# The XDC project

**Data Management for extreme scale computing**

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XDC – Project Coordinator

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# XDC

- The eXtreme DataCloud is a software development and integration project

- Develops scalable technologies for federating storage resources and managing data in highly distributed computing environments
  - Focus on efficient, policy driven and Quality of Service based DM

- The targeted platforms are the current and next generation e-Infrastructures deployed in Europe
  - European Open Science Cloud (EOSC)
  - The e-infrastructures used by the represented communities

- Addresses the EINFRA-21-2017 (b)-2: "Computing e-infrastructure with extreme large datasets"
  - Deal with heterogeneous datasets
  - Bring to TRL8 and include in a unified service catalogue services and prototype at least at TRL6
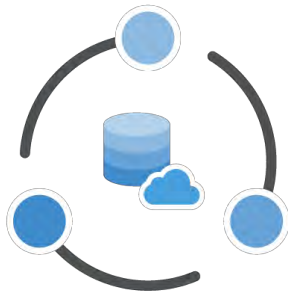
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# The Approach

**Improve already existing, production quality Data Management services**

- → By adding missing functionalities requested by research communities
- → Based mainly on technologies provided by the partners and by the INDIGO-Datacloud project
- → Must be coherently harmonized in the European e-Infrastructures
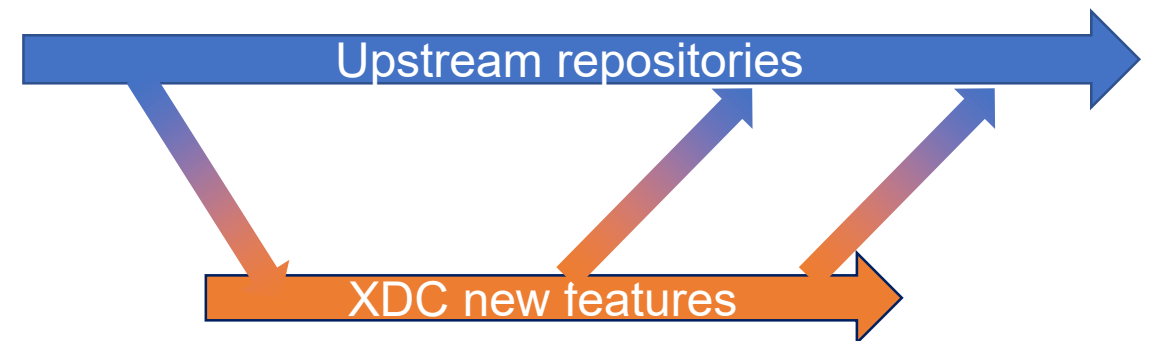
INDIGO PaaS Orchestrator

INDIGO CDMI Server

ONEDATA

EOS
FTS
DYNAFED
CERN

dCache

RUCIO

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# XDC Approach

- The partners owning/involved in each of the tools are the main developers for that solution in XDC

- We always aim **to push back the code** in the main development tree on the **original projects**
  - This widely increase the **sustainability** of the services



Upstream repositories

XDC new features

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# A User Driven Project



The long tail of science

Few large projects → Many smaller projects

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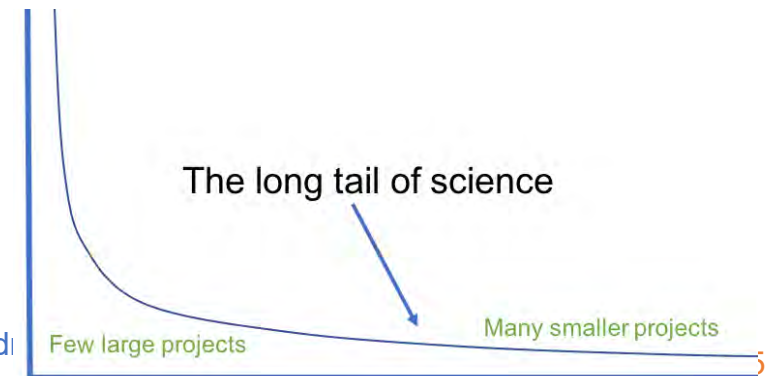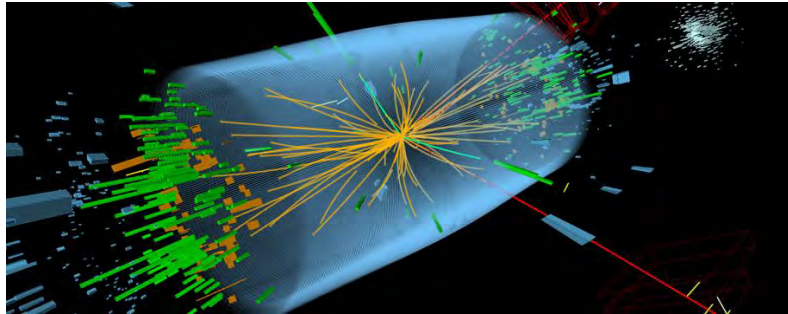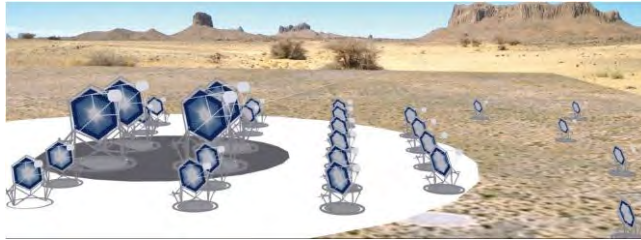
# XDC Topics

✘ Intelligent & Automated Dataset Distribution
- ➔ Orchestration to realize a policy-driven data management
- ➔ Data distribution policies based on Quality of Service (i.e. disks vs tape vs SSD) supporting geographical distributed resources (cross-sites)
- ➔ Data lifecycle management

✘ Data pre-processing during ingestion

✘ Metadata management

✘ Data management based on storage events

✘ Smart caching
- ➔ Transparent access to remote data without the need of a-priori copy
  - ➔ To support dynamic inclusion of diskless sites
  - ➔ To improve efficiency in multi-site storage systems and storage federations (i.e. Datalakes)

✘ Sensitive data handling
- ➔ secure storage and encryption

# XDC Consortium

| ID | Partner | Country | Represented Community | Tools and system |
|---|---|---|---|---|
| 1 | INFN (Lead) | IT | HEP/WLCG | INDIGO-Orchestrator |
| 2 | DESY | DE | Research with Photons (XFEL) | dCache |
| 3 | CERN | CH | HEP/WLCG | EOS, DYNAFED, FTS, RUCIO |
| 4 | AGH | PL | | ONEDATA |
| 5 | ECRIN | [ERIC] | Medical data | |
| 6 | UC | ES | Lifewatch | |
| 7 | CNRS | FR | Astro [CTA and LSST] | |
| 8 | EGI.eu | NL | EGI communities | |

- ✘ 8 partners, 7 countries
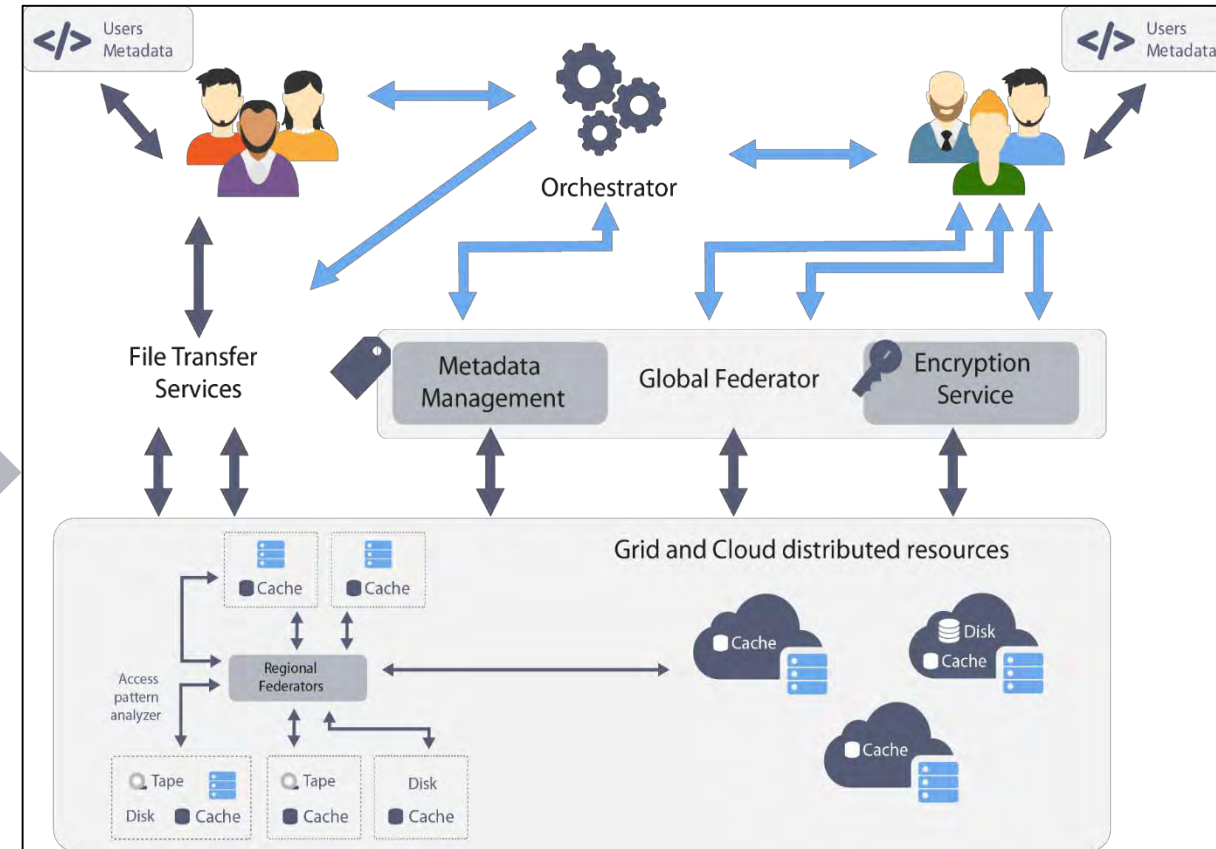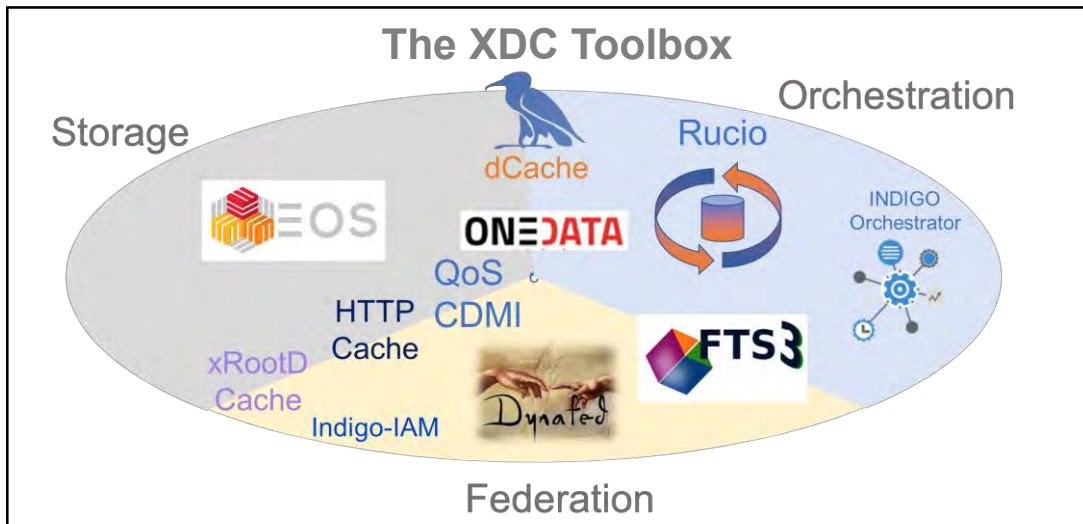- ✘ 6 research communities represented + EGI
- ✘ XDC Total Budget: 3.07Meuros

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# General Architecture Definition

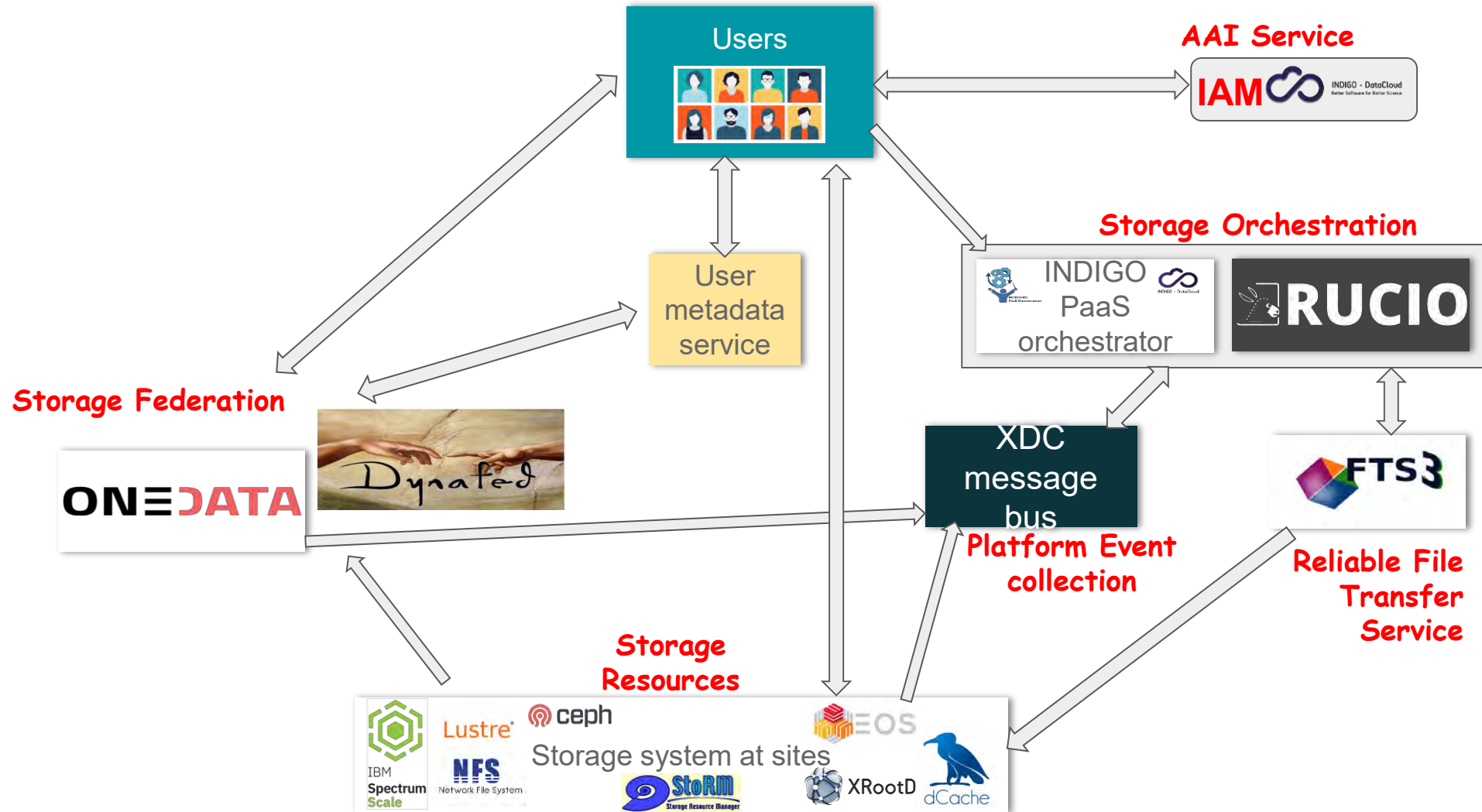✖ XDC acts at all the e-infrastructure levels
- ⇢ Storage systems at sites
- ⇢ Federations of storage systems
  - ⇢ regional and global
- ⇢ High level orchestration
- ⇢ User experience

✖ The "toolbox" was mapped in those levels to define the general architecture
- ⇢ Taking into account the user requirements

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# XDC General Architecture

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# Connection to external Entities

✘ DEEP-DataCloud
  - Connection to compute workloads
  - SQA common baseline

✘ DOMA (Data Organization, Management, Access)
  - DOMA "Access"
  - DOMA "QoS" (XDC Workgroup Leader)
  - DOMA "3rd Party Copy"

✘ ESCAPE – WP2 (XDC Task Leader)
  - Deployment of a European Data Lake

✘ RDA
  - Defining QoS vocabulary
  - Data Management workshop at the next plenary in Helsinki

✘ SNIA
  - Rendering CDMI to reflect QoS
  - XDC introduced at 2018 SNIA conference

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# SQA baseline

"A set of Common Software Quality Assurance Baseline Criteria for Research Projects" - http://hdl.handle.net/10261/160086

✘ **What?**

⋯➤ Set of conventions and recommendations for software development, aiming "to serve as a reference within the European research ecosystem related projects"

✘ **Why?**

⋯➤ Enhance the visibility, accessibility and distribution of the produced software

⋯➤ Promote code style standards => readability & reusability

⋯➤ Reliable operation

## A set of Common Software Quality Assurance Baseline Criteria for Research Projects

### Abstract

The purpose of this document is to define a set of quality standards, procedures and best practices to conform a Software Quality Assurance plan to serve as a reference within the European research ecosystem related projects for the adequate development and timely delivery of software products.

### Document Log

| Issue | Date | Comment |
|-------|------|---------|
| V1.0 | 31/01/2018 | First draft version |
| V2.0 | 05/02/2018 | Updated criteria |

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# XDC Components

The Components

✖ **Orchestration and Federation Components**
  - ➡ XDC Orchestrator
    - ➡ INDIGO PaaS Orchestrator
    - ➡ Flowable © (BPM)
    - ➡ Rucio Data Management System
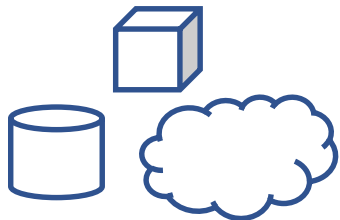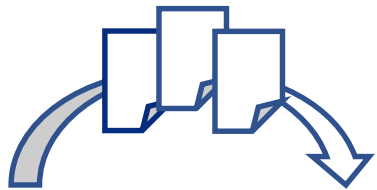
✖ **Data Transfer and Data Federation technologies**
  - ➡ FTS, File Transfer Service,
  - ➡ Dynafed, Data Federator, Onedata

✖ **Storage Systems**
  - ➡ dCache
  - ➡ EOS
  - ➡ StoRM

# XDC Orchestration Components

## INDIGO PaaS Orchestrator

- Based on INDIGO-DataCloud developments.
- Allows to coordinate complex deployments on hybrid clouds featuring advanced scheduling and federation capabilities
- Orchestrates compute resources and provides data-aware scheduling of jobs through data placement plugins (XDC extensions)
- Integrates with Rucio for data location and transfer orchestration (XDC developments)
- Operates with a professional BPM system. (Flowable)

## Flowable © (BPM)

- Provides a workflow and Business Process Management (BPM) platform for developers, system admins and business users

## Rucio

- Originally LHC ALTAS data management tools.
- Recently adopted by a growing number of other communities.
- Already provides interfaces to most XDC components

# XDC Transport Components

## ✖ FTS, File Transfer Service

- ➡ WLCG data transfer workhorse.
- ➡ Transfers around 1 Exabytes of WLCG data per year between hundreds of storage sites around the word.
- ➡ Performs request queueing and network shaping.
- ➡ Can be used as "micro service" or with GUI (WebFTS).
- ➡ Support X509 and token based authentication for endpoints.
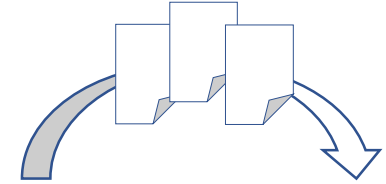
## ✖ Dynafed, Data Federator

- ➡ Federates storage endpoints to a single root namespace.
- ➡ Supported Protocols: http/WebDAV, S3.
- ➡ Performs metadata prefetching.
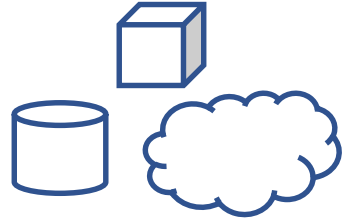- ➡ Provides location meta data to high level services.

# XDC Storage Components

## The Components

**✘ dCache**

- → Open Source Storage system provided by DESY, Fermilab and NDGF.
- → Handling 150 PBytes at more than 60 big data centers, including 7 WLCG Tier 1 centers.
- → Supports industry standard data access and security protocols on top of a geo-aware multi tier storage stack.

**✘ EOS**

- → Scalable storage running at CERN and elsewhere.
- → Geo-aware management of hundred of PBs.
- → HTTP interface.

**✘ StoRM**

- → Provided by INFN/CNAF
- → Engine providing multiple data transport and control protocols on top of GPFS and Lustre.

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# XDC Storage Components
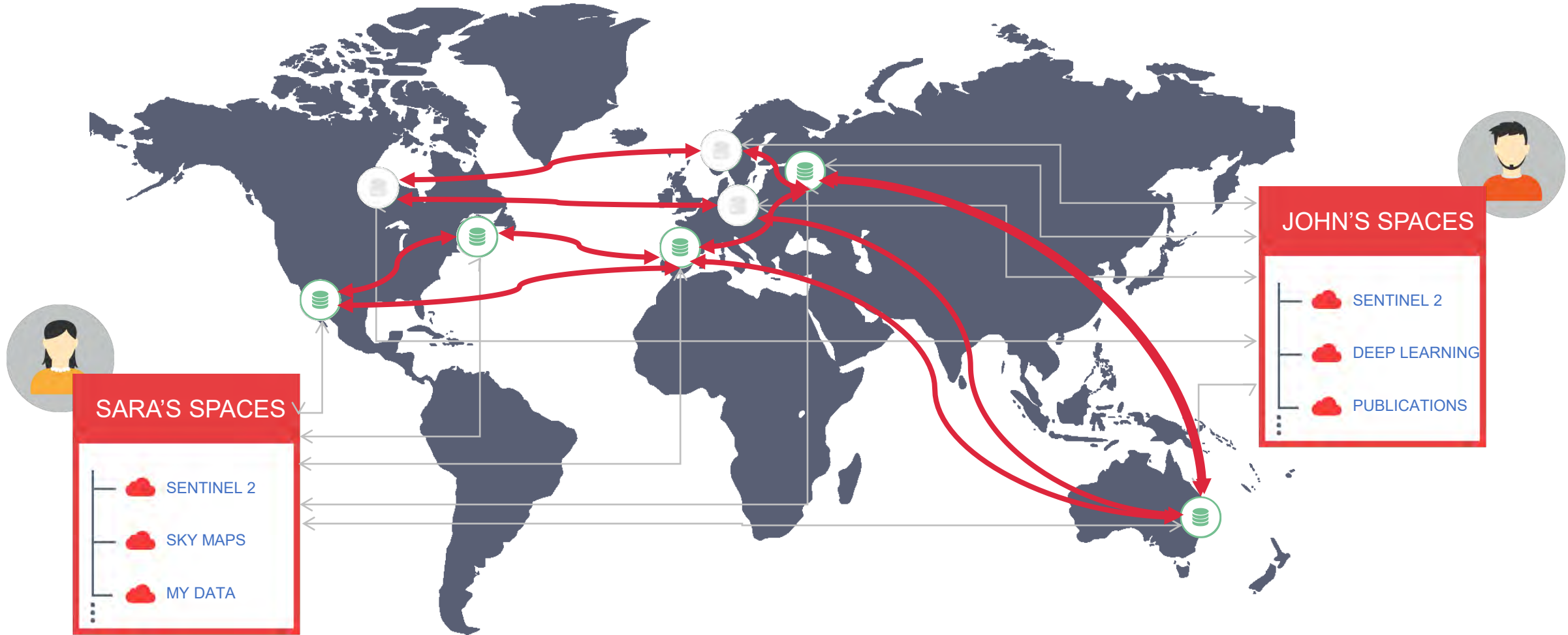
- ## INDIGO CDMI Reference Implementation
  - → INDIGO re-implementation of the SNIA CDMI reference implementation, now hosted by SNIA.
  - → Provided the CDMI protocol engine and forwards the requests to a plug-in system.
  - → Provides plug-ins for a REST protocol dialect as well as for CEPH and GPFS.
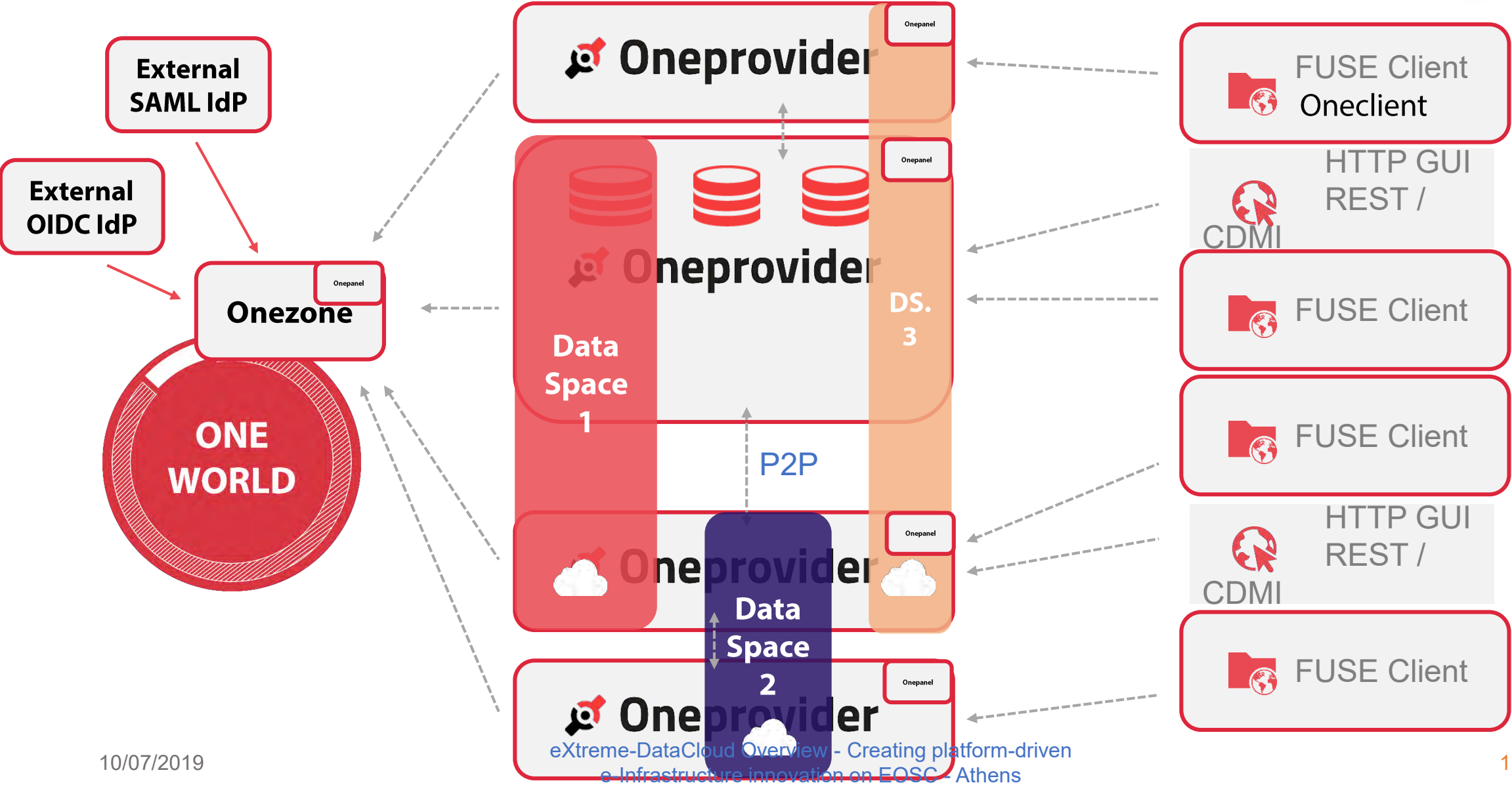
- ## XCache
  - → Read-only, block-level data cache
  - → Deployed close to CPU to hide latency and reduce WAN traffic
  - → HTTP interface

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# ONEDATA DISTRIBUTED DATA IN HYBRID CLOUDS



JOHN'S SPACES
- SENTINEL 2
- DEEP LEARNING
- PUBLICATIONS

SARA'S SPACES
- SENTINEL 2
- SKY MAPS
- MY DATA

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# ONEDATA SYSTEM ARCHITECTURE

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# First XDC Release

## Involved tools

- CachingOnDemand
- dCache
- Dynafed
- EOS

- FTS,GFAL
- Onedata
- PaaS Orchestrator plugin
- TOSCA types & templates plugin

## Key technical highlights

- OpenIDConnect support for token based authentication
- New QoS types integration and support in dCache, FTS, GFAL
- Orchestrator integration with other components
- Performance improvements in Onedata
- Support for groups and roles in Onedata
- EOS-dCache integration
- Caching systems instantiation
- Storage events notification in dCache
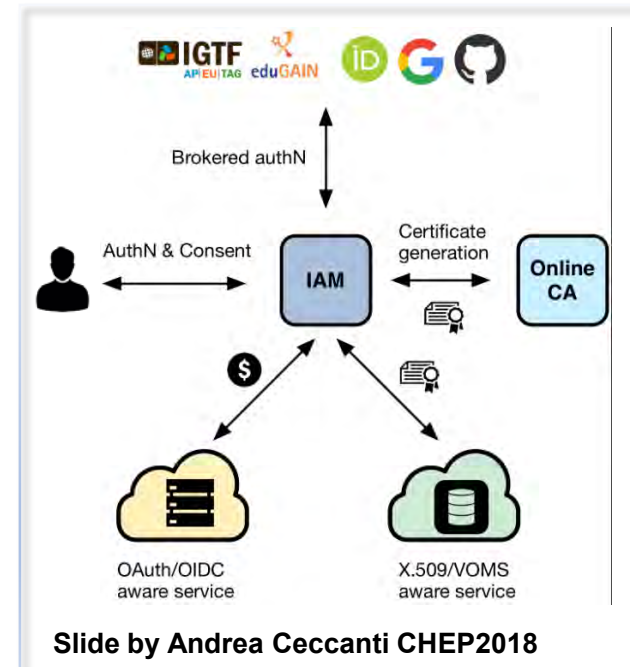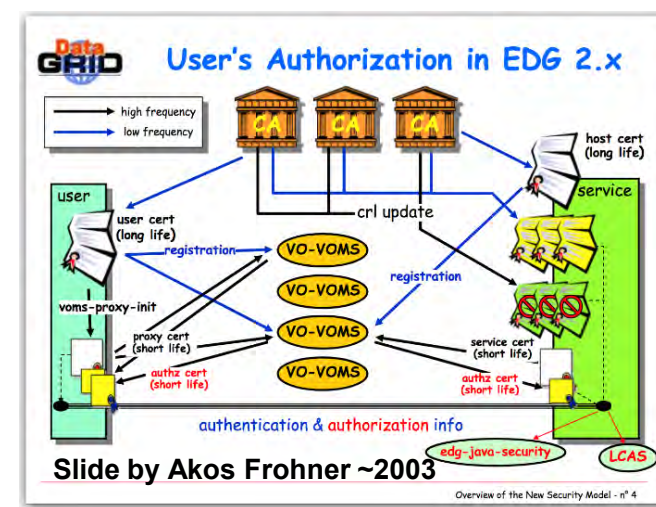- EOS caching with XCache for geographic deployment
- EOS external storage adoption

**XDC-1/Pulsar**

eXtreme-DataCloud

First software release

https://releases.extreme-datacloud.eu/en/latest/releases/pulsar/index.html

# First XDC Release

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**User's Authorization in EDG 2.x**

Slide by Akos Frohner ~2003



Slide by Andrea Ceccanti CHEP2018

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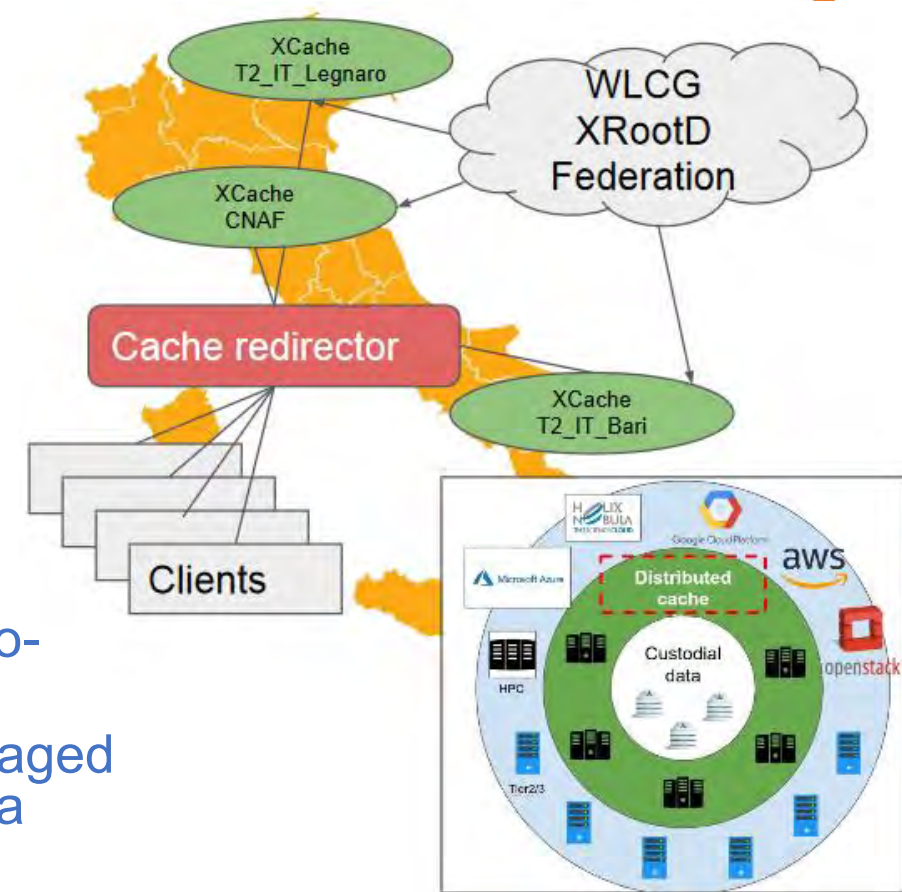
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- Deployment of Geo-distributed caches
- Network of unmanaged storage for hot data
- On-demand cache resources

**Based on xRootD/xCache**

**See D.Ciangottini talk on "Integration of the Italian cache federation within CMS computing model":**
**https://indico4.twgrid.org/indico/event/8/session/23/contribution/45**



**Slide © Diego Ciangottini**

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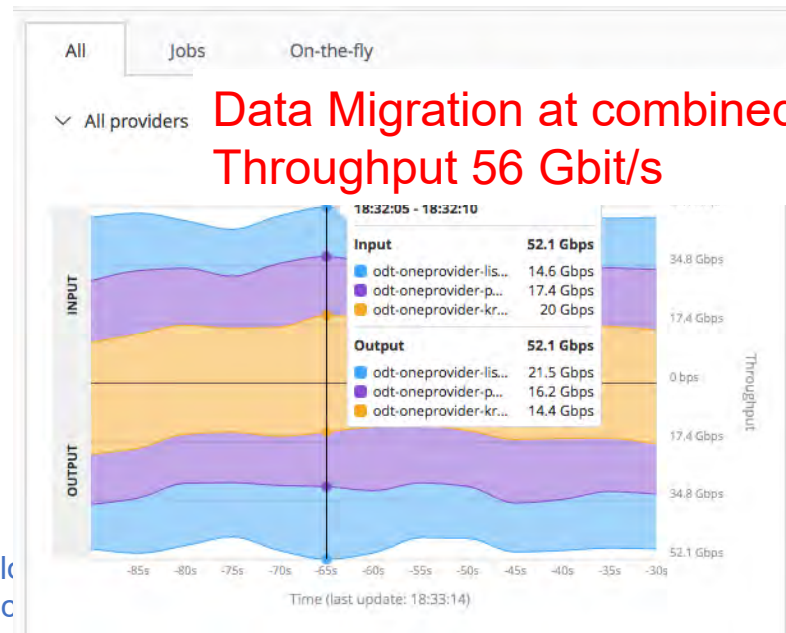e-Infrastructure innovation on EOSC - Athens

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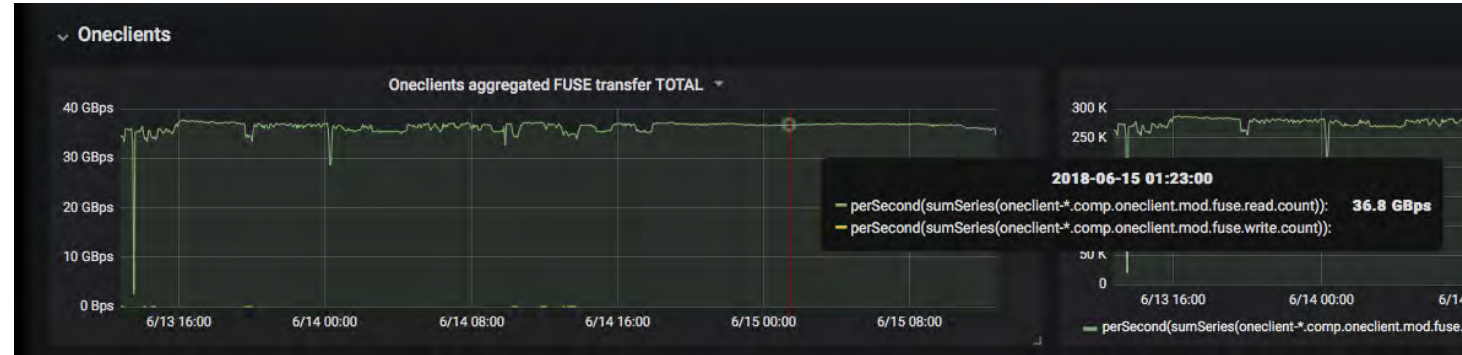


Onedata Transparent POSIX File System
Processing transparently cached data - 37GBytes/sec



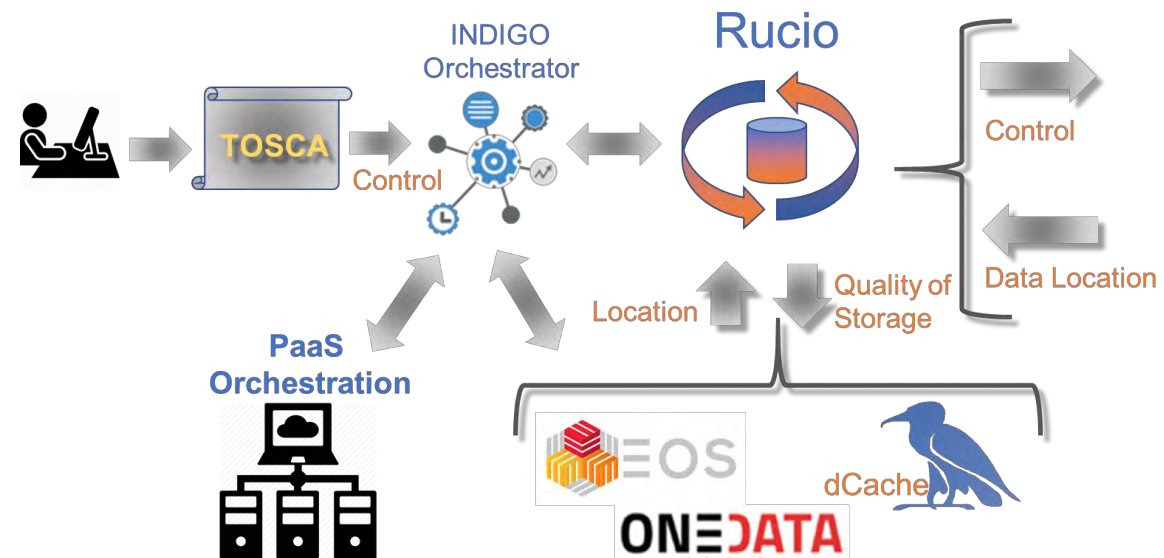Data Migration at combined Throughput 56 Gbit/s

- Data Transfer Mesh
- 3 Oneproviders connected by 20+Gbit/s links
- Transfer data between all them
- Single VM Node per Provider
- Linear scalability
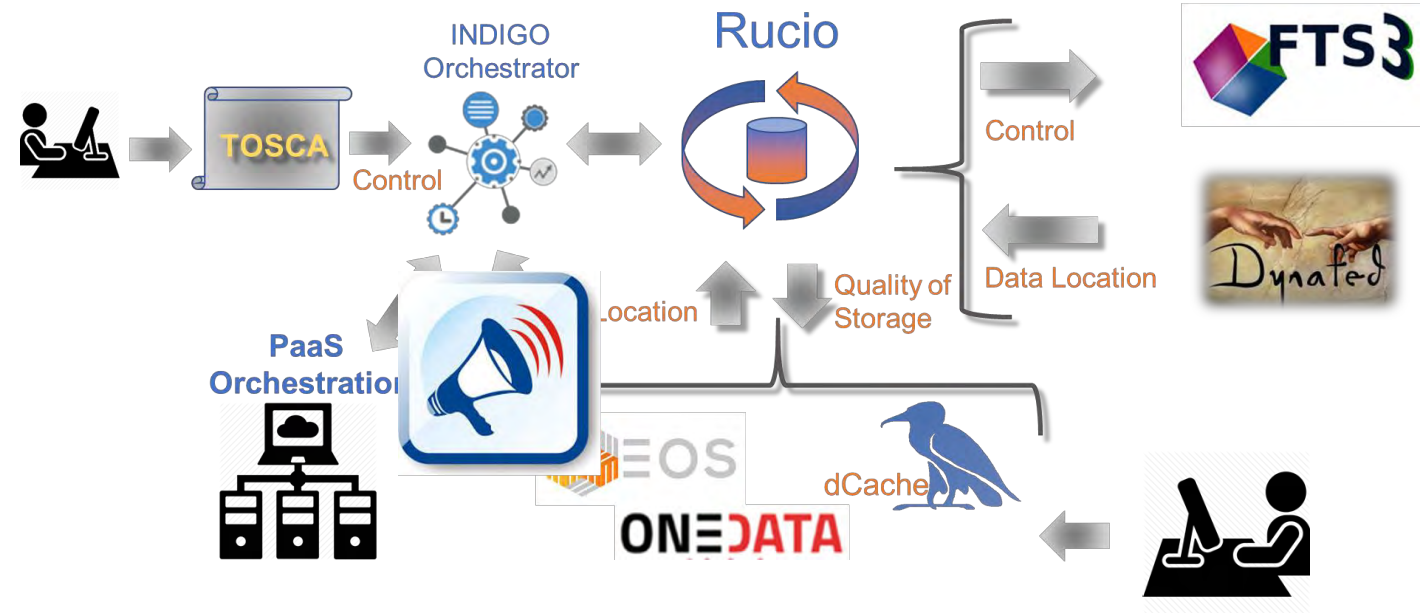
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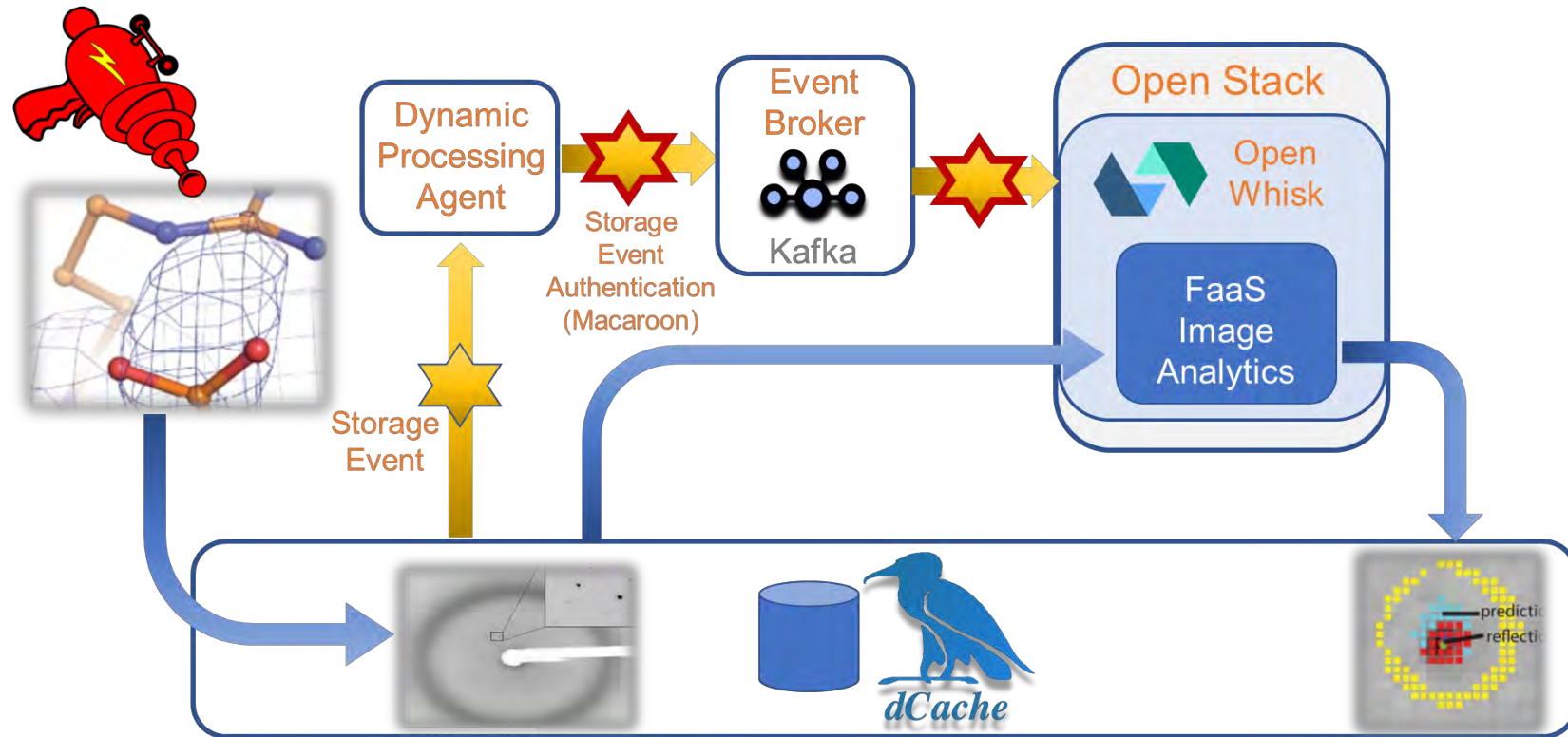
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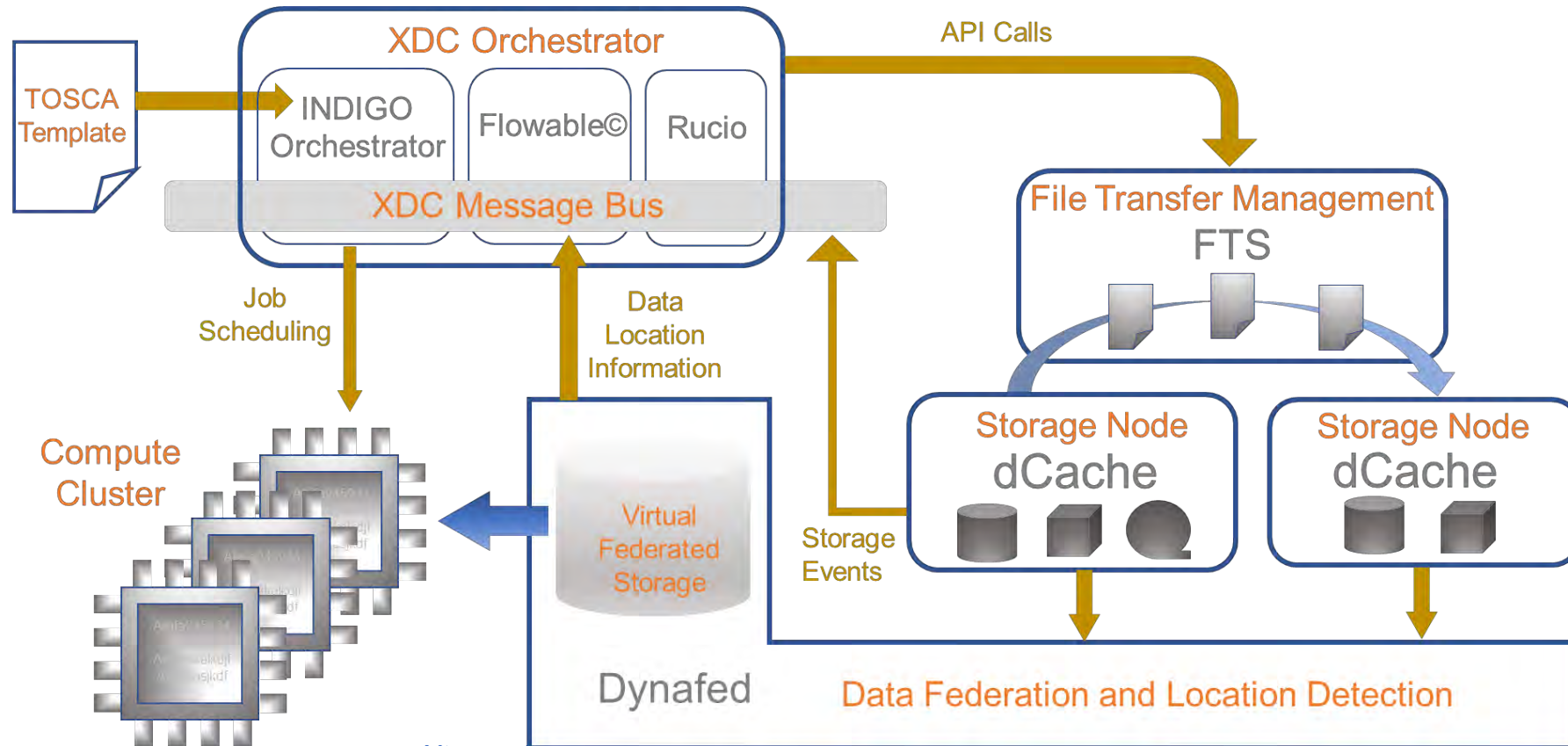- EOS external storage adoption

# XFEL Use Case in XDC

- The XFEL UseCase is driving the developments on storage events notifications support
  - A reference implementation is done using dCache as backend
- Refer to the Patrick's presentation:
  - https://indico4.twgrid.org/indico/event/8/session/15/contribution/9

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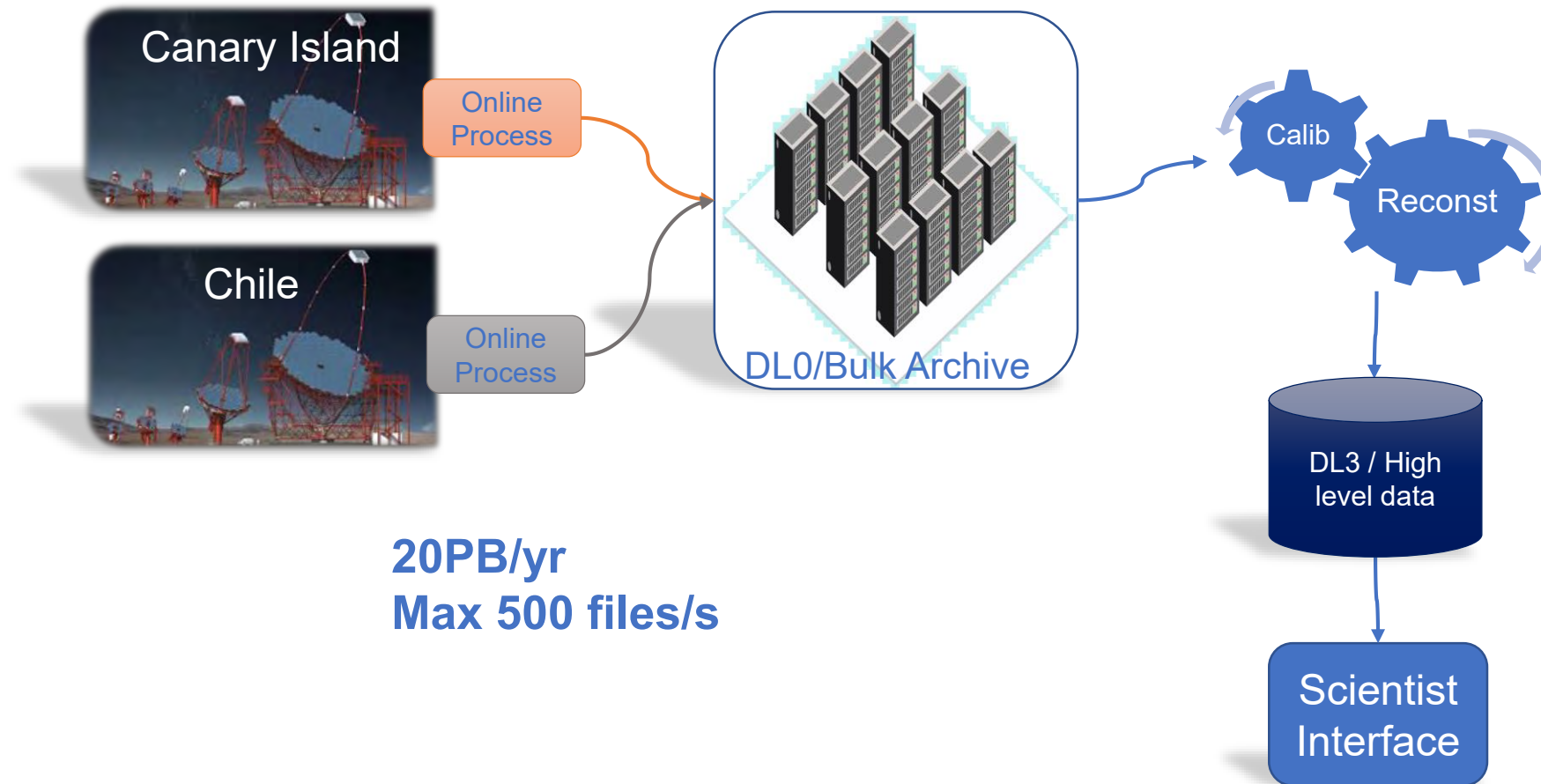
© Patrick's Fuhrmann
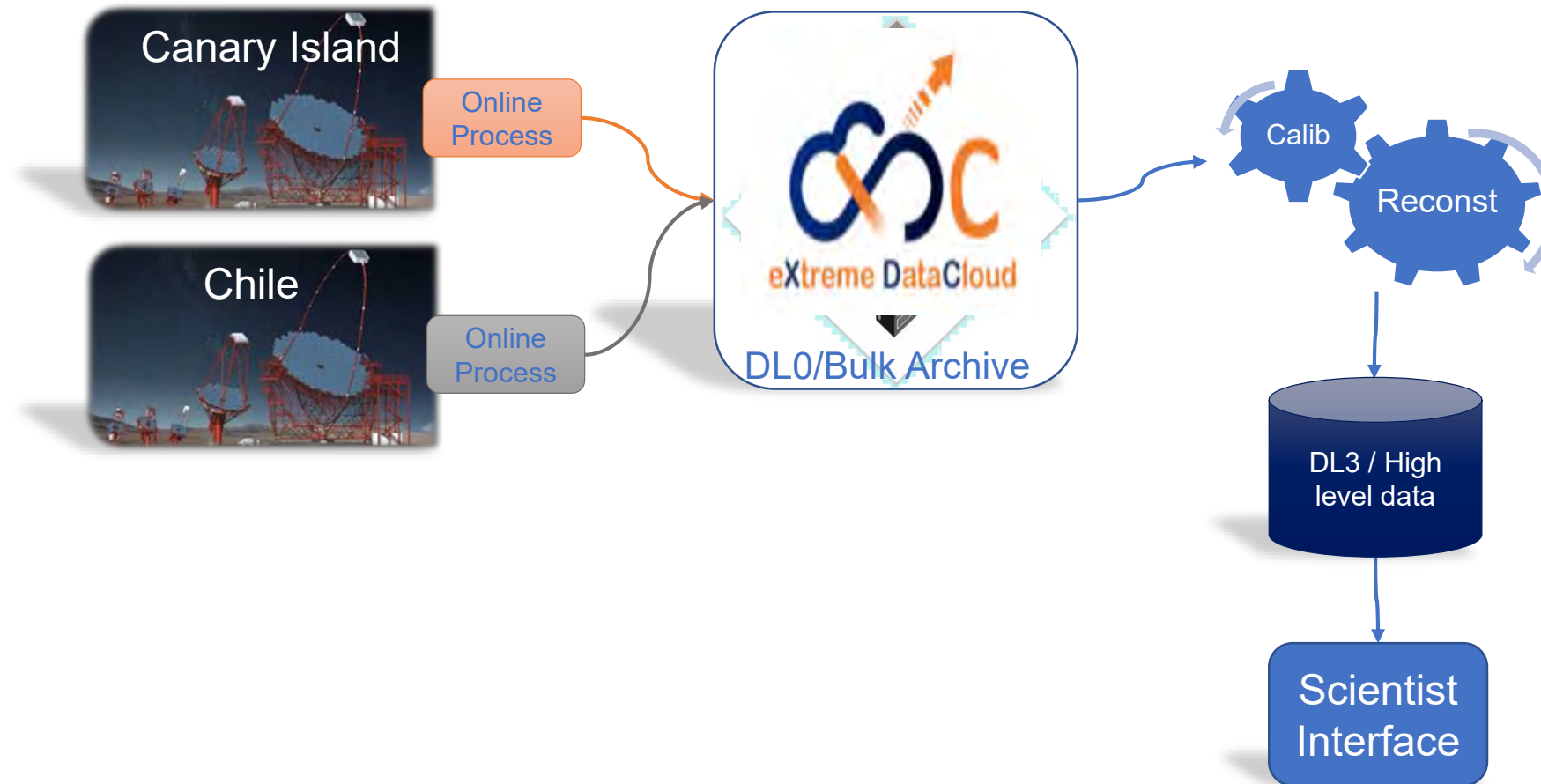
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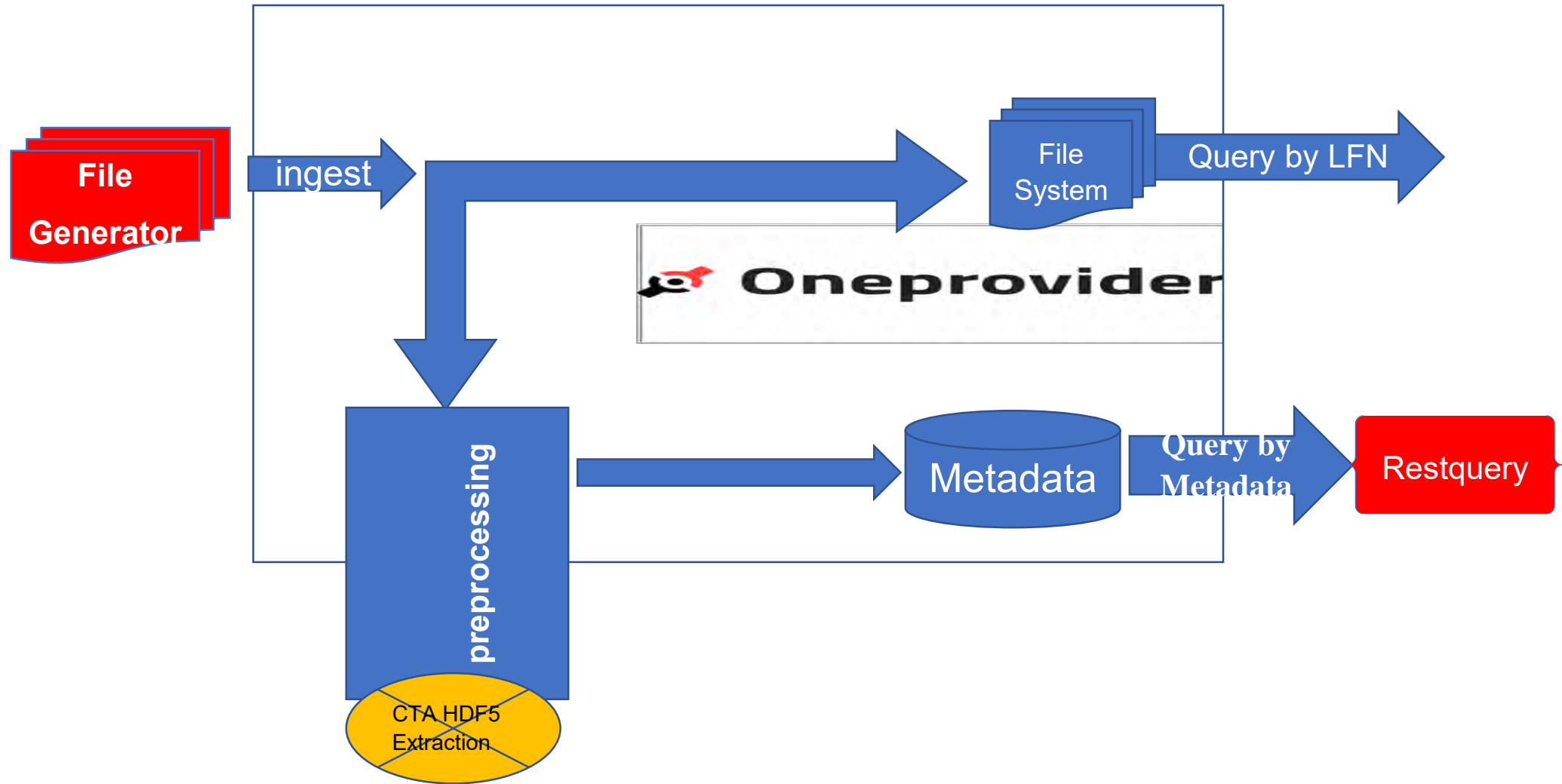- ✖ Refer to the Patrick's presentation:
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# CTA Use Case Workflow in XDC



Canary Island

Chile

Online Process

Online Process

DL0/Bulk Archive

Calib

Reconst

DL3 / High level data

Scientist Interface

**20PB/yr
Max 500 files/s**

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# CTA Use Case Workflow in XDC

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# CTA Use Case Workflow in XDC

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# CTA Use Case Workflow in XDC

# CTA Use Case Workflow in XDC



File Generator

ingest

INDIGO PaaS orchestrator

preprocessing

CTA HDF5 Extraction

ONEDATA

MANAGE ACCOUNT

GO TO YOUR FILES

Choose Provider

LAPP-PROVIDER-01

CC-PROVIDER-02

DATA SPACE MANAGEMENT

SPACE-CTA    4 TIB

LAPP-PROVIDER-01

CC-PROVIDER-02

Add storage...

SPACE-CTA

Query by LFN

Query by metadata

Restquery

LAPP-PROVIDER

CC-PROVIDER-02

POSIX 40TB

S3 4TB

POSIX 6TB

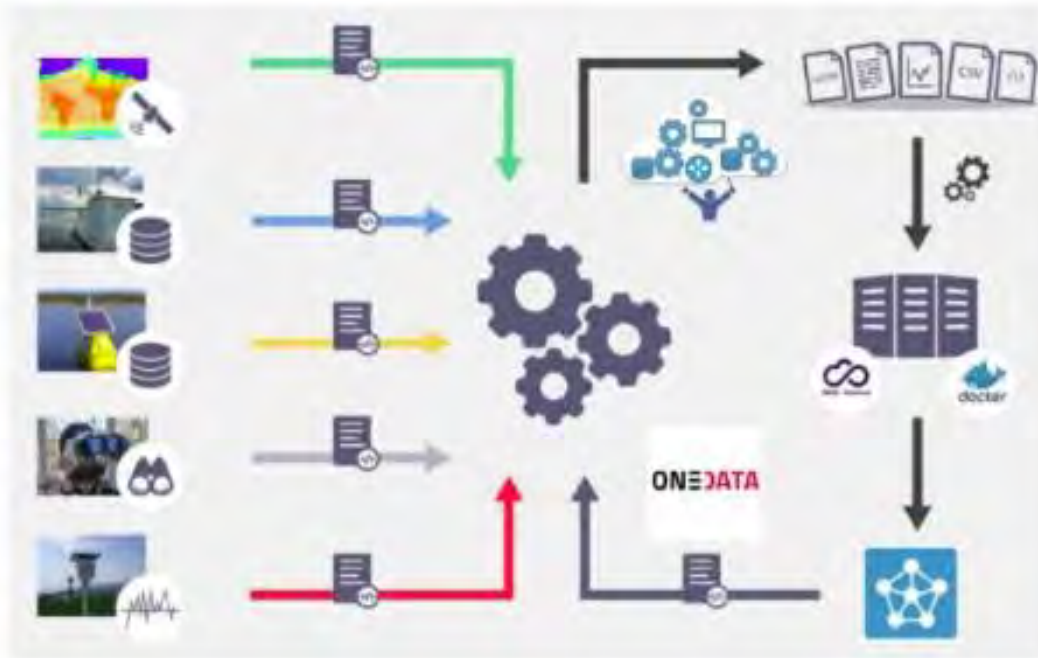eXtreme-DataCloud Overview - Creating platform-driven e-Infrastructure innovation on EOSC - Athens

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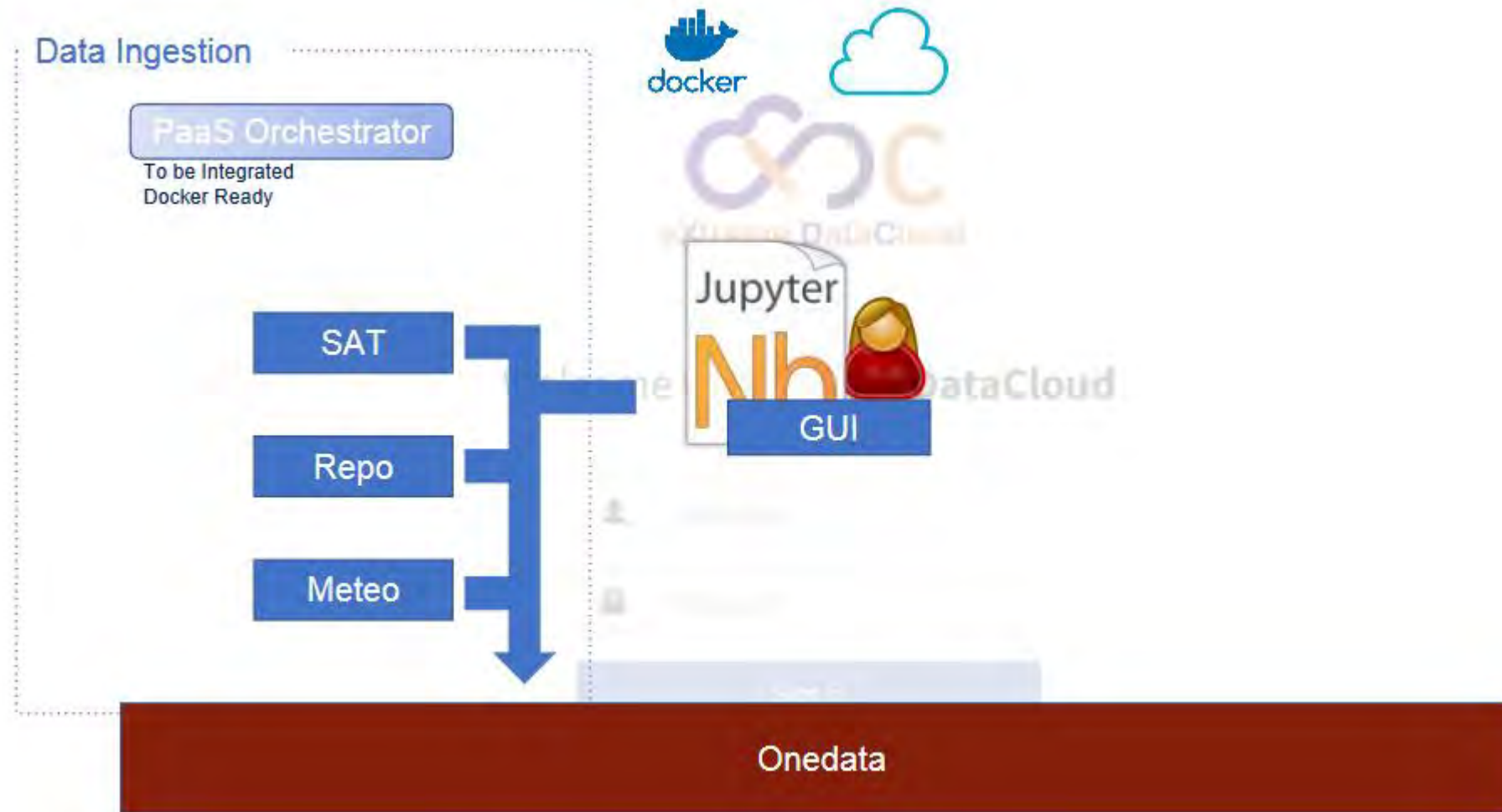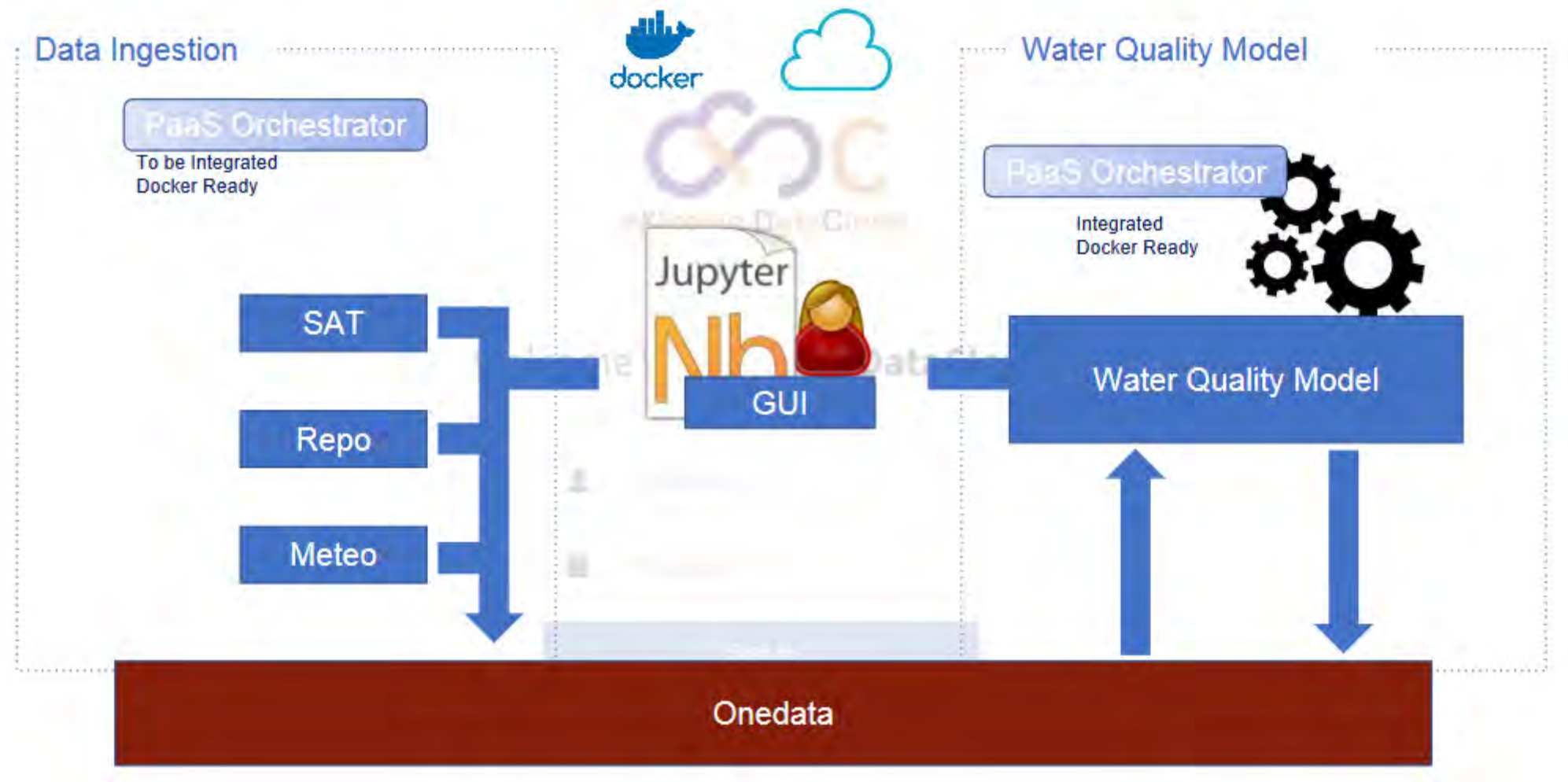
# LifeWatch Use Case in XDC



- **Objetives:** Integrate different and heterogeneous data sources: **satellite data, real-time monitoring system based on sensors, observations, and meteorological data** to feed the **hydrological and water quality models**, thus automating modeling and prediction of water quality.

- **XDC Services Requirements:**
  - **XDC IAM**
  - **Onedata:**
    - Onedata Attachment
    - Onedata Discovery
  - **PaaS Orchestrator**

# LifeWatch Use Case in XDC

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# LifeWatch Use Case in XDC

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# Use cases vs tool matrix

| | Problem | Goal | XDC services | Status |
|---|---|---|---|---|
| **Lifewatch** | Data Life Cycle Management of data related to Water Quality involving heterogeneous data sources | Integrate data sources and different types of modelling tools | Onedata PaaS Orchestrator | Data Sources integrated Analysis with Orchestrator |
| **CTA** | Complex and Big Data management in a distributed environment. Data quality Assurance. | Integration of tools for FAIR Data Management and user access control | Onedata QoS PaaS Orchestrator | Metadata extraction and storing/attachment |
| **ECRIN** | Distributed information about clinical studies and data objects across different registries and repositories. | Single environment to find data objects across repositories and registries, based on metadata | Onedata | Sources integration. Metadata harmonization |
| **WLCG** | Growing needs on storage space | Reduce costs, resource aggregation, smart data allocation | QoS Xcache EOS | QoS and http caching implemented |
| **XFEL** | Complex Data management in a distributed and heterogeneous environment. | Data lifecycle management. Processing and analytics | QoS PaaS Orchestrator dCache Message BUS | Orchestration configured based on events |

# XDC Main Releases

✘ A second major release is foreseen before the end of the project

- XDC Message bus implementation
- full orchestration
- finalize integration of RUCIO
- secure storage in Onedata
- finalize the ECRIN Use Case
- complete caching reference workflows with HTTP based systems

|  | Release Date | End of Full Updates | End of Standard Updates | End of Security Updates & EOL |
|---|---|---|---|---|
| XDC 1 | Jan 2018 | May 2019 | Sep 2019 | Nov 2019 |
| XDC 2 | Oct 2019 | Apr 2020 | Jul 2020 | Sep 2020 |

XDC products can be downloaded from XDC repositories or from each components upstream repositories after they have been pushed back

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# Software quality process and testbeds

- XDC defined a rigorous process for ensuring software quality
  - Definition of roles
  - SQA Policies and Procedures
  - Development testbed
  - Integration testbed
  - Pilot testbed
  - Maintenance of Tools and Repositories

- Pilot Testbed is for internal use but can be opened to external communities for specific activities

### Integration and Development Testbeds
Creato da Doina Cristina Dum

Development tes

| Type of reso |
| --- |
| PaaS/Orchestrator |
| PaaS/CMDB |

### Pilot Preview testbed
Creato da Doina Cristina Duma, ultima modifica il feb 19, 2019

| Type of services | Partner | Endpoint of service/resource | |
| --- | --- | --- | --- |
| Onedata | CYFORNET | onedata.org | |
| Onedata (Onezone) | INFN - CNAF | https://onezone.cloud.cnaf.inf | |
| Onedata (OneProvider) | INFN Padova | https://one-data-01.pd.infn.it | |
| | | https://cloud-90-147-75-163.c | |
| PaaS Orchestrator | INFN | https://paas-xdc.cloud.cnaf.inf | |
| PaaS SLAM | INFN | https://paas-xdc.cloud.cnaf.inf | |
| PaaS CMDB | INFN | http://paas-xdc-tools.cloud.cn | |
| PaaS CPR | INFN | http://paas-xdc-tools.cloud.cn | |
| PaaS Zabbix | INFN | http://paas-xdc-tools.cloud.cnaf.infn.it | Deployed - alpine-3.2-latest |
| PaaS Zabbix Wrapper | INFN | http://paas-xdc-tools.cloud.cnaf.infn.it:8082 | **Deployed - v1.0.2** |
| IAM | INFN | https://iam.extreme-datacloud.eu/ | Deployed - v1.4.0 |
| **External services** | | | |
| VOMS | LIP | https://voms01.ncg.ingrid.pt:8443/voms/vo.indigo-datacloud.eu/ | registration link: https://voms01.ncg.ingrid.pt:8443/voms/vo.indigo-datacloud.eu/register |
| WaTTS | INFN | https://tts-01.cloud.cnaf.infn.it:25554/ | |
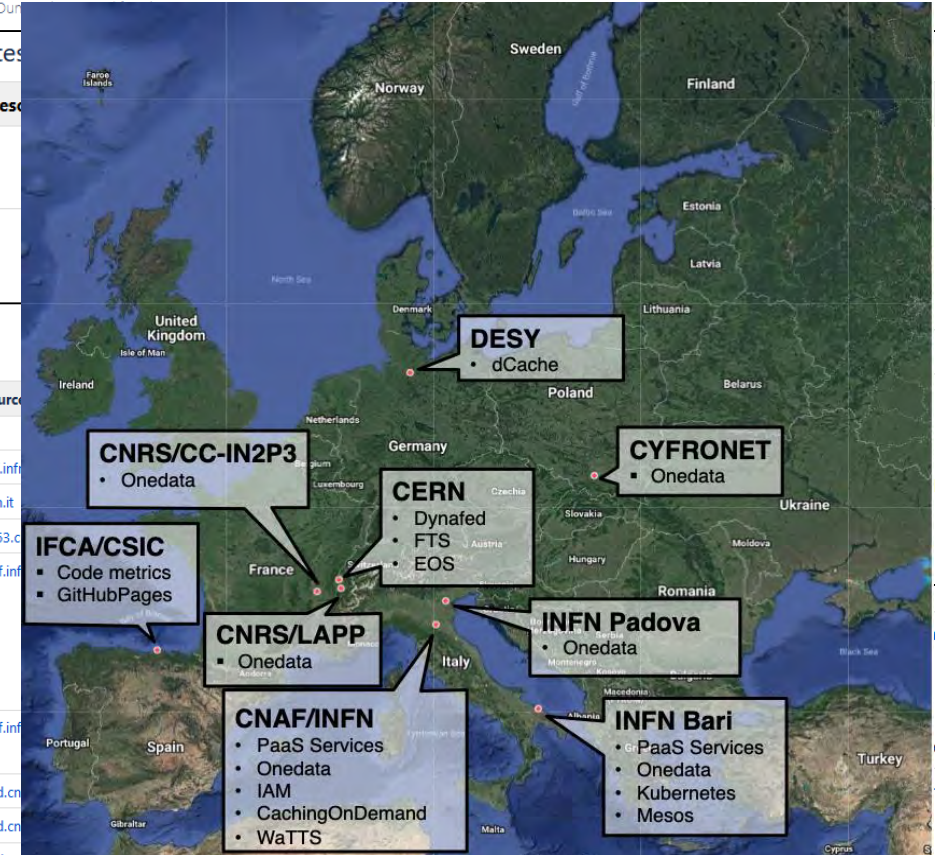
### Integration testbed

| Type of resource | Partner | Endpoint of service/resource |
| --- | --- | --- |
| Onedata | CYFORNET | onedata.org | - |

**DESY**
- dCache

**CNRS/CC-IN2P3**
- Onedata

**CYFRONET**
- Onedata

**IFCA/CSIC**
- Code metrics
- GitHubPages

**CERN**
- Dynafed
- FTS
- EOS

**CNRS/LAPP**
- Onedata

**INFN Padova**
- Onedata

**CNAF/INFN**
- PaaS Services
- Onedata
- IAM
- CachingOnDemand
- WaTTS

**INFN Bari**
- PaaS Services
- Onedata
- Kubernetes
- Mesos

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# Conclusion

✖ XDC is adding new functionalities to already existing, production quality, data management services

✖ XDC-1/Pulsar was released in January 2019
- ➔ A step towards the complete implementation of the defined architecture
- ➔ Research communities can already start implementing their use cases using Pulsar

✖ A second release is foreseen by next October

✖ Scalability verification is in progress and is one of the core activities in 2019

✖ XDC consortium members are acting as service providers to facilitate the uptake of the XDC services by the EOSC communities
- ➔ We are involving external service providers to increase the uptake of new user communities

# XDC Contacts



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