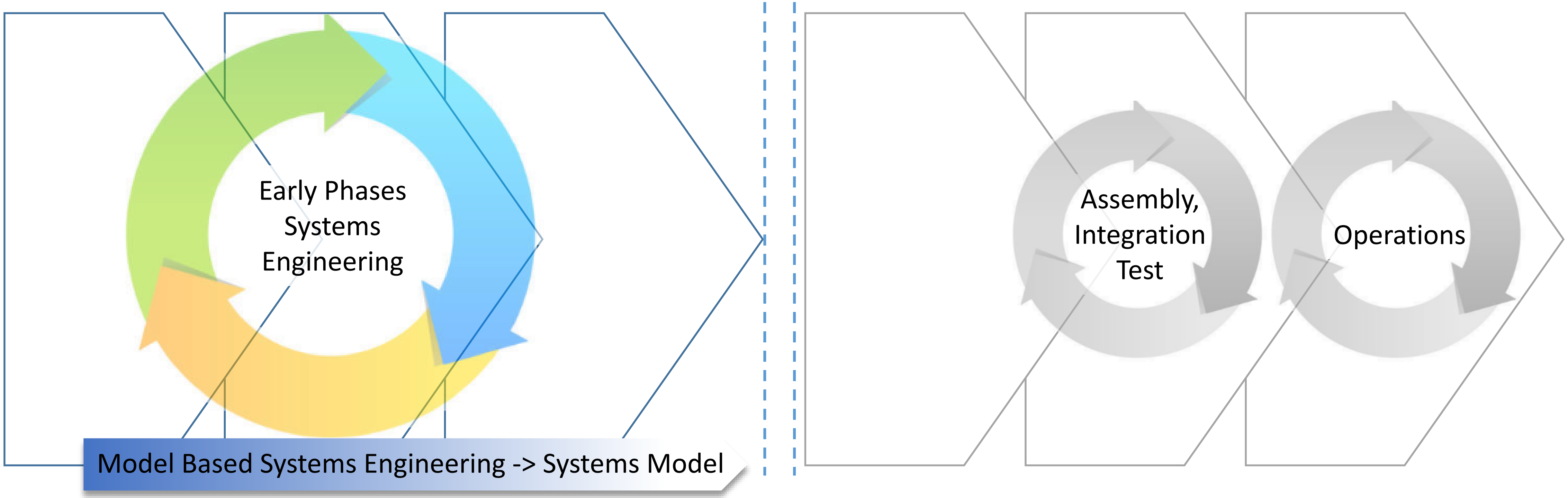
The Integrated MBSE Analytics Platform

Tracing AI based analysis of AIT/AIV telemetry data results to MBSE models

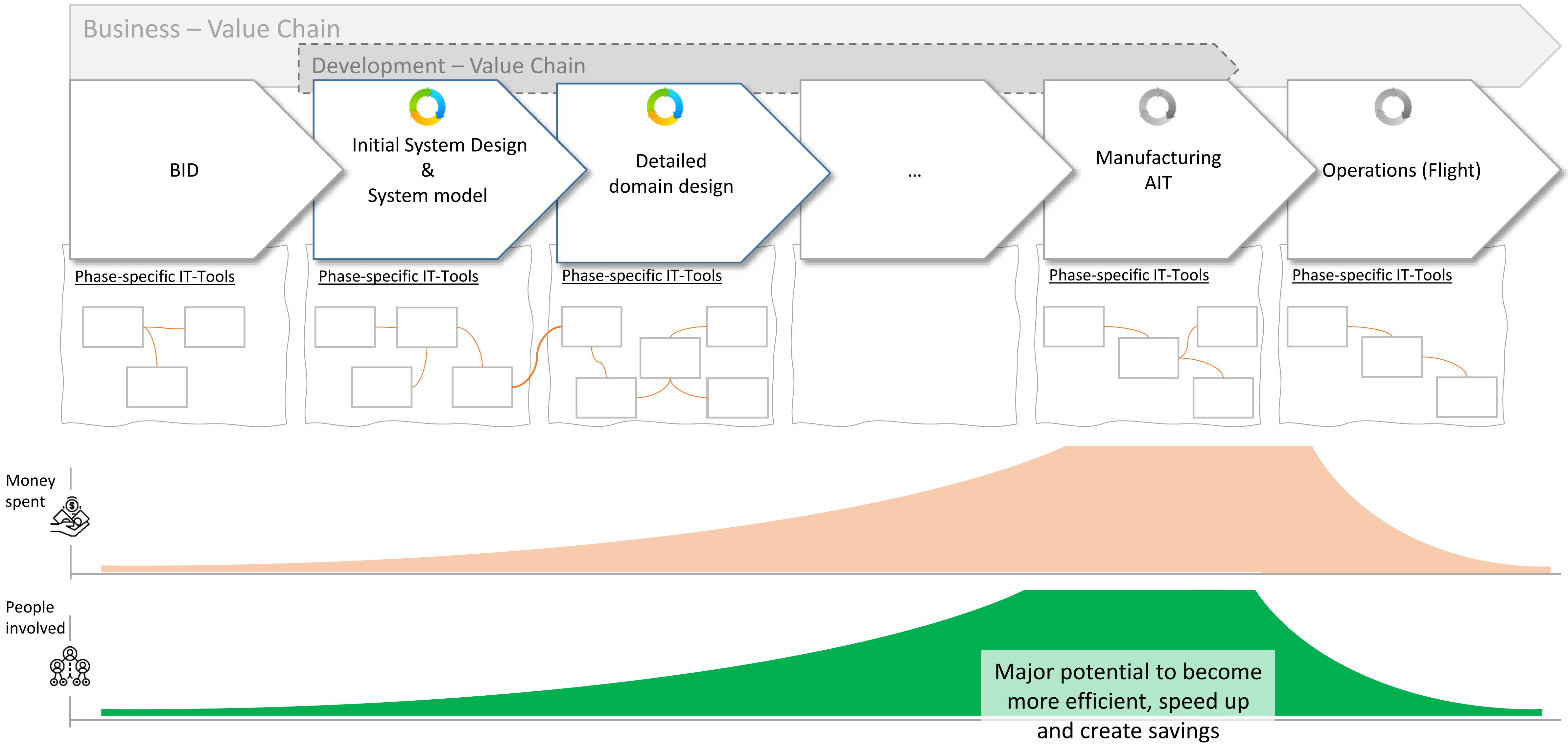
November 22, 2022, ScopeSET

Where we are today – State of the Art in MBSE use

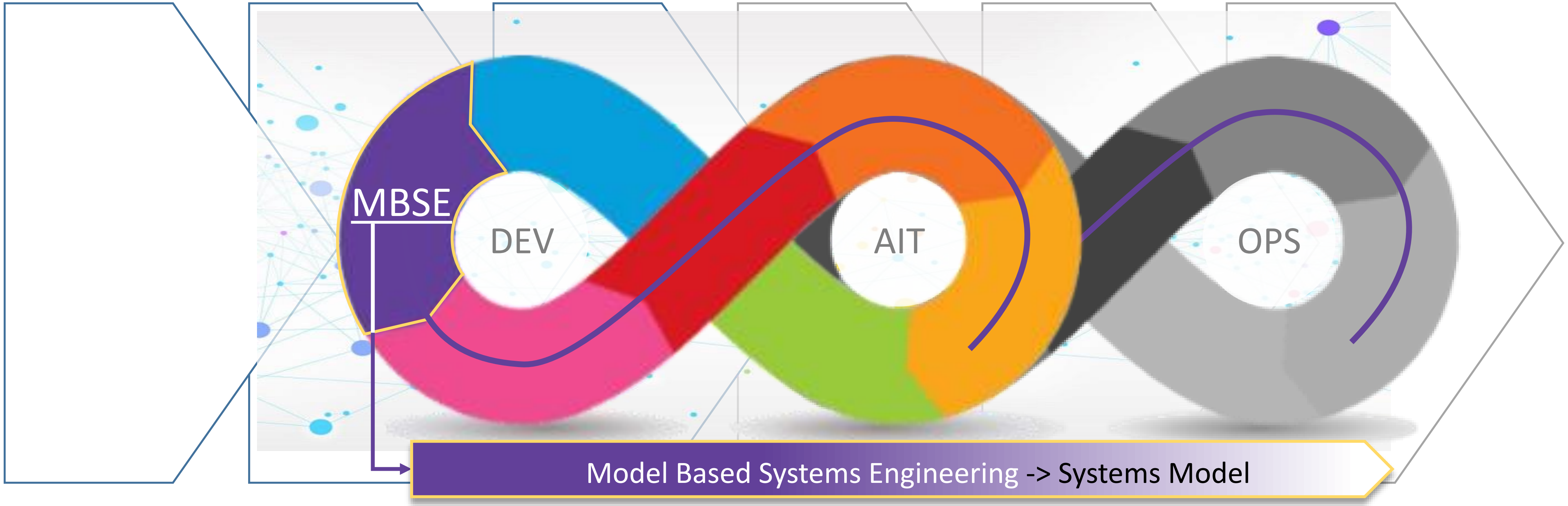


- Disconnected Data Silos and Teams along the lifecycle, mainly Point-to-Point interface
- Interconnected knowledge still in experts brains mostly
- Benefits of MBSE (System Models) do not pay out in later phases
  - Models become outdated and are no longer used in AIT and Operations

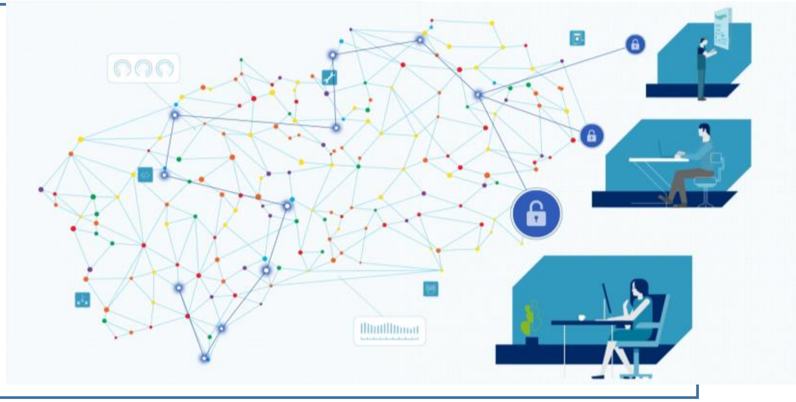
State of the Art – Detailed View



The Answers – Hypothesis of this Project



- Integration of MBSE and AIT / Operations into a holistic Workflow
  - Elimination of (functional) failures in the context of the AIT process
- Supported by suitable visualisations
  - less system failure
  - faster troubleshooting
  - improved communication between the project participants.



Integrated MBSE Analytics Platform - IMAP

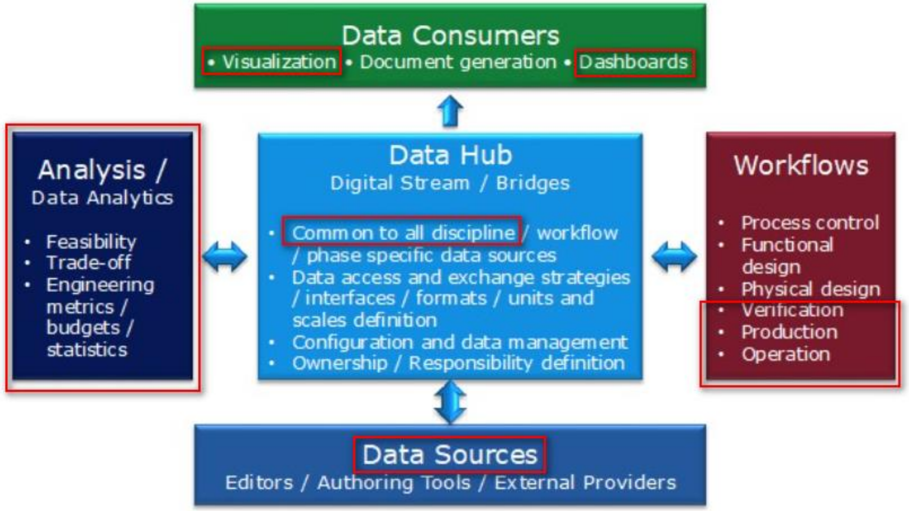
- Integrate MBSE and AIT with MachineLearning based anomaly detection into one platform

- Developed as technology demonstrator in an ESA funded research project within the OSIP activity

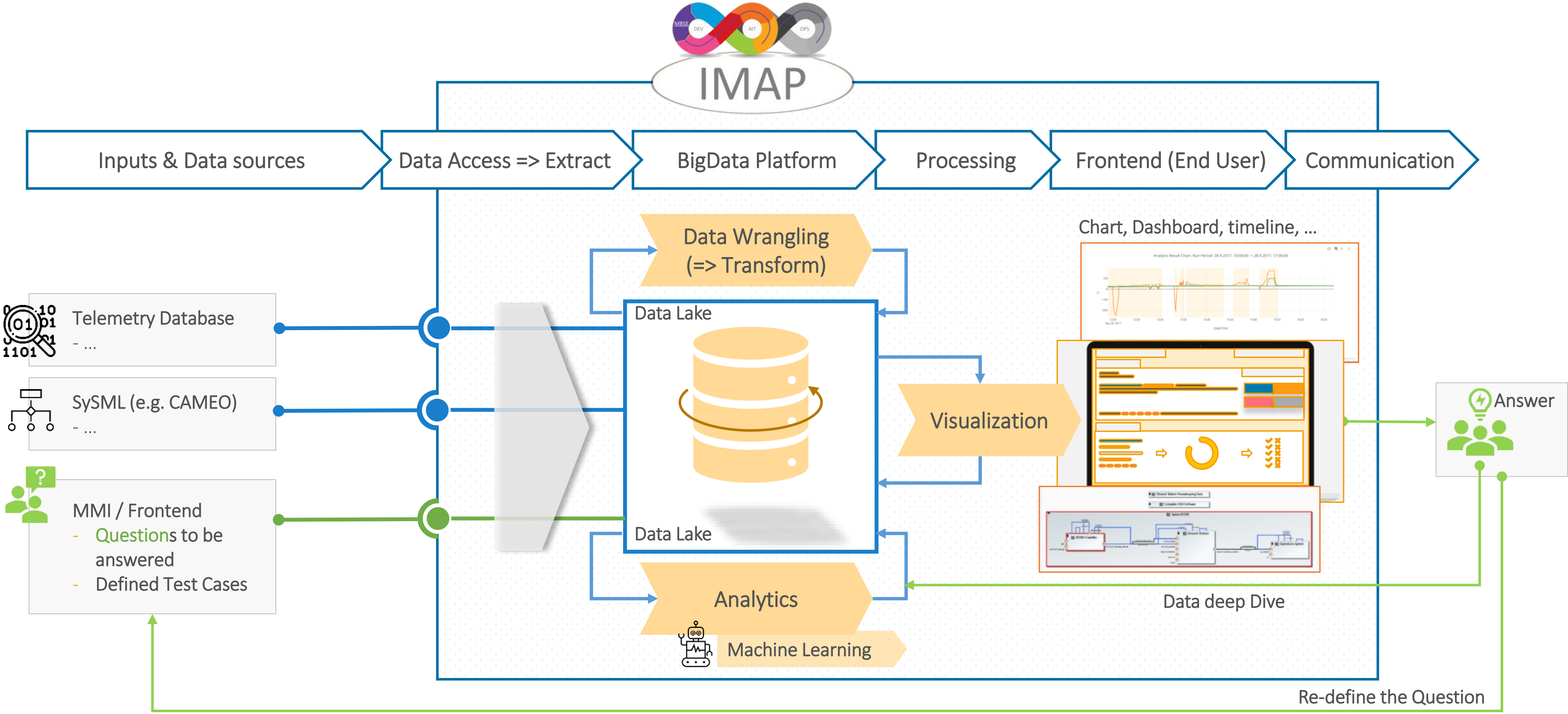
- Aligned with ESA's MBSE strategy
(https://essr.esa.int/project/mb4se-model-based-for-system-engineering)

- Aligned with results and user stories from Expert interviews in Spring 2021

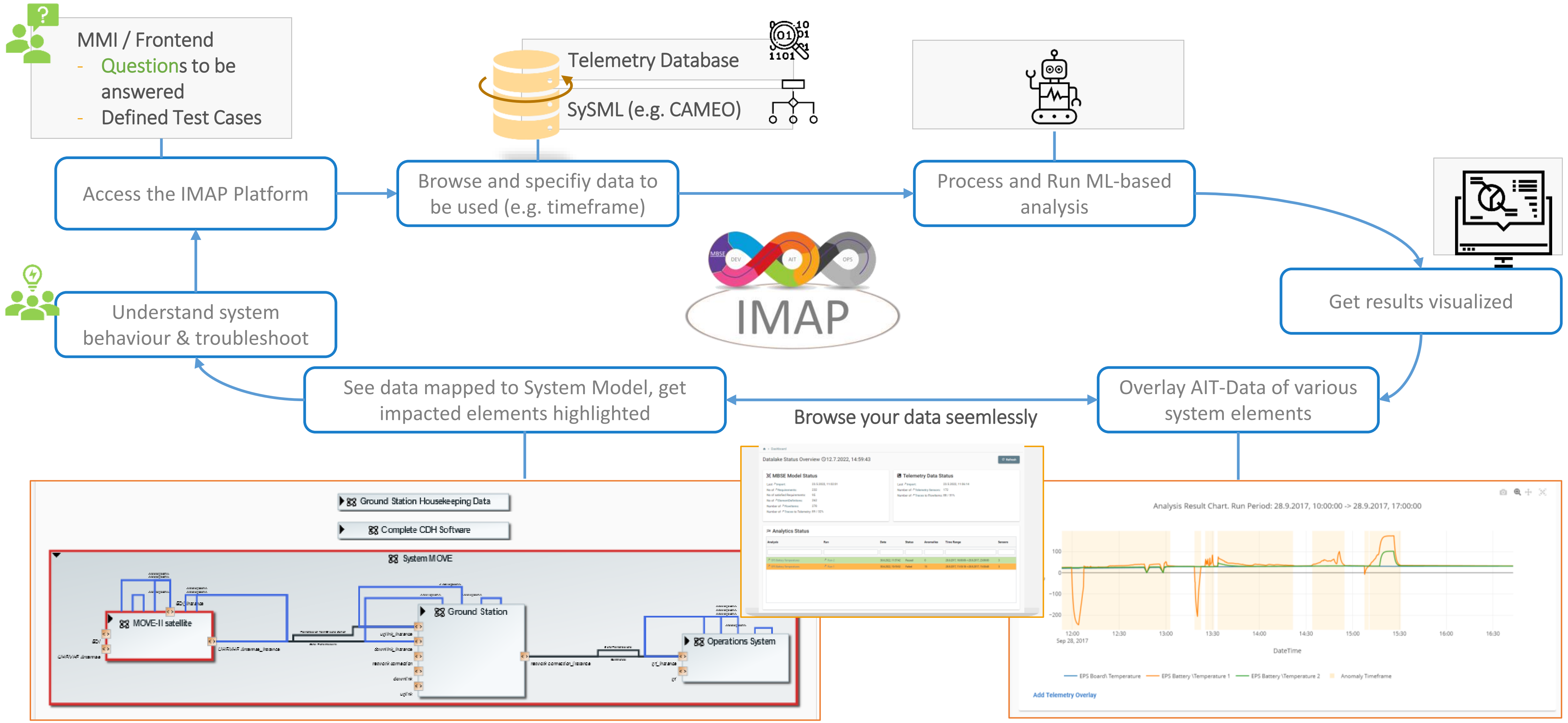
- Project completion July 2022



IMAP – Overall Process

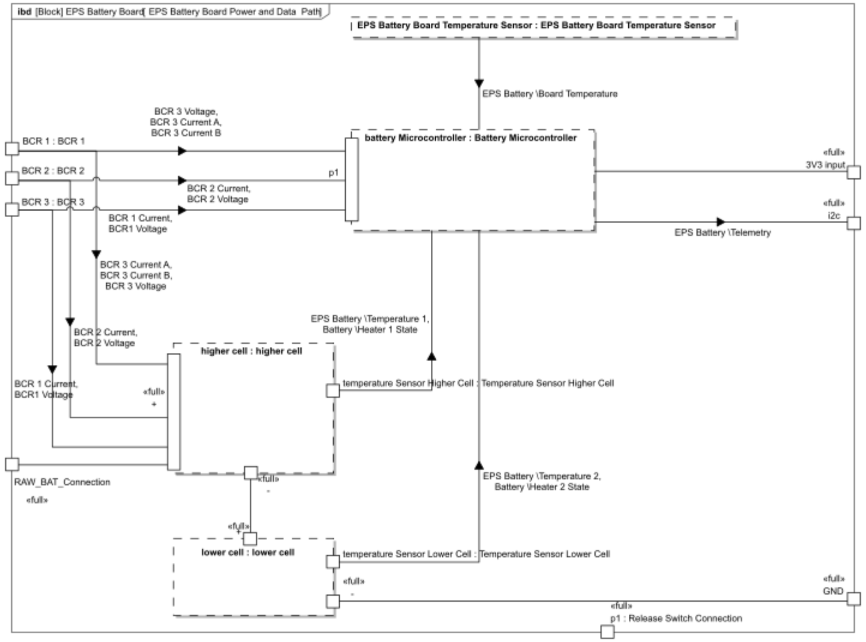


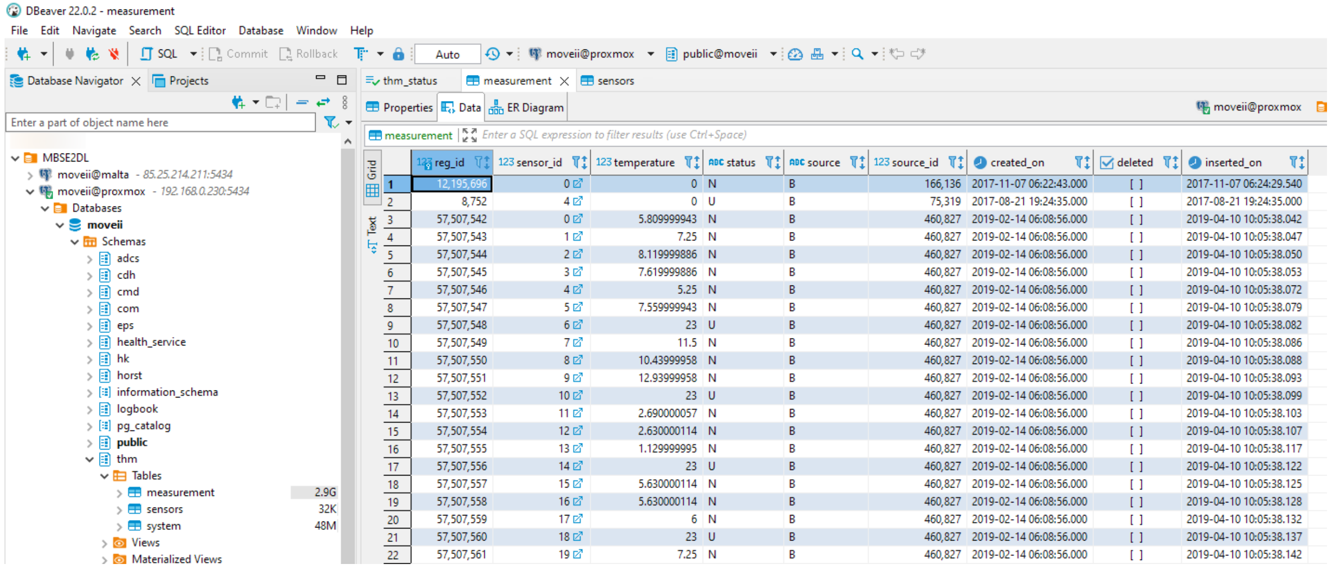
IMAP – Integrated MBSE to AIT Workflow



Demonstration Data

- All demonstration data is completely based on the operational MOVE-II CubeSat mission which has been developed by the Chair of Astronautics at TU Munich

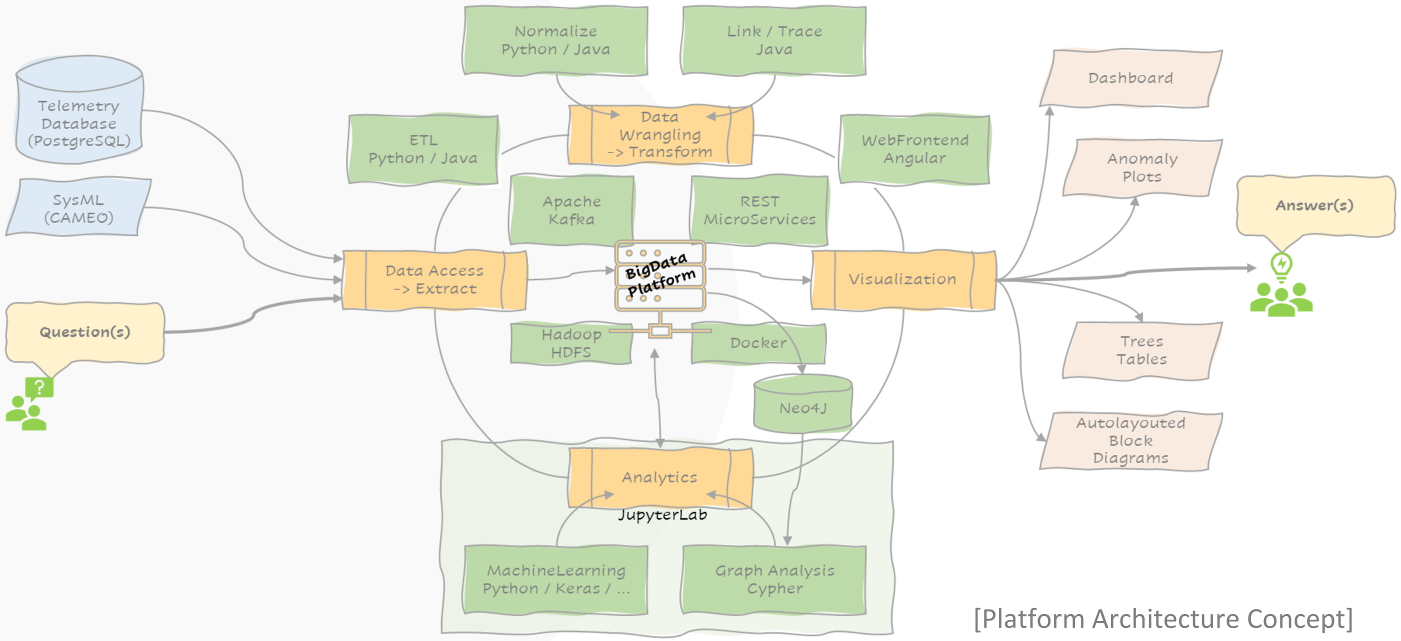




- For details: See https://docs.mbse2dl.org/overview/demo-data/

The Platform

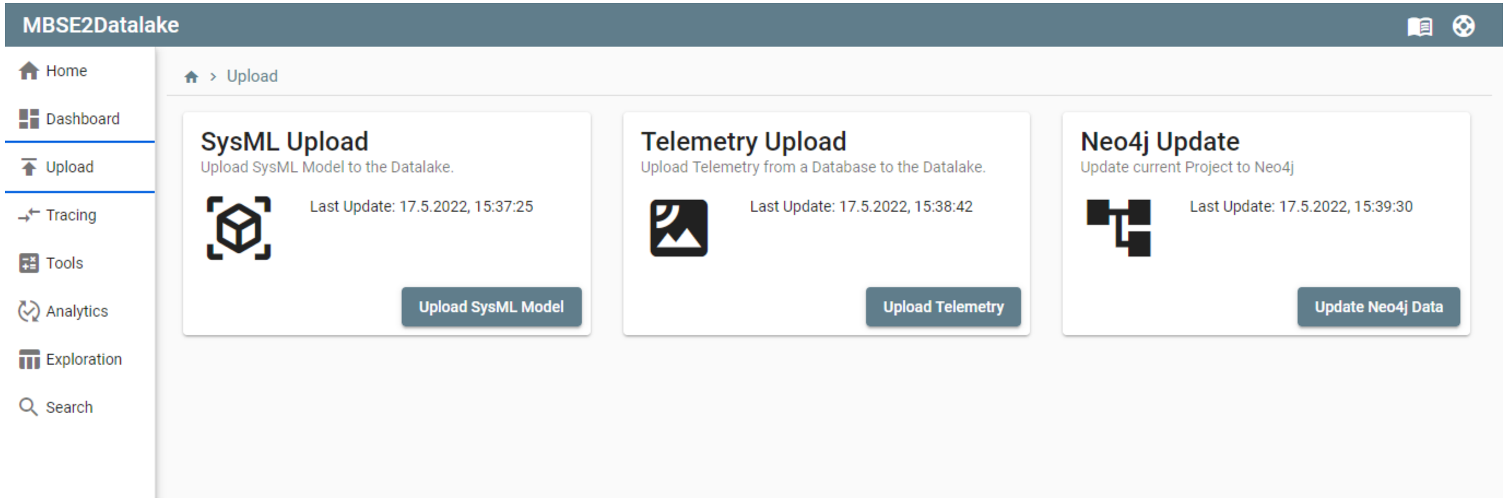
- Scalable for BigData
  - State of the art building blocks: Docker based micro services, Hadoop Filesystem, Kafka Messaging, …
- Formalized
  - Semantic DataLake concept, underlying Ontology modeled in OWL – based on CIP metamodel, MBSE storage in RDF
- Flexible
  - Analytics functions implemented in industry standard Jupyter Notebooks – for expert users
  - Integrated into end-user-friendly web frontend
- Extensible



[Platform Architecture Concept]

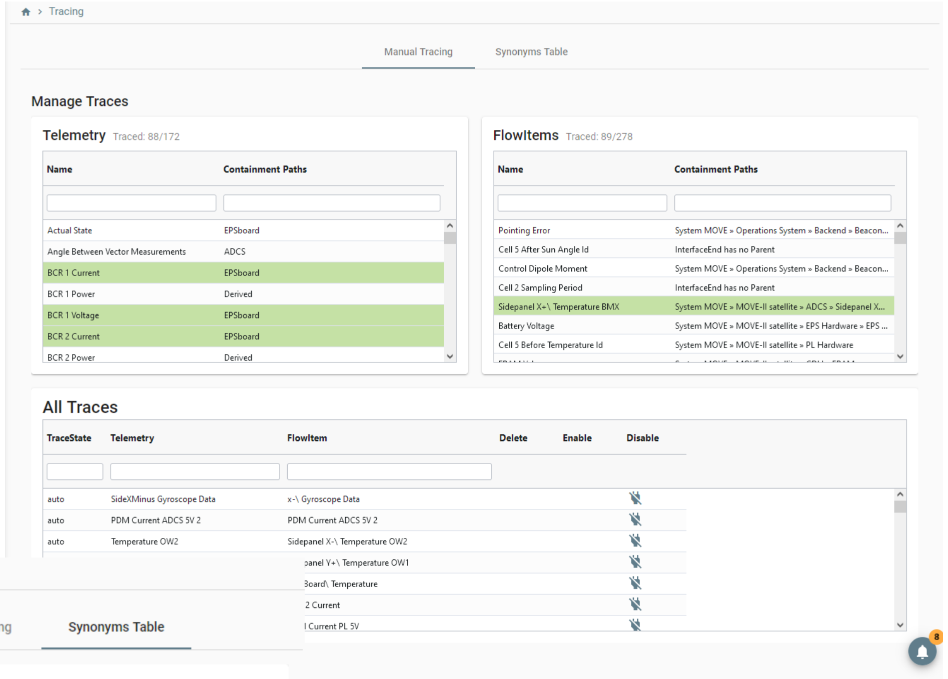
Importing Data

- In the technology demonstrator, data imports are specifically tailored for MOVE-II data (MagicDraw SysML model and PostgreSQL Telemetry Database)
- These 2 importers will need to be adapted or rewritten for different MBSE models and Telemetry Databases!

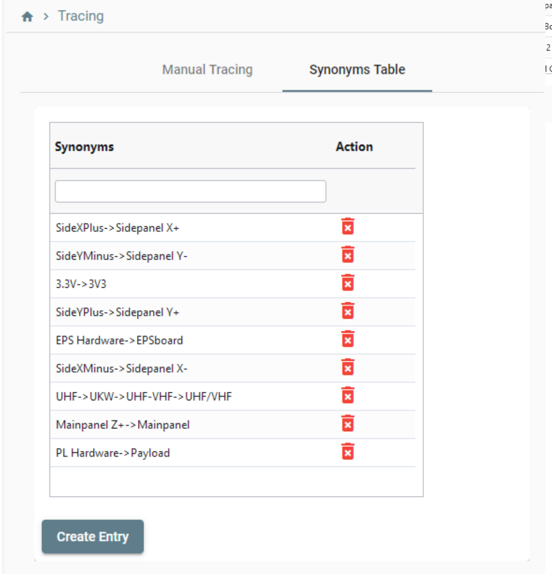


Tracing MBSE to Telemetry Data

- Traces between MBSE FlowItems and Telemetry sensors can be detected
  - Automatically (to a certain degree, depending on Model and Sensor structure)
  - By manual drag&drop

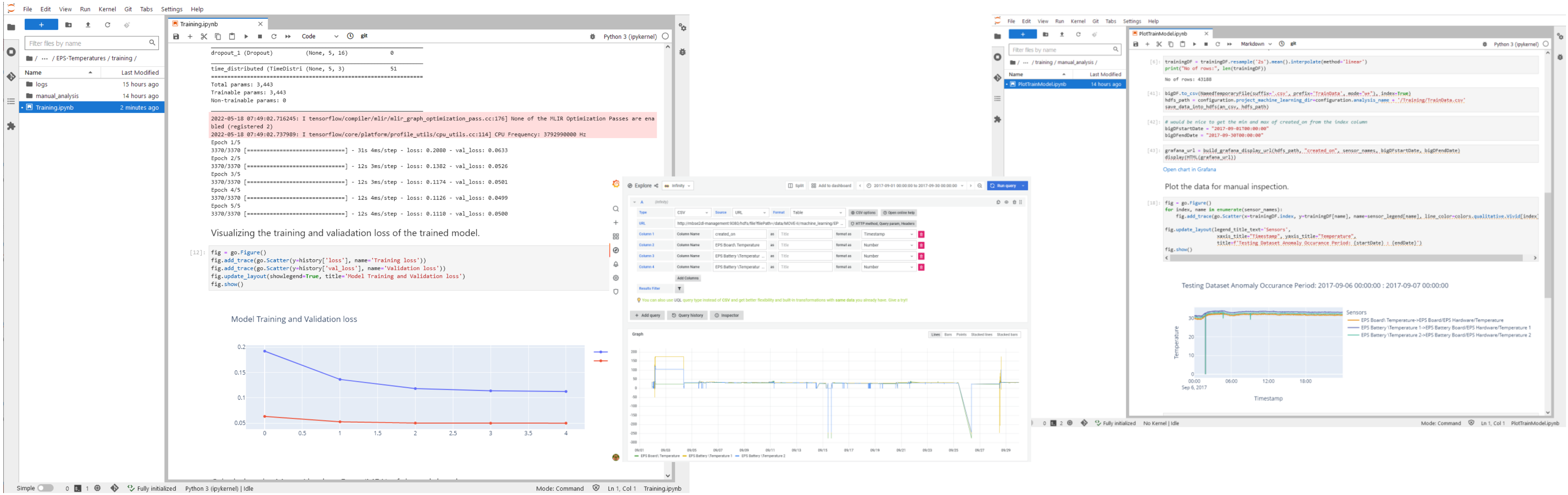


- By defining a list of synonymous terms



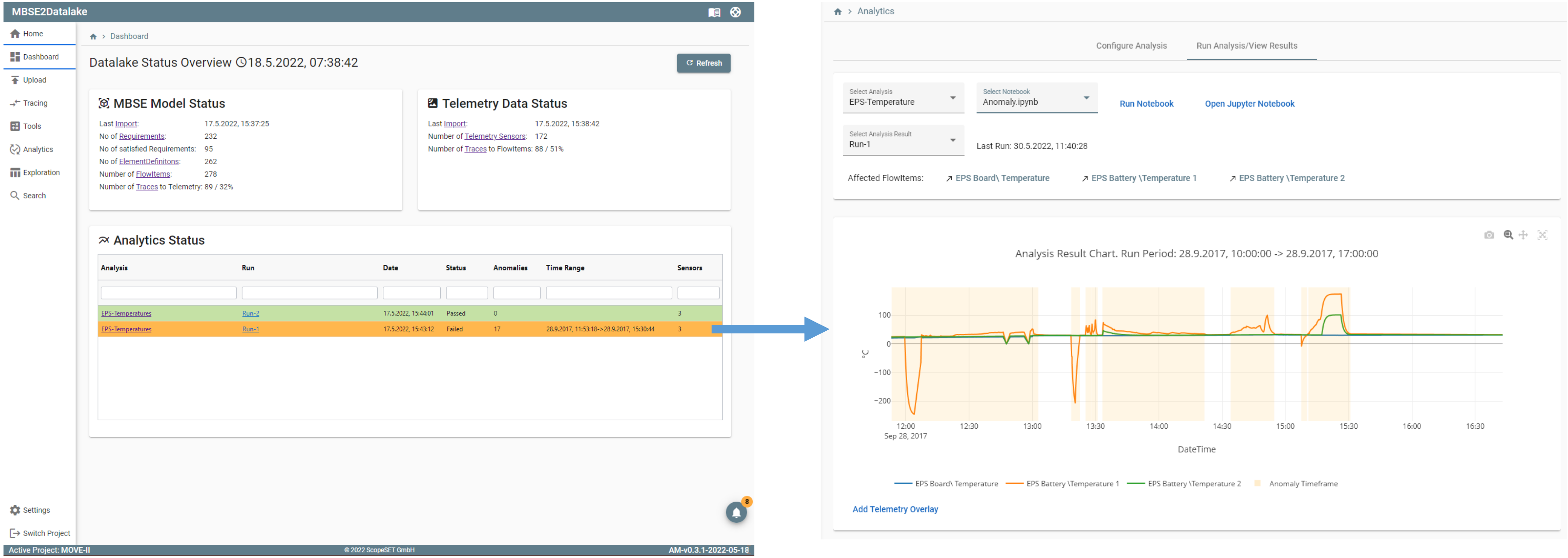
Feature: ML based automated Anomaly Detection

- On-platform setup of MachineLearning models and AnomalyDetection with JupyterLab for expert users/data analysts – no need to care about the technical infrastructure
- Results flow into DataLake for storage and end-user friendly front-ends

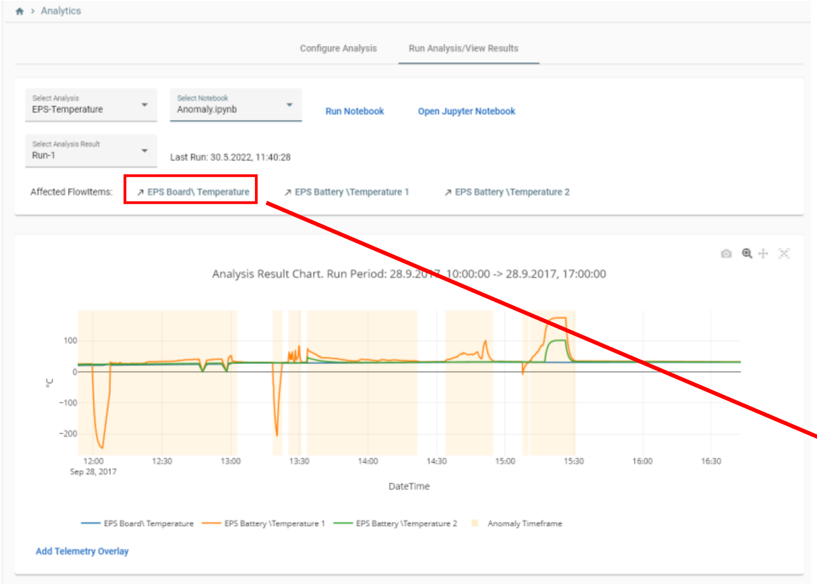


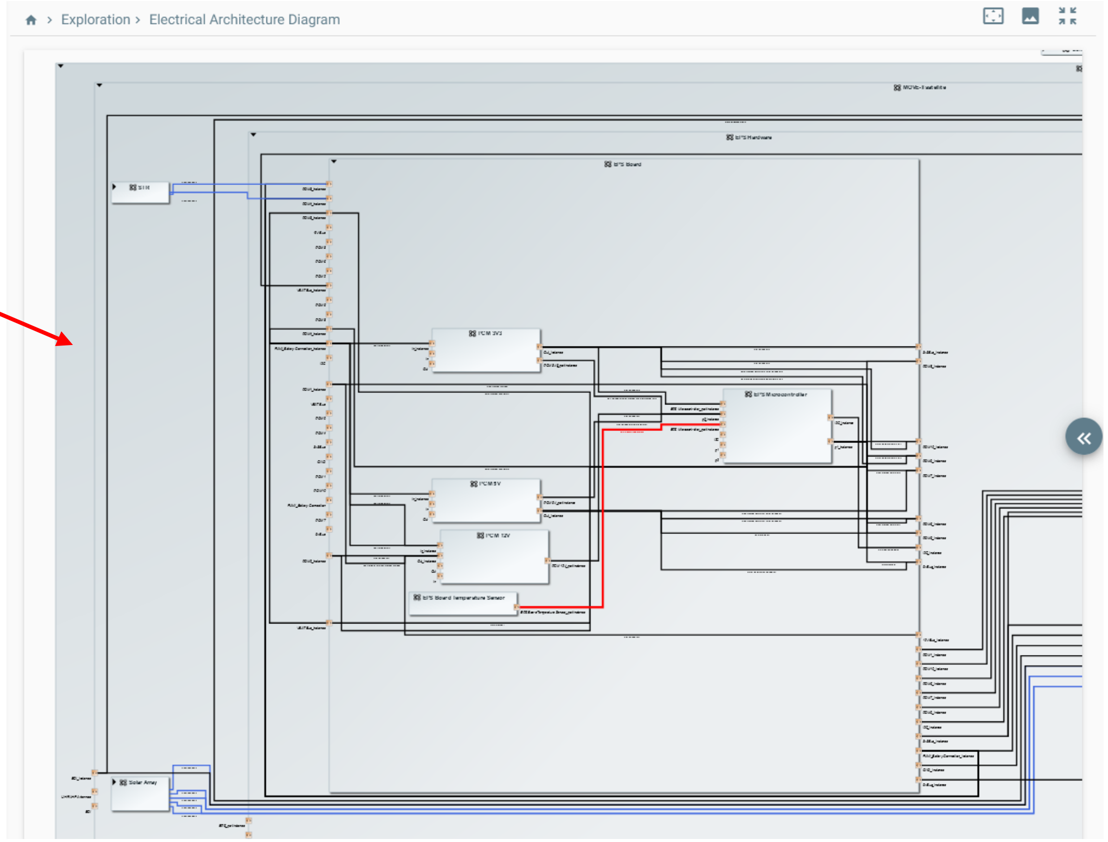
Feature: MBSE and Analytics – Overview

- All data in one place
- From Dashboard to ML based analysis results…



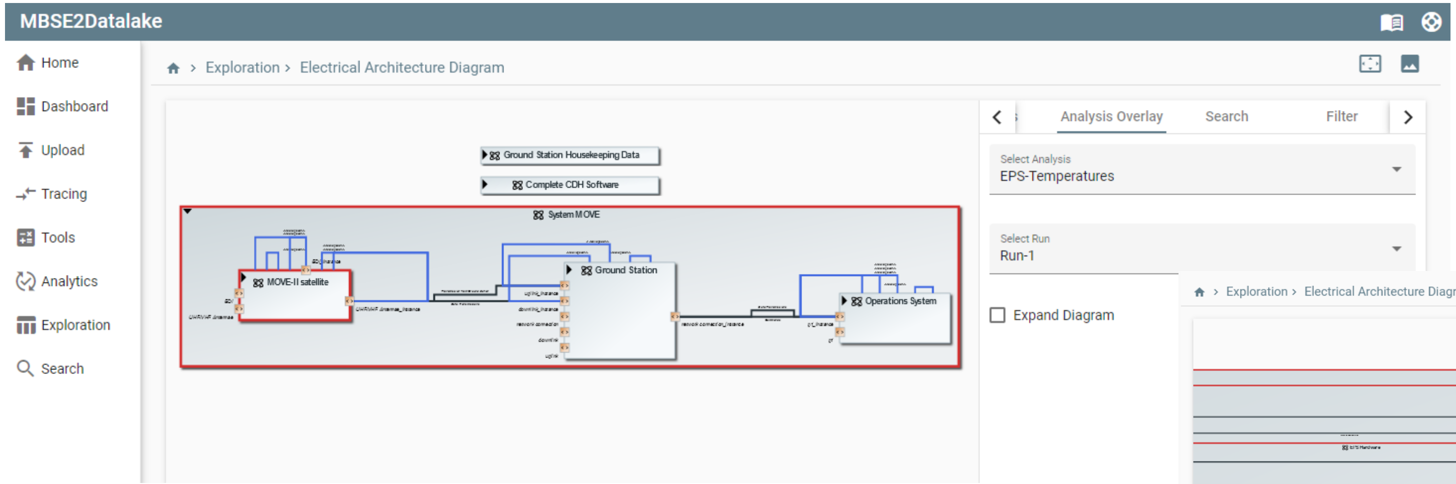
Feature: Block Diagrams with Failure Highlighting

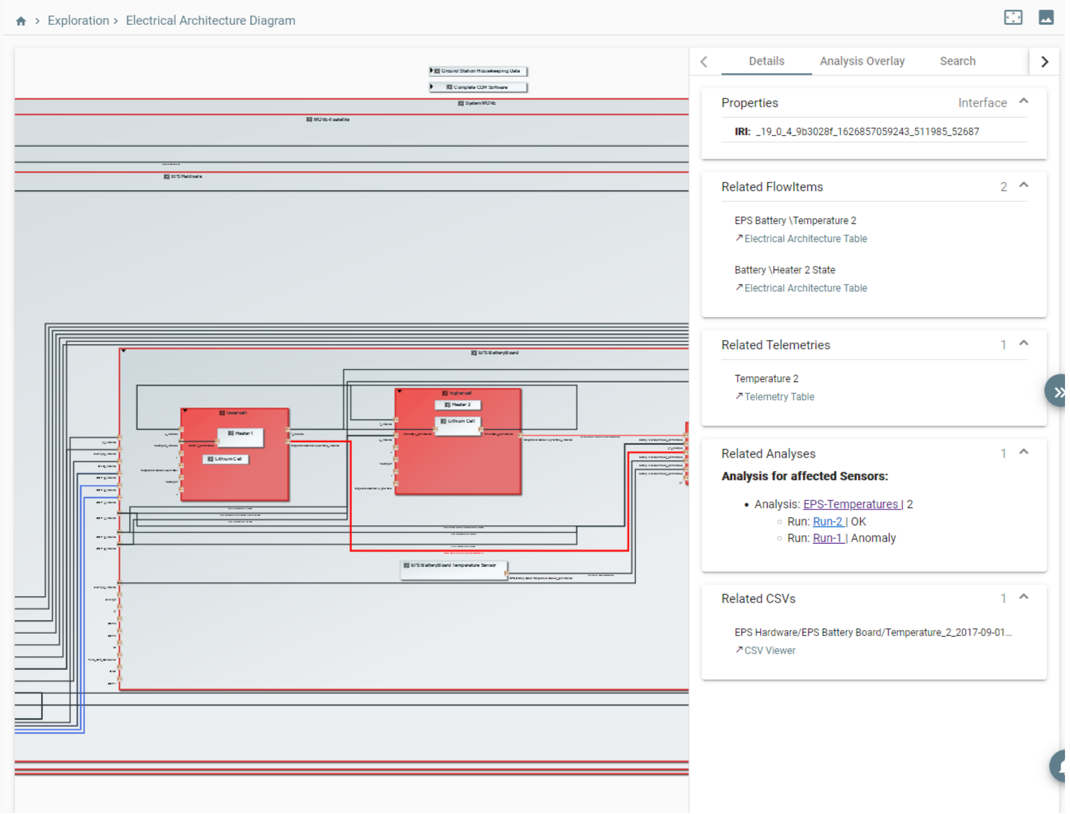




- Navigate from detected Anomaly to affected FlowItem in auto-layouted Block Diagram

Feature: Block Diagrams as Entry Points

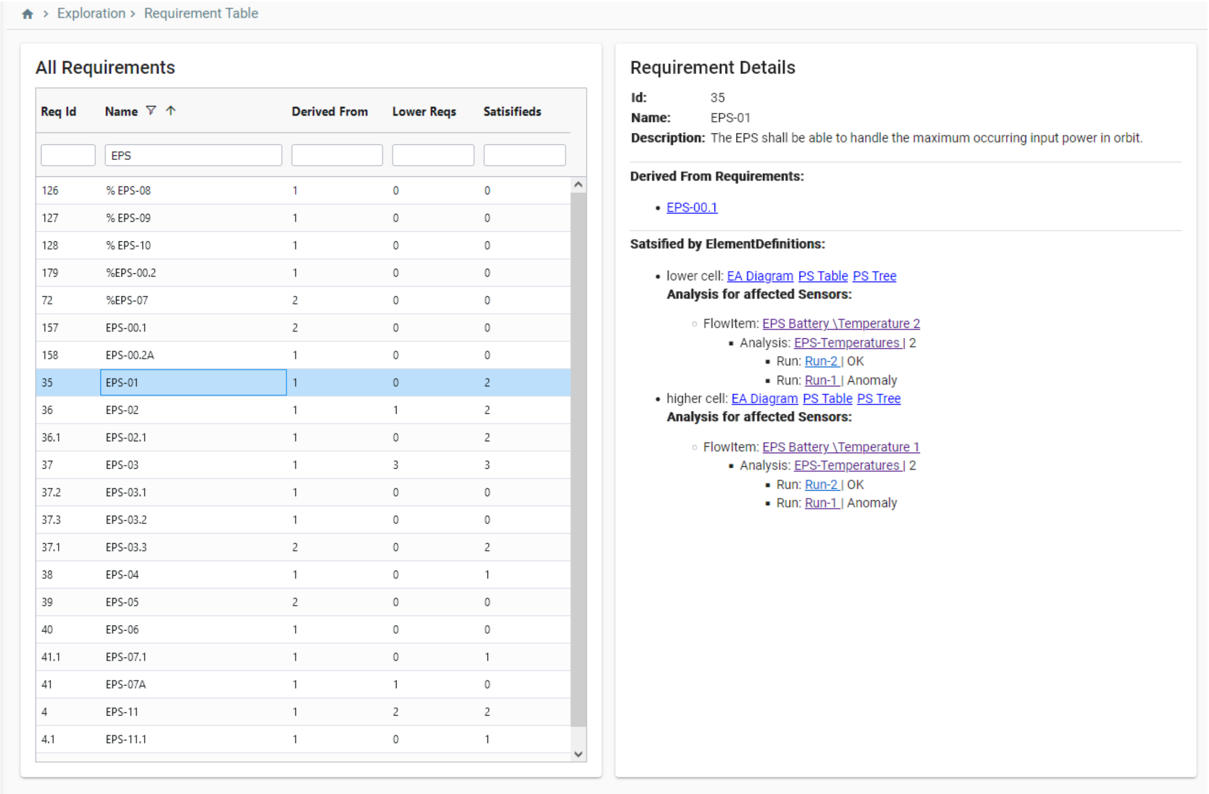




- From SysML to associated Analysis:
  - Overlay Analysis Results in auto-layouted block diagrams
  - Dynamically drill in/expand/collapse to see more detail
  - Navigate to all other views

Feature: Assistance Functions

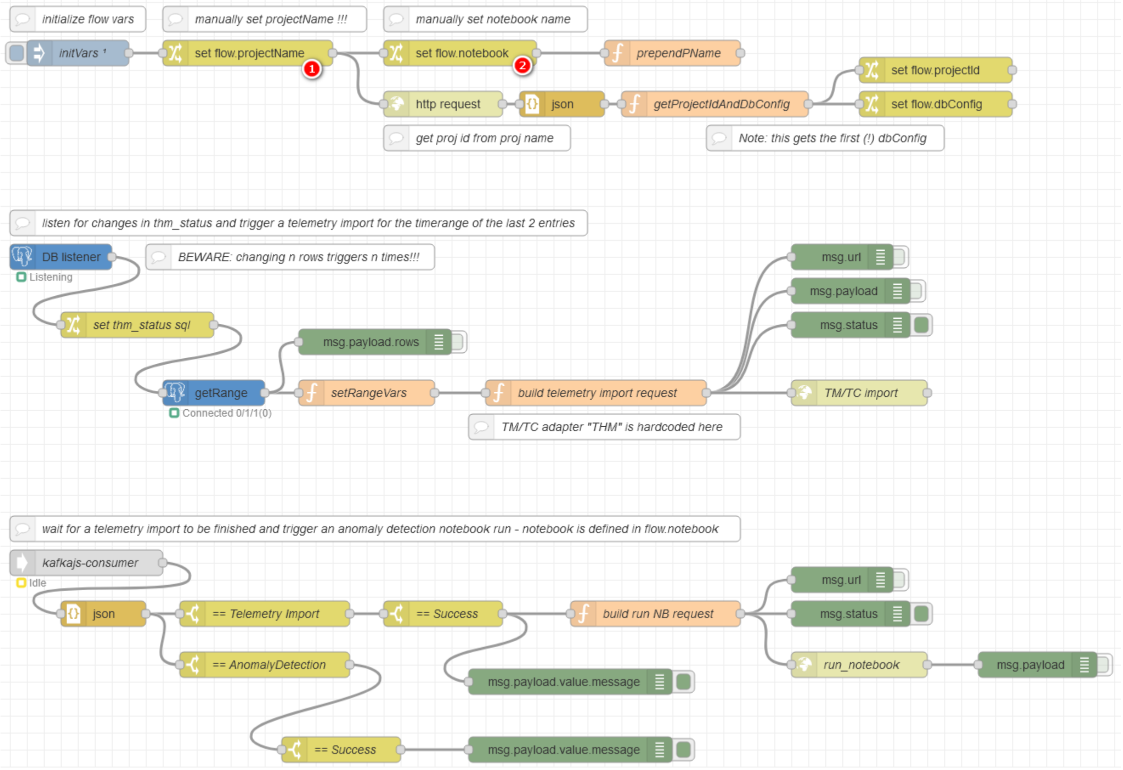
- MBSE centric views, Trees, Tables
- Drill-in capable autolayouting block diagram with Search, Filters, …
- Integration with state-of-the-art Chart Visualization (Grafana)
- Global search



Feature: Orchestration of Data Ingestion

- Automated data ingestion and triggering of Analytics functions

- Node-Red flow diagram:
  - Model the ingestion workflow based on specific input data access and trigger tailored Analysis scripts
  - Result will be displayed in standard dashboards and views



User Feedback
Workflow Comparison – Design Phase

Model Design

- Easy connectability to other data sources e.g. to connect requirements to test documentations etc. with high degree of freedom
- Automated model-checking via Cypher-Routines/queries, seamless integration of checking connected data sources

Model Exploration with IMAP

- Intuitive Model explorer and interactive diagram layouter
- No necessity to build or maintain large amounts of diagrams for user views
  - ➢ Less effort for maintenance
  - ➢ Less update latency
  - ➢ Increased confidence in model by users

Classical Model Design

- Limited and cumbersome interoperability with other data sources (e.g. lots of manual tracking)
- Model checking limited to pre-defined toolset, no checking of interconnected data sources

Classical Model Exploration

- Scrawling for content of diagrams, need to view X diagrams to gain understanding of context
- Necessity to build and maintain a large amount of diagrams for user views
  - ➢ High effort for maintenance
  - ➢ High latency for updates
  - ➢ Low confidence in model by users

User Feedback
Workflow Comparison – Testing and Operations

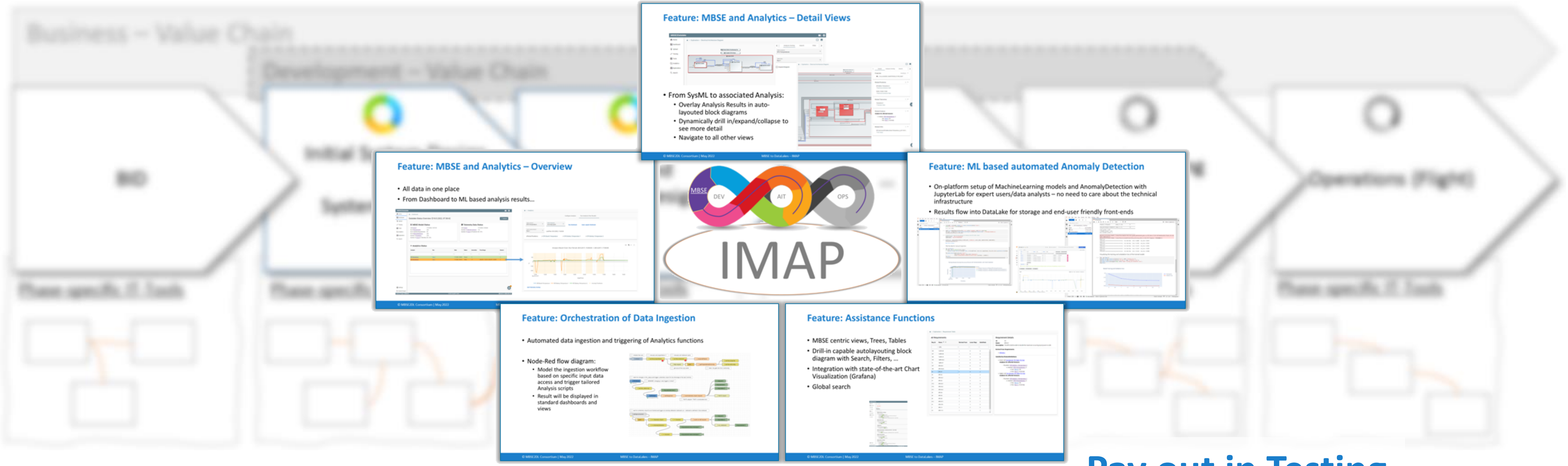
IMAP Integration Debugging Process

- Fault detection facilitated by AI
- Fault tracing simplified by automated model analysis
- Proposal of „best guess“ for components likely at fault based on deductions from Model and telemetry

Classical Integration Debugging Process

- Reliant on key personnel
- Requires holistic understanding of the system
- Trial and error based on intuition

Summary And Final Hypothesis



Pay out in Testing and Operations

Additional resources in early phases

Deployment and Demo

- Available online on https://www.mbsd2dl.org
- Including extensive documentation at https://docs.mbsd2dl.org

- Questions and Support: amueller@scopeset.de

Feedback on Solution Demo(s)

Stephan Finkel

3DSE, SE-Principal - Defence, Space and Automotive

"... many of our customers use (MBSE) system models extensively in the early phases of complex system developments, for example in naval shipbuilding and automotive engineering. However, there is often a gap in the use of models, which is due to time, organisational, but also competence-related reasons. A solution like IMAP can become a valuable building block in the E2E tool landscape. In addition, we see the opportunity that such a tool could both strengthen the end-to-end SE idea and enable the desire of many customers to shorten and agilise projects."

Patrik Krause

3DSE, Project Lead AMELIE, Advanced SE for SMEs

"... in our experience, SMEs in particular find it difficult to implement systems engineering holistically. This is due on the one hand to the extensive methodology, and on the other hand to the fact that people are often involved in projects in multiple roles. In the field of medical device development, we often have teams of < 15 people. We see the potential of the IMAP solution in the fact that a system expert can create the test cases and train the ML-system for approval-relevant test scenarios. The highly qualified person can then take on other tasks and only provide support in the event of an anomaly, then also with direct reference to the system model."

Feedback on Solution Demo(s)

Rupert Amann

Head of Space Development and Co-Founder of OroraTech

"... after an internal presentation of the MBSE2DL system, we hereby express our interest in the technology. The fast and clear failure analysis, as well as the possibility to automatically generate analyses and graphs for reports from the DataLake, are technologies with which we recognise a considerable added value for our satellite development. We see huge potential in machine-learning based telemetry analysis for the mission operations of our future satellite constellations."

Felix Firmbach

WARR MOVE Student Lead

"After learning about the IMAP tool with the MBSE2DL system, we are certain that it would be highly beneficial in the development and operation of our satellites. By directly coupling a SysML model with telemetry data, existing SysML models are enhanced and put at the forefront of development. The automatic analysis and the display of which systems are affected by an identified anomaly in the SysML model have the potential to significantly enhance and speed up problem discovery and resolution. Both the development and operation of satellites would greatly benefit from this. Furthermore, the tool uses well-known technologies such as Python with JupyterLab and Grafana. This makes it easier to get started with the tool."