MyMONIT

Collecting measurements to monitor CERN’s experiments

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High-level description

CERN uses a variety of independently developed systems to monitor its infrastructure (Aimar et al., 2019). MyMONIT will be a solution to unify the monitoring of experiments into a single software integrating different streams of measurements to centralize this information.

MyMONIT will be scalable to ensure that it can cope with increasing demand. The solution will also include monitoring to detect anomalies in the system itself and the flow of the measurements.

Functional requirements

There will be two user types: administrators and scientists with the role matrix in Appendix F.

For each source, an adapter will normalize the measure and transmit it to MyMONIT.

The measures will be persisted, indexed per experiment, and made available through APIs to authorized scientists.

A complete audit will be available from a separate interface.

Appendix B contains a complete use-case diagram.

Non-Functional Requirements

Access points will be authenticated.

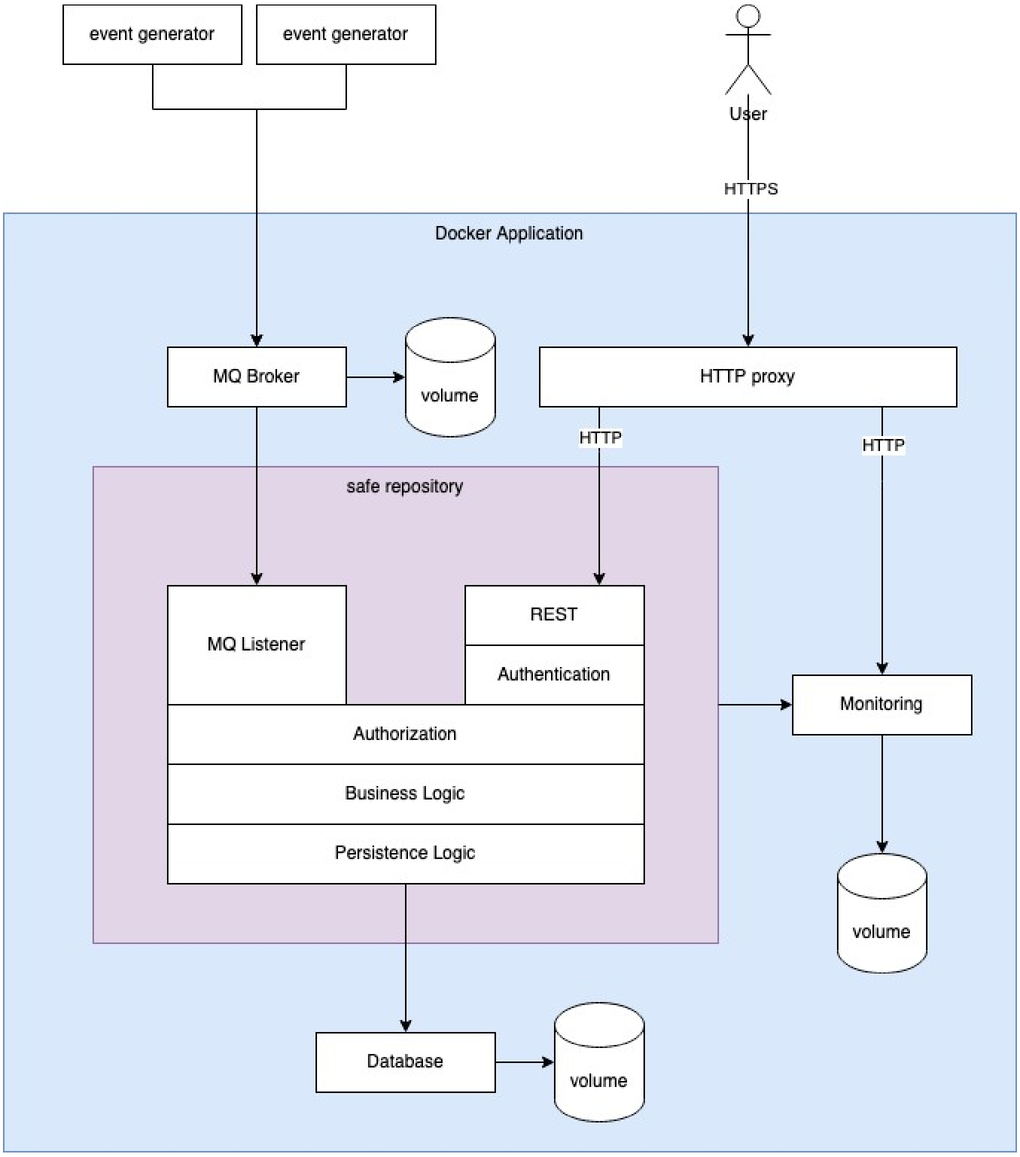
Access to experiments will require per-user authorization.

The system's capacity must accommodate at least 10 years of data.

The system must serve concurrent users and concurrent experiments.

The loss of data is not acceptable.

Architecture



Components

The solution comprises multiple components responsible for different aspects. The core solution (in the blue area of the diagram) will receive the measures from the adapters and expose APIs to the users.

Deployment

The core solution will be containerized with Docker and orchestrated with Docker Compose. This choice makes it easier to deploy the solution in other platforms such as Kubernetes with minimal changes to the configuration. This strategy also aims to reduce the attack surface by hiding all the services that do not need to be reachable by the user.

The adapters will be Python scripts customized to each specific case.

HTTP Input

An HTTP proxy is responsible for encrypting the communications with the solution, offloading the incoming encryption, and adding encryption to the output. All HTTP-based communication will flow through the proxy hiding the corresponding services.

For this purpose, the implementation will use Nginx, which could also implement load-balancing functions should it be necessary to scale the application with additional nodes.

Data Streams

An MQ Broker will expose queues to accept data streams from the experiments.

RabbitMQ is one of the most popular tools on the market for this particular need (Souza, 2020). RabbiMQ supports TLS to encrypt communications and clustering to address scalability issues.

Storage

A database is responsible for the storage of the application's data. Being the model of the data known, a SQL Database represents a simple solution. Further expansions could consider moving the experiments' data to a NoSQL database that may offer better scalability (Khasawneh, 2020).

There are no special requirements to guide the choice of a product. MySQL will be the initial choice. The application's design will ensure a level of abstraction to minimize the impact of a change should new insights suggest a different product would be a better fit.

MyMONIT

Safe Repository is the core component responsible for storing Hadron Collider's experimental data. It will expose multiple HTTP endpoints to configure the application resources and will process parallel data streams through input queues. The application stores the information on an external database. Safe Repository will not be exposed directly to outside traffic.

Safe Repository will be implemented in Python using Flask to expose REST APIs and Pika to process MQ Queues.

Filesystem encryption

Filesystem encryption can be used to host the filesystems of the storage and the broker. This configuration is transparent for the solution.

Logging and Monitoring

All services will forward their logs to a centralized log aggregator responsible for the parsing and storage into a database. The logs will be visible in a dashboard exposed through the HTTP proxy.

This requirement will be implemented with the ELK Stack. Except for Safe Repository, all services will include Filebeats to forward their logs to Logstash. Safe Repository will send the logs directly to Logstash instead. Logstash will be responsible for the parsing and the storage in Elasticsearch. Kibana will expose a dashboard to let users monitor the functioning of the whole system.

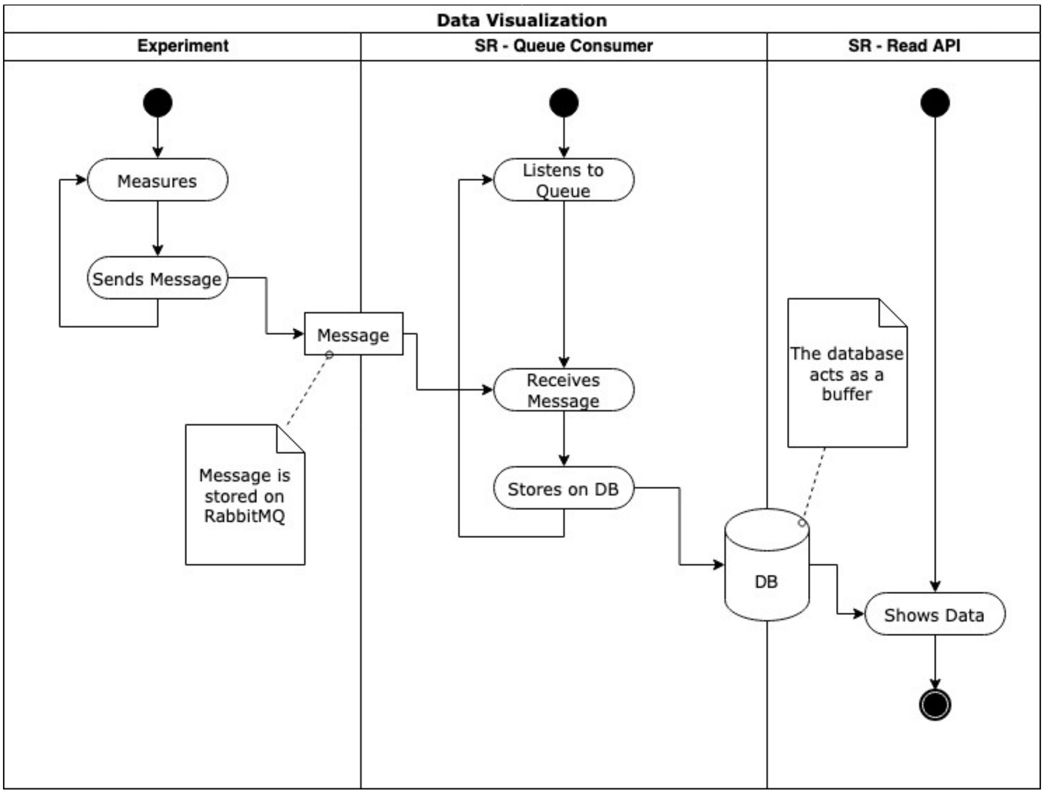
Application Layer

The following diagram illustrates the layers of the application and the interaction of the components. “Appendix C”

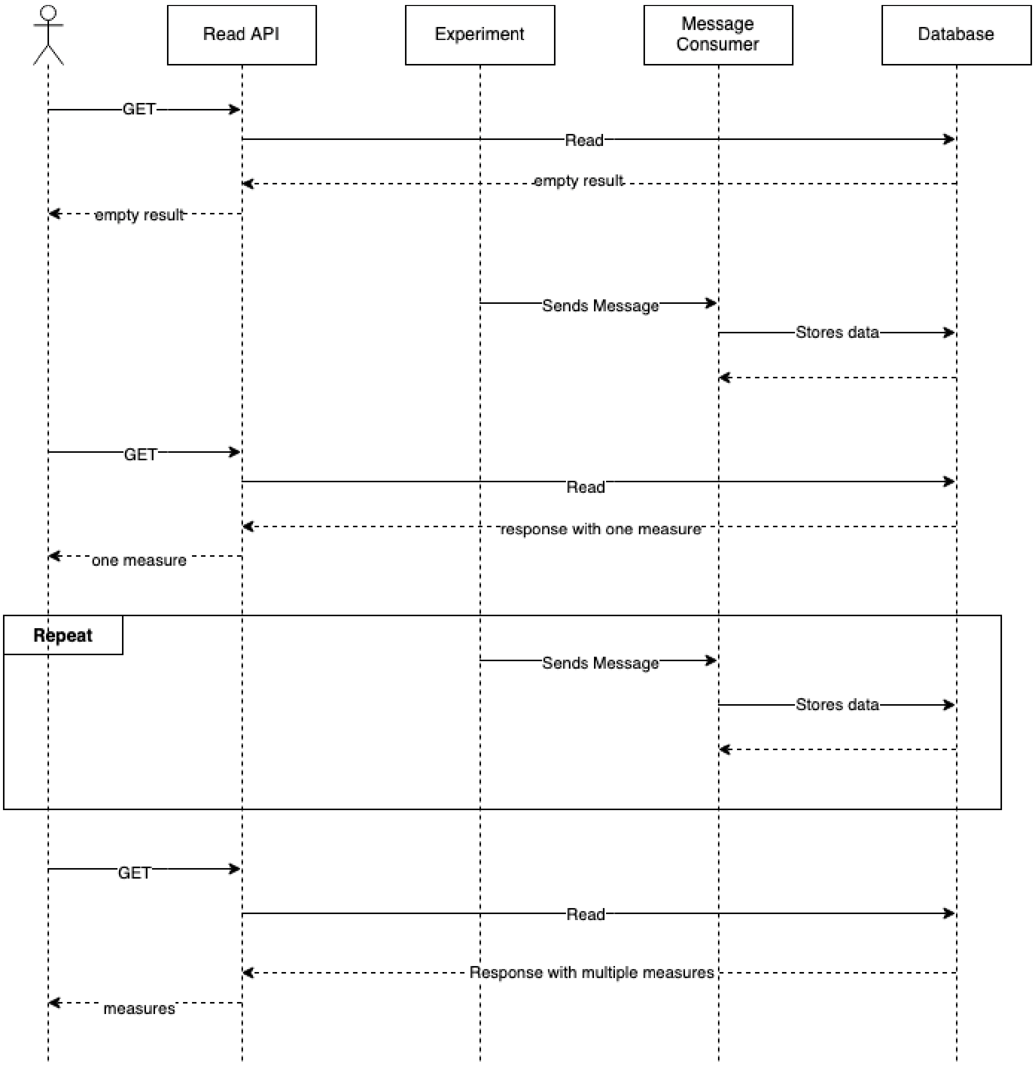
There will be no direct interactions between the components consuming messages from the broker (in blue) and the components exposing REST endpoints (in green). The Storage (in yellow) will mediate the communications between the two parts.

Usage

The following diagrams illustrate the flow of information in the application.



From a timeline perspective, repeated calls to the APIs will return more results as more data is inserted into the database.



Authentication

The authentication endpoint will validate credentials by comparing the input with the hashes stored in the database. The endpoint will return a JSON web token that will remain valid for a limited time. The token will be required in the calls to all other APIs. The authentication endpoint will require the inclusion of a shared secret (API key) in the request. This additional measure will limit the chances to perform a brute force attack (OWASP, N.D.).

Authorization

Authorization will be handled at the level of the storage. Whenever a user will perform a query, his identity will be part of the query. (TBD pattern)

For example:

```
SELECT d.* from user_experiments ue, data d
where d.experiment_id = :experiment_id -- clause to select the data
and ue.experiment_id = d.experiment_id -- join
and ue.user_id = :user_id              -- safety measure
```

If the id of the current user is not associated with the experiment, the result of the query will be empty thanks to the last two lines.

Security Risks

Using the STRIDE model, the following threats were identified and classified with DREAD in Appendix G.

Spoofing

- User's credentials violation

Tampering

- Introducing fake measurements on the message broker

Repudiation

- Administrator denies a sabotage

Information disclosure

- Database breach

Denial of service

- DDoS on APIs

Elevation of privilege

- Scientists becoming administrators

Scalability

Periodic pressure on resources

Except for the database, all components of the solution will be stateless and allow for horizontal scalability. Clustering solutions such as Kubernetes have autoscale functionality to regulate the number of running instances and deal with variable demand (Kubernetes, N.A).

Substantial data download requirements

It is expected an elevated flow of data coming from queues while users will visualize them almost in real-time. The database will act as a buffer between the component responsible for storing the incoming data and the component responsible to make it available to the users. It is expected that the highest pressure could come from the input flow. Since reading a large amount of data could put pressure on the database, queries should be paginated.

System Requirements

Storage space

User and experiment data will require less than 1Kb per record, and their number is expected to be in the range of thousands. Therefore, it is safe to assume that a few megabytes will be sufficient to store them.

Each measurement is expected to require at least 22 bytes. With 1 million measures per experiment, each experiment will require about 21Mb of space. (Appendix A)

CPU and memory

TBD

GDPR Consideration

The application design requires only a minimal amount of personal information (Appendix H). All users will be able to retrieve, update and delete their own information, in compliance with GDPR. For users unable to access the application, an administrator will be responsible for any GDPR request.

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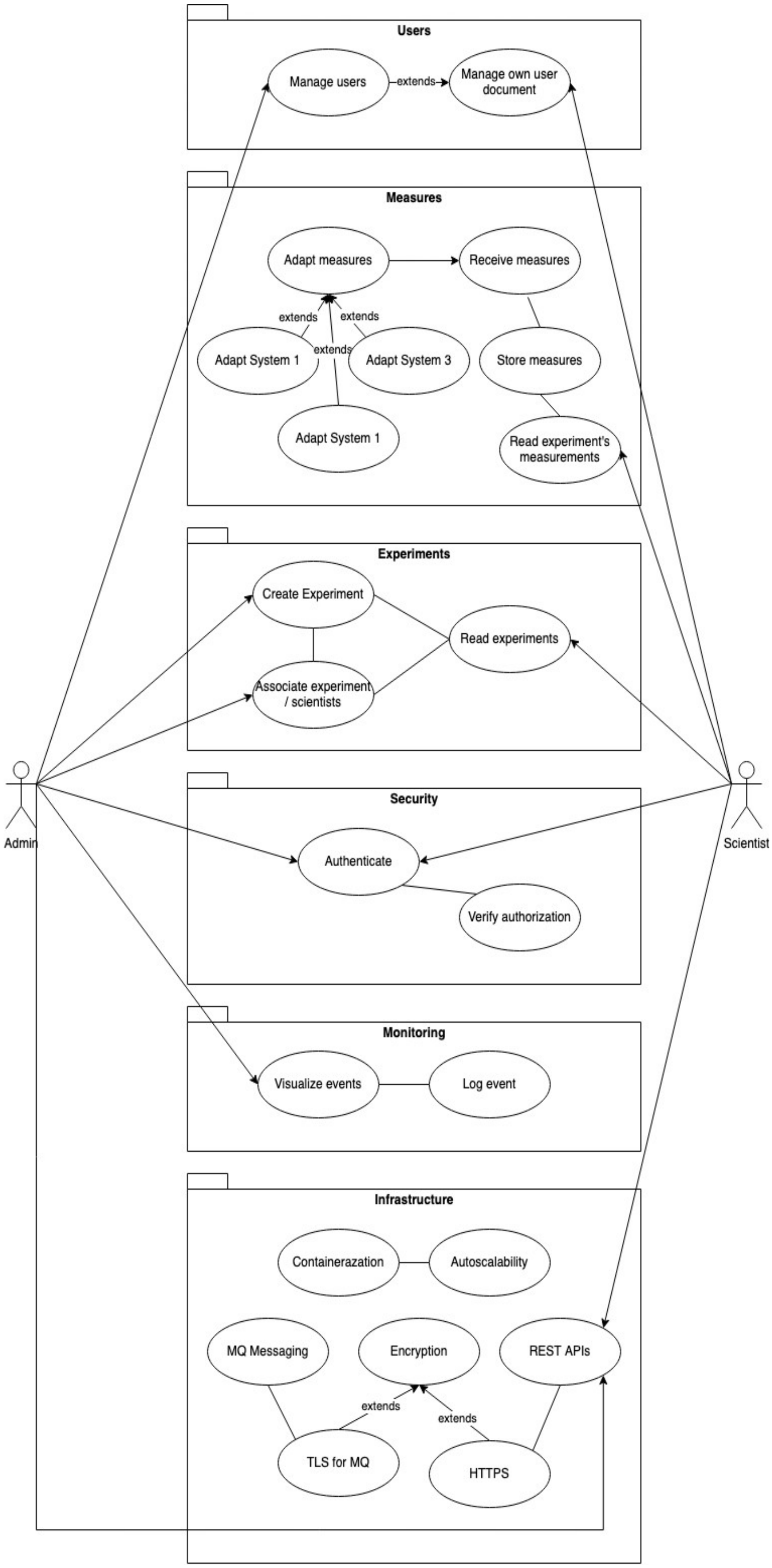
Appendix A – Disk requirements

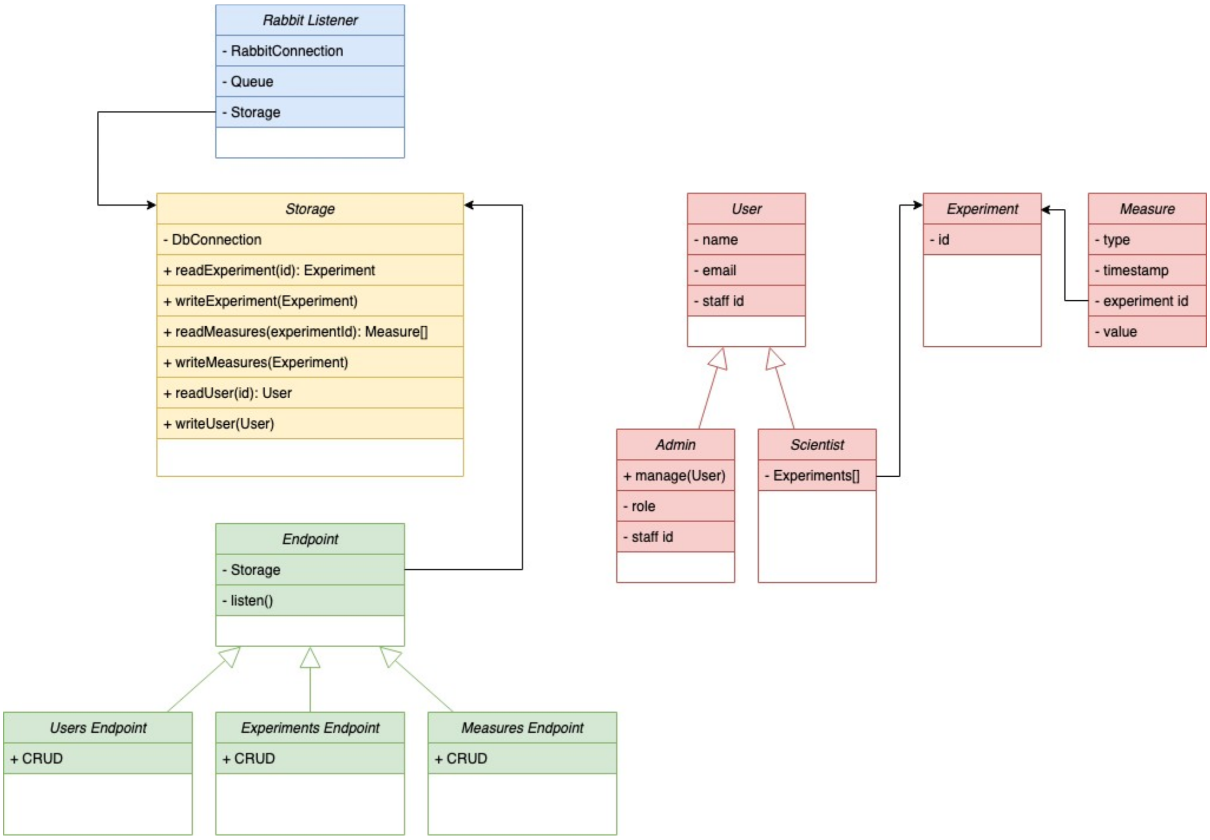
Measurements

field	type	size
Measure type	integer	2 bytes
Timestamp	Timestamp with nano precision	8 bytes
Experiment id	integer	4 bytes
Measure	Double precision floating point	8 bytes

Appendix B - Use Case Diagram



Appendix C - Class Diagram



Appendix F – Role Matrix

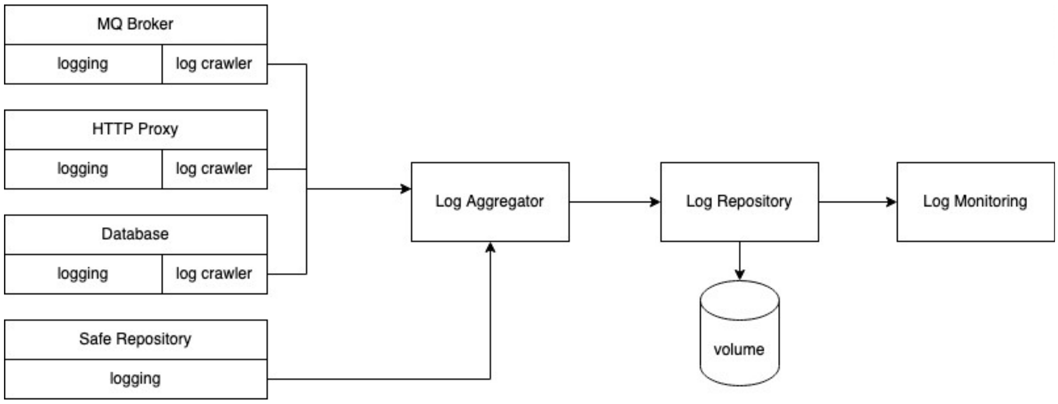
Administrators

resource	scope	access
users	complete	RW
experiments	complete	RW
measurements	complete	R

Scientists

resource	scope	access
users	user's record	RW
experiments	only records associated with user	RW
measurements	only records associated with user's experiments	R

Appendix G – Monitoring



Appendix G – DREAD

Spoofing

User's credentials violation

Type	Level
Damage	High, experiments would be exposed, users' records compromised, data leak
Reproducibility	High
Exploitability	High
Affected users	One user. All, if the user is administrator
Discoverability	Medium. User's credentials may be easy to guess

Tampering

Introducing fake measurements on the message broker

Type	Level
Damage	High, experiments would be invalidated
Reproducibility	Medium. The highest risk is broker's authentication
Exploitability	High. Discovering credentials would make it easy to exploit the vulnerability
Affected users	All scientists
Discoverability	Medium. The broker is public, but credentials are highly secure

Repudiation

Administrator denies a sabotage

Type	Level
Damage	High, experiments would be invalidated
Reproducibility	Low. All actions are audited. Administrator do not have W access to audits
Exploitability	Low. Administrators do not have W access to audits
Affected users	All scientists
Discoverability	Low. It requires the discovery of additional vulnerabilities

Information disclosure

Database breach

Type	Level

Damage	High, data would be exposed
Reproducibility	Low. Database is not directly exposed, authentication is in place
Exploitability	Low. Attacker should compromise at least another system first
Affected users	All
Discoverability	Low

Denial of service

DDoS on APIs

Type	Level
Damage	High, system may become inoperative
Reproducibility	Low. The system should be exposed only in the internal network
Exploitability	Low. It would be easy to block the attack in the internal network
Affected users	All
Discoverability	Low. It would be difficult to plan an effective attack.

Elevation of privilege

Scientists becoming administrators

Type	Level
Damage	High, the attacker could disrupt the system
Reproducibility	Low. It would require database access since no system function manipulates roles
Exploitability	Low. Attacker should compromise at least another system first
Affected users	All
Discoverability	Low

Appendix H – Personal data

Document	Field	Description
User’s record	Staff identification	Unique id number from the HR system
User’s record	Name	Given name(s)
User’s record	Surname	Family name
User’s record	Email Address	Professional email address