run the operations of SCOAP3 Phase 4 (2025-2027/2029) and prepare tPhase 5 (2028/2030 and beyond)

- Continue to offer diverse Open Access mechanisms to allow CERN authors to publish their worksOpen Access, with the aim to further reduce the share of closed publications, and monitoring the related costs.

- Develop focused communication materials and training to continue to increase awareness and knowledge among the community.

- Assess the need to adapt the Open Access strategy for the next years focusing in particular on:
    - Reviewing the mpact and efficiency of Transformative Agreements at CERN and define the needs for such agreements in the coming years.
    - Maintain or increase support for "collective models" ("Diamond"), when relevant for the CERN community, and continue to participate in and inform the global movement.

Open Data and Reuse

Review for 2023/2024

The Open Data Working Group (ODWG) was established in February 2020 to define an Open Data policy for the large LHC experiments. The group successfully created both a public policy document[11] outlining broad aims and an internal implementation document[12] detailing per-experiment release schedules.

By the end of 2020, the policy was endorsed by the Collaboration Boards of the four large LHC experiments, with implementation required to begin within five years. In 2021, following discussions with the Data Resources Committee (DRC), the IT department committed to providing storage resources for the first five years of the policy (until the end of 2025) and subsequently hired a new staff member in 2022 to work on tape integration of Open Data storage to reduce long-term costs.

[11] https://cds.cern.ch/record/2745133/files/CERN-OPEN-2020-013.pdf
[12] https://cds.cern.ch/record/2745081

The large LHC experiments have made significant progress in releasing data consistent with the policy:

- CMS has continued their already extensive data releases, including the full Run 1 pp dataset (December 2022), Run 2 pp data (April 2024), and Run 1 HI data (September 2023)
- LHCb delivered major data releases in December 2022 and December 2023 (full Run 1)
- ATLAS released 2015 and 2016 pp data in July 2024 and their first Heavy Ion release (2015 PbPb data) in December 2024
- ALICE's first large release appears to be forthcoming

The ODWG's mandate expanded in 2023 to include small LHC experiments (TOTEM, LHCf, MoEDAL, FASER, SND), all of which endorsed the existing policy by March 2023, though implementation policies remain pending. Further expansion to non-LHC experiments has begun, with ISOLDE developing their own tailored policy while discussions continue regarding other facilities.

Outlook

While the Open Data implementation plan continues to progress, several key questions require focused attention to ensure its long-term success.

Resource planning: Securing storage resources beyond 2025 is a critical priority, as the current agreement with IT expires at the end of 2025.

LHCb will finalize "ntuple wizard" in 2025, enabling more efficient storage and use of data without extensive storage requirements on the portal.

Expanded implementation: Follow-up is needed in 2025 regarding Open Data policies for:

- ISOLDE;
- Antiproton Decelerator (AD) experiments and nTOF;
- Discussions with SPS experiments about adopting the LHC policy, with a particular focus on addressing human resource concerns.

Monitoring framework: Ongoing discussions within the ODWG and the CERN Open Science Office aim to define Open Data monitoring metrics and KPIs to track implementation progress. This effort, coordinated by the OS office, needs to be continued in 2025 and 2026, with the definition of an initial set of KPIs as an early outcome.

Legacy data preservation: Efforts regarding older experimental data (JADE and LEP experiments) highlight important lessons about data preservation, particularly regarding software, operating systems, and hardware consistency.

The successful expansion of Open Data policies across CERN's experimental program will require continued coordination, resource allocation, and technical solutions to address the diverse needs of different experimental communities.

Open Source Software

Review for 2023/2024

CERN founded its Open Source Program Office[13] (OSPO) in September 2023 to support open source activities at CERN, including those of CERN teams and users. The OSPO consists of representatives from 10 departments and groups: BE, EP, HSE, IPT-KT, IR, IT, RCS-SIS, SY, TE, and TH. These departments represent diverse open source use cases and thus allow the OSPO to address a wide range of requirements and expectations.

On May 30th, 2023, the mandate of the CERN OSPO was officially endorsed by the CERN Enlarged Directorate. The approval of the mandate can be seen as the OSPO's first significant achievement, aligning virtually the whole Organization around open source. In this context, the mandate defined "internal" obligations of the OSPO, geared towards facilitating best practices in the CERN community, and "external" facing objectives, focused on showcasing CERN's open source contributions to the world.

To account for the OSPO's internal and external facing roles, its inauguration in 2023 was split into a public event on November 28th which hosted a number of renowned open source experts, and an internal event which focused on discussions with the CERN open source community on November 29th.

In 2024, the Open Source Program Office (OSPO) significantly modernized CERN's approach to open source software by developing comprehensive new guidelines and best practices. Building upon the recommendations published by the Open Source License Task Force[14] in 2012, the OSPO brought together key stakeholders from across the Organization —including representatives from BE, IT, and EP, the legal service, and the Knowledge Transfer group—to create a streamlined framework acceptable to all parties. This collaborative effort resolved a long-standing friction between CERN's status as an international organization and standard open-source licensing requirements, enabling publication under unmodified open-source licenses and ensuring compatibility with the global open-source ecosystem.

The new guidelines and recommendations[15] represent a transformative shift for CERN: software is now open-source by default, contributing to external projects requires minimal bureaucracy with simplified Contributor License Agreement (CLA) procedures, and developers can focus on technical aspects rather than administrative hurdles. This achievement not only reduces burdens across the Organization, but also enhances CERN's standing in the open-source community, with external organizations including the Bank for International Settlements and UN working groups expressing appreciation for the documentation produced by the CERN OSPO.

[13] The first OSPO report is available at https://repository.cern/records/xm77y-fbp66
[14] Report at https://cds.cern.ch/record/1482206
[15] The OSPO's recommendations are published at https://ospo.docs.cern.ch

A proof of concept of the CERN Open Source Software Catalogue (OSSCAT) has been developed and deployed, and will be made available to the public during 2025. The catalogue will allow developers to submit their project for inclusion themselves.

The OSPO provides essential guidance on open source implementation through a structured ticketing system. During 2024, the office received 9 formal requests for assistance, successfully resolving 2 of these inquiries. The resolved cases involved helping projects with licensing selection, managing contributor consent requirements, copyright assignments, and ensuring license compatibility across complex codebases. These services demonstrate the OSPO's role in facilitating the practical aspects of open source adoption throughout the organization.

An event was organised in November 2024 to increase awareness of the OSPO in the CERN Open Source community; to showcase its work and to collect feedback. The event also included invited talks on the importance of open source and the OSPO in the wider scope of open science, as well as on data commons in the context of AI and challenges of sustainable open source software. Feedback by the community touched on topics such as how CERN can contribute to open-source projects, requests for stronger focus on open-source alternatives, and concerns raised on the ethical use of AI.

Outlook

During the course of 2025, the OSPO foresees:

- publishing the Software and Hardware Catalogues, after populating them with CERN open-source projects.
- finalising a workflow and tool for selecting the most appropriate license for a project
- a collaboration with Zendis and the Sovereign Tech Agency, and to actively join the European Commission’s European OSPO network.

Open Source Hardware

Review for 2023/2024

In the field of Open Source Hardware, two major milestones have been achieved in 2023. First, the CERN Open Source Program Office (OSPO, see previous chapter) was inaugurated, with a special focus on Open Source Hardware (OSHW) which is considered a “first-class citizen” along with Free and Open Source Software (FOSS).
Second, a plan for the evolution of the Open Hardware Repository (OHR) was developed. When it was initially created, it played a double role: that of a “forge” in which to store and version design files, and that of a catalogue. With places like github.com and gitlab.com now offering forge-like services much more efficiently, it was decided to focus the future evolution of the OHR on its role as an easy-to-browse catalogue of OSHW solutions. Considerable efforts were undertaken to facilitate this evolution of the OHR to a catalogue website.

Open source hardware activities in the context of the OSPO

https://cds.cern.ch/record/2919182

In 2024, the OSPO addressed the categorization of gateware—the Hardware Description Language (HDL) code used to configure Field-Programmable Gate Arrays (FPGAs) and design Application-specific Integrated Circuits (ASICs)—which had previously occupied an ambiguous position between software and hardware in CERN's open source policy framework. After careful consideration, gateware was classified alongside hardware, establishing the Knowledge Transfer group as the default entry point for designers seeking dissemination guidance, whether through open source or proprietary channels.
Another important area of activity was documentation, in particular the provision of guidance on best practices to open-source hardware designs. These recommendations have been published on the OSPO documentation website.
Finally, the following three Key Performance Indicators (KPIs) were established to gauge progress in the implementation of the OSHW part of CERN's Open Science Policy:

- Percentage of OSHW designs in CERN's electronics drawing office. The drawing office is a central point for electronics design at CERN. Even though not all designers at CERN use the service, it is a good estimation for the amount of open-sourcing happening in the hardware realm. In 2024, 15 out of circa 200 designs (7.5%) were open sourced.
- Many OSHW designs are currently being performed using proprietary design tools. Since a fully open-sourced design should be made using OSS tools[16], a KPI representing the percentage of designs in CERN's electronics design office using KiCad, an OSS tool supported by CERN IT to design PCBs, was added. In 2024, 8 out of the circa 200 designs (4%) in the electronics drawing office were using KiCad.
- One big contribution of CERN to the OSHW ecosystem is the CERN Open Hardware Licence (OHL), which designers around the world use to share designs in a legally-sound way. The number of designs using the CERN OHL version 2 in github.com indicates the impact of the licence. In 2024, there were 1343 projects on Github using one of the three CERN OHLs, out of which 520 used the permissive, 286 the weakly-reciprocal, and 537 the strongly-reciprocal license. These numbers will serve as a baseline to measure the growth in usage every year in the future.

From these numbers it is apparent that there is room for improvement in implementing open source hardware practices at CERN. To improve CERN's performance in the KPIs defined above, future activities are geared towards facilitating better KiCad support and spreading information more widely, including public presentations on the benefits of open-sourcing hardware in many domains and applications.

Outlook

New OSHW Catalogue (H1 2025)

- Launch of the new Open Hardware Repository (OHR) catalogue at ohwr.org

Guidance on Best Practices

- Develop a license chooser web application for both OSS and OSHW

[16] For an explanation for this see https://medium.com/@j.serrano/why-you-should-use-free-and-open-source-software-to-design-your-hardware-aa36d6adda06

- Improve PCB design guidelines in collaboration with ATS Electronics Forum
- Create documentation for OSHW ASIC design using OSS tools

Promote KiCad Adoption at CERN

- Automate migration of CERN component libraries to KiCad format and open-source them
- Add KiCad guidelines on the OSPO documentation site
- Liaise with the CERN drawing office to ensure KiCad meets their functionality needs
- Communicate with electronics designers to raise awareness about KiCad

Expand OSHW Scope (2026)

- Initiate CERN-wide debate on extending OSHW activities to mechanical design
- Implement support for OSHW in CERN's Product Lifecycle Management solution

Resource Requirements

- Several months of work in 2025 to properly open-source CERN KiCad libraries
- Resources for PLM system integration in 2026 (specific requirements to be determined)

Research Integrity, Reuse and Reproducibility

Review for 2023/2024

The implementation plan lists several measures towards the reusability of physics analyses and connected research products as well as the metadata linking them together. Overall, progress has been limited due to missing coordination and unclear responsibilities.

The plan on what research integrity entails for particle physics, planned to be drafted within the next two years, has not been drafted. On the positive side, as an independent effort there has been significant work led by the chair of the ICFA Data Lifecycle panel (Kati Lassila-Perini) in this direction, drafting “recommendations for best practices for open science” (in particle physics).

There has been an exchange across the LHC experiments on analysis preservation, either thanks to initiatives of well-connected individuals or through topical groups of the HEP Software Foundation (HSF). Specifically, a workshop on analysis workflow languages was organised by individual members of the LHC experiments in April 2024[17]. The event took place at CERN IdeaSquare with participation from all LHC experiments and beyond. The exchange and discussions led to the organisation of a Snakemake Hackathon in March 2025[18], also hosted at CERN, attracting a lot of participation from bioinformatics in addition to particle physics.

[17] https://indico.cern.ch/event/1380367/
[18] https://indico.cern.ch/event/1441041/

The HSF Data Analysis Working Group (DAWG) held a handful of meetings on various topics and common efforts in the wider community[19]. The LHC Reinterpretation Forum, which in particular facilitates exchange between the experimental and theoretical communities, continued to hold its roughly annual workshops[20]. In 2025, this will be continued as an official LHC Reinterpretation Working Group.

The development of templates to facilitate analysis preservation has largely been confined to the individual experimental collaborations. For example, within CMS, significant effort has been made by a newly created Common Analysis Tools Group to promote the reusability and reproducibility of analyses. Templates and services to facilitate the creation of software container images and for automated testing of analysis code have been developed. Furthermore, mechanisms to publish statistical models were developed which were subsequently approved by the CMS collaboration board . Such model publication remains voluntary, however, and only few analyses have released their models so far.

Of particular importance are the regularly organised training events of the HSF Training Group. Training events on analysis preservation/pipelines were organised once per year[21] in addition to other software training[22]. In-between those events, hackathons to improve the existing training material were held. As a pre-event to the 2024 Conference at Computing in High-Energy and Nuclear Physics, a community event on training took place in Krakow, Poland[23].

To facilitate analysis preservation and reuse, the REANA platform plays an important role. Individual members of the community using the platform provided feedback to improve its usability and user experience, leading to several patch releases[24]. With the exception of the workshop on analysis workflow languages, there, however, has been no exchange on needs and priorities concerning analysis preservation services.

Outlook

Dedicated Coordination

- Allocate personnel resources for coordination and implementation
- Appoint responsible persons/bodies with dedicated FTE share

Research Integrity Framework

- Build on ICFA Data Lifecycle panel's "recommendations for best practices for open science"
- Develop a formal plan for research integrity in particle physics

Analysis Preservation Templates

[19] https://indico.cern.ch/category/10914/
[20] https://twiki.cern.ch/twiki/bin/view/LHCPhysics/InterpretingLHCresults
[21] https://indico.cern.ch/event/1219810/ and https://indico.cern.ch/event/1375507/
[22] https://indico.cern.ch/category/11386/
[23] https://indico.cern.ch/event/1410343/
[24] https://blog.reana.io/

- Organize focused workshops for sharing templates across collaborations
- Identify dedicated contacts within experiments
- Integrate templates with REANA platform

Enhanced Training

- Provide more regular training events on CERN-specific tools like REANA
- Define regular frequency for training programs

Automated Preservation Checks

- Develop automatic preservation and integrity checks
- Ensure analyses remain functional despite technological upgrades

Reporting and Monitoring

- Require experiments to report progress to the OSSB or another CERN body
- Establish connections between OSPF, HSF DAWG, and other relevant groups

Infrastructure provision for Open Science

Review for 2023/2024

Due to a lack of resources among the different teams, there has been no coordinated strategic alignment with the implementation plan 2023/2024. However, numerous valuable developments have emerged across the various infrastructures existing at CERN.

INSPIRE remains a key platform for HEP research globally, with 9 million visits from users in 2024. It now totals 1.7 million literature records and tracks 36 million citations between papers. In order to increase the accuracy of the citation data, users can now easily correct reference lists themselves; 9.4 thousand references have been corrected by users in 2024.

Open Data Portal: celebrating its 10 years anniversary
In 2014, the CERN Open Data portal was launched to make data from LHC experiments publicly available. The portal was designed to provide both the general public and researchers access to searchable, downloadable data for educational and theoretical analysis purposes. Since its launch in 2014, the portal has grown exponentially, now hosting over 5 petabytes of open data from not only LHC experiments but also other particle physics experiments like DELPHI and PHENIX.

REANA
A key success in demonstrating the impact of preservation and reuse of analyses is the reinterpretation of ATLAS Run-2 data to search for supersymmetry using the pMSSM model. This effort, led by ATLAS physicists, showcases how REANA enables large-scale workflow

execution—over 9,000 workflows were run, as presented by Ben Hodkinson[25]—to extract new physics insights from existing data[26].

CDS
The current CERN Document Server (CDS) platform serves as the official archive for the organization's research output. Its adoption continues to grow among research collaborations, currently receiving approximately 40,000 submissions annually. Simultaneously, CDS is undergoing a significant migration to a new, modern, user-friendly, and FAIR platform built upon InvenioRDM (repository.cern). This transition aligns with contemporary Open Science standards and best practices. Select collaborations have already begun using the new platform for publishing and archiving their content. The content migration started in 2024 and will extend over the coming years. Notably, the first migrated collection has been preserved long-term through integration with the CERN Digital Memory project.

Zenodo continues to see strong global engagement, with over 400,000 users affiliated with 9,000 research organizations across 161 countries. Notably, 50% of users and 40% of organizations are from CERN Member States. The platform hosts over 4.5 million records, totaling approximately 1 PB of logical data (equivalent to ~4 PB of physical disk space due to replication).
Zenodo plays a key role in supporting EU-funded research dissemination: 23% of all FP7, H2020, and Horizon Europe projects have deposited research outputs on the platform.

CERN Analysis Preservation:
Between 2023 and 2024, the CERN Analysis Preservation (CAP) project expanded its capabilities and reach significantly. In 2023, CAP strengthened its technical foundation, improved user experience with advanced form features and fostered adoption through the Landscape Project and new collaborations, such as the Analysis Description Languages (ADLs) and CMS Monte Carlo Generator working groups. The year also saw the launch of the react-formule form-builder as an open-source tool and the introduction of an Admin Panel to give users more control. Building on this momentum, 2024 saw CAP transition towards broader external adoption, as demonstrated by its presence at DPHEP 2024, where its utility was showcased across various institutions. Meanwhile, infrastructure was upgraded for scalability and independence from CERN-specific systems, and AI-driven form generation and deeper integration of ADLs signalled CAP's continued innovation. Together, these developments reflect CAP's evolution into a more robust, accessible and collaborative platform for preserving scientific analyses.

CERN Digital Memory project has completed the digitization of twentieth-century analog multimedia carriers, including films, videotapes, negatives, slides and audio reels, with the aim of ensuring their digital preservation. At the same time, an IT strategy and platform were put in place to facilitate standard preservation processes. This has enabled the contents of

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[25] https://indico.cern.ch/event/1380367/contributions/5880484/attachments/2831190/4946672/RECAST%20in%20ATLAS.pdf

[26] The methodology and impact are described in recent publications and summarized in a blog post by Matthew Feickert (March 2024)
https://ep-news.web.cern.ch/content/extending-atlas-physics-reach-analysis-reuse-technology

https://cds.cern.ch/record/2919182

the ILC document server to be preserved after it was phased out, and has been activated as a service for all data submitted to CERN's new institutional repository (repository.cern).

CERN also supports the Global Open Infrastructure beyond CERN

CERN actively supports ORCID[27] (Open Researcher and Contributor ID) by integrating it into its scientific publishing and data systems to ensure accurate attribution of research outputs. By encouraging researchers to link their ORCID iDs with CERN's institutional platforms, such as INSPIRE and CDS (CERN Document Server).

CERN supports DataCite[28] by using its services to assign Digital Object Identifiers (DOIs) to datasets, software, and other research outputs hosted on platforms like Zenodo, CDS and the CERN Open Data Portal. By leveraging DataCite's infrastructure, CERN ensures that these digital resources are citable, persistent, and easily discoverable, thus promoting transparency, reproducibility, and credit for data sharing.

CERN contributes further to Open Science efforts through its support of the SCOSS[29] (Global Sustainability Coalition for Open Science Services) initiative. SCOSS serves as a funding platform for key infrastructure services essential for the OA and OS ecosystem. By supporting SCOSS, CERN SIS ensures the sustainability and continued operation of essential services that facilitate OA and OS practices (e.g. ROR[30], DOAJ[31])

First discussed in 2023, the DOAB[32] and OAPEN[33] projects have been successfully migrated to CERN infrastructure by the end of December 2024. This milestone marks a significant step forward in increasing the operational efficiency and reliability of OAPEN and DOAB as vital open access book infrastructure for the global research community.

In 2024, CERN signed the Barcelona declaration on Open Research Information[34]: it is a commitment by research organizations to make openness the default for the research information they use and produce, supporting the transition to open science through transparent, accessible, and auditable data.

Outlook

- Create a light-weight Open Infrastructure Working Group to progress on the tasks of the implementation plan.
- This Working Group, in collaboration with the different service providers, will:
    - Define a non-comprehensive and initial (pilot) list of core open services needed to practise reusable and open research, and that allow the community to comply with the open science policy.

[27] https://orcid.org/
[28] https://datacite.org
[29] https://scoss.org/
[30] https://ror.org/
[31] https://doaj.org/
[32] https://www.doabooks.org/
[33] https://oapen.org/
[34] https://barcelona-declaration.org/

https://cds.cern.ch/record/2919182

    - These services, when it makes sense, should do a FAIR assessment, like Zenodo did[35], make it available to the service users and share it with the OS office
    - Define a list of key principles to assess the openness of infrastructure services and evaluate them, in line with best practices and recommendations from the OS community.
    - Define an initial set of KPIs that the services should track to assess the implementation of the policy
    - Recommend solutions to identified gaps within services as well as interoperable solutions between services.
- The WG shall meet regularly (e.g. once a month)
- It will produce a short document and make it public with the assessments and implemented actions

Research Assessment and Evaluation

Review for 2023/2024

CERN is an early signatory of the Coalition for Advancing Research Assessment (CoARA), an association of more than 700 institutions[36] promoting qualitative research assessment practices, supported by the appropriate use of quantitative indicators. CoARA constitutes an important initiative in the context of CERN's open science activities since it challenges research assessment based solely on publication based metrics and promotes the consideration of a broader spectrum of research practices in the evaluation of researchers and research proposals, including open software, data and hardware activities, as well as education and teaching.

During the past two years, CERN SIS has created general awareness amongst management of the CERN research sector regarding the need for a reform of research assessment and worked towards the creation of a CoARA Action plan as foreseen in the Implementation Plan. The first version of this Action Plan[37] was published in December 2024 after management approval.

As part of the efforts of drafting the action plan, SIS has worked together with representatives of HR and EP to discuss current practices of hiring, promotion, annual performance assessments (MERIT), and limited duration to indefinite contract transitions (LD2IC). These practices have been identified as central research assessment practices through interviews with researchers involved in these processes in the Experimental Physics (EP) and Theoretical Physics (TH) department. Deliberations with the human resources department ensured that the already existing HR Excellence programme aligns with the measures foreseen in the CoARA Action Plan.

[35] https://about.zenodo.org/principles/
[36] https://coara.eu/coalition/membership/
[37] https://cds.cern.ch/record/2919182

Outlook

The Implementation Plan will be adjusted in accordance with the CoARA Action Plan. This includes the harmonization of timelines between the Implementation Plan and the Action Plan. The Action Plan will be reviewed and amended annually.

As a first deliverable of the Action Plan, a review of central CERN guidelines will be undertaken in the course of 2025 and information material will be developed to create awareness among hiring managers and promotion committee members.

Further actions laid out in the Action Plan will also consider procedures of research proposal assessment, as measures taken so far have only targeted assessment processes of individual researchers.

Training, Education and Outreach

Review for 2023/2024

Open Science Training

The implementation plan aimed to establish training courses on Open Science principles, including FAIR data, Data Management Plans, and Open Access publishing. However, as of April 2025, no formal training had been put in place, with the exception of the scientific writing course containing one session on Open Science and Open Access, and the onboarding sessions organised by SIS containing information about Open Access publishing and the Open Science Office.

Open Science Education

Several education initiatives were successfully carried out and are listed below. Where specific statistics for 2023 and 2024 are available, they are indicated (for 2023, being based on CERN's annual report[38]), otherwise, stable numbers are assumed. The activities listed were identified through discussions with various stakeholders and a review of available resources, however, this may not represent an exhaustive list of all relevant initiatives.

A. Hosting Education Programmes

- Hands-on workshops in the Science Gateway engaged about 5,200 people in 2023 and over 25,000 in 2024.
    - There were four workshops designed for 16 to19 year-olds, covering topics such as superconductivity and electron beams. Additionally, six workshops for ages 5 to 15 explored subjects like the nature of science, programming and magnets.

[38] https://cds.cern.ch/record/2897082?ln=en

https://cds.cern.ch/record/2919182

    - Workshops open to the public were highly appreciated, receiving a Net Promoter Score of over 80%.
- Interactive science shows in the Science Gateway attracted over 2,500 attendees in 2023 and 40,000 in 2024.
    - The shows covered topics such as detectors and the structure of matter.
- Close to 183,000 people took part in guided tours in 2023[1] (stable numbers assumed for 2024).
- 27 teacher programs in 2023 and about 40 in 2024 welcomed 801 teachers in 2023 and over 1,000 in 2024.
- The CERN Solvay education programme received over 600 student applications, with about 100 high school students attending one of the week-long summer camps.
- The Beamline for Schools competition saw an increase from 379 proposals in 2023 to 461 in 2024, with participation growing from about 2,500 to 3,000 students.
    - In 2023, 8 high school students from the USA and 10 from Pakistan were selected to pursue their projects at CERN. In 2024, 5 students from Estonia and 5 from Japan were chosen.

B. Offer Online Materials

- Over 100 virtual tours reaching nearly 4,000 participants in 2023 (assuming stable numbers for 2024).
- A pilot version of “A Particle Physics Course for High-School Students” launched in late 2024[39], including 16 chapters of videos and quizzes.
- 12 new education videos published as part of the Solvay programme in 2023 reached approximately 2 million online views.
- Launched in 2024, CERN’s educational resources platform[40] serves as a hub for promoting CERN-produced educational materials to students and teachers. Resources created by the IR-ECO-TSP section are hosted directly on the site under an open license, while other resources are linked externally, often without a clearly defined license.
    - Teachers frequently express their gratitude for these materials, with many implementing e.g. cloud chambers at their schools using the provided manual. Since the resources are freely available, an exact usage count is not available.
- The IT department and LHC experiments maintain their own databases of resources, though these could benefit from a more streamlined and coordinated approach.

C. Conduct Physics Education Research

- In 2023, 11 scientific papers were published on this topic and 1 student finished their doctorate degree. In 2024, 3 scientific papers were published and 1 student finished their doctorate degree.
    - The research explores various themes, including approaches to improving physics teaching and student engagement, the integration of particle

[39] cern.ch/PPC
[40] educational-resources.web.cern.ch

detectors into classrooms and the development of learning materials for advanced physics.
    - Contrary to the implementation plan, no research was conducted to promote the conceptual understanding of the open nature of science.

D. Offer Academic Training

- In 2023, CERN organised 2 physics schools, 3 accelerator schools and 4 computing schools. These numbers grew to 2, 4 and 5 in 2024.
    - The schools host public Indico pages that provide the lecture slides.
    - In some cases, student outreach presentations are recorded and uploaded.
    - Proceedings are published as CERN Yellow Reports.
- About 30 academic lectures were made public in 2023 and 10 in 2024[41].
- Around 70 summer student lectures per year were also made public[42].

Open Science Outreach

A. Host Outreach Events using Open Data

- International Masterclasses organised by IPPOG involving LHC Open Data reached approximately 10,000 high school students in 2023 (assuming stable numbers for 2024).
- Independent initiatives, such as those led by German schools, have organised about 70 Masterclasses in 2023 and 2024, reaching around 1,500 high school students.
    - A similar, though less centralised, initiative exists in the UK, but no official participation numbers are available.
- On the International Day of Women and Girls in Science, around 500 students participated in dedicated education and outreach activities in 2023 and 700 in 2024.
- On the World Wide Data Day, nearly 50 schools participated in dedicated education and outreach activities in 2023, reaching about 1,000 students (assuming stable numbers in 2024).

B. Develop Exhibitions

- Exhibitions developed at the Science Gateway include about 50 hands-on experiments, over 120 CERN videos, nearly 50 real objects, and 4 art commissions.
- A Science Gateway Inspiration Book was created in 2024 to inspire and assist science centers, museums, and institutions in developing exhibitions and events.

Outlook

Open Science training courses were not launched as planned. Communication with key stakeholders suggested revisiting the plan in early 2025 to assess resource requirements

[41] indico.cern.ch/category/72
[42] indico.cern.ch/category/97

and implementation steps. However, as training is a cross-cutting challenge that spans multiple areas, it may not be best addressed in this chapter.

While extensive educational activities were undertaken, it remains unclear whether the open nature of science was adequately incorporated into these programs. This issue relates to the first Open Science Education aim: "host education programmes (e.g. hands-on workshops) for teachers, school and university students **covering the open nature of science.**" The existence of the programs outlined above may already be considered a contribution to Open Science, although they don't directly cover the topic of Open Science. Additionally, this concern ties into the second Open Science Outreach aim: "develop exhibitions for visitors (on- and off-site) **on the theme of Open Science and the importance of open data practices for wider society** (e.g. data driven decision making)." In the next chapter it will be described how part of the exhibition can be used to serve as a unique example for public engagement through Citizen Science.

The current approach to publishing educational and outreach materials lacks a unified strategy. Many online materials are without an open license. Discussions are currently ongoing with stakeholders on how to best archive CERN-produced education and outreach resources, and how to best associate them with an appropriate license. Moving forward, a standardised approach to licensing CERN's education and outreach materials should be established, aligning with open science principles such as CC-BY for text and CC0 for data.

For the updated implementation plan we suggest:

- Removing OS training from this chapter and instead requiring each chapter to cover its respective training efforts.
- Removing the requirement to explicitly cover the topic of Open Science in hosted education programmes and the exhibitions
- Add the need to collect the examples of education programs using CERN Open data.
- Continue efforts to make CERN-produced education and outreach resources publicly available under an open license.

Citizen Science

Review for 2023/2024

While no central strategy or coordinated effort has been undertaken in the past two years regarding citizen science at CERN, several ongoing and completed projects demonstrate an active engagement with the public. These initiatives reflect CERN's long-standing commitment to citizen science and its potential for inclusive scientific practices.

Volunteer Computing

LHC@Home

Operating since 2004, LHC@home[43], CERN's volunteer computing initiative, enables citizens to contribute computing resources for particle physics simulations. It delivers an average of 80 TFlops—comparable to a Tier-2 Grid site—across multiple LHC experiments. The project utilizes the Berkeley Open Infrastructure for Network Computing (BOINC), which provides infrastructure for similar projects[44] in various fields. The project relies on the BOINC infrastructure and continues to evolve through community engagement, including the 2024 BOINC workshop[45] co-organised by CERN.

Data Analysis and Classification Platforms

Zooniverse's New Particle Search - CERN & Oxford
In collaboration with the University of Oxford, this initiative invites citizens to participate in the classification of collision data, furthering discovery potential through distributed visual pattern recognition.

ATLAS Citizen Science
ATLAS has piloted multiple initiatives inviting public participation in data interpretation and classification tasks related to particle collision events.

The REINFORCE Project
As part of the EU-funded REINFORCE project, CERN collaborated on a demonstrator[46] involving the CMS and ATLAS experiments, engaging citizens in gravitational wave and neutrino detection data tasks.

Educational and Research Engagement

Citizen-Cyberlab & **Crowd4SDG**
Jointly operated with UniGE, UNITAR and CERN, this initiative[47] explores public involvement in solving sustainability challenges from SDGs, fostering both innovation and education.

Particle Physics Playground
Educational resources and environments, including data analysis toolkits, encourage young learners to explore physics and computing.

CMS Open Data and Masterclasses
Open access to CMS data has been leveraged for education and outreach, including global Masterclasses enabling students to engage with real particle physics data.

Hackathons and Innovation Challenges

THE Port
THE Port Humanitarian Hackathons[48] running at CERN in Autumn since 2014 are curated hackathons organised in-person in IdeaSquare (until 2019) and online (during the COVID

[43] https://lhcathome.cern.ch/lhcathome/index.php
[44] https://boinc.berkeley.edu/projects.php
[45] https://indico.cern.ch/event/1379525/overview
[46] https://www.reinforceeu.eu/demonstrators/new-particle-search-cern
[47] https://sdgsolutionspace.org/citizen-cyberlab/
[48] https://theport.ch

pandemic), with the final presentation held or streamed from the Globe of Science and Innovation.
These hackathons combine creative minds from CERN and non-profit organisations in interdisciplinary teams to work on humanitarian technology-related benefits to society. Interdisciplinary teams of hand-selected innovators work together on topics such as infrastructure, health, communication, and education. Since 2014, 54 projects have been tackled[49] by over 500 participants during 10 hackathons.

The availability of CERN's IdeaSquare and Globe to host this series of events has been instrumental in attracting participants and enabling them to tackle their challenges in optimal conditions.

CERN Webfest
The CERN Webfest[50], held annually in summer between 2012 and 2023, brings together bright minds to work on creative projects. Participants work in small teams, often designing web and mobile applications that can be of benefit to society. Webfest isn't just for those who can code: everyone is welcome to join in and contribute with their unique set of skills. Though most of the participants in the on-site iterations were from CERN and the Geneva area, the intake was truly global during the COVID pandemic, as there was no requirement to travel to CERN.
The main question that every project has to answer is how a certain technology developed at CERN can help enhance an aspect of educational and scientific activity. The goal for the projects is to be based on CERN's technological infrastructure to enhance the learning and research process, and, in that way, directly or indirectly help improve science.

Experimental Involvement

ELISA (Experimental LInac for Surface Analysis)
Housed in the CERN Science Gateway, ELISA—a 2 MeV proton accelerator—offers a promising platform for direct public engagement. In 2024, Solvay students participated in a hands-on surface analysis activity using PIXE techniques. The accelerator holds potential for expanding citizen-led research, such as mapping environmental samples across Member States.

Outlook

Citizen science at CERN has primarily manifested in volunteer computing, educational programmes and thematic hackathons. However, as computing becomes increasingly centralized and personal computing is switching increasingly to mobile devices where battery life matters, there may be reduced public engagement with volunteer computing. Simultaneously, participatory formats such as hackathons and small-scale experimental collaborations are gaining traction.

This signals an opportunity to renew CERN's strategic engagement with citizen science, aligning it with broader trends in open science and public engagement.

[49] https://theport.ch/projects
[50] https://webfest.cern/

Generally, for the updated implementation plan, we suggest:

- Establish a Coordination Mechanism
    - Appoint a focal point within the Open Science Office to coordinate citizen science efforts.
    - Initiate discussions through the OSPF on CERN's strategic approach to citizen science within the next two years.
    - Encourage collaboration between experiment teams, outreach groups, and the Open Science Office.

- Define Citizen Science Typologies
    - Map and differentiate citizen science activities at CERN by their methodology, public engagement level, and scientific output.

- Foster Institutional Support and Visibility
    - Depending on the discussion in the OSPF, e.g., include Citizen Science projects in CERN's communication strategy
    - Assess resource needs for citizen science projects

- Evaluate and Monitor Impact
    - Develop Key Performance Indicators (KPIs), such as:
        - Number and type of citizen science projects
        - Number of participants and retention rates
        - Participant satisfaction
        - Impact on public understanding of science and perception of scientists

    - This evaluation should include resource allocation for research-based assessment of long-term effects on participants and scientific outputs.

Hackathons as Strategic Elements for Citizen Science at CERN

Hackathons at CERN represent a powerful manifestation of the principles outlined in CERN's Open Science Policy, particularly in fostering "meaningful public participation in citizen science programmes." Events like THE Port Humanitarian Hackathons and the CERN Webfest serve as unique bridges between CERN's scientific expertise and societal challenges, embodying true bidirectional knowledge exchange. These events transcend traditional citizen science models by not merely inviting citizens to contribute to predefined scientific tasks, but by encouraging them to co-create solutions to humanitarian and social challenges using CERN's technological infrastructure and expertise.

THE Port series demonstrates a particularly effective approach through its curated methodology, where careful selection of diverse participants and extended preparation periods create interdisciplinary communities blending scientific rigor with real-world problem-solving. Meanwhile, the CERN Webfest shows how accessible formats can engage broader audiences in applying CERN technologies to educational and scientific activities. These complementary models align with the UNESCO Recommendation on Open Science, emphasizing "open engagement of societal actors" and "collective intelligence for problem solving."

Moving forward, CERN should continue supporting hackathons as one of several strategic approaches to citizen science by: 1) developing formal mechanisms to track and support promising prototypes beyond the hackathon phase; 2) creating educational resources based on hackathon methodologies for broader dissemination; and 3) establishing metrics to evaluate their impact on both scientific advancement and societal benefit. This would position CERN's hackathon model as an innovative template for research institutions worldwide seeking to make science more inclusive, responsive, and relevant to society's needs.

CERN Science Gateway – ELISA Proton Accelerator: A Platform for Public Participation

ELISA (Experimental LInac for Surface Analysis) is a 2 MeV proton accelerator designed for surface analysis using techniques such as PIXE (Proton-Induced X-ray Emission). These methods have applications across multiple fields, including materials science, cultural heritage preservation, and environmental monitoring.

In 2024, a small group of students from the Solvay Programme participated in a hands-on session where they performed material analysis alongside a CERN physicist. They were able to analyse the resulting data independently on their own laptops. This pilot activity demonstrated the potential of ELISA for future public engagement.

The project is now part of a broader discussion on how to incorporate citizen science into the activities of the upcoming Science Gateway. In particular, it opens up opportunities for collaborative research projects—for example, creating sample-based environmental or mappings across different Member States based on the origin of analysed materials.

Moving forward, CERN should support this project as one of several strategic approaches to citizen science by: 1) establishing collaboration between the scientific team, the education and outreach team, and members of the public; 2) bringing together the necessary expertise to define the types of research that can be carried out and the appropriate levels of public involvement; and 3) allocating sufficient resources to support all aspects of the project, including participant coordination, accelerator operation, experiment execution, collaborative data analysis, results communication, and project evaluation.

Conclusion

The 2023-2024 period has marked an important period of Open Science implementation at CERN. Building on CERN's long standing dedication to openness, the organization has formalized and expanded its efforts in various domains of open science practice.

While many of these efforts constitute grassroots initiatives, new governance structures have been created in some areas to facilitate institutional coordination. Notably, the CERN Open Source Program Office (OSPO) was launched in 2023 to coordinate and support open source software and hardware activities of both CERN employees and users.

While progress has been uneven across different domains of the Open Science policy, the foundation has been laid for more systematic advancement. Areas requiring further

development include research integrity frameworks and analysis preservation templates. Citizen science activities, though not centrally coordinated, have demonstrated the potential for meaningful public engagement through platforms like the ELISA accelerator and hackathon programs.

Summary of future directions and resource needs

Enhanced Coordination and Governance

The Open Science Office must facilitate coordination, connecting various initiatives that have previously operated in isolation. This requires:

- Defining clear roles and responsibilities, when not defined, for Open Science implementation
- Establishing lightweight working groups across functional areas

Community Engagement, Communication and Training

A critical component of advancing Open Science at CERN is strengthening community engagement. To this end, a community engagement manager was hired in the SIS Open Science Section to address training and communication needs across the different Open Science activities and departments.

Monitoring Framework Development

To measure progress and impact effectively, CERN must continue to develop a comprehensive monitoring framework with:

- Clearly define Key Performance Indicators (KPIs) for each domain
- Regular data collection and analysis procedures

Strategic Resource Allocation

Looking ahead to 2025-2026, several resource needs have been identified to sustain and advance CERN's Open Science activities:

- Infrastructure Support: Securing storage resources for Open Data beyond 2025 requires dedicated funding and IT department commitment
- Personnel Resources: The development of analysis preservation templates, research integrity principles, the implementation of support for OSHW, KiCad in CERN’s Product Lifecycle Management (PLM) solution or citizen science coordination demand dedicated FTE allocation.

Open Science in the Age of AI

AI is not highly present in this review, but we have to acknowledge that as artificial intelligence transforms scientific research, CERN will have to address emerging Open

Science challenges including, for example, ethical considerations around AI application in scientific writing and publication.

CERN's progress in implementing its Open Science policy has yielded significant achievements, though there are still areas requiring further attention. While the initial two years established foundational structures and processes, realizing the full potential of open science will require sustained commitment, adequate resources, and cultural change.

If the Open Science Strategy Board (OSSB) approves this review and its proposals, a new implementation plan will be written for 2025/2026, followed by immediate concrete actions.