Rucio

ECMWF EUMETSAT CERN Technical Meeting

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on behalf of the Rucio team

RUCIO
SCIENTIFIC DATA MANAGEMENT

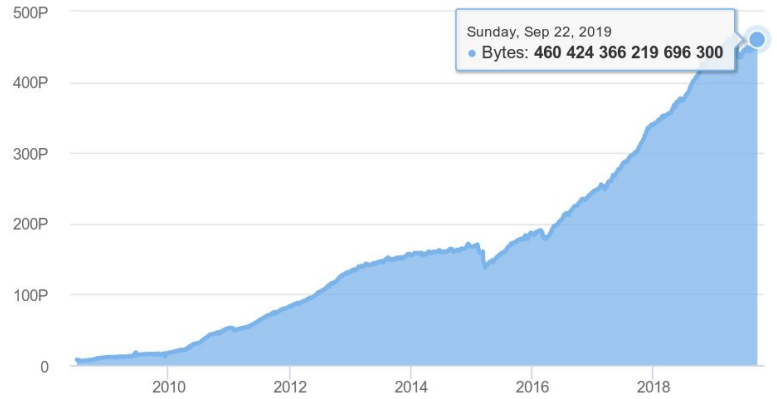
ATLAS
EXPERIMENT

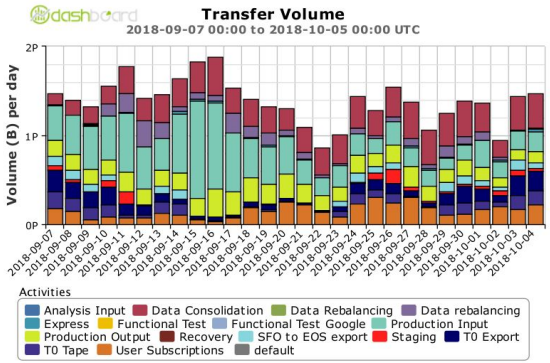
Rucio in a nutshell

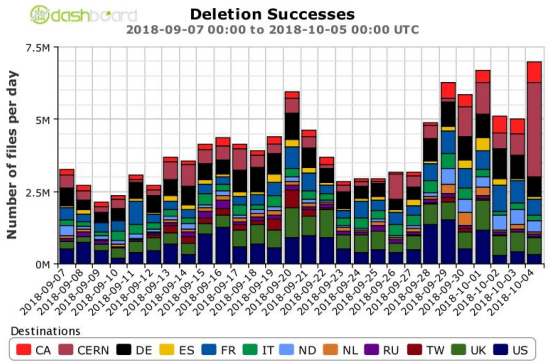
- Rucio provides a complete and generic scientific data management federation
  - Seamless integration of scientific and commercial storage and their network systems
  - Data is stored in files and can contain any potential payload
  - Facilities can be distributed at multiple locations belonging to different administrative domains
  - Designed with more than a decade of operational experience in very large-scale data management
- Rucio manages location-aware data in a heterogeneous distributed environment
  - Creation, location, transfer, deletion, and annotation of data
  - Orchestration of dataflows with both low-level and high-level policies
- Principally developed by and for the High-Energy Physics experiment ATLAS
- Rucio is open source and available under Apache 2.0 license
- Make use of established toolchains for and with the community

Data management for ATLAS

- A few numbers to set the scale
  - 1B+ files, 450 PB of data, 400+ Hz interaction rate
  - 120 data centres, 5 HPCs, 600 storage areas
  - Up to 4M files/2.5 PB transferred per day
  - 10PB access from clients per day; >1000 active users
- Increase 1+ order of magnitude for LHC Run 4







Community


Advanced European Network of E-infrastructures
for Astronomy with the SKA


LCLS


Belle II


Science & Technology
Facilities Council


COMPASS

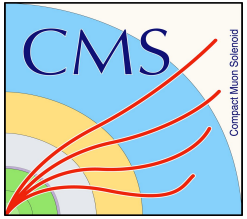

CERN


ARC


ATLAS
EXPERIMENT


Alpha Magnetic Spectrometer
AMS-02
Europe • Asia
North America


Xe
XENON
Dark Matter Project

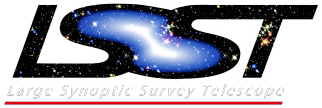

CMS
Compact Muon Solenoid


DUNE
DEEP UNDERGROUND
NEUTRINO EXPERIMENT


egi


3D
EISCAT


cta
cherenkov telescope array


LSST
Large Synoptic Survey Telescope


IceCube
SOUTH POLE NEUTRINO OBSERVATORY


FTS


eXtreme DataCloud


Fermilab


BROOKHAVEN
NATIONAL LABORATORY


SKA
SQUARE KILOMETRE ARRAY

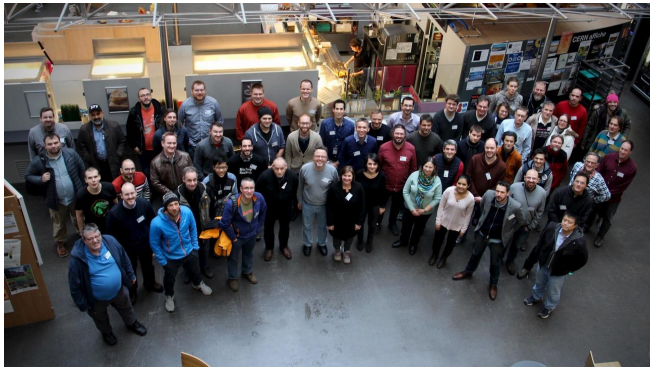

LIGO


Open Science Grid


EUXDAT

Regular events

- Rucio Community Workshops [2018] [2019]
- Rucio Coding Camps 2018 [2018] [2019]
- Development Meetings [Weekly]



Rucio main functionalities

- Provides many features that can be enabled selectively
  - File and dataset catalog
  - Transfers between facilities including disk, tapes, clouds, HPCs
  - Web-UI, CLI, and API to discover/download/upload/transfer/annotate data
  - Extensive monitoring for all dataflows
  - Support for caches and CDN workflows
  - Expressive policy engines with rules and subscriptions
  - Automated corruption identification and recovery
  - Data popularity based replication
  - …

More advanced features

- Rucio can be integrated with Workload and Workflow Management System
  - Already supporting PanDA, the ATLAS WFMS
  - Belle-II is driving the integration with DIRAC

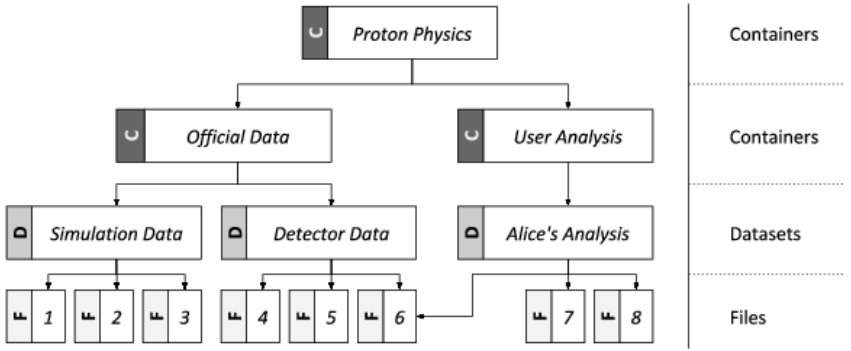
Operations model

- Objective was to minimise the amount of human intervention necessary
- Large-scale and repetitive operational tasks can be automated
  - Bulk migrating/deleting/rebalancing data across facilities at multiple institutions
  - Popularity driven replication and deletion based on data access patterns
  - Management of disk spaces and data lifetime
  - Identification of lost data and automatic consistency recovery
- Administrators at the sites are not operating any Rucio service
  - Sites only operate their storage exposed via protocols (POSIX, ROOT, HTTP, WebDAV, S3, gsiftp, …)
  - Users have transparent access to all data in a federated way
- Easy to deploy
  - PIP packages, Docker containers, Kubernetes

Rucio concepts - Namespace

- All data stored in Rucio is identified by a **D**ata **ID**entifier (DID)

- There are different types of DIDs
  - Files
  - Datasets Collection of files
  - Container Collection of dataset and/or container
- Each DID is uniquely identified and composed of a scope and name, e.g.:




```
detector_raw.run34:observation_123.root
```

scope name

Rucio concepts - Declarative data management

- Express what you want, not how you want it
  - *e.g., "Three copies of this dataset, distributed evenly across multiple continents, with at least one copy on TAPE"*
- Replication rules
  - Rules can be dynamically added and removed by all users, some pending authorisation
  - Evaluation engine resolves all rules and tries to satisfy them by requesting transfers and deletions
  - Lock data against deletion in particular places for a given lifetime
  - Primary replicas have indefinite lifetime rules
  - Cached replicas are dynamically created replicas based on traced usage and popularity
  - Workflow system can drive rules automatically, e.g., job to data flows or vice-versa
- Subscriptions
  - Automatically generate rules for newly registered data matching a set of filters or metadata
  - e.g., *project=data17_13TeV* and *data_type=AOD* uniformly across *T1s*

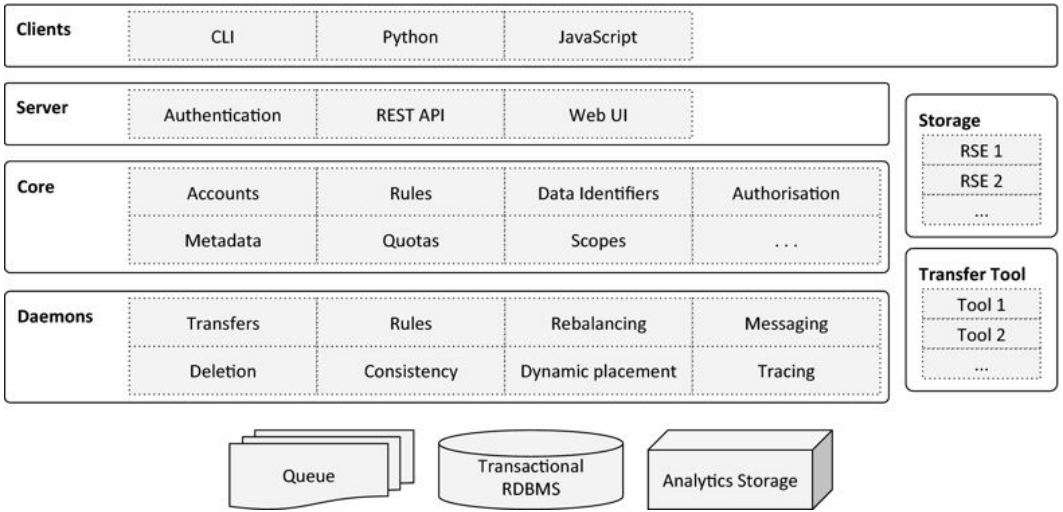
Rucio concepts - RSEs

- Rucio Storage Elements (RSEs) are logical entities of space
  - No software needed to run at the facility except the storage system, e.g., EOS/dCache/S3, …
  - RSE names are arbitrary, e.g., "CERN-PROD_DATADISK", "AWS_REGION_USEAST", …
  - Common approach is one RSE per storage class at the site
- RSEs collect all necessary metadata for a storage system
  - Protocols, hostnames, ports, prefixes, paths, implementations, …
  - Data access priorities can be set, e.g., to prefer a different protocol for LAN-only access
- RSEs can be assigned metadata as well
  - Key/Value pairs, e.g., *country=UK*, *type=TAPE*, *is_cached=False, …*
  - You can use RSE expressions to describe a list of RSEs, e.g. `country=FR&type=DISK` for the replication rules

Rucio concepts - Metadata

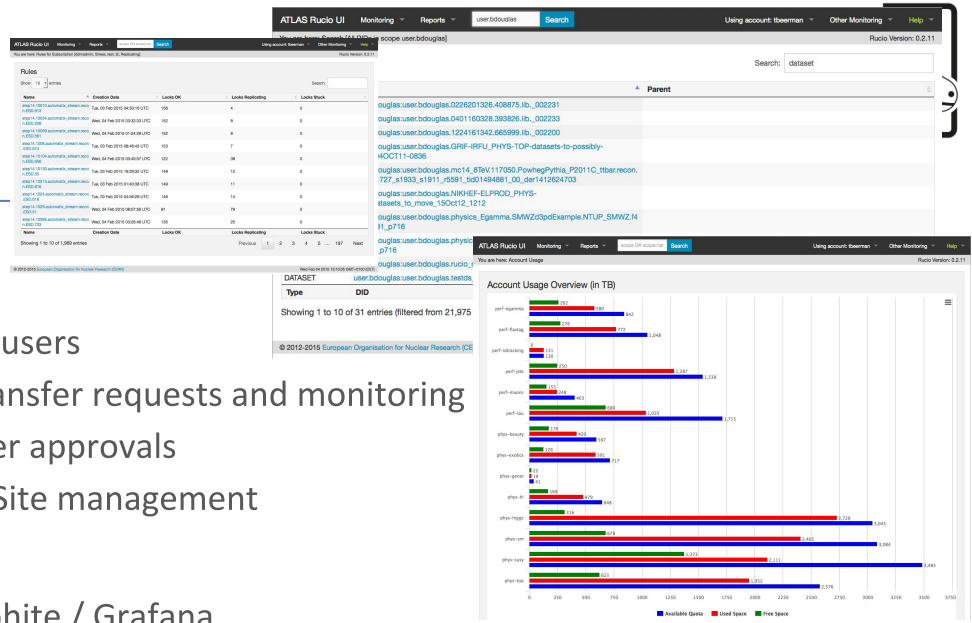
- Rucio supports different kinds of metadata
  - File internal metadata, e.g., *size, checksum, creation time, status*
  - Fixed physics metadata, e.g., *number of events, lumiblock, cross section, …*
  - Internal metadata necessary for the organisation of data, e.g., *replication factor, job-id,*
  - Generic metadata that can be set by the users
- Generic metadata can be restricted
  - Enforcement possible by types and schemas
  - Naming convention enforcement and automatic metadata extraction
- Provides additional namespace to organise the data
  - Searchable via name and metadata
  - Aggregation based on metadata searches
  - Can also be used for long-term reporting, e.g., evolution of particular metadata selection over time

Architecture



- **Servers**
  - HTTP REST/JSON APIs
  - Token-based security (x509, ssh, kerberos, …)
  - Horizontally scalable
- **Daemons**
  - Orchestrates the collaborative work
    e.g., transfers, deletion, recovery, policy
  - Horizontally scalable
- **Messaging**
  - STOMP / ActiveMQ-compatible
- **Persistence**
  - Object relational mapping
  - Oracle, PostgreSQL, MySQL/MariaDB, SQLite
- **Middleware**
  - Connects to well-established products,
    e.g., FTS3, DynaFed, dCache, EOS, S3, …
- **Python**
  - Support for Python2 and Python3

Monitoring & analytics



- RucioUI
  - Provides several views for different types of users
  - Normal users: Data discovery and details, transfer requests and monitoring
  - Site admins: Quota management and transfer approvals
  - Central administration: Account / Identity / Site management
- Monitoring
  - Internal system health monitoring with Graphite / Grafana
  - Transfer / Deletion / … monitoring built on HDFS, ElasticSearch, and Spark
  - Messaging with STOMP
- Analytics and accounting
  - e.g., Show which the data is used, where and how space is used, …
  - Data reports for long-term views
  - Built on Hadoop and Spark

Development

- Release cycle and support period
  - Bi-weekly patch releases (Bugfixes, minor enhancements)
  - ~3 feature (named) releases per year (Features, major changes)
  - Once a year a feature version is designated as a Long-Term Support (LTS) release
- Development organized as open-source community project
  - Weekly development meetings; Release roadmap for each feature release
  - Contributors describe their planned developments, receive comments from community
  - Extensive integration and unit testing across all supported databases

Current developments

- Multi-experiment data management
  - Smart sharing of infrastructure across experiments
  - Smart sharing of data across experiments
- Quality of Service
  - Replication rules can take storage quality descriptions into account
- Expanding support for even more commercial cloud providers
  - Already support signature-based clouds (Google) and S3-compatible (Amazon, OpenStack, Ceph, …)
  - Addition of more cost control parameters
- Capability-based authentication, authorisation, and permissions
  - Data embargoes, JWT bearer tokens, Macaroons, OpenID, EduGain
- Network interface integration with SDNs
- Integration with research publication databases, e.g., Zenodo

More information

Website	http://rucio.cern.ch
Documentation	https://rucio.readthedocs.io
Repository	https://github.com/rucio/
Images	https://hub.docker.com/r/rucio/
Online support	https://rucio.slack.com/messages/#support/
Developer contact	rucio-dev@cern.ch
Journal article	https://doi.org/10.1007/s41781-019-0026-3
Twitter	https://twitter.com/RucioData