Superseded by the [ITS Infrastructure Roadmap - 2024 - 2026]

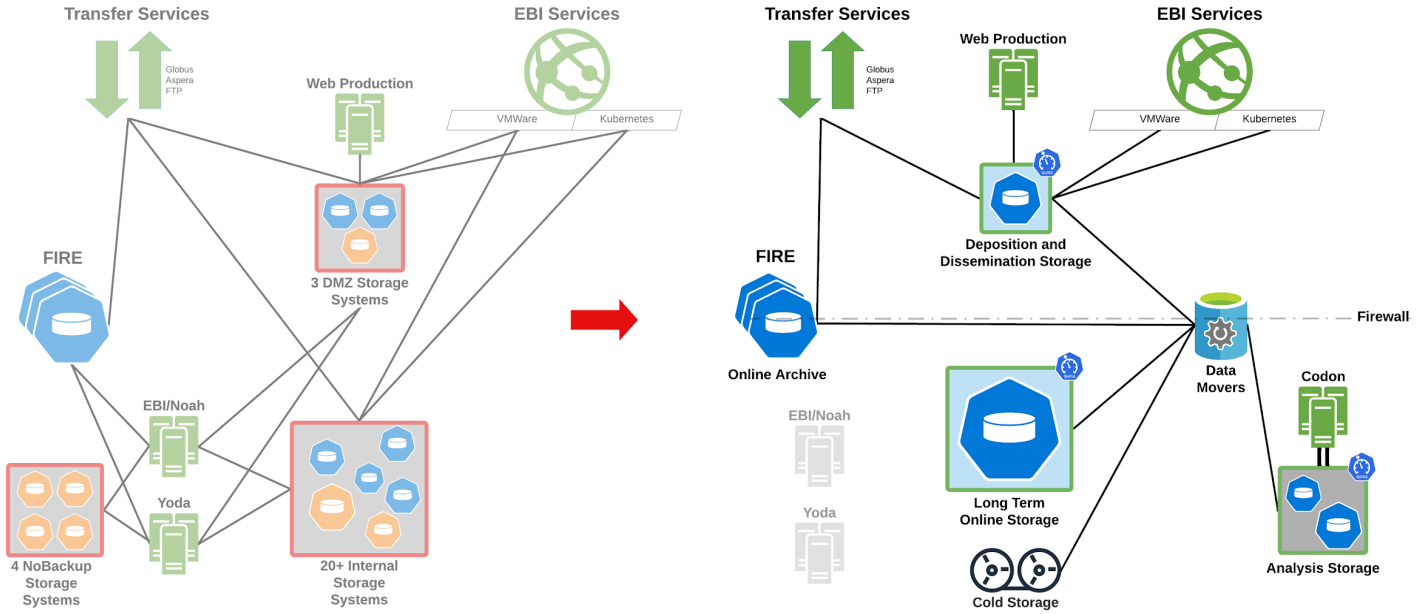
Introduction

EMBL-EBI had until recent years managed to keep its data storage capacity just ahead of its exponential data growth by increasing budgets and relying on technological evolution to deliver ever cheaper hard drive capacity. Over the last several years the budget has flattened, hard drive capacity increases have slowed and EMBL-EBI's storage infrastructure has aged.

The document seeks to present the current storage landscape, recommend a new storage model and outlines the transformation of the storage infrastructure through a range of initiatives. Throughout this document potential impacts, impediments, threats and opportunities are identified. The success of this transformation is heavily dependent on budget, staffing and the transition to the section model delivering coherent technical scientific leadership to data management and resource allocation through the new Senior IT Stakeholder Committee (SITSC).

The new storage infrastructure recommended herein would see better cost performance through:

- Substantial consolidation of the EMBL-EBI storage infrastructure into fewer, larger systems
- Tiering of data by performance requirements, resulting in faster analysis and lower cost[1]
- Enabling more structured management of data and its lifecycle
- Readiness for cloud interoperability where cost or other benefit exists
- Next generation data management and tooling to support the next stage of EMBL-EBI's development



The migration sees a dramatic simplification of the storage estate; with fewer, larger storage systems accessed from fewer places, facilitating a secure and fit for purpose storage estate at reduced overall cost.

SWOT Analysis of Proposed Roadmap - 2022 - 2025

Strengths • Separates intermediate data from persistent • Aligns to models elsewhere • Prepares for cloud	**Opportunities** • Consolidation of storage resources • File to object storage transition • Move toward structured data and metadata
Weaknesses	**Threats**

[1]See the [Compute Roadmap 2022-25 - Google Docs]

● Substantial changes to culture and code ● Lack of clarity around “2-copy” data retention policy	● Resistance to change ● Lack of coherent scientific leadership in data management and resource allocation ● Evolving security requirements around data

Key Drivers and Trends

Constrained Budget

The new indicative scheme has been approved, and will see year-on-year increases in funding to support EMBL-EBI activities. These increases will be gradual however, and will come with a range of new initiatives and requirements. Present EMBL-EBI storage budget is heavily bound in legacy storage infrastructure and services. To move forward, EMBL-EBI will need to optimise where possible, curtailing or ceasing some activities to reduce data volumes, and substantially reducing the cost of its infrastructure through consolidation and restructuring. All future purchases will also need to account for lead delivery lead times, especially where global shortages or issues arise.

Data Growth

The growth rate of data stored across EMBL-EBI continues to exceed predictions year-on-year, and this uncontained growth draws resources away from other IT services when capital budgets are limited. Data storage at the scale and growth of EMBL-EBI, under the present storage model and in the absence of scientific governance of resource allocation and data management standards, has become untenable. A new model that allows for sustainable infrastructure investment, aligned to the missions, must be established. Failure to establish a new model will see the present data storage crisis worsened by the coming deluge of bioimaging data, where dataset size and volume will again increase.

Governance and Data Debt

Only two general models exist that would provide the technical support and storage management required for EMBL-EBI’s sustained success; distributed or centralised. EMBL-EBI subscribes to a distributed model, but has lacked the governance and resource allocation mechanisms to ensure that service teams and research groups are tasked with, and retain, the technical skills needed to maintain their workflows and curate the data over which they are custodian. The advent of the Senior IT Stakeholders Committee (SITSC) provides a forum for resource allocation, technical, infrastructure and data debt to be deliberated and recommendations on policy made.

Efficiency and Infrastructure Debt

Service teams, research groups, computational resources and services operate at increasingly poor efficiency, accessing storage systems where network performance or other design factors severely limit performance. Most significant here is the creeping expansion of access to legacy internal storage systems by users of the Virtual Machine (VM) infrastructures, Embassy Cloud, Web Production and VMware. Many workflows and pipelines have been written with the assumption that all data is immediately available at all times, a paradigm which is not sustainable nor cost effective. The lack of consolidation of storage has also led to the creation of multiple copies of data, and increased pressure on the network as data is moved around to access the limited free spaces that exist.

Cloud Evolution

The present storage access model is not aligned with the move toward cloud as it creates little chance or impetus for users to prepare their code to operate with object storage (e.g. S3). Containerised workloads designed to work with file based systems (NFS) are common, and place users in a no-man's land between on

premise and cloud solutions, and providing poor overall performance at high cost. EMBL-EBI must be placed to leverage cloud, especially where access to free dataset hosting associated with open research programs could deliver benefits.

Principles

In evolving the EMBL-EBI storage landscape we define the following basic principles:

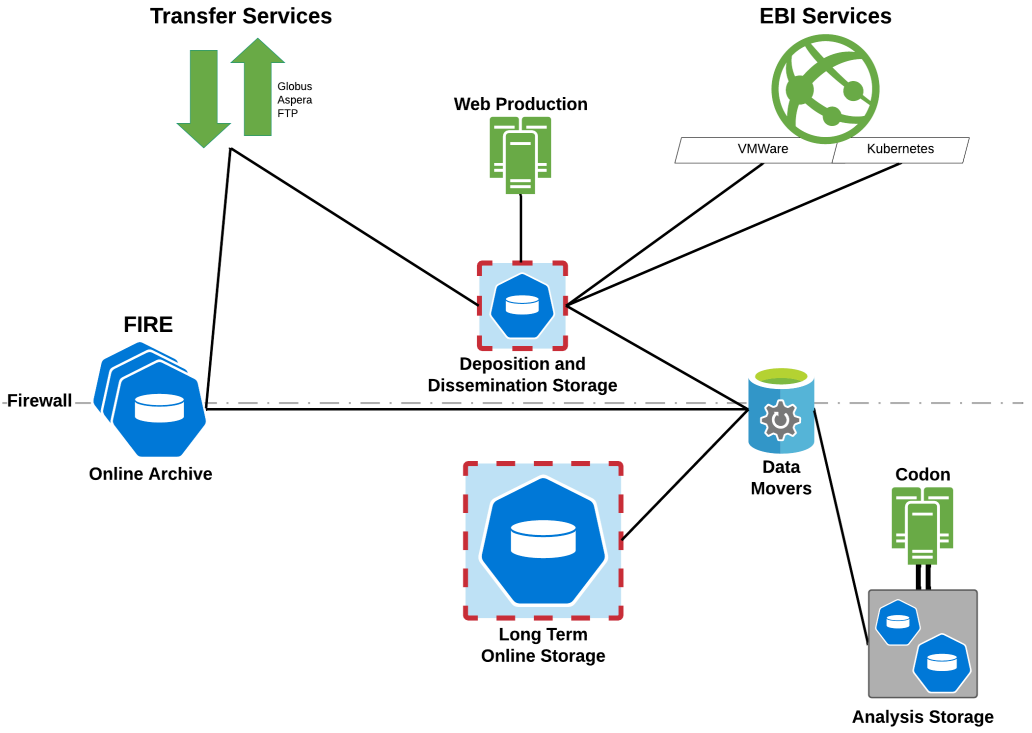
- Overall storage costs are not sustainable and must be reduced. To achieve this data must be separated by its stage in the life cycle, and its performance requirements
- Data management practises must be developed, implemented and enforced
- EMBL-EBI must move to enable cloud access to the data it holds; all future storage technologies must enable this interoperability
- EMBL-EBI is handling an increasing volume of controlled access data, any solutions developed should conform to relevant standards wherever possible
- All solutions purchased or developed should use open standards or be open source wherever possible

Initiatives

Below is a proposed set of projects which, enabled by new governance structures, will address the issues raised above and better place EMBL-EBI to achieve its missions. These projects set EMBL-EBI down a path of consolidation, toward object storage and improved data management. This timeline is dependent on staffing and resourcing, neither staffing nor budget are presently sufficient to complete these works without a reduction in technical, infrastructure or data debt.

Production Migration

The compute roadmap[2] and the activities of the Database, VAC and Web Administration teams within the Technical Service Cluster focussed over 2021 and 2022 on working closely with teams and groups to migrate production activities to the Harlow data centre. This was a massive undertaking across all of EMBL-EBI. This migration has allowed TSC to dramatically consolidate the compute and storage estate, and contingent on the evolution of data management and governance of resource allocation, has the potential to greatly reduce operational costs associated with EMBL-EBIs largest fiscal commitment, storage.

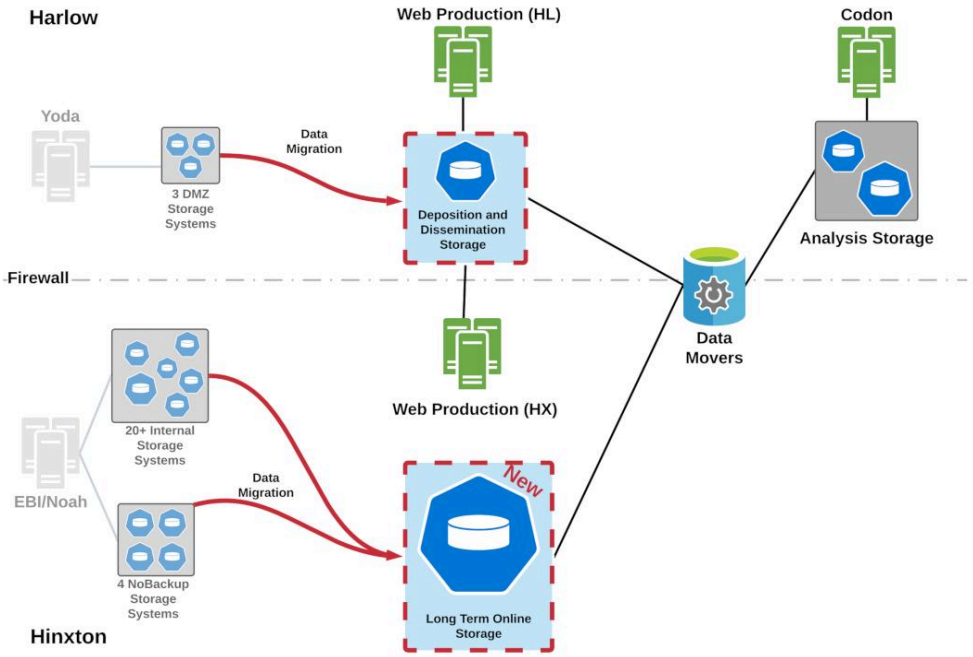


Fundamentally the consolidation of the storage sees data migrated to one of 4 storage areas:

Storage Area	Data Type	Cost
Analysis Storage *High performance storage*	Data under active computational analysis	££££
Deposition and Dissemination Storage *Lower performance online storage*	Data actively accessed by WP or Transfer Services as part of dissemination	£££
FIRE *Low cost capacity object storage*	Invariant data archives over 1PB, under dissemination via transfer services	££
Long Term Online Storage *Low cost traditional (NFS) storage*	Data which is not under active analysis but may need to be quickly restored to Codon, transfer services or web production	££

[2] Compute Roadmap 2022-25 - Google Docs-

Storage Consolidation



Analysis Storage Consolidation (Codon Migration) - 2020 - 2022

Continuing the Codon migration, data from all storage systems under active cluster analysis will be moved to the Codon Isilon or Codon scratch storage systems and quotas imposed to prevent storage space contention. Data from all other storage systems can be staged to the Codon cluster at high speed at any time via the data movers. This migration sees a change in data movement, with data staged from deposition locations onto the cluster for analysis and staged back for dissemination. This separation of dissemination and deposition from analysis will prevent the intense workload of the ever growing Codon cluster overloading dissemination and deposition storage, impacting publicly visible services. The tight coupling of the Codon storage to the Codon cluster greatly improves the speed of analysis and lowers networking congestion and costs.

Deposition and Dissemination Consolidation - 2022 - 2023

The storage presently supporting web production activities will be upgraded to support the migration of data accessed as part of deposition or dissemination activities. Some data may also be migrated to FIRE in the case where it is very large and invariant.
The migration will proceed in the following order:

1. Public transfer deposition areas[3]
2. Private deposition areas

Over time, public and private transfer areas have been increasingly accessed from the legacy clusters (EBI/Noah/SRA/Yoda) as well as transfer and web production services, forcing ever higher performance requirements that these systems cannot support. This access also requires complex configurations in order to traverse the firewall, reducing service performance and overloading the firewall, while also severely degrading the security posture of EMBL-EBI. This consolidation will see the use of data movers to stage this data onto performance storage on the cluster, and back to this storage for dissemination. This will reduce cost overall and dramatically increase computational efficiency and lower time to result.

[3] Initially focusing on the end of life ftp-public NetApp storage system, then moving out to others on

Many groups and teams use a synchronisation script between storage mirrors at the Hinxton and Harlow sites to control release cycles (sync-project). As part of the migration, TSC will work with each team to migrate away from this where not required, or flip the direction of this synchronisation process where required.

Long Term Online Storage Consolidation (New Storage System) 2022 - 2023

With data under deposition, dissemination and analysis migrated to fit-for-purpose performance storage, the remaining data on these four systems, along with other inactive data, will be moved to a new long term storage area. This will greatly reduce the cost associated with storing this data, and provide a location from which data can be rapidly restored to the cluster storage or dissemination storage at any time.

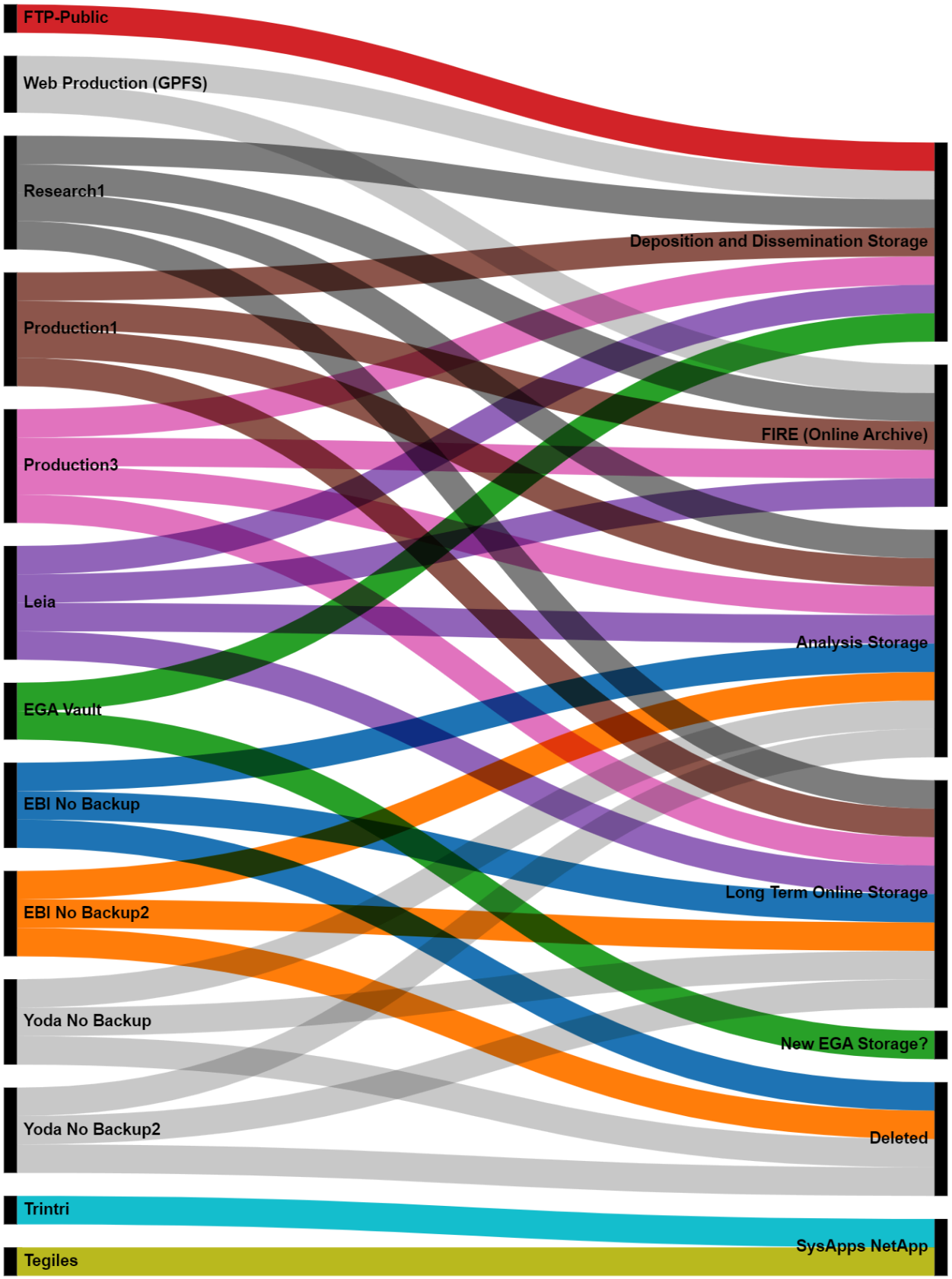
Controlled Access Data (CAD) Consolidation 2022 - 2023

As part of the production migration all datasets on the Controlled Access Data (CAD) register are being migrated and consolidated on the Codon cluster storage. This process will be complemented by a review of processes around the acceptance and handling of CAD, working with the CAD manager and the relevant teams and groups to develop better processes for the management of this data.

Consolidation: Where Does My Data Belong?

Data Activity and Type	**Storage System**
Data under active analysis	Codon Research ○ hl-isi-prod:/ifs/research ■ Accessible only from Codon and Data Movers ● Scratch ○ hl-vast-01:/hps/nobackup ■ Accessible only from Codon and Data Movers
Data actively accessed by WP or Transfer Services as part of dissemination	Deposition and Dissemination Storage ● Transfer Services ○ hh-isi-srv:/ifs/ftp-public/ ■ Writable only from transfer services and Data Movers ● Web Production Services ○ hh-isi-srv:/ifs/public/services ■ Writable from Harlow ■ Daily replication ○ hh-isi-srv:/ifs/public/rw/ ■ Writable from Harlow ■ NOT replicated or backed up ○ hx-isi-srv:/ifs/public/rw/ ■ Writable from Hinxton ■ NOT replicated or backed up ● Web Production Services (sync-project) ○ hh-isi-srv:/ifs/public/ro/ ■ Uses ‘sync-project’ on demand snapshots
Invariant data archives over 1PB, under dissemination via transfer services	FIRE (Online Archive)
Data which is not under active analysis but may need to be quickly restored to Codon, transfer services or web production	Long Term Online Storage ● Long Term Storage ○ /lts ■ Accessible only from Data Movers

Consolidation Map 2020 - 2023[4][5]



[4] Not all of these migrations require data migration, some can be achieved through the migration of the virtual storage servers holding the data within the storage systems, where data profiles are mixed migration is likely required.
[5] Data volumes to each storage system are rough estimates based on filesystem usage data, Raw data visualised via RAWGraphs 2.0

Storage System Deprecation

Legacy storage systems will be deprecated in order of priority, based on known risks with the health or supportability of the systems. Data will be migrated to other systems, as in the consolidation map above.

System Name	Aliases (not exhaustive)	Storage Device	Timeline	Comment
EBI NoBackUp EBI:/hps/nobackup Codon datamover: /hps/ebi/nobacku		10.7.70.12@tcp:10.7.70.13@tcp:/hxcstr03	Migrated	Intended as scratch storage only. Spare parts no longer exist, the vendor is now defunct and the version of the filesystem unsupportable.
EBI NoBackUp2 EBI: /hps/nobackup2 Codon datamover: /hps/ebi/nobackup2		10.7.105.13@tcp0:10.7.105.14@tcp0:/hxcstr07	Migrated	Intended as scratch storage only. Spare parts no longer exist, the vendor is now defunct and the version of the filesystem unsupportable.
Yoda NoBackUp Yoda: /hps/nobackup Codon datamover: /hps/yoda/nobackup		10.36.8.4@o2ib:10.36.8.5@o2ib:/cstor02	Migrated	Intended as scratch storage only. Spare parts no longer exist, the vendor is now defunct and the version of the filesystem unsupportable.
Yoda NoBackUp2 Yoda: /hps/nobackup2 Codon datamover: /hps/yoda/nobackup2		10.36.9.4@o2ib:10.36.9.5@o2ib:/hhcstr08	Migrated	Intended as scratch storage only. Spare parts no longer exist, the vendor is now defunct and the version of the filesystem unsupportable.
FTP-Public (NetApp) Codon datamover: /nfs/ftp/public EBI: /nfs/ftp/pub	/ebi/ftp/pub	OLD: vnas-hl-ftppublic:/ftp-public-sm NEW: hh-isi-srv:/ifs/ftp-public	Migrated	Pending transfer of all data to new storage, and flip of services. This system is very old and out of support.
Web Production (GPFS) EBI: /nfs/public/release Codon: /nfs/public/release		hxhh-cstor06	Late 2022	This version of GPFS is End of Life and no longer supportable. The licensing model for this product has changed to prevent it, rendering our installation defunct. The hardware is also very old and failing.
Research 1 EBI:/nfs/research1 Codon datamover: /nfs/ebi/research1		vnas-research:/fg_research	Late 2022	Unsupported, out of warranty hardware. Pending migration of data to new long term storage. This system is in a highly delicate configuration. Migration away from this system is of high priority.
Production 1 EBI:/nfs/production Codon datamover: /nfs/ebi/production	/net/isilon3/production /ebi/medline /ebi/production /ebi/uniprot/production /nfs/panda /ebi/www/uniprot-data /nas/seqdb	vnas-production:/fg_production	Late 2022	Unsupported, out of warranty hardware. Pending migration of data to new long term storage

	/ebi/uniprot/data /ebi/msd/data /nfs/seqdb /ebi/extserv/projects/srs /ebi/extserv/data1/biosapiens /ebi/extserv/local_work /ebi/extserv/data1/enfin /ebi/extserv/data1/googlemap_data /ebi/extserv/data1/ebibbs /ebi/extserv/data1/spine /ebi/extserv/data1/embrace /ebi/extserv/data1/doc2loc /ebi/extserv/jdispatcher /ebi/extserv/data1/appbin /ebi/extserv/projects/joblogs /ebi/extserv/vusers /ebi/extserv/data1/symbiomatics /ebi/extserv/projects/pdispatcher /ebi/extserv/bin			
Production 3 EBI:/nfs/production3 Codon datamover: /nfs/ebi/production3	/nfs/spot /nfs/ma /nas/microarray /nfs/euratrans /nfs/komp2 /nfs/dgva /nfs/encode /nfs/pride /nfs/pride_ext /net/isilon5/pride /net/isilon5/pride_ext /ebi/microarray/home	vnas-production3:/ivol_production3	Late 2022	Unsupported, out of warranty hardware. Pending migration of data to new long term storage
Leia Yoda:/nfs/leia Codon datamover: /nfs/yoda/leia		vnas-leia:/fg_leia	Migrated	Unsupported, out of warranty hardware. Pending migration of data to new long term storage
Hadoop /nfs/nobackup /nfs/software Codon datamover: NOT mounted		vnas-hadoop02:/hadoop_nobackup vnas-hadoop02:/hadoop_software	Early 2023	Very old Hadoop infrastructure supporting some users and Web Production logging systems. Most of this has been migrated to Spark. Hadoop storage is local to Hadoop, it is not exported to other systems, thus not mounted on Codon, for example.

Home Areas

The new Codon cluster has a separate homes (/homes/*username*) area. Building on the lessons learned and issues encountered in the Noah and EBI clusters, this new home area has been isolated to the Codon cluster by design to ensure cluster performance is not compromised. For the same reasons this area will not be exported as a windows file share. If needed can be accessed graphically via common SSH/SCP tools.

The legacy home areas provided for the Noah and EBI clusters will continue to exist as the home area of some web applications and databases.

Homes areas should be used to store only minimal data, the vast majority of data should exist in team and group spaces and software areas. Users seeking space to store or share files should consider more modern alternatives such as the ownCloud File Synchronisation service, Google Drive etc.

Teams Drives (CIFS)

The Teams areas have served as a Windows File Sharing space for groups. This provides some limited space for sharing administrative files. The infrastructure providing this service (PCSERV) has many issues and is highly unreliable. Teams and Groups now have access to Google Drive. TSC would like to ask teams and groups to use Google Drive instead of the team areas. Google Drive provides many benefits over the Team areas, including better document management, file versioning control and 2 factor authentication.

The remaining CIFS presence will be rationalised as follows.

1. Production or research data for the purpose of annotation or analysis
    a. Migrated to via a new hardware based CIFS storage system
    b. Data movement on and off controlled via the data movers
    c. Quota controlled
    d. Maximum data retention periods set and enforced
2. Team and group sharing areas (remaining after teams/groups evaluate Google Drive)
    a. Achieved via a hardware based CIFS target
    b. Quota controlled, no more than 1TB per team/group
3. Administrative file sharing (Finance, HR, Directors)
    a. Moved to the Windows based administrative file sharing area which already exists
    b. Will be isolated away from service and research applications and networks as part of the network segregation activities

Quotas and Usage Reporting - 2022

All new storage systems are delivered with quotas enabled from the outset. This prevents the serious issues presently seen through full file systems heavily impacting or preventing service and research activities. Quotas will allow each team and group to work within known limits, and prevent them contending for storage resources.

As the section model delivers coherent technical scientific leadership to data management and resource allocation through the new Senior IT Stakeholder Committee (SITSC), these quotas can be controlled through a technically informed scientific body. This will allow EMBL-EBI to target its limited storage resources where they will deliver maximum benefit, and inform TSC decision making. In facilitating decision making about the evolution of EMBL-EBI storage and resource allocation enhanced monitoring will be put in place, to include:

- Daily reports of quotas delivered to the RUP system or its replacement
- Detailed reporting of storage utilisation and clean-up campaigns with specific teams and groups, identifying data which can be deleted or moved to archive

This has previously been accomplished through the use of tools like Starfish. With the enabling of quotas and the consolidation of data onto fewer systems, this reporting becomes far simpler to achieve.

Cold Archive Pilot - 2022

EMBL-EBI holds a substantial volume of data which must be retained but need not be accessed immediately. This work will pilot a range of tape and archive management technologies to determine which would best suit EMBL-EBIs requirements, paving the way for cold data storage within the Next Generation Data Management and Tooling initiative later.

Secure Data - 2023 - 2024

EMBL-EBI presently holds all patient identifiable or other high security data in the Vault; an isolated infrastructure. This infrastructure has grown very old, and uses a range of technologies for which more modern alternatives may exist. This initiative will see service teams, research groups and TSC members work to develop a more secure, common infrastructure for handling more sensitive data at EMBL-EBI, working toward meeting relevant audit requirements and security standards. This work will require that the new governance

model be in place and a group of relevant representatives from services and research established to define standards for the management of secure data at EMBL-EBI.

Next Generation Data Management and Tooling - 2023 - 2025

EMBL-EBI must make a paradigm shift in its data management, away from treating datasets as 10's of billions of files and directories, to treating entire datasets as an entity. In so doing the challenge shifts from the expensive one of creating a massive coherent namespace containing 10's of billions of files, to creating a dataset catalogue with at most millions of datasets. This change, accompanied by a move to object storage, would allow for far greater cost efficiency while also enabling cloud and inter-site data sharing. This model is the one used by all other scientific data providers at our scale, and by both Google and AWS in their provision of public research datasets.

Under this model teams and groups would be allocated a substantial storage quota on clusters, transfer areas or other services. This area serves to hold all data under active analysis. All datasets not under active analysis are "checked-in" to the object storage and catalogue via a simple set of tools. The data can be rapidly restored ("checked-out") to active storage whenever needed. The major advantage here being that these tools can be equally deployed in EMBL-EBI, other EMBL sites or provided to international partners and other consumers of our public data resources. Using this model, initiatives such as planetary biology or other large scale analysis efforts can recall and process any of the datasets held within EMBL-EBI at any time at greatly reduced cost.

This change will be implemented in a series of phases:

Cold Archive

Providing users with an archive into which they can deposit datasets via a "check-in" model; capturing metadata as part of the deposition process and potentially compressing all files in a dataset into a single object for ease of management and space efficiency. As a first step this archive may be best provided either atop existing infrastructure or as a service within the cloud. Overall this step would measure the readiness of EMBL-EBI to accept the deposition of data with metadata, while testing that the solution is functional and scalable.

Cloud accessible storage

EMBL-EBI has begun to move some data resources and services to the cloud, a transient storage area with quotas will provide a secure but unified storage presence for both internal and external access to facilitate further cloud native applications and utilisation where benefit exists.

Data life cycle management and tooling

Building on the experience gained through the deployment of a cold archive using a "check-in" model, and extensive consultation and testing with teams and groups, EMBL-EBI then looks to the future of large scale data storage. The cold archive model would be extended to allow the rapid "check-in" and "check-out" of datasets via a web-based or command line interface. This may be further extended to provide transparent cloud access to EMBL-EBI data, allowing for equivalence of operation internal and external to EMBL-EBI and improved code portability globally; best fulfilling the mission of EMBL-EBI as a data archive. Most critically the underlying storage can be object based and internally tiered between classes of storage, dramatically reducing costs.

It should be noted that a "check-in" and "check-out" storage model would result in a dataset catalogue which could support the GA4GH framework.

The final step in this process would see encryption and authentication layers added to these tools, greatly simplifying the distribution of encrypted data.

High Level Timeline[6]

A high level Gantt chart of all initiatives is maintained: Gantt Chart of Initiatives.

Key Dates

See the Compute Roadmap 2022 - 2025 for shutdown dates of key storage systems as part of the storage consolidation process.

Blockers

- Who governs resource allocation; specifically who approves storage quota increases or changes?
- What level of resilience is required of storage holding datasets?
    - Is storage of data across three sites, where the failure of any one of the sites is recoverable an acceptable interpretation of the mandatory 2 copy policy for datasets?

Summary

EMBL-EBI has the opportunity to escape its present technical debt around storage infrastructure and establish a scalable, exemplar storage model which best places it for the future. Before this can occur EMBL-EBI must embed the section model to foster change, tackle the issues around the maintenance of its data and workflows and data management. Fostered by the SITSC[7], formal roles around data custodianship and management must be established, and mechanisms put in place to govern the allocation of resourcing. With these mechanisms and processes established EMBL-EBI can embed exemplary data management practices and develop next generation tooling to make access to EMBL-EBI data both on campus and off campus far simpler and easier.

[6] Infrastructure Strategic Plan - 2022 - 2025 - High Level Gantt - Google Sheets
[7] Senior IT Stakeholders Committee