OCAI: The Operations Companion to support decision making of flight control teams

European Space Operations Centre
29.06.23 – CNES COMET Event

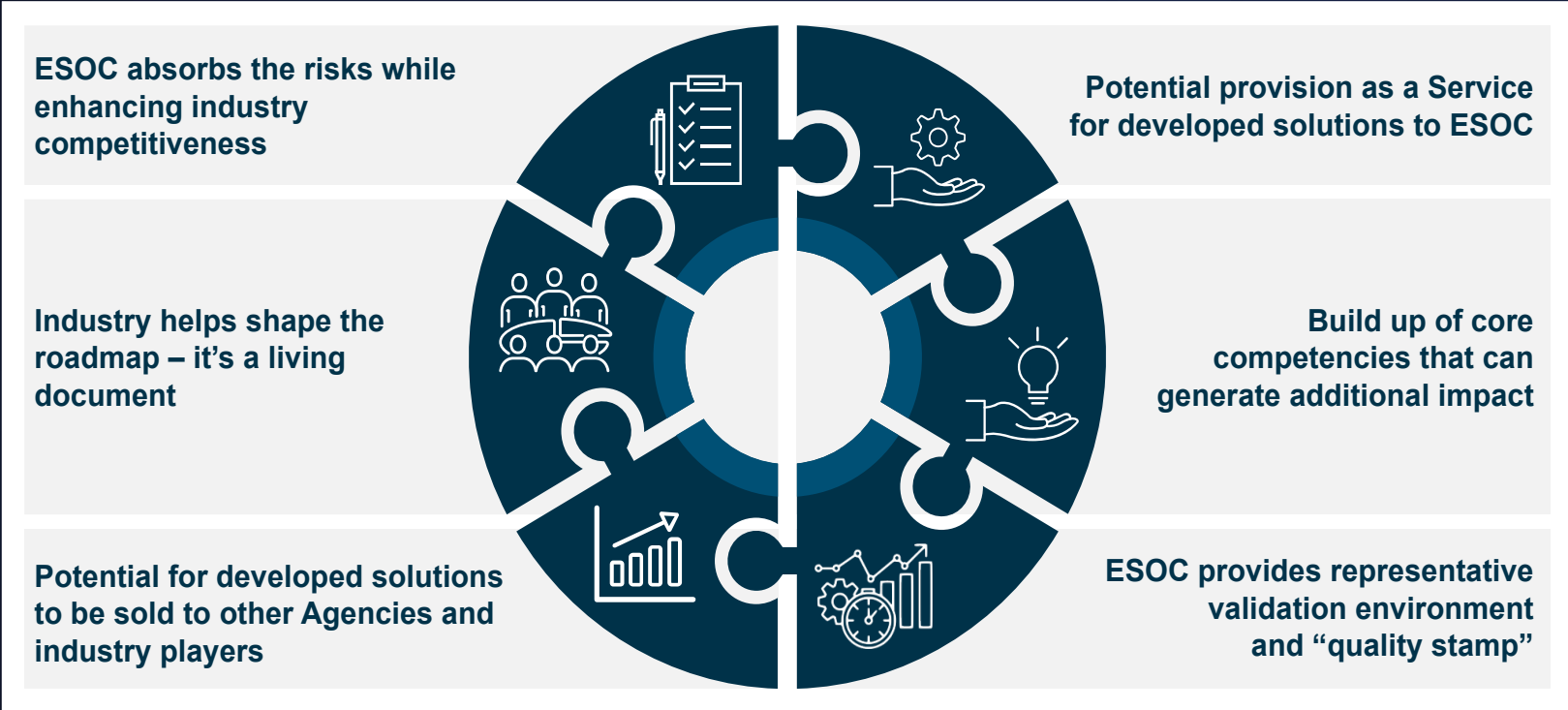→ THE EUROPEAN SPACE AGENCY
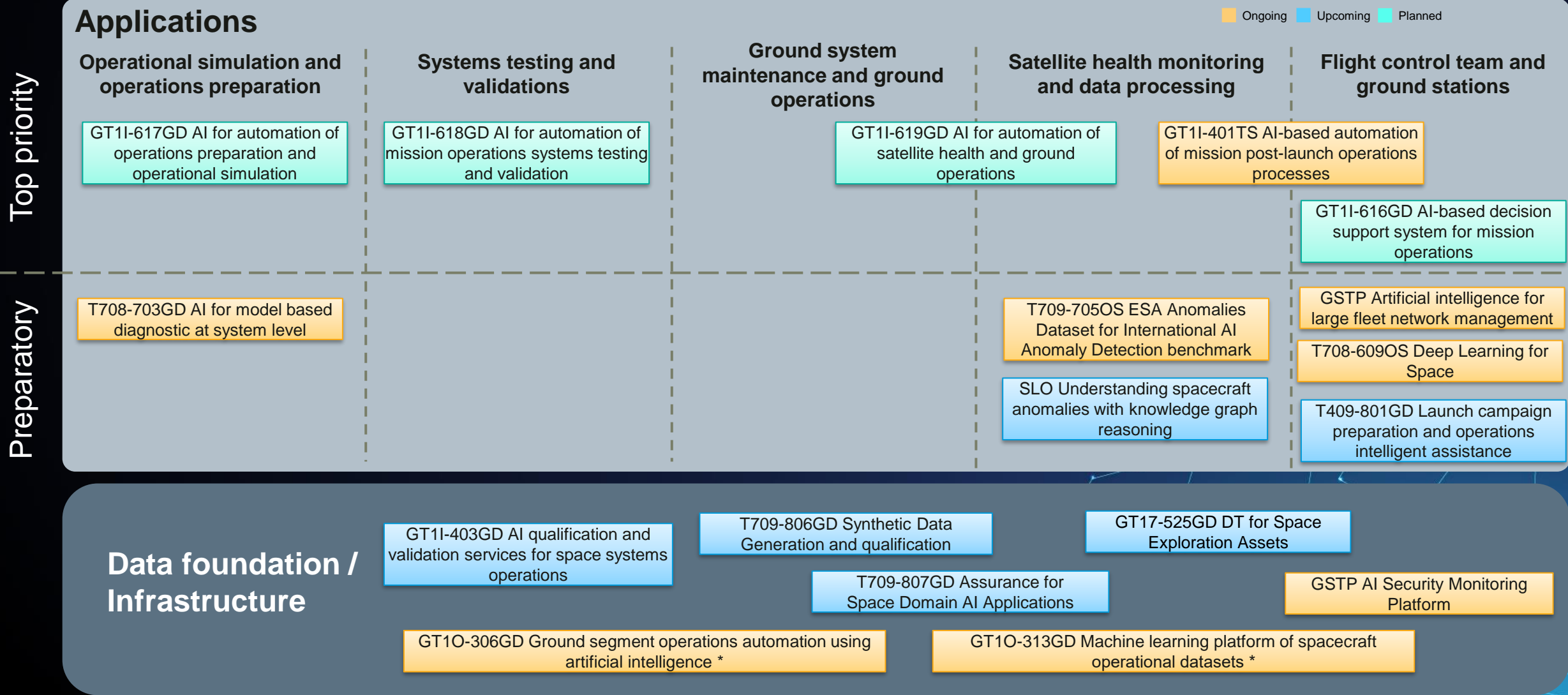
ESOC is very active in AI

5 prioritized domains

Operations preparations and operational simulation

System testing and validation

Routine operations, flight control teams & ground stations

Ground system maintenance and ground operations

Satellite health monitoring and data processing

AI as an enabler to bring automation to the next level

ESOC absorbs the risks while enhancing industry competitiveness

Industry helps shape the roadmap – it's a living document

Potential for developed solutions to be sold to other Agencies and industry players

Potential provision as a Service for developed solutions to ESOC

Build up of core competencies that can generate additional impact

ESOC provides representative validation environment and "quality stamp"

→ THE EUROPEAN SPACE AGENCY

AI portfolio at ESOC

Applications

Legend: Ongoing | Upcoming | Planned

	Operational simulation and operations preparation	Systems testing and validations	Ground system maintenance and ground operations	Satellite health monitoring and data processing	Flight control team and ground stations
Top priority	GT1I-617GD AI for automation of operations preparation and operational simulation	GT1I-618GD AI for automation of mission operations systems testing and validation	GT1I-619GD AI for automation of satellite health and ground operations		GT1I-401TS AI-based automation of mission post-launch operations processes
					GT1I-616GD AI-based decision support system for mission operations
Preparatory	T708-703GD AI for model based diagnostic at system level			T709-705OS ESA Anomalies Dataset for International AI Anomaly Detection benchmark	GSTP Artificial intelligence for large fleet network management
				SLO Understanding spacecraft anomalies with knowledge graph reasoning	T708-609OS Deep Learning for Space
					T409-801GD Launch campaign preparation and operations intelligent assistance

Data foundation / Infrastructure

- GT1I-403GD AI qualification and validation services for space systems operations
- T709-806GD Synthetic Data Generation and qualification
- GT17-525GD DT for Space Exploration Assets
- T709-807GD Assurance for Space Domain AI Applications
- GSTP AI Security Monitoring Platform
- GT1O-306GD Ground segment operations automation using artificial intelligence *
- GT1O-313GD Machine learning platform of spacecraft operational datasets *

* Developed on **Space CODEV** under ESA Community license at https://ainabler.space-codev.org/

3

→ THE EUROPEAN SPACE AGENCY

AI portfolio at ESOC

Applications

Legend: Ongoing | Upcoming | Planned

Mission analysis and flight dynamics	Space debris and space weather	Navigation	Human and Robotic Exploration	X-Reality
	GT17-682SD Manoeuvre pattern inference for safe operations	T610-701GN Artificial Intelligence for Improved GNSS Precise Products	ExPeRT Vision based knowledge extraction using AI	T709-706GD AI aided AR/VR applications and VR aided ML
	GT17-683SD Robust attitude uncertainty estimation for debris removal			
	T711-801SD Ensemble and surrogate modelling for debris environment long-term simulation			
	T711-803SD Robust atmosphere error modelling for sustainable operations			
	T709-809GD Advanced computer vision methods for object detection, classification and segmentation on optical sensors images			

→ THE EUROPEAN SPACE AGENCY

Motivation

Fragmented & Heterogeneous Systems Landscape

Ops Logs
Free text, REST API

Procedures / System element tree
json files REST API

Procedures
Pdf files Dedicated parser
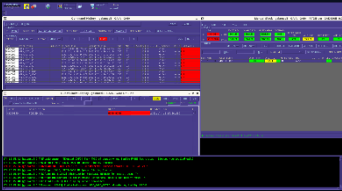
MCS Logs
Csv files Structured text

TM / TC / on-board events
Hadoop DB REST API
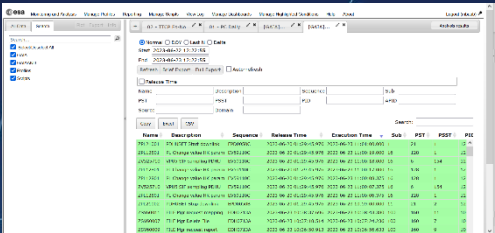
Anomaly DB
csv files Unstructured text

Uberlog

FOP

OPEN-M

f

S2K MIB

MCS Logs

f

ARES

ARTS

f

Motivation

As a user, I want to know…

> What other similar events, touching the sub-systems XYZ occurred within this mission?

> What contingency procedure do I have to use for a certain XYZ Out Of Limit or OOL combination?

> What was the s/c Latitude/Longitude and space weather condition at time of the OOL triggering?

> What procedure and which parameter settings are needed to modify the on-board monitoring of parameter XYZ to threshold value XYZ?

> Which are the related information for XYZ command across ARES, Uberlog, ARTS, FOPs and MCS & GS logs?

> Could you correlate frequency of oscillation parameter XYZ with any other parameter reading?
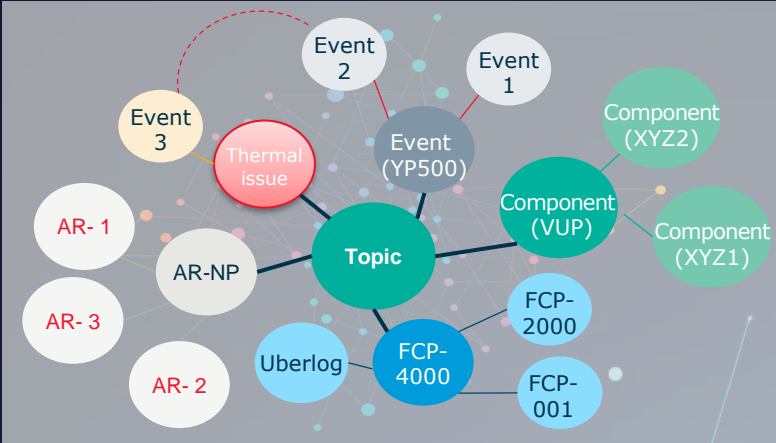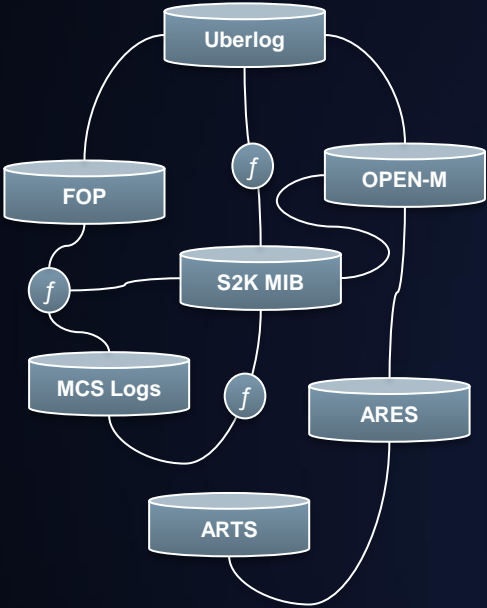
> If you can call the engineer on call and send them the current anomaly and associated information

What is an Operations Companion?

"An AI-powered software agent that is able to interact with a user (with the use of human language) and answer questions or complete tasks relevant to space mission operations"

Understand the input

Find / correlate information

Act on the request / question

Provide response

← Key pain point

High impact Low disruption

→ THE EUROPEAN SPACE AGENCY
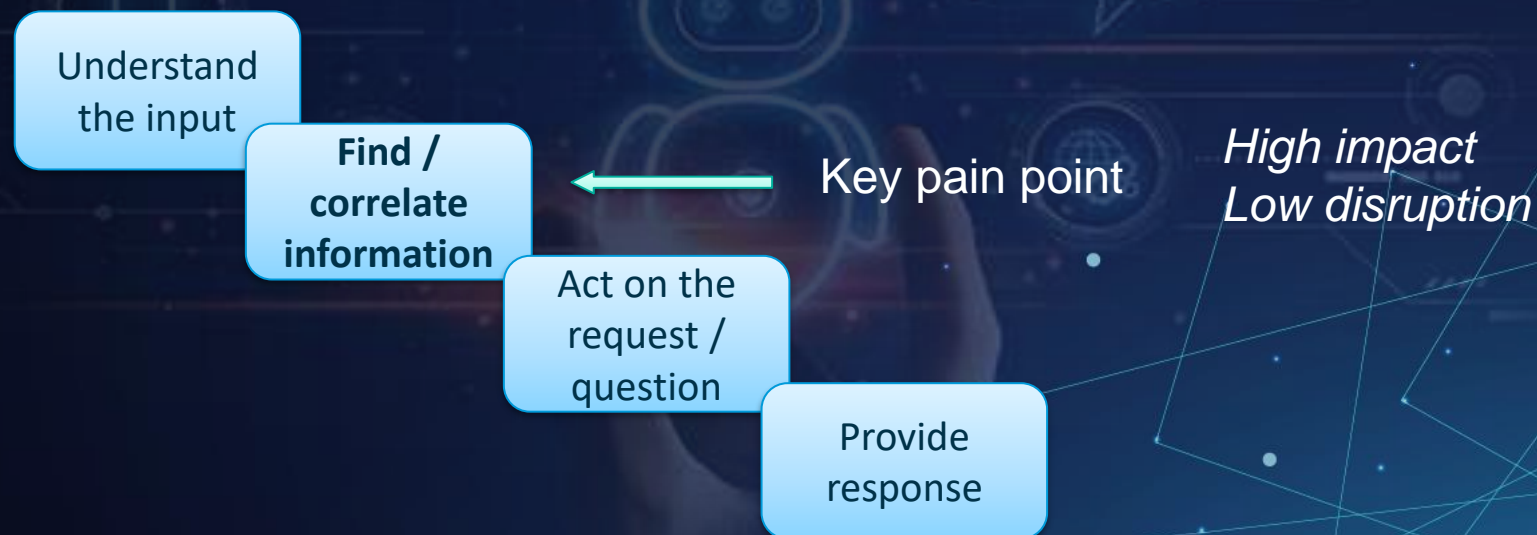
OCAI Knowledge

Structured knowledge base

User Interface & core functionality

Cross-mission, multi key word queries

Today's On-board Events

GAIA   CLUSTER   SENTINEL-5P   EUCLID

Chronological order

Spacecraft Events

DateTime	Mnemonic	Description
2023-06-27 02:45:50.440		
2023-06-27 03:01:04.264		
2023-06-27 03:01:10.012		
2023-06-27 09:19:51.440		
2023-06-27 02:45:50.440		
2023-06-27 03:01:04.264		
2023-06-27 03:01:10.012		
2023-06-27 09:19:51.440		

Telecommand History

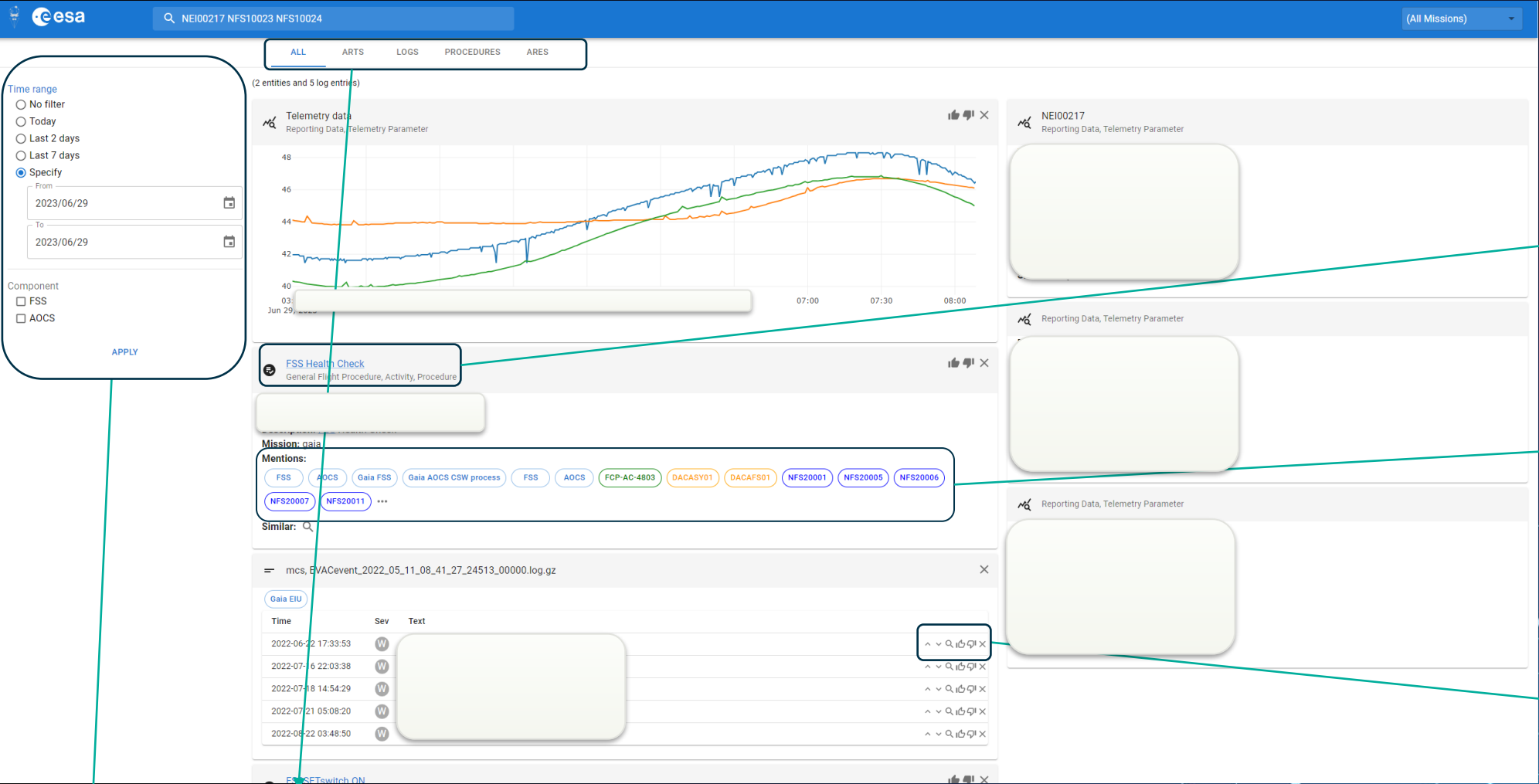| Execution Time	Name	Description
2023-06-26 23:26:27.375		
2023-06-26 23:26:28.375		
2023-06-26 23:26:29.375		
2023-06-26 23:26:38.000		
2023-06-26 23:26:39.000		
2023-06-26 23:26:40.000		
2023-06-27 00:30:01.375		
2023-06-27 00:30:02.375		
2023-06-27 00:30:03.375		
2023-06-27 00:30:12.000		

(All Missions)
Gaia
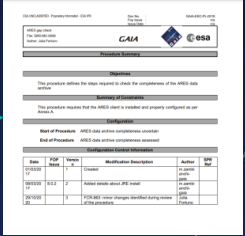Cluster
Sentinel-5P
Euclid

→ THE EUROPEAN SPACE AGENCY
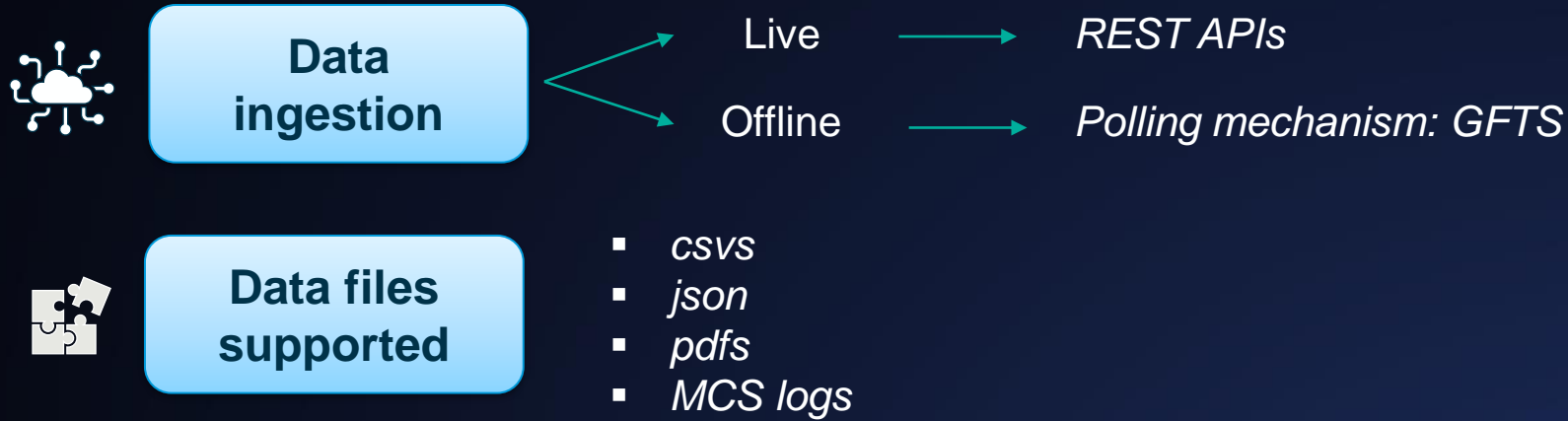
User Interface & core functionality

Retrieve / Open Procedures

Mentions

Explicit feedback on result relevancy

Filtering

Information split per knowledge source

Getting started

Data ingestion
- Live → *REST APIs*
- Offline → *Polling mechanism: GFTS*

Data files supported
- *csvs*
- *json*
- *pdfs*
- *MCS logs*

Installation & run
- Docker images
- Setting up local file system

Tailoring for new missions
- Pipeline configuration
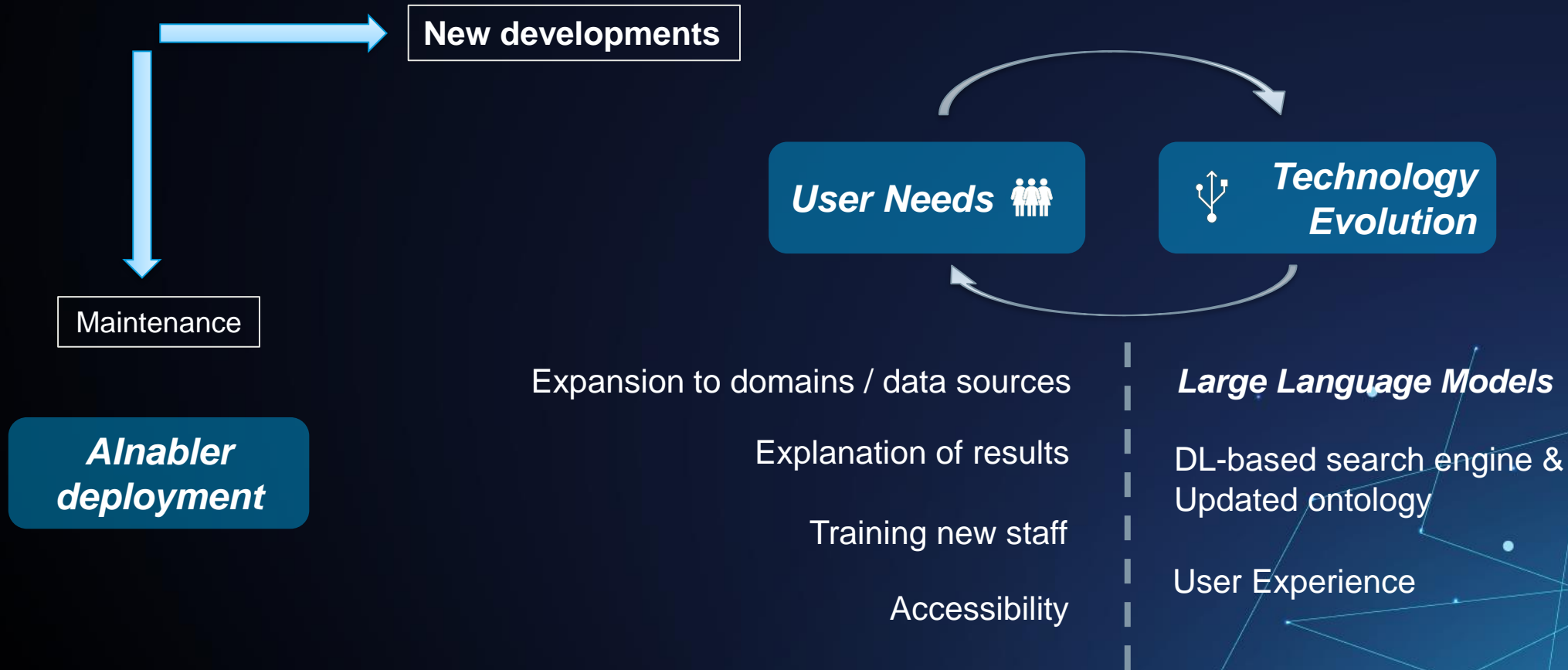- Mission File system
- Permissions

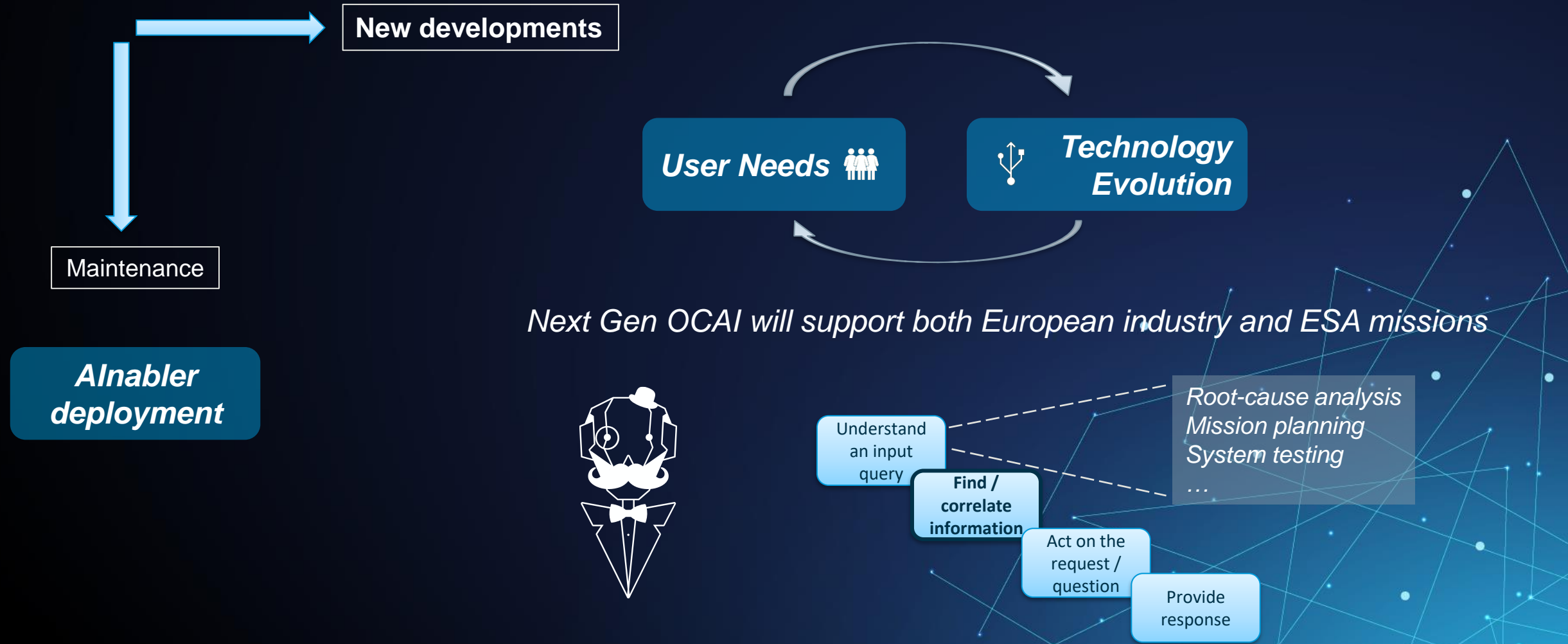## Source code and documentation
Will become available at:
https://www.space-codev.org/

- *ECSS*: SRS, SDD, SUM, CIG, SVS, ...
- TN with SoTA, Workshop output

→ THE EUROPEAN SPACE AGENCY

Preparing the Next Gen Operations Companion

New developments

Maintenance

AInabler deployment

User Needs

Technology Evolution

Expansion to domains / data sources

Explanation of results

Training new staff

Accessibility

Large Language Models

DL-based search engine & Updated ontology

User Experience

→ THE EUROPEAN SPACE AGENCY

Preparing the Next Gen Operations Companion

New developments

Maintenance

AInabler deployment

User Needs 👫👫

Technology Evolution

Next Gen OCAI will support both European industry and ESA missions

Understand an input query

Find / correlate information

Act on the request / question

Provide response

Root-cause analysis
Mission planning
System testing
…

→ THE EUROPEAN SPACE AGENCY

Data foundation

Data Sources
- Oper. Logs
- OPEN-M
- FOP
- MIB
- MCS Logs
- ARTS

ETL
Batch, Real-time

Data Repos

Object storage
- Store data on cheap, reliable and infinitely scalable media

Databases
- Relational, NoSQL, Data Warehouse

Data Processing
- Transform and analyse data in RT / batches
- Train and optimise ML models

Services and UX

Data as a Service

Visualisations

Applications (Mob / Web)

Emerging Data + AI Roles

ML Validator
Knowledge Engineer
Model Manager
Decision Engineer
MDM Manager
Data Translator

…

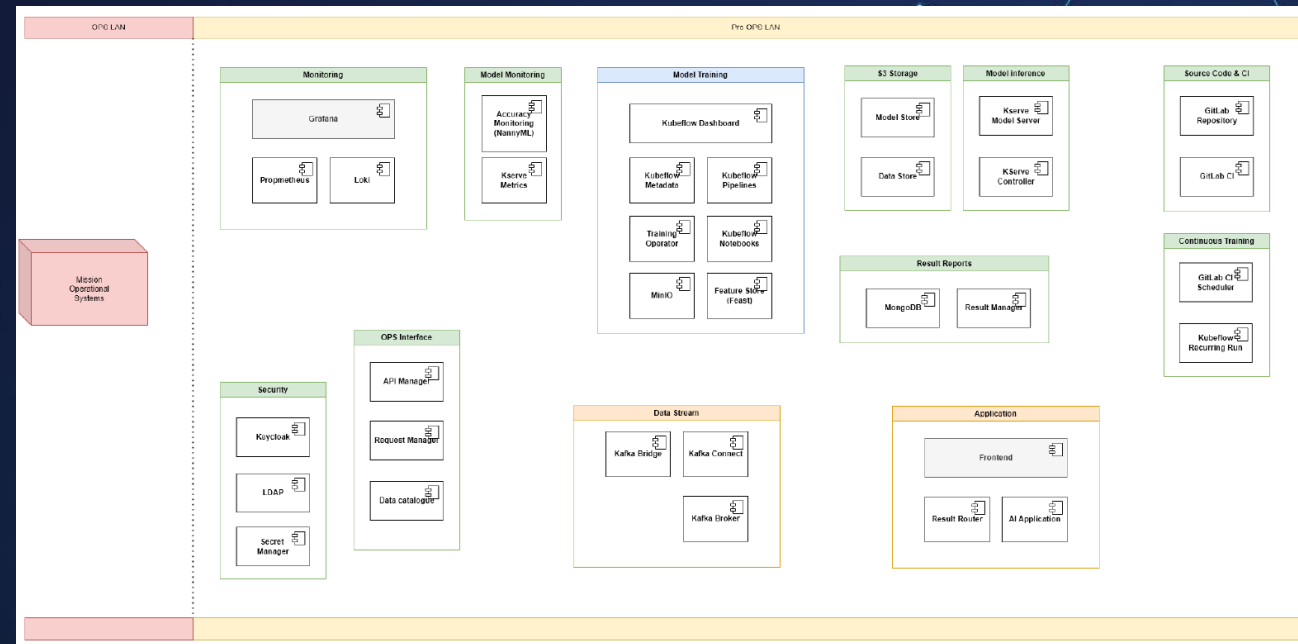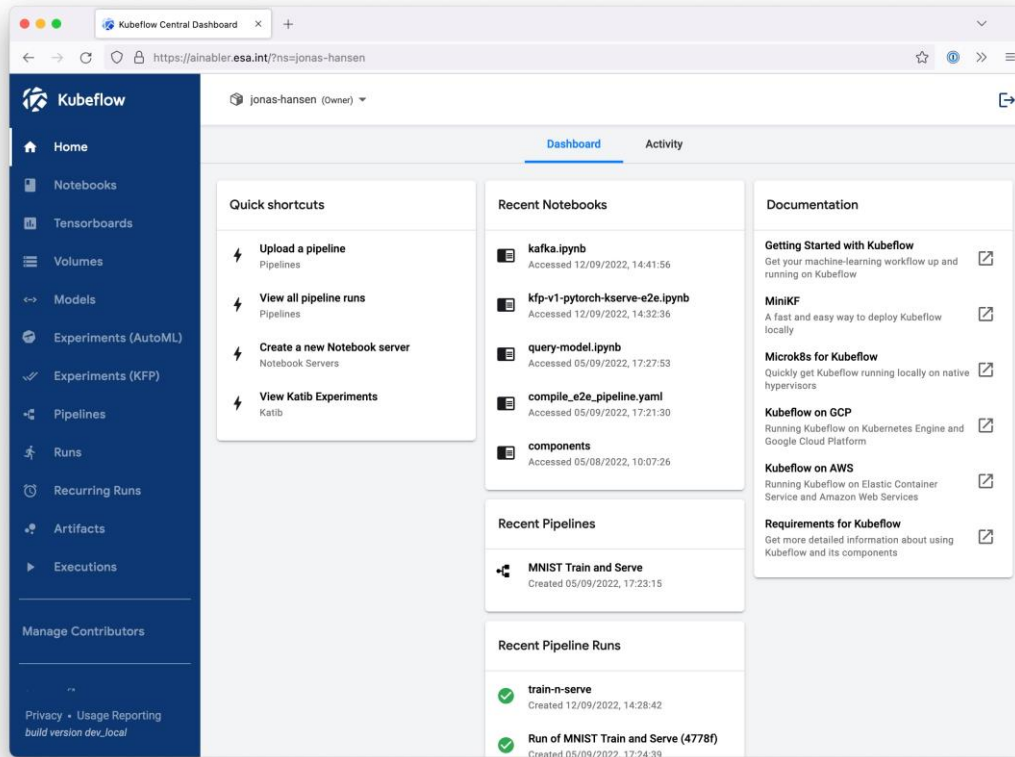|	
Data pipeline authoring & orchestration	Author data pipelines, schedule data processes
Data and model governance	Controls access, track model activity, Data catalogue, quality and metadata
Data Security	Authorisation, authentication, encryption, data privacy
Infrastructure operations	DevOps and automation, logging, monitoring

→ THE EUROPEAN SPACE AGENCY

AInabler @ SPACE CODEV

Codebase hosted on Space CODEV (https://www.space-codev.org/) at (https://ainabler.space-codev.org/)

- ESA Community License, Weak Copy Left
- Initial version available now, update due Q3

"The AInabler platform is at its core a data platform, which enables its users to build, (re-)train, and deploy machine learning (ML) models"

Platform Includes: Model Training, Versioning, Monitoring & Inference, Storage & Results, Data Streaming, Model, Security Monitoring System

→ THE EUROPEAN SPACE AGENCY

Upcoming activities

Applications

Ongoing Upcoming Planned

	Operational simulation and operations preparation	Systems testing and validations	Ground system maintenance and ground operations	Satellite health monitoring and data processing	Flight control team and ground stations
GSTP	GT1I-617GD AI for automation of operations preparation and operational simulation – **1.7M**	GT1I-618GD AI for automation of mission operations systems testing and validation – **2.3M**	GT1I-619GD AI for automation of satellite health and ground operations – **3M**		GT1I-616GD AI-based decision support system for mission operations – **1.2M**
TDE					T409-801GD Launch campaign preparation and operations intelligent assistance – **400k**

Data foundation / Infrastructure

(Transversal activities)

GT1I-403GD AI qualification and validation services for space systems operations – **700k**

AI ready Multi mission and multi asset archiving – **400k**

T709-807GD Assurance for Space Domain AI Applications – **600k**

T709-806GD Synthetic Data Generation and qualification – **400k**

GSTP – *AI Compendium*

TDE – *Workplan*

* Developed on **Space CODEV** under ESA Community license at https://ainabler.space-codev.org/

→ THE EUROPEAN SPACE AGENCY

Mentimeter – OCAI Enhancements

Follow:

https://www.menti.com/al81yxou41vt

Or, go to www.menti.com

Enter code: 1324 7846

- Which new user story / feature should OCAI support?
- What data sources are you using on your day-to-day work?

Or:

→ THE EUROPEAN SPACE AGENCY

Discussion with the operators

"One stop shop"

"The mentions are super cool!"

"One other feature that I am using a lot is to browse the procedure content. This is super helpful."

"OCAI is quite a powerful and useful tool! Quite nice as you can get FOPs, TM data or anomaly DB entries in the same place."

→ THE EUROPEAN SPACE AGENCY

Thank you COMET community!

evridiki.ntagiou@esa.int

Follow:
https://www.menti.com/al81yxou41vt

Or, go to www.menti.com
Enter code: 1324 7846

→ THE EUROPEAN SPACE AGENCY