

# From Dependence to Resilience

## Building Ecumenical Digital Sovereignty for Software

Roberto Di Cosmo

CEO, Software Heritage  
Inria & Université Paris Cité

20 May 2026  
GARR conference  
Pisa



# Software Heritage

THE GREAT LIBRARY OF SOURCE CODE

- 1 Why software source code matters
- 2 The regulation / infrastructure gap
- 3 Ecumenical digital sovereignty
- 4 Software Heritage: the ecumenical infrastructure
- 5 From archive to strategic backbone
- 6 A Very Large Telescope to explore the software development galaxy
- 7 We (happen to) have the answer at arm's reach
- 8 A path forward, together

## Digital sovereignty

Often framed in terms of *cloud*, *data*, or *infrastructure*.

Beneath lies a more fundamental layer:  
**software source code**

Invisible fabric that powers our economies, administrations, and research systems.

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## Knowledge is in the source

```
/**
 * @brief The basic unit of the simulation and is associated to a geographical location.
 *
 * Interventions (e.g., school closures) are tracked at this level. It contains a list of its
 * members (people), places (schools, universities, workplaces etc.), road networks, links to
 * airports etc.
 */
struct Microcell
{
    /* Note use of short int here limits max run time to USHRT_MAX*ModelTimeStep - e.g. 65536*0.25=16384 days=44 yrs.
     * Global search and replace of 'unsigned short int' with 'int' would remove this limit, but use more memory.
     */

    int n; // Number of people in microcell
    int adunit; // admin unit microcell belongs to
    int* members; // array of members/hosts of microcell

    int* places[MAX_NUM_PLACE_TYPES]; // list of places (of various place types) within microcell
    unsigned short int NumPlacesByType[MAX_NUM_PLACE_TYPES]; // number of places (of various place types) within microcell
    unsigned short int keyworkerproph, move_trig, place_trig, socdist_trig, keyworkerproph_trig;
    unsigned short int move_start_time, move_end_time;
    unsigned short int place_end_time, socdist_end_time, keyworkerproph_end_time;
    TreatStat moverest, treat, vacc, socdist, placeclose;
    unsigned short int treat_trig, vacc_trig;
    unsigned short int treat_start_time, treat_end_time;
    unsigned short int vacc_start_time;
    IndexList* AirportList;
};
```

## Covid Sim ( [excerpt](#) )

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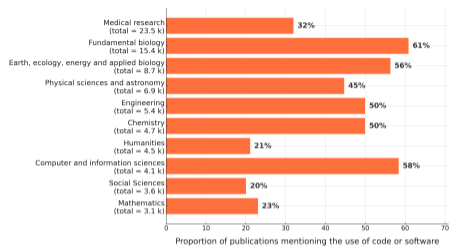
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## Covid Sim ( [excerpt](#) )

Sovranità digitale: governare dati, infrastrutture e — innanzitutto — *codice sorgente*.

# A global undertaking...

## Pillar of Science across all research areas



## From all continents

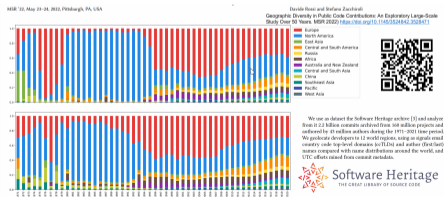
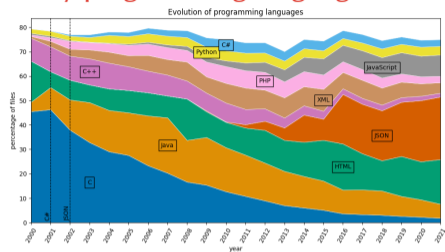


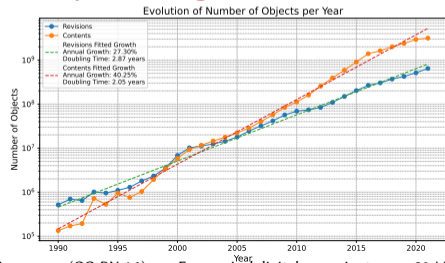
Figure 3: Ratio of commits (above) and active authors (below) by world zone over the 1971-2020 period.



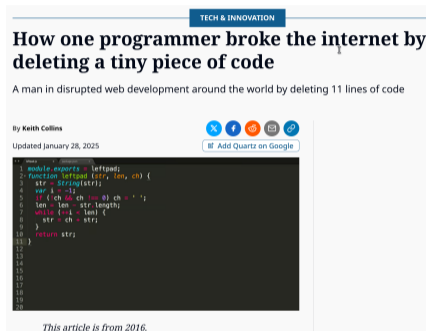
## Many programming languages



## An exponential growth



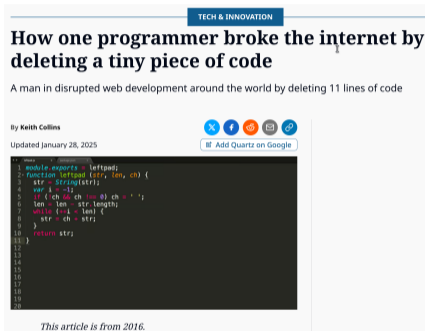
## An early warning: left-pad (March 2016)



See the [Wikipedia](#) article:

- Facebook, PayPal, Netflix, Spotify affected
- web broken worldwide ~2.5 hours

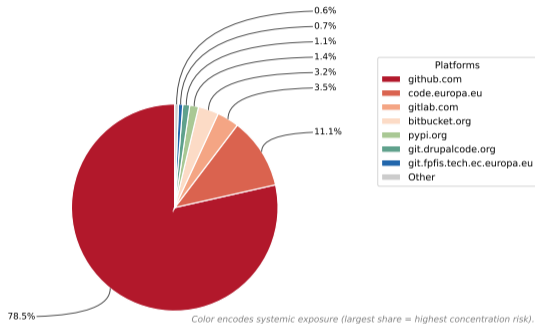
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## A clear and present danger



Used by europa.eu devs (Source: Software Heritage)

*"If GitHub or PyPI disappeared tomorrow, Europe would not just slow down — it would stop."*

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## Regulation

## Europe's Software Sovereignty

### REGULATION



- **Cyber Resilience Act (CRA) & NIS2**  
Mandate strict software security, long-term maintenance, and end-to-end supply-chain resilience.
- **AI Act Transparency**  
Legal requirements for the transparency and reproducibility of training data and the underlying algorithms.
- **Open Science Policies**  
Policies requiring long-term availability and reproducibility of research software for scientific integrity.

**“Legal obligations assume permanent access to source code.”**

# Regulation Without Infrastructure: Europe's Software Sovereignty Gap

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## INFRASTRUCTURE



- **Dependence on Non-European Platforms**  
Relies on **proprietary platforms** like GitHub, GitLab.com, and package managers (PyPI, npm, Maven Central).
- **No EU-Wide Continuity Guarantee**  
Existing platforms provide **no Service Level Agreements (SLA)** for preservation and operate under **no legal obligation** to protect European sovereignty.
- **Fragmented National Initiatives**  
Current efforts are often national, not interoperable, and lack a shared global governance structure.

**"Legal obligations assume permanent access to source code."**

**"Critical dependencies outside European control."**

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**! THE STRUCTURAL GAP !**

**"Legal obligations assume permanent access to source code."**

**Europe regulates software as critical infrastructure – but does not operate a software continuity infrastructure**

**"Critical dependencies outside European control."**

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## What it is *not*

- it is not *autarky*
- it is not *national silos*
- it is not *forking the world*
- it is not *owning everything*

## What it is

- shared, **open**, **non-rival** infrastructure
- that benefits *all* while preserving autonomy for *each*
- resilient against disruption upstream
- *ecumenical* by design

“Sovereignty is not about owning everything  
— it is about ensuring that nothing essential can disappear.”

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Software Heritage  
THE GREAT LIBRARY OF SOURCE CODE

Inria with  **unesco**





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# The largest open source code archive: one infrastructure, open, shared, non profit

Unique digital common good *built in France since 2015*

Cultural Heritage



Industry



Research



Public Administration



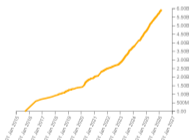
Source files

28,152,651,759



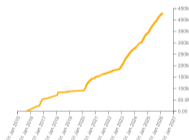
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Projects 

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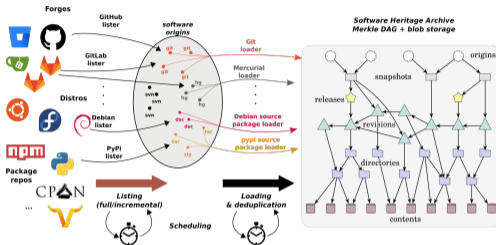
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5000+ platforms

All versions, all history development in a single graph



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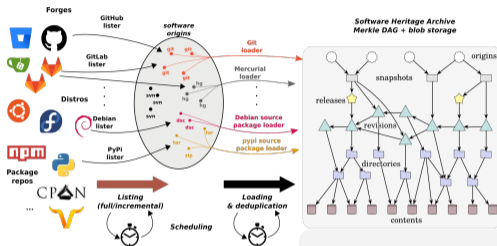
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- 50 × 10<sup>9</sup> nodes
- 1000 × 10<sup>9</sup> edges
- ~ 3 PB of storage



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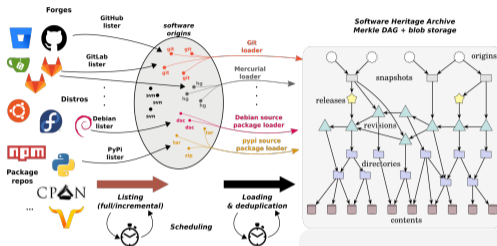


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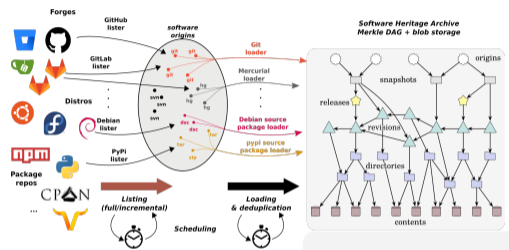
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## Standards (Software Hash ID, SWHID)



Intrinsic identifier  
integrity, traceability  
50B+ SWHID in archive

## Software Pillar of (Open) Science EOSC SIRS report (2020)



National Open Science Plan  
(2021)  
French National RI Roadmap  
(2022)

## Pillar of transparent AI



StarCoder2/The Stack v2  
(Hugging Face)  
CodeCommons (BPI, France)  
AI Factory (AI2F, EU)

## Next gen Cybersecurity



Global Vulnerabilities  
(Sec4AI4Sec, SWHSec)  
Software supply chain  
(CRA, SBOM,...)

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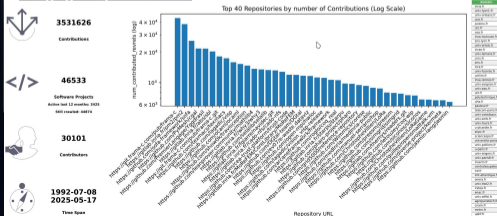
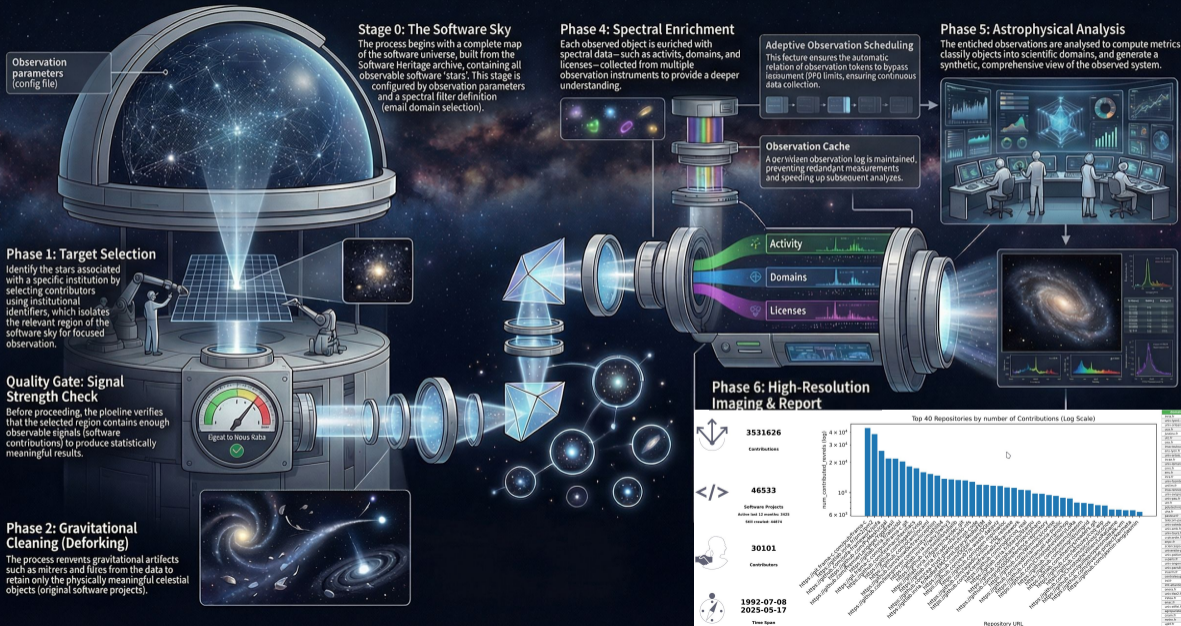
Global Vulnerabilities  
(Sec4AI4Sec, SWHSec)  
Software supply chain  
(CRA, SBOM,...)

*A (version of a) dependency of a critical software vanishes from GitHub, Gitlab, ...:*

- how to **audit** it five years later?
- how to **reproduce** the results?
- how to **ensure** continuity of service?
- how to **retrieve** them?

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# From the Software Sky to Institutional Insight: Anatomy of an Observational Pipeline



## Software Heritage

### Report on the public software collected, preserved and referenced for Acad-It-Garr

Version 1.0 – 2026-05-11

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# A peek inside: full analysis charts



**2765958**

Contributions



**38309**

Software Projects  
Active last 12 months: 1993  
Still crawled: 35505



**19065**

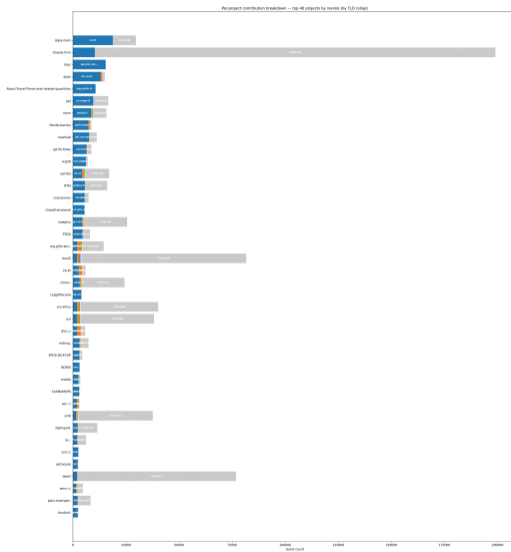
Contributors



**1968-02-12**

**2026-05-06**

Time Span



domain	count
github.it	2901
github.k	2296
github.x	1435
github.l	1039
githuba2.it	958
github.z	949
github.r	732
github.e	661
github.it	619
github.g	549
github.t	529
github.k	522
github.c	421
github.f	397
github.a	379
github.h	336
github.n	287
githubm.it	286
githubo.it	269
github.c.k	223
githuba3.it	199
github.e	183
github.it	175
github.g	161
github.t	161
github.t	154
github.g	151
github.c	149
github.t	146
github.c	127
github.k	117
githubfrance.k	117
github.t	109
github.g	103
github.c	92
github.c	85
github.g	85
github.c	76
github.g	70
githubsub.it	64
github.g	63
github.t	56
github.c	49
github.c	49
githubcompany.k	48
githuba2.it	47
githubo.it	43
github.g	37
github.c	36
githuba3.it	35

Note: Showing top 10 of 83 total domains

# A peek inside: who contributes from Italian academia?

## Major hubs

- **CNR** (7) — sigla-main, EPAS, sprint-flows, cool-jconon, MeshLab, VCGLib, ITTIG/LeggiToscana
- **INFN** (5) — chaosframework, Belle II, gLite WMS, wms-ui, INDIGO-IAM
- **Università di Bologna** (3) — HELM, Matita, tuProlog
- **Università di Parma** (4) — PPL, FSDA, Project Chrono, fondinfo
- **Politecnico di Milano** (3) — PandA-Bambu, RTAI, pacs-examples
- **Multi-institute Italian-led** (6) — Yambo, Q-E, Q-E SIRIUS, sctk, MDSplus, **deal.II**

## Smaller hubs and single contributions

- **Università di Trento** (2) — CoSMoMVPA, About-Travel-Times (abouthydrology)
- **INAF** (2) — DISCOS, astrocook
- **Leaning Tech / Sant'Anna Pisa** (2) — Cheerp, lightspark
- **One each:**
  - UniPi — netmap
  - UniTo — BORIS
  - UniCa — SecML
  - INGV — EPOS-DCAT-AP
  - UniRoma1 — vsrlab
  - personal-research — CLIPS fork

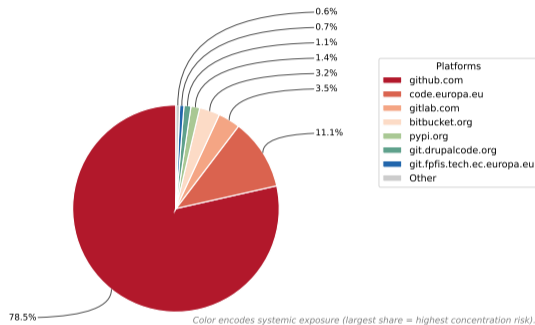
Source: Software Heritage — Strategic Software Insights, Italian academic cut

# A peek inside: Italian flagships in the top-40

- **deal.II** — SISSA + UniPi + PoliMi:  
world-class FEM library, massive external uptake
- **MeshLab + VCGLib** — CNR-ISTI:  
biggest Italian 3D-graphics open-source impact
- **Quantum ESPRESSO** (q-e, q-e-sirius, sctk)  
— SISSA/CNR-IOM/CINECA:  
Italian DFT flagship
- **Matita / HELM** — UniBo:  
Italian theorem-proving heritage
- **PandA-Bambu HLS** — PoliMi:  
hardware/software co-design
- **netmap** — UniPi:  
high-performance packet I/O
- **Parma Polyhedra Library** — UniPR:  
foundational static-analysis library
- **Belle II / italiangrid / chaosframework / INDIGO-IAM** — INFN:  
scientific-computing + grid pillars
- **DISCOS + astrocook** — INAF:  
radio-telescope control + spectroscopy
- **Cheerp + lightspark** — Leaning Tech / Sant'Anna Pisa:  
web-runtime engineering
- **BORIS** — UniTo:  
behavioural-sciences research software

# Back to our core digital sovereignty challenge, can we act?

## A clear and present danger

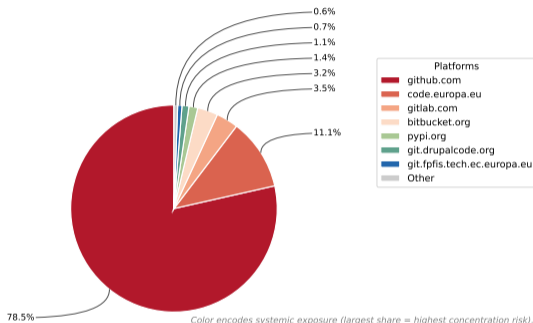


Used by europa.eu devs (Source: Software Heritage)

*"If GitHub or PyPI disappeared tomorrow,  
Europe would not just slow down  
— it would stop."*

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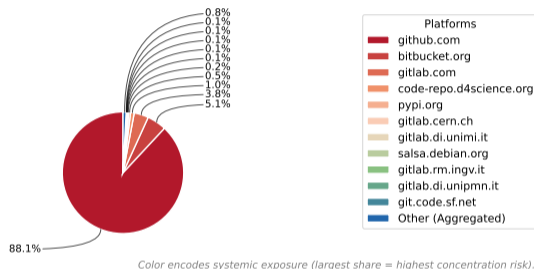
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Used by GARR devs (Source: Software Heritage)

*"If GitHub or PyPI disappeared tomorrow, GARR members would not just slow down — they would stop."*

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# Resilience, demonstrated: Guix integration

Software Heritage and GNU Guix join forces  
to enable long term reproducibility



Guix demonstrates automated recovery using the Software Heritage archive

When a platform or registry fails...

Guix fallbacks to Software Heritage

## Connecting reproducible deployment to a long-term source code archive



Ludovic Courtès — March 29, 2019

GNU Guix can be used as a “package manager” to install and upgrade software packages as is familiar to GNU/Linux users, or as an environment manager, but it can also provision containers or virtual machines, and manage the operating system running on your machine.

One foundation that sets it apart from other tools in these areas is reproducibility. From a high-level view, Guix allows users to declare complete software environments and instantiate them. They can share those environments with others, who can replicate them or adapt them to their needs. This aspect is key to reproducible computational experiments: scientists need to reproduce software environments before they can reproduce experimental results, and this is one of the things we are focusing on in the context of the Guix-HPC effort. At a lower level, the project, along with others in the [Reproducible Builds](#) community, is working to ensure that software build outputs are [reproducible, bit for bit](#).

Work on reproducibility at all levels has been making great progress. Guix, for instance, allows you to [travel back in time](#). That Guix can travel back in time and build software reproducibly is a great step forward. But there's still an important piece that's missing to make this viable: a stable source code archive. This is where [Software Heritage](#) (SWH for short) comes in.

When source code vanishes

and continues to build!



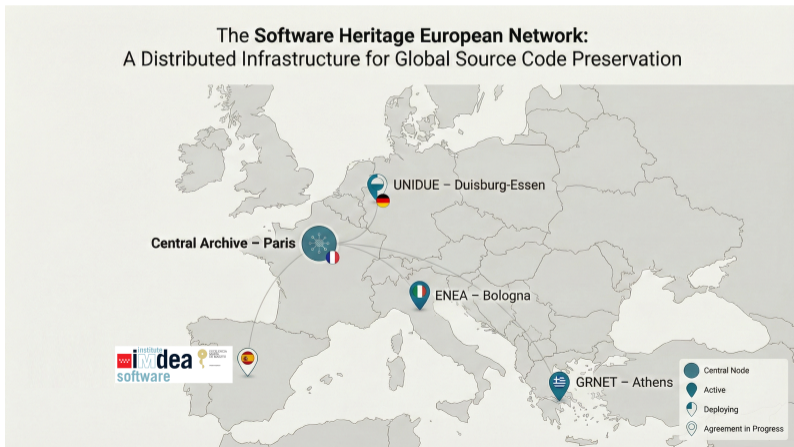
Since 2019

# A sovereign fallback for Europe's build chains is possible

Extend to key package managers

*npm, PyPI, Maven Central, Cargo, CPAN, RubyGems, Packagist, ...*

Realize ecumenical resilience



# Software Heritage: one infrastructure, six strategic levers

## Research infrastructure

two facets:

- support Open Science
- enable Software Science

## Traceability and compliance

- Software supply chain (SBOM)
- integrity (SWHID)
- availability
- support CRA/NIS2 mandates

## Cybersecurity

Cyber forensics, vulnerability tracking at world scale

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## Resilience

when npm/PyPI/Maven **fail**,  
Europe **continues to build**

## Transparent AI

- **CodeCommons** : provenance and attribution for LLMs
- AI Act, Art. 11, 12, 15:
  - technical documentation
  - record-keeping
  - reproducibility

## Metrics we can count on

- Objective Strategic Insights
- Support policy implementation

## Regulation Without Infrastructure: Bridging Europe's Software Sovereignty Gap

### REGULATION



- **Cyber Resilience Act (CRA) & NIS2**  
Mandate strict **software security**, long-term maintenance, and end-to-end supply-chain resilience.
- **AI Act Transparency**  
Legal requirements for the **transparency** and **reproducibility** of training data and the underlying algorithms.
- **Open Science Policies**  
Policies requiring long-term availability and reproducibility of research software for scientific integrity.

"Legal obligations assume permanent access to source code."

### INFRASTRUCTURE



- **Dependence on Non-European Platforms**  
Relies on proprietary platforms like GitHub, GitLab.com, and package managers (PyPI, npm, Maven Central).
- **No EU-Wide Continuity Guarantee**  
Existing platforms provide **no Service Level Agreements (SLA)** for preservation and operate under **no legal obligation** to protect European sovereignty.
- **Fragmented National Initiatives**  
Current efforts are often national, not interoperable, and lack a shared global governance structure.

"Critical dependencies outside European control."

⚠️ THE STRUCTURAL GAP ⚠️

Europe regulates software as critical infrastructure – but does not operate a software continuity infrastructure

### SOFTWARE HERITAGE

Over **24 billion**

#### Universal Archive of Source Code

An operational global archive containing over 24 billion files and 375 million projects (and growing).



#### Intrinsic Identifiers (SWHID – ISO 18670)

Provides a standardized "fingerprint" for software to ensure absolute traceability, auditability, and citation.



#### Sovereign Mirror Network

Resilient, neutral network of nodes (e.g., Italy, Greece, Spain) ensuring archive cannot be destroyed or controlled by a single entity.

#### Ready for Scaling, Not Invention

Already operational; requires political and financial scaling to fully support European regulatory ambitions.

"Infrastructure that makes European regulation enforceable."

- 1 Why software source code matters
- 2 The regulation / infrastructure gap
- 3 Ecumenical digital sovereignty
- 4 Software Heritage: the ecumenical infrastructure
- 5 From archive to strategic backbone
- 6 A Very Large Telescope to explore the software development galaxy
- 7 We (happen to) have the answer at arm's reach
- 8 A path forward, together

# What this means for Italy and for Europe

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**Public administrations and enterprises** *join* as members, mirror operators, contributors

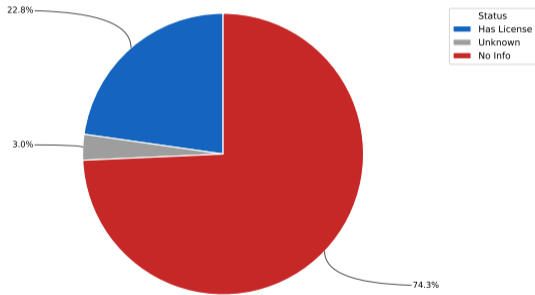
- turn *dependence* into *shared resilience*
- position Italy as a leader in this **ecumenical** approach

*True digital sovereignty is not control — it is resilience.*

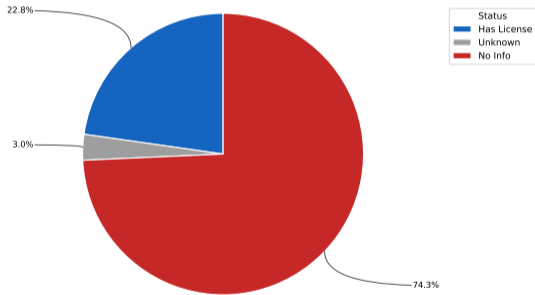
<https://www.softwareheritage.org>



## Licences status across GARR members' projects



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