

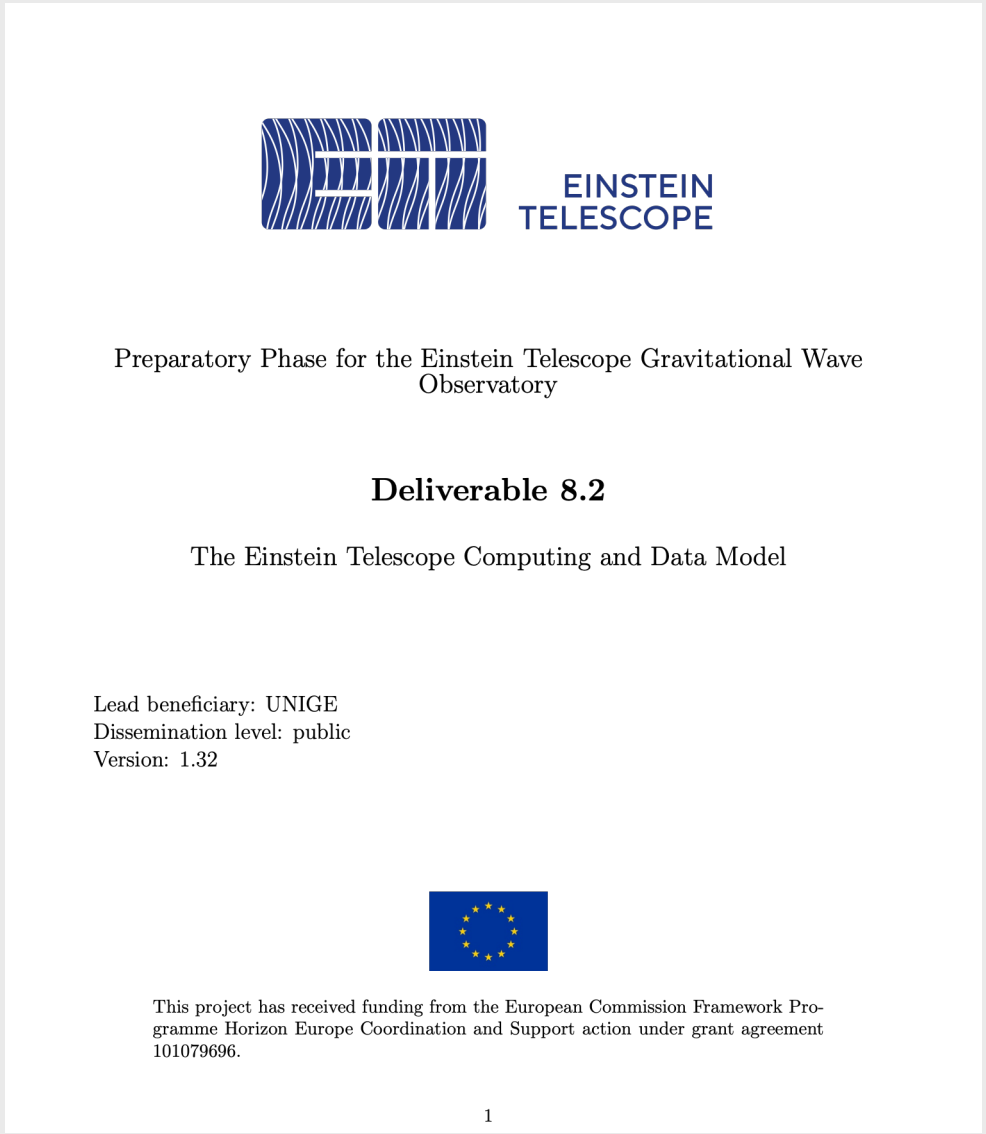
COMPUTING

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Stefano Bagnasco, INFN Torino

EINSTEIN TELESCOPE | Cagliari
Jul 30, 2026

THE ET COMPUTING MODEL



EINSTEIN TELESCOPE

Preparatory Phase for the Einstein Telescope Gravitational Wave Observatory

Deliverable 8.2

The Einstein Telescope Computing and Data Model

Lead beneficiary: UNIGE
Dissemination level: public
Version: 1.32

This project has received funding from the European Commission Framework Programme Horizon Europe Coordination and Support action under grant agreement 101079696.

1

- **Main question:** Can we analyse data that contains 1000 times more events, including long-lasting and overlapping signals?
- **Main strategy:** Build on the experience of LVK, leverage expertise particularly from WLCG/CERN/HSF/HEP
  - Much of LVK computing relies on the "Open Science Grid" (OSG), used to provision resources for the CERN experiments (WLCG) - tools like HTCondor and Rucio
  - For ET, there are also synergies with EOSC / ESCAPE
- **Main challenges:** There is no formal LVK Computing Model document; ET's site and geometry have not been decided
- **Main task (for now):** run MDCs and make sure we converge on viable numbers!

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GORDON WATTS @ CHEP2026

Two years ago, I knew what coding and analysis would be like in 2030…

(what a horrible time to write a computing TDR)



G. Watts (UW/Seattle)

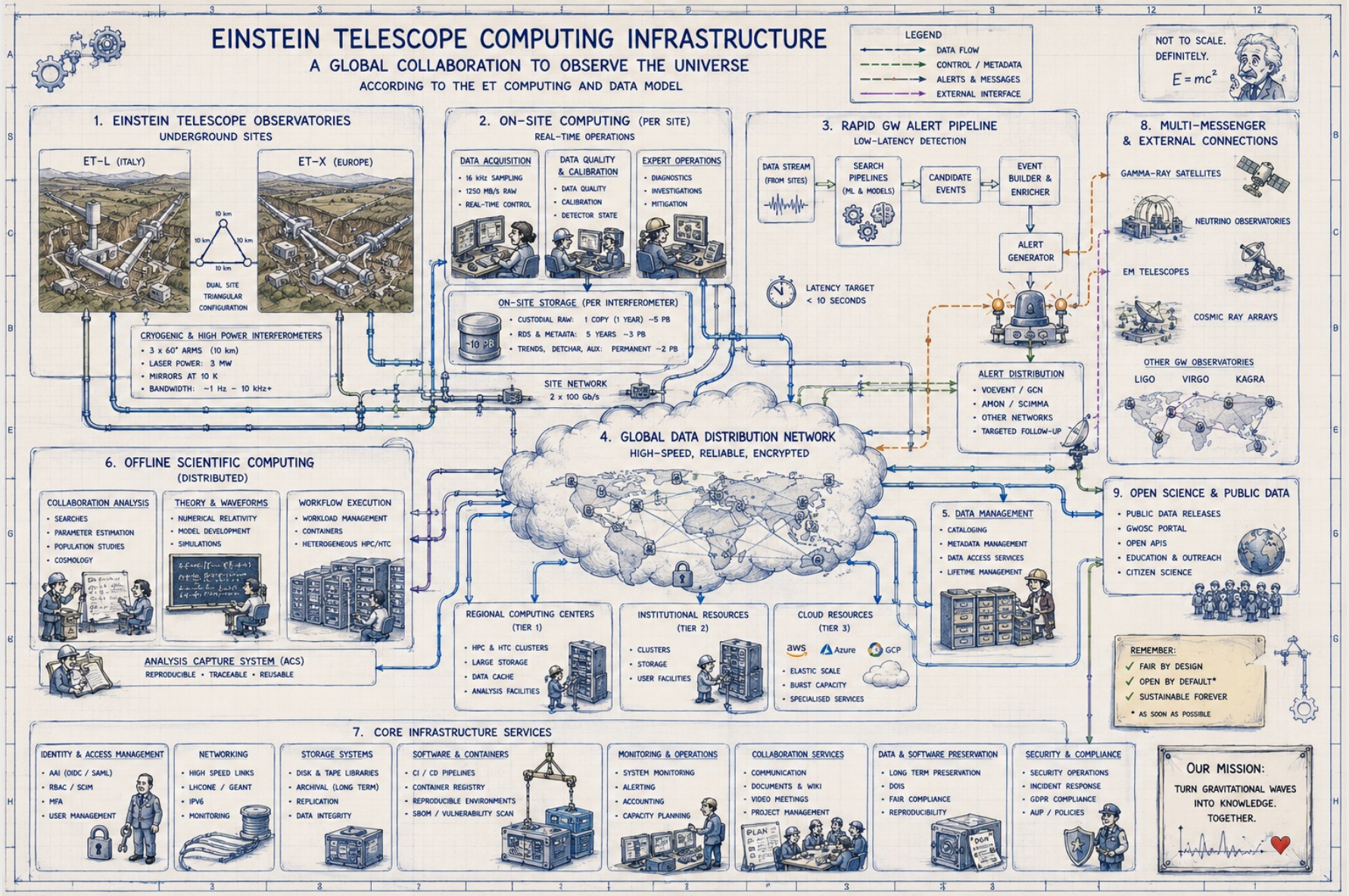
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WILL AI FIX EVERYTHING FOR US?

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WILL AI FIX EVERYTHING FOR US?



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OVERALL STRUCTURE

I. Introduction
1. Scope
2. ET Science Goals
3. Gravitational Wave Detection
4. Overview of the ET Computing Use Cases
5. Computing Model Design Principles

II. Online Workflows and Use Cases
1. Detector Operations
2. Rapid GW Alerts

III. Computing Resources and Utilization Plans
1. ET Computing Resources
2. Distributed Computing

IV. Sustainability
1. Sustainable Computing Resource Usage
2. Training the Next Generation of Experts

Appendix A: The e-Infrastructure

And caveats! E.g. we're still very Far in time from actual running

Short, sweet and to the point (that's what the Blue Book is for)

- Start from IGWN (LVK)
- Leverage HEP experience
- Use shared resources
- Plan for sustainability
- FAIR-by-design

Assumption: these comprise the core mission for ET

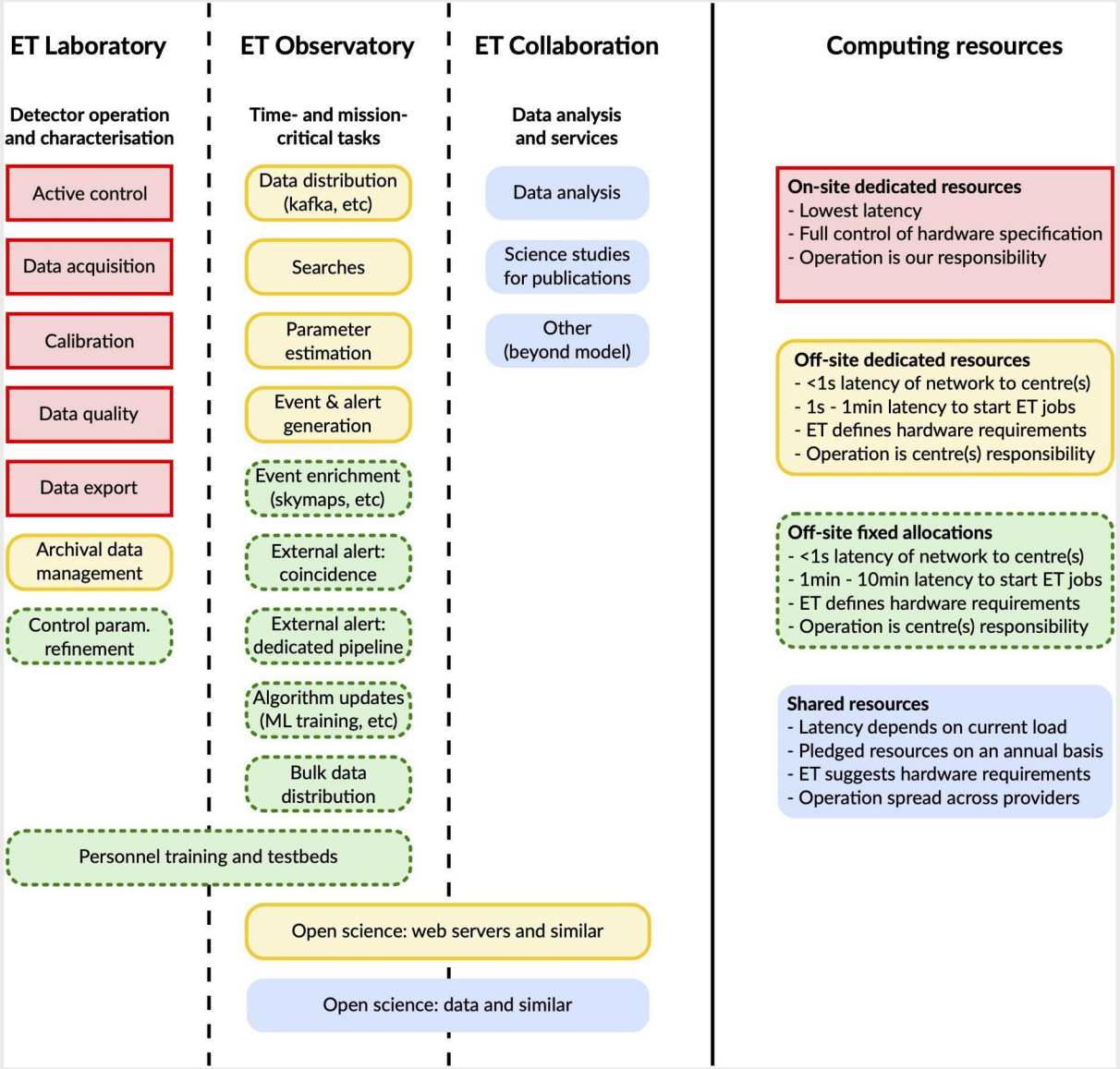
(See next slides)

ET lifetime is at least 50 years

We need computing experts

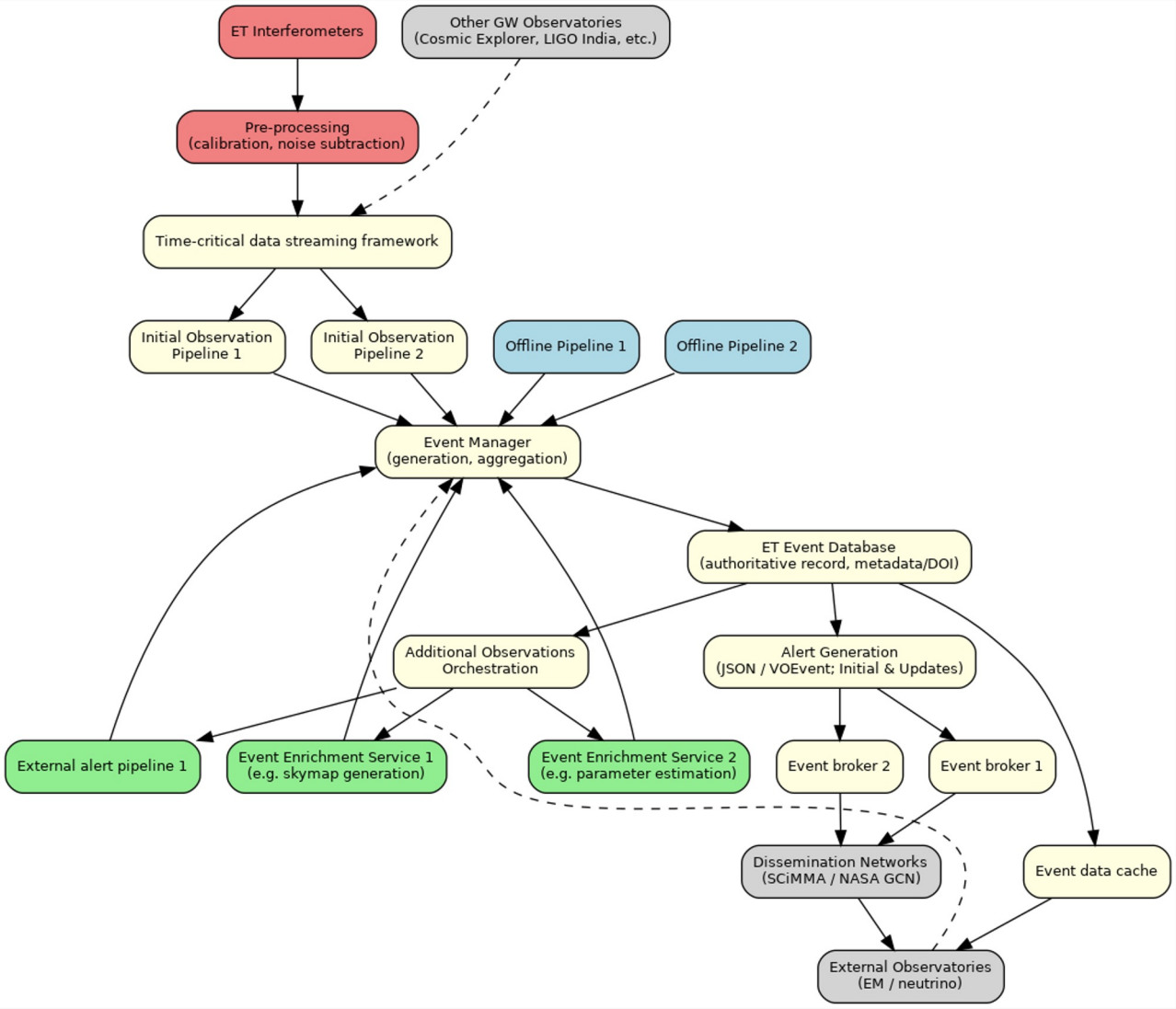
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WHERE



- Assumption: ET will most likely share data with other GW detectors
- The implementation may (indirectly) depend on the site decision
- There can be good reasons to minimise the number of computing sites
- Strategy is however still the same: use as much as possible distributed resources in shared centres

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- The challenge is to support ET (resources, software, people) for its 50 years lifespan
- First, we are not alone: exploit the wider community: WLCG, IGWN, HSF, ESCAPE, EOSC, you name it
- Then, there are clear needs for a small, dedicated team of software and computing professionals to provide

A common software framework

- One single, sustainable, efficient computing ecosystem for ET
- Comprehensive end-to-end testing of all ET software
- Intelligent analysis platforms minimising duplication
- Scalable, portable computing infrastructure
- Fully single sign-on

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Why software engineering matters

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LVK circa 2015

- Scientists write and run the code
- It produces excellent science
- The results get deserved credit, LVK software helped deliver a Nobel-prize

LVK today

- Ad hoc software becomes difficult to maintain (bus factor, people move on and even out of the field)
- Ad hoc deployment strategies become technical debt and increasing operations burdens
- No end-to-end testing means updates become operational risks

What ET needs

- Software that has a long-term support model, can be rerun by others and adheres to best practices
- A common deployment model that can run anywhere ET has resources
- A common development environment enabling end-to-end testing as standard

The issue is not whether the code (once) worked; it is whether ET can safely depend on it for decades

Software engineering best practice must be the foundation of ET software development

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A new software engineering division for the EIB



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Div 1
Data Challenge Support

End-to-end MDC workflow evaluation
Resource-footprint measurements

X-coord: OSB-Div10

Div 2
Collaborative Services

IAM, helpdesk, onboarding
collaboration tooling
(Security incubator)

Div 3
Distributed Computing

Federated computing sites and services (data, WMS, accounting, monitoring...)
Resource estimates

Div 4
Multi-messenger Alerts

Low-latency alert infrastructure

X-coord:
MMMB Coordinator
OSB-Div4

Technology Tracking WG

Ensuring a place for R&D

Future divisions

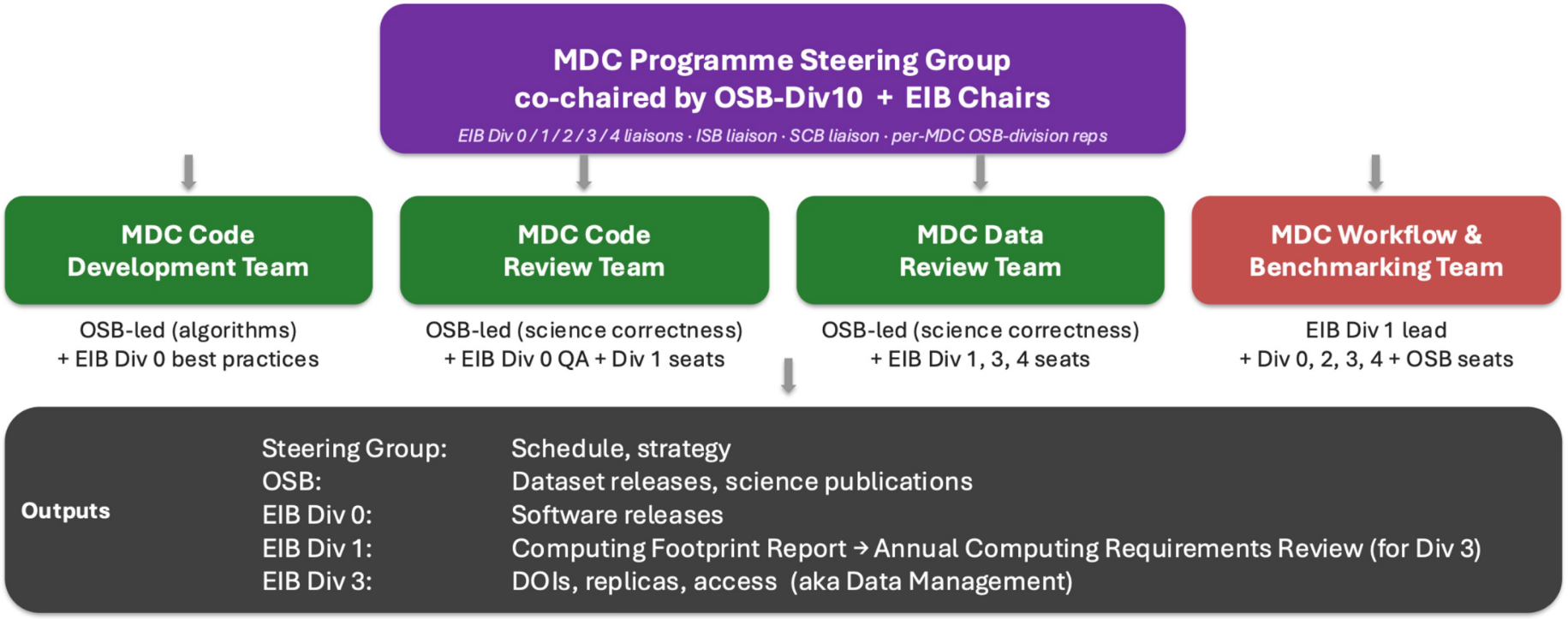
Div 5 Security | Div 6 Open Science | Div 7 Site Operations

Division 0 — Core Software and Engineering Foundations

Best practices | FAIR-by-design | CI/CD | **Software framework** | **versioned software releases** | support | training

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MDCs for estimating ET computing needs



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AS USUAL, PEOPLE

- EIB has low participation
  - Somewhat inheriting the lack of computing expertise in Virgo
  - The handful of existing experts are heavily over-subscribed
  - And yet we need to on-board new computing sites to support Mock Data Challenges
- AI-4-ET will be a fantastic accelerator, but we still need people!
  - and real effort in the EIB for the services that AI-for-ET catalyses
- Strategy: **community building**
  - We need to bootstrap a “tradition” of infrastructural computing for GW
  - Upcoming INFRA-SERV calls and the ESCAPE context might help, as might HSF
  - This is also about sustainability: student grants, training, etc.
- Nevertheless, we also need people **now**
  - Involve Computing Centres? GW research groups often don’t have the relevant expertise at hand.

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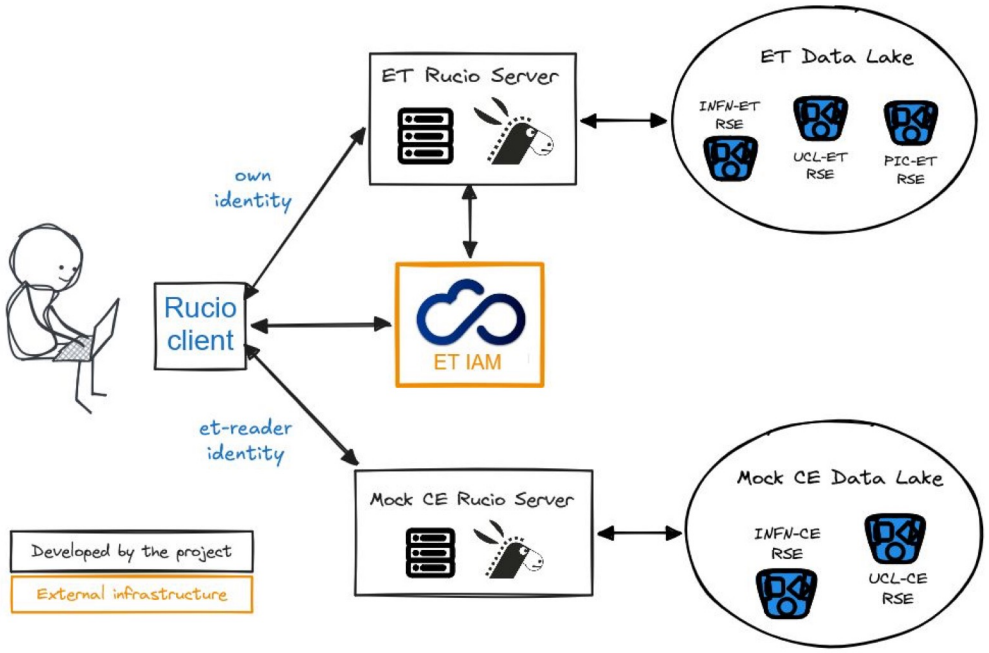
TOWARDS ADVANCED PROTOTYPES

- Two OSCARS-funded projects developed data management and analysis environment (and more) prototypes
  - ETAP and MADDEN, see next slides
  - Also, other existing tools, like Wavefier
- So the initial “toolkit” candidates might include:
  - The CTLab4ET and BETIF/DIFAET clusters (but this will be an open platform!)
  - The ET-IAM single sign-on
  - The ESCAPE Datalake as adapted for GW by MADDEN
  - The ESCAPE Virtual Research Environment as adapted for GW by ETAP
  - The Wavefier framework for pipeline management
  - More conventional WMS tools like HTCondor
  - …
- Step 1: define an easy-to-deploy configuration to onboard computing sites in an open infrastructure
  - PIC already tested some of this (ask Gonzalo!)
  - ETIC-funded laboratories in Italy can provide a starting platform and a “seed”
  - But everybody is welcome already at this stage!

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The Multi-RI Data Lake

OSCARS



The **ET user** connects to:

- the **ET Rucio server** with his/her own ET IAM identity and obtains a valid token
- the **CE Rucio server** with a common et-reader identity assigned to tokens with **ET IAM as issuer**

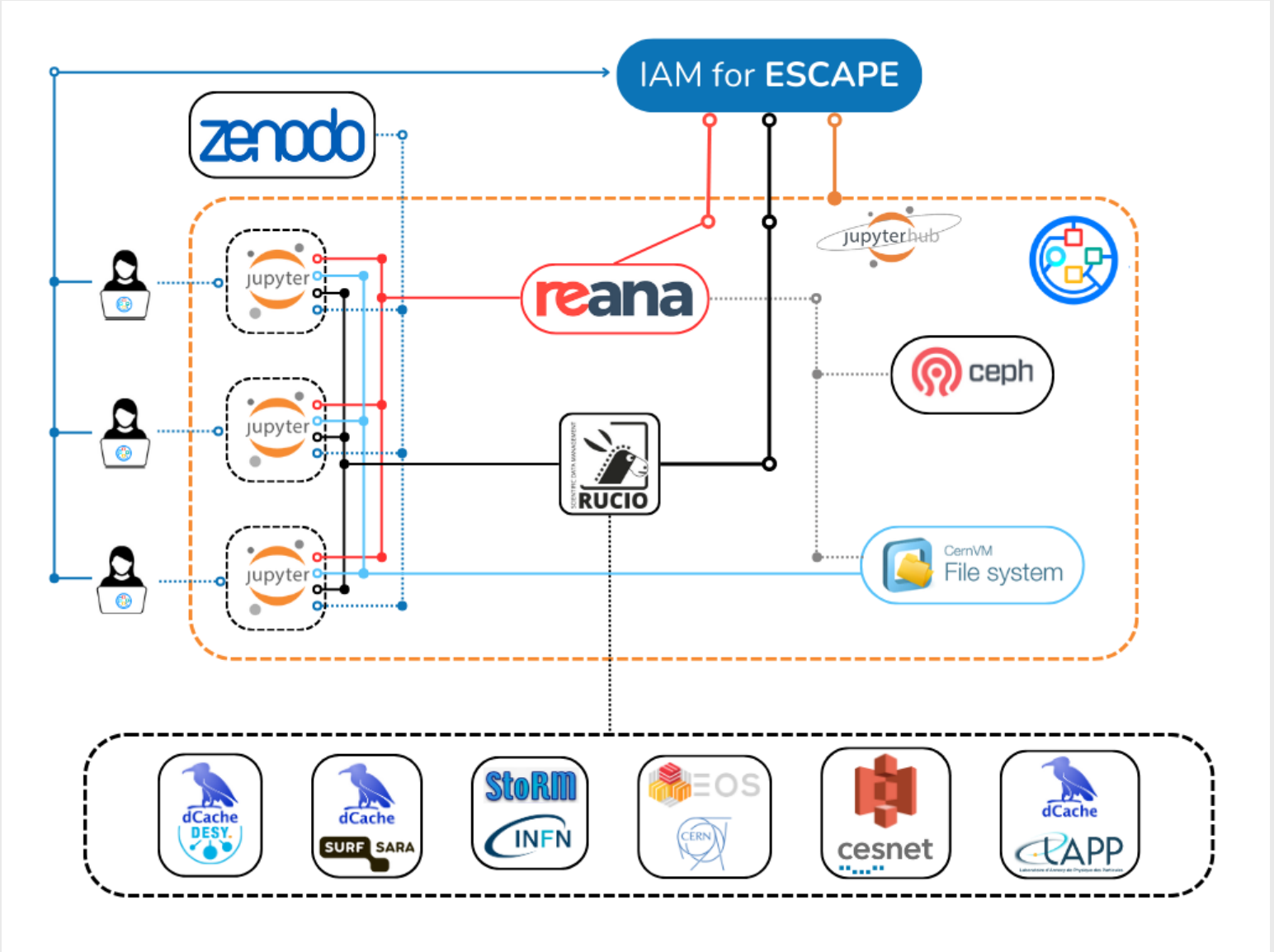
- The Multi-RI Rucio client extension enables simultaneous access to multiple servers
- Available from Rucio 39.2.0

Feerica.Legger@to.infn.it

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THE ESCAPE VRE

CERN VRE



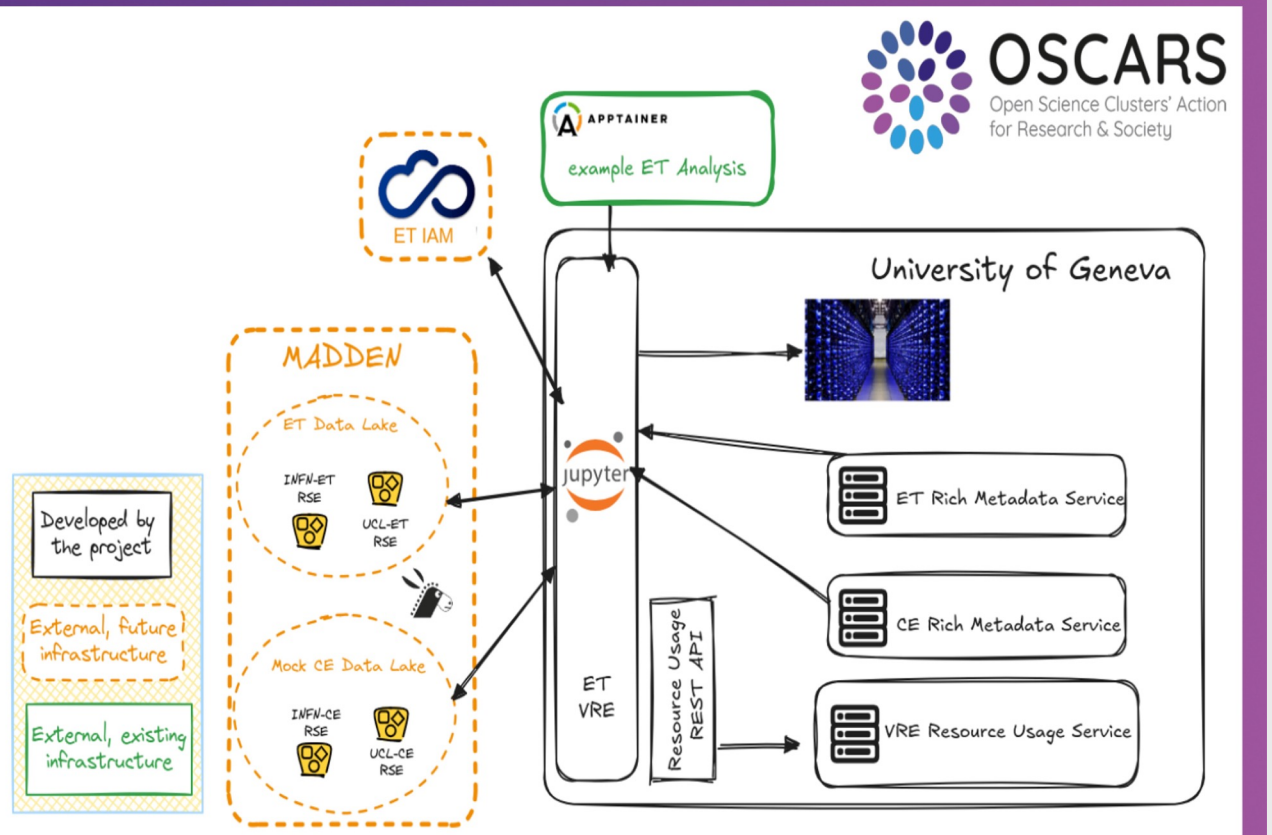
https://vre-hub.github.io

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What is ETAP?

ETAP builds on the CERN Virtual Research Environment (VRE), packaging everything into one helm chart:
https://github.com/vre-hub/helm-charts

Jupterhub	- UX
Rucio / MADDEN	- data access
REANA	- workflow control
Indigo IAM	- AAI
HSF CDB	- metadata access
Prometheus/Grafana	- monitoring



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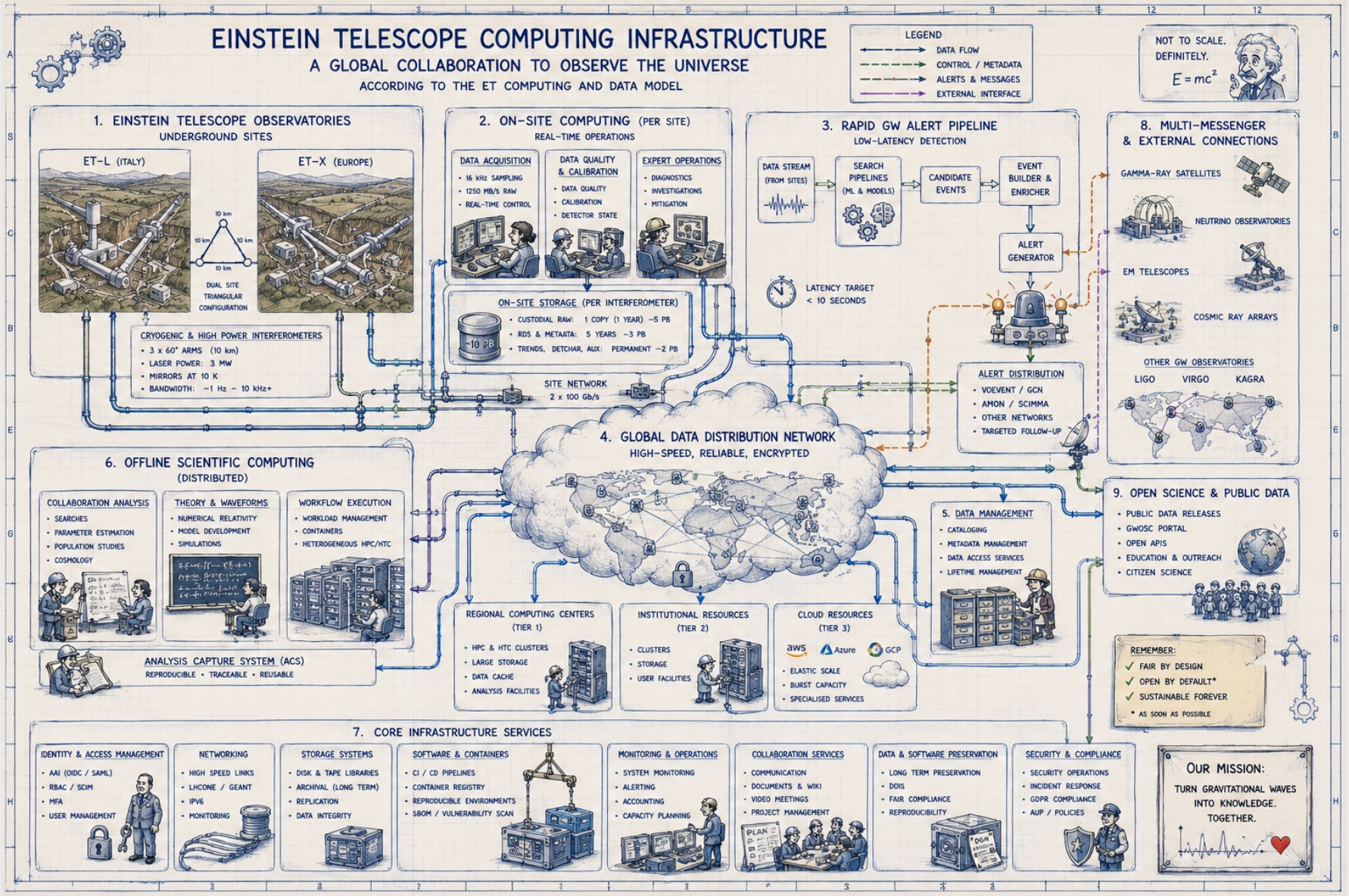
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CONCLUSIONS

- The Computing Model deliverable was delivered
  - Still several open points, as expected
- MDCs are (also) the tool to define those open points
  - Or at least the ones we can define now: technologies and context are evolving faster than ever
  - AI is wonderful, but servers are 4 × the price wrt two years ago, not to speak of energy prices
- We need to build a **community** and an **infrastructure**
  - Both need to be **sustainable**: plan for 50 years!
  - For **software**, this means excellent software engineering, quality control, best practices etc.
  - For **resources**, besides carbon/energy footprint, flexibility, ease of management and integration of heterogenous resources, and prompt adoption of new technologies
  - For **people**, building a community that sustains itself over time and be integral part of the wider context

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THAT'S ALL, FOLKS!



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