MBSE in AIT and Operations of MOVE-II and its Impact on the MBSE2DL Activity and the MOVE-III Mission

Presented by Armin Müller and Florian Schummer

Over the Next 10 Minutes

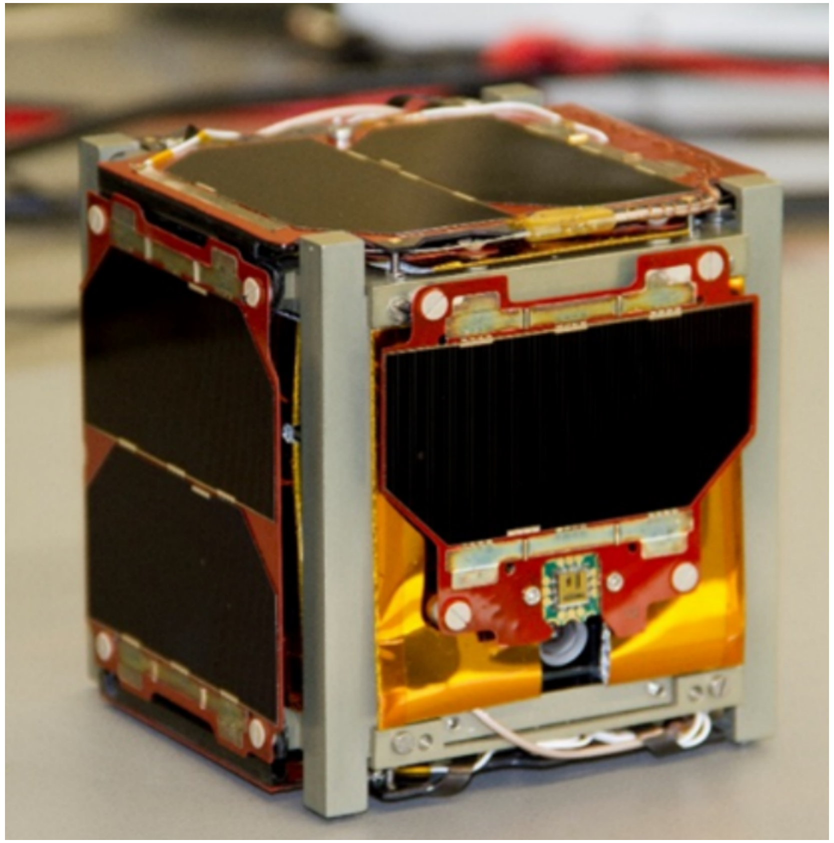
1. … Insight into MBSE at a University-Based CubeSat Project
   - From Whiteboard, Pens and Paper to employment of a distributed full scale MBSE Modeller
   - From PDR to operations and the next mission
   - From two people drawing diagrams by hand to a team of 50 developers which are able to read and discern information from the model

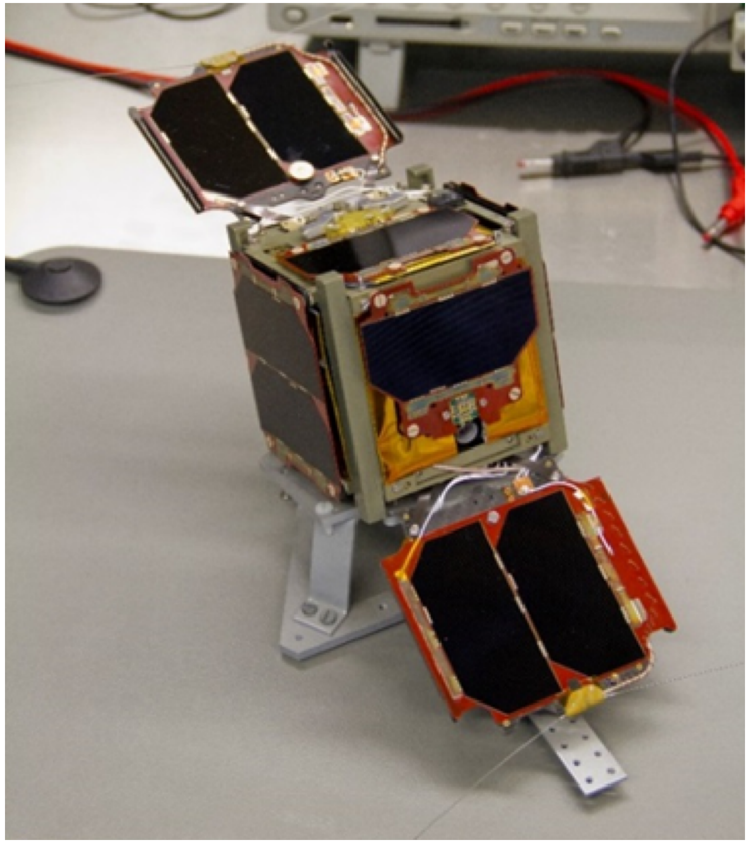
   \+ What we learned from all this

Over the Final Five Minutes

2. Insight into the MBSE2DL Project
   - Goals and Process of the Semantic Data Lake Platform
   - User needs according to interviews conducted with ESA specialists in AIT and MBSE
   - Current state of the project, w.r.t. Machine Learning and Graph Analysis

Overview of the Munich Orbital Verification Experiment





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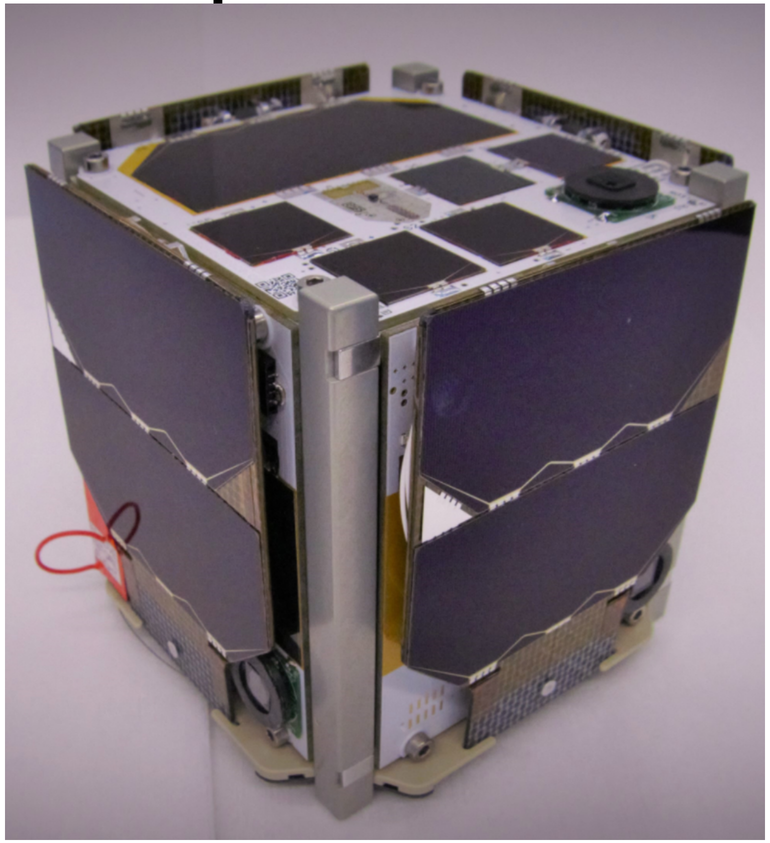

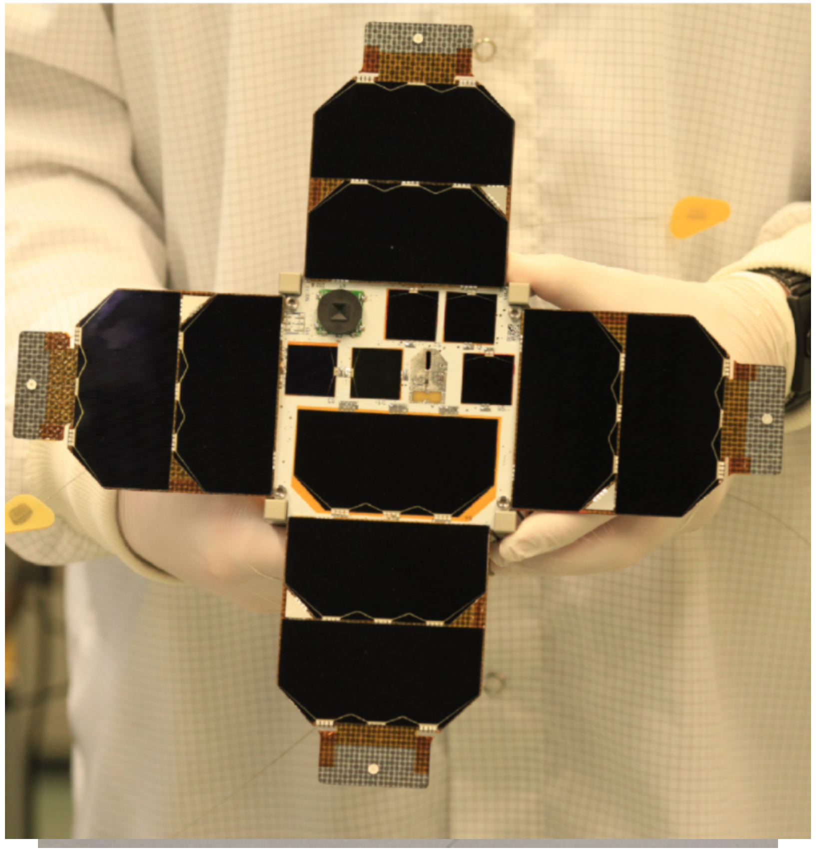

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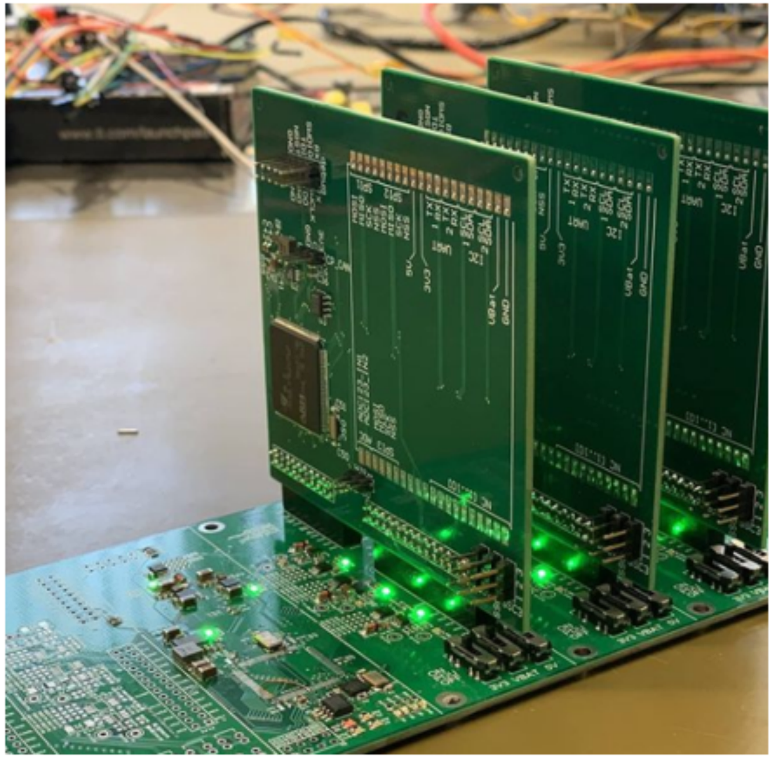
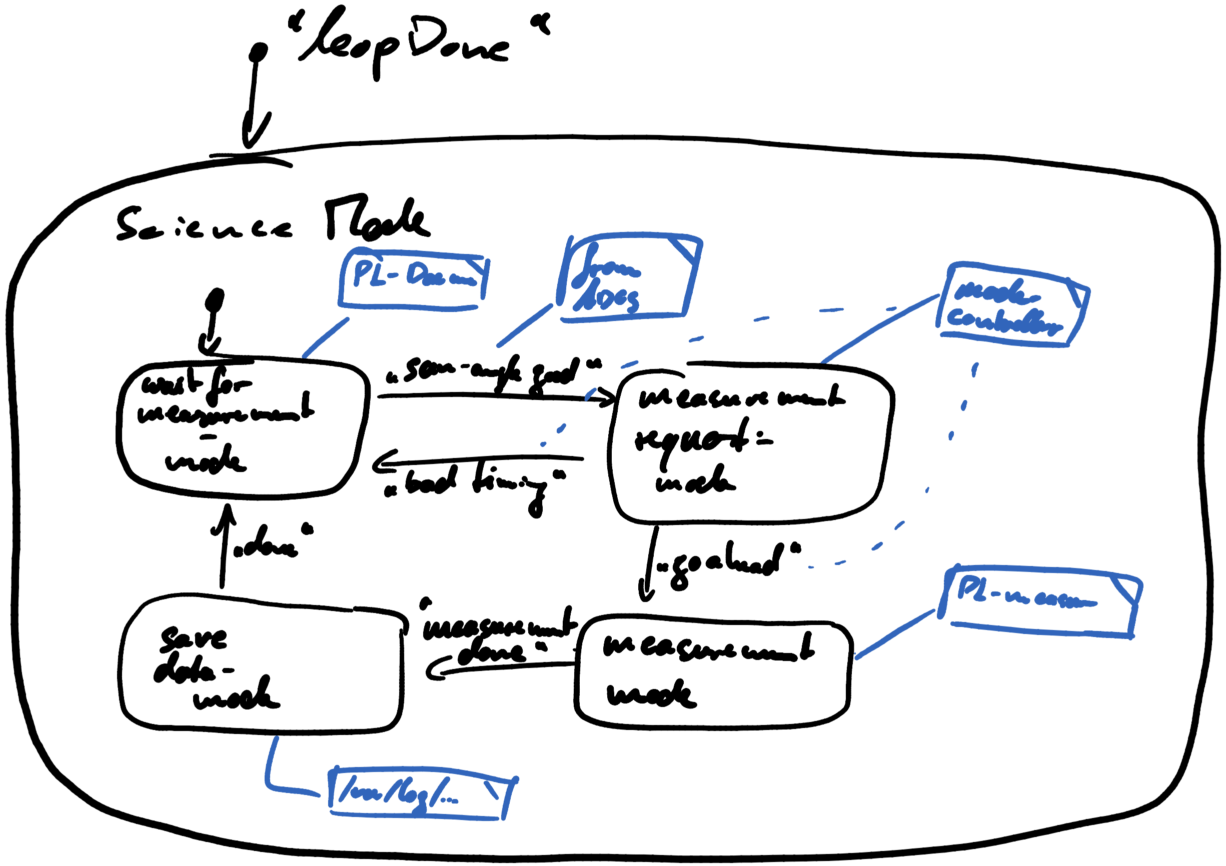


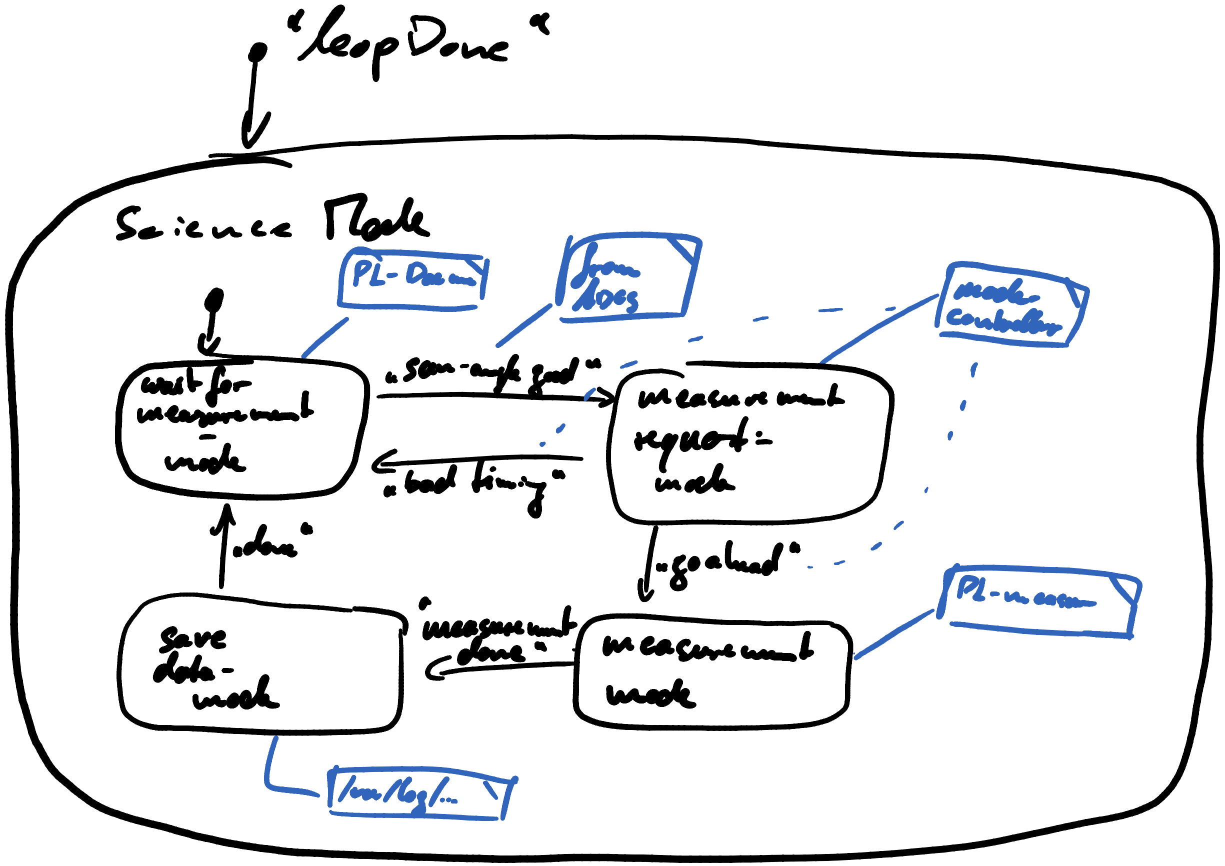
The Beginnings of MBSE for the MOVE-II Team

- SysML used as means of communication
  - During meetings
  - To record results
  - To define work packages



Benefits and Drawbacks of the Approach

- Increase in meeting efficiency
- Easy way of defining functionalities
- Shallow learning curve for a broad range of developers
- Impossible to maintain over a longer period of time



There is always something you can do.
No matter how little time you have and
how scarce your resources are.

Benefits of the Approach

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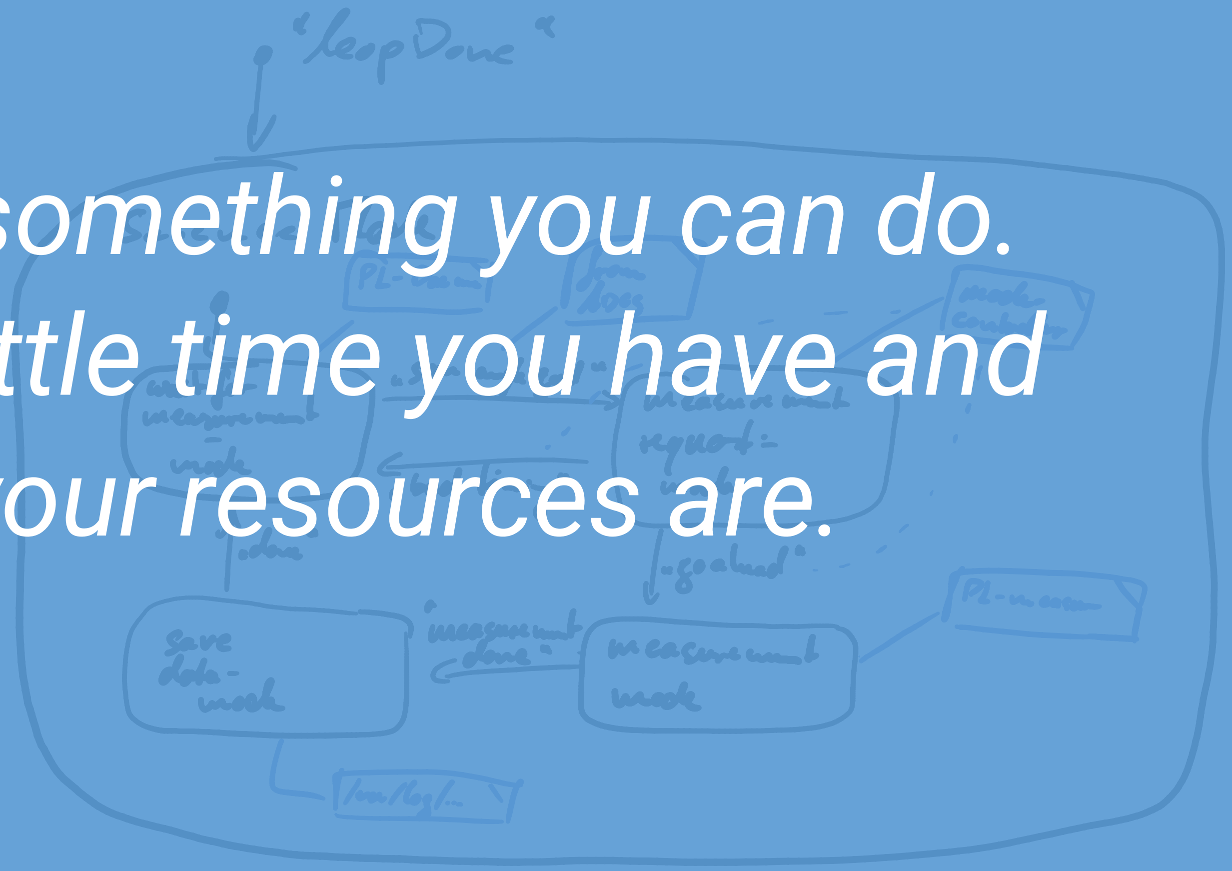
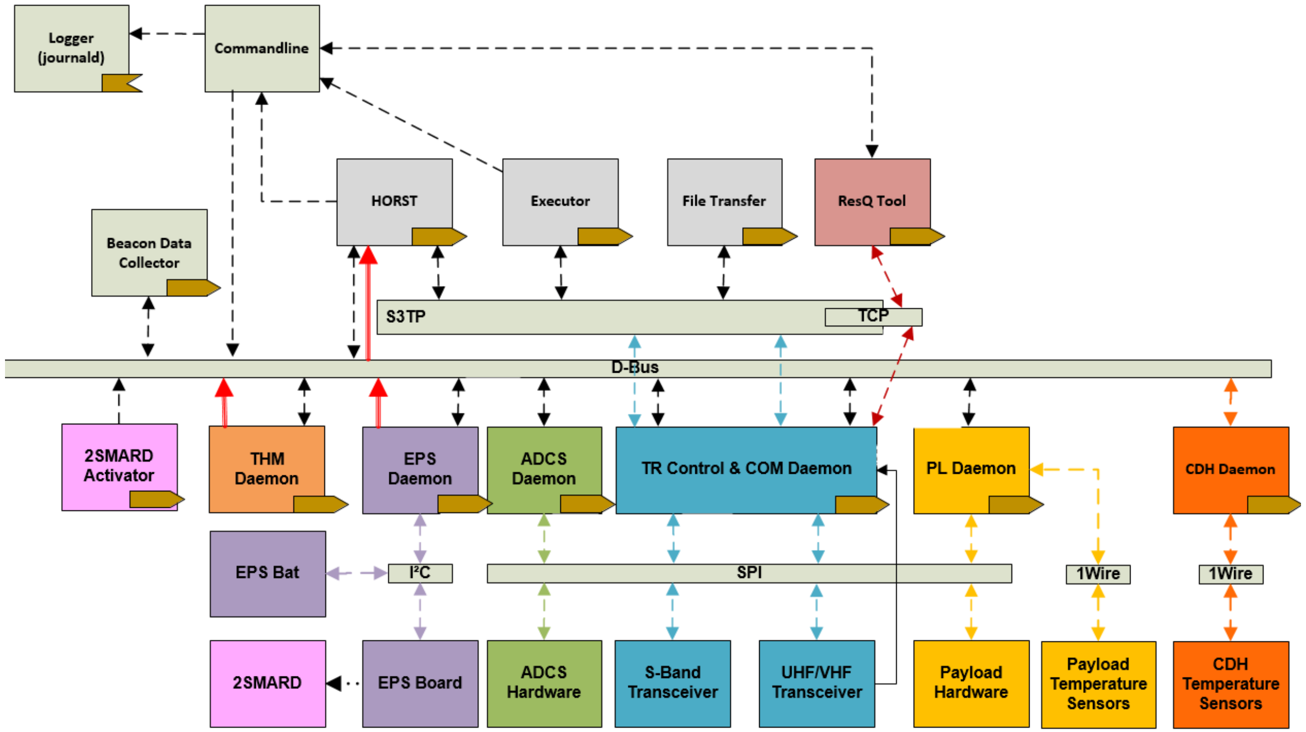


Stage Two, MBSE in Phase C and D1

- Teched Diagrams
- Show weekly progress to the whole team
- Varying level of technical detail



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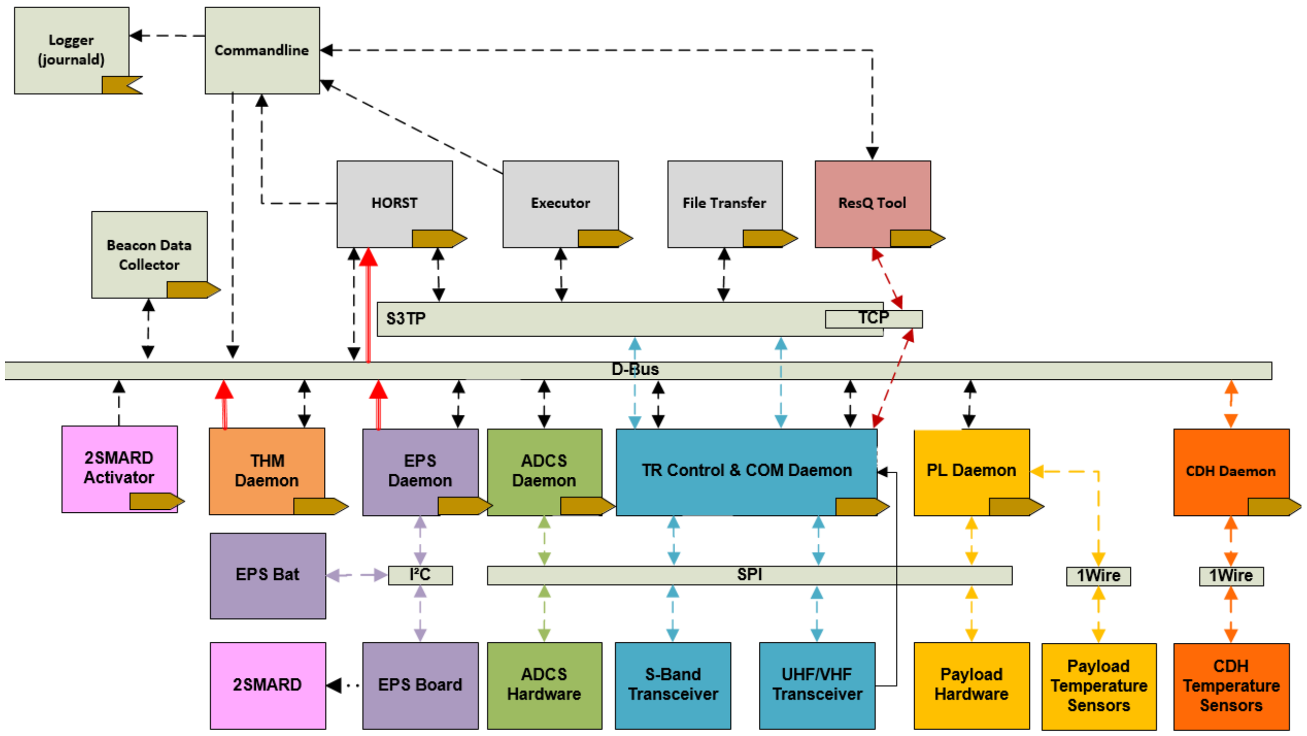
Benefits and Drawbacks of the Approach

- Easier to access and read, thereby more in use
- Few core diagrams
- ➢ Easy to keep up to date
  - ➢ Increased confidence in model by developers
- Lack of informational depth
- ➢ Limited Usability



Benefits and Drawbacks of the Approach

When the system is evolving and changing fast, provide the team with a shallow but always up-to-date model

- thereby more in use
  - ➢ Easy to keep up to date
    - ➢ Increased confidence in model by developers
- Lack of informational depth
  - ➢ Limited Usability

Stage 3, MBSE in Assembly Integration and Testing

- Realization I: The Top-Level Model does not cut it once you get to troubleshooting anomalies
- Realization II: Testing Personnel lacks overview of the „larger picture“

➢ Attendance of systems engineer and/or software engineer required for every anomaly

- ➢ Inefficient
- ➢ Unprofessional level of dependency on key personnel

For Assembly Integration and Testing,
only a detailed model will be of real help.

Also:

Once you enter AIT, the system does not change
often anymore.
I.e. the model is not outdated as quick.

Stage 4, MBSE in Operations

- Sufficient time
  - Holistic model of the entire spacecraft, ground station and operations systems
  - Down to the telemetry of every single sensor
  - Top-Level Model of the complete state-space of the satellite (printed: 2 sheets DIN A0)
  - Knowledge preserved for next generation of operators
  - Model used a lot for troubleshooting during LEOP
  - It takes more time to understand the model
  - Without knowing all the diagrams, operators are limited in drawing conclusions

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A holistic model for operations, including spacecraft, ground station and operations systems is a very good basis for tense troubleshooting in orbit.

The MBSE2DL Project

Project Setup

- Project name: **“MBSE to DataLakes and Machine Learning”**
- Part of ESA’s OSIP and MB4SE strategy
- Consortium lead by ScopeSET, with participation of 3DSE and the TUM’s Chair of Astronautics
- Duration: Jan 2021 – Summer 2022
- Scope: Demonstrator Development

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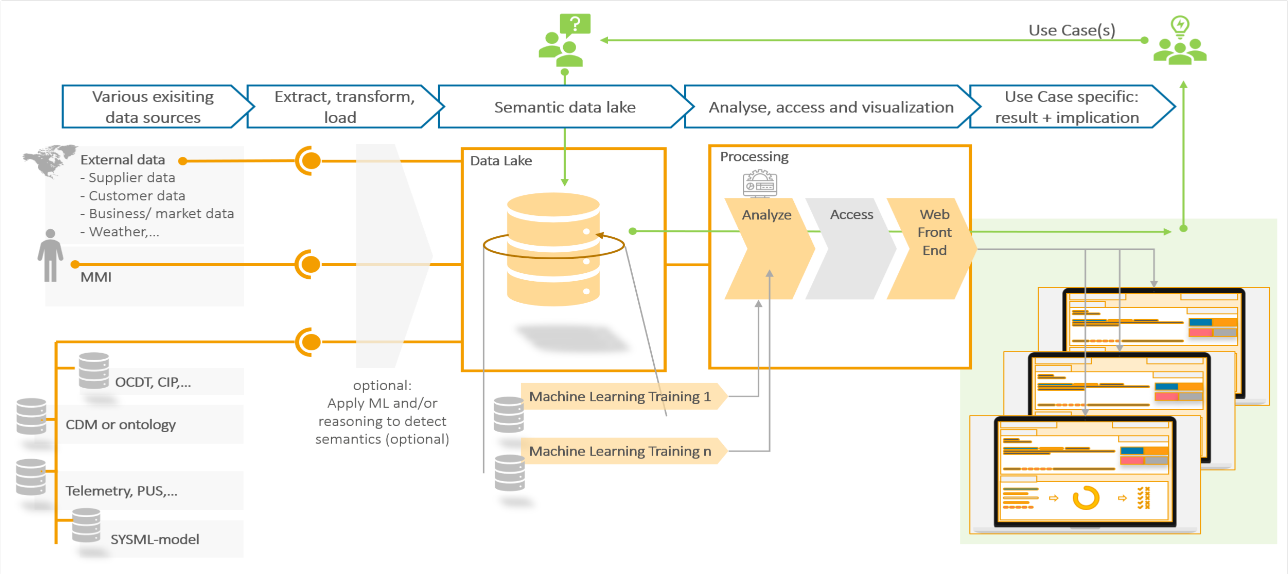
Project Goals

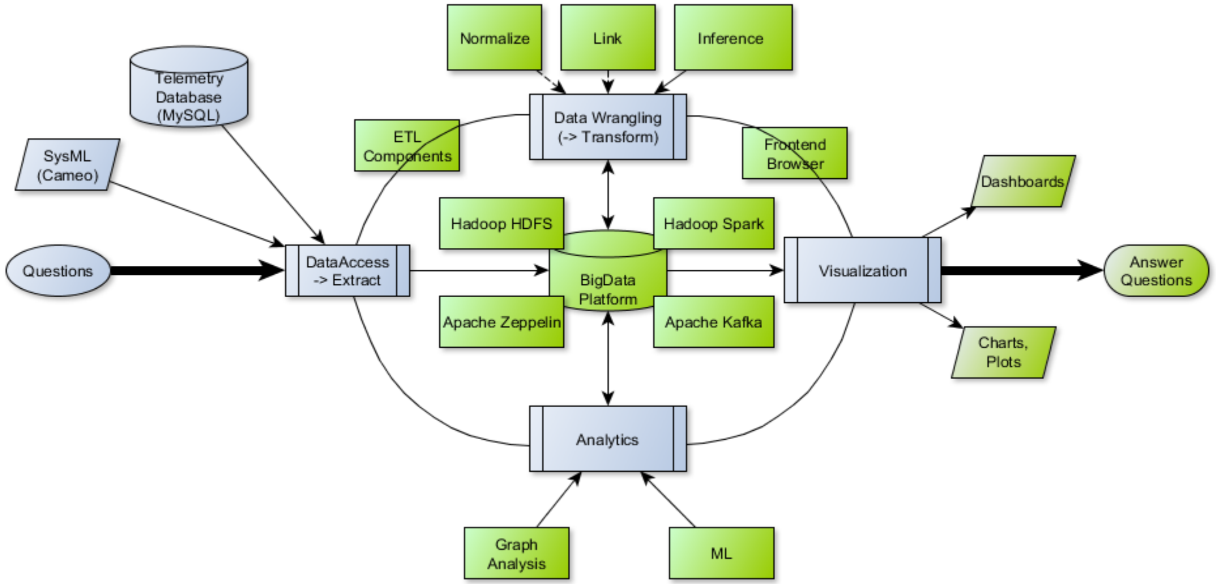
- Increase efficiency during AIT by
  - Combining data from relevant source, in particular MBSE/SysML models and telemetry databases
  - Connecting data paths of the MBSE model with non-MBSE data to simplify understanding of anomalies
  - Enabling graph-enhanced queries for troubleshooting
  - Employing Machine Learning to find points of interest in measurement data
  - Providing efficient web-based access to data and analysis results



- Re-use state-of-the-art open source components
  - DataLake Frameworks
  - DataAnalytics technologies

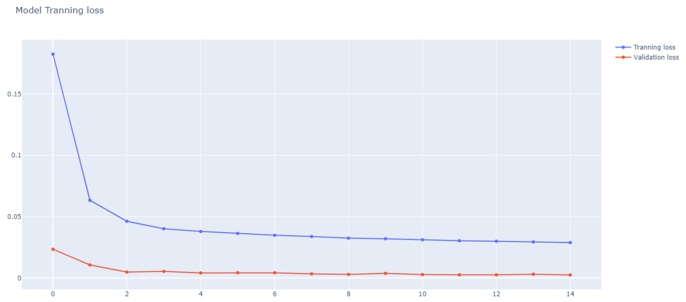
Process Overview

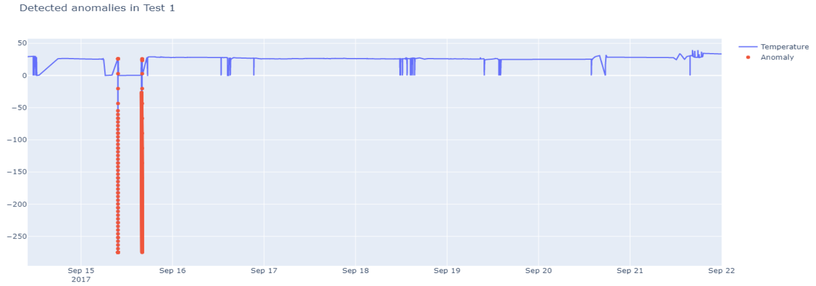
- Import Models, Semantics, Telemetry Data into a flexible RDF based DataLake
- Semi-Automated Tracing of SysML Models to Telemetry Data
- Generic Data-Analytics using a Notebook approach
- Integrated Search&Query and Analytics
  - Graph Analysis
  - Anomaly Detection
- Dedicated Visualizations with Charts and Dashboards

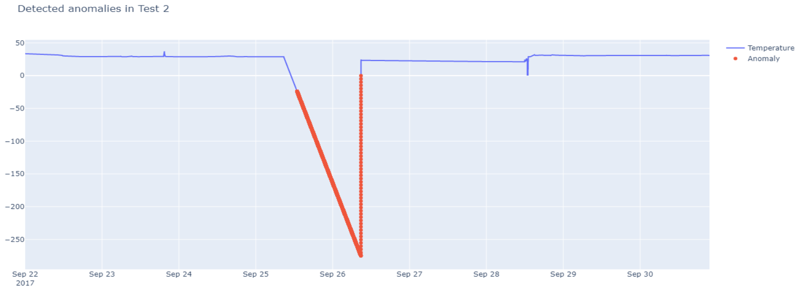


MachineLearning

- Focus on Anomaly Detection on a set of sensor values – which are traced back to the SysML model
- Using LSTM Autoencoders
- Objective is to establish a PoC implementation which will serve as a blueprint on how to use ML within the platform
- Expected to be extended in the future
    - Higher fidelity ML approaches
    - Possibly also use ML for trace detection between SysML model and telemetry data

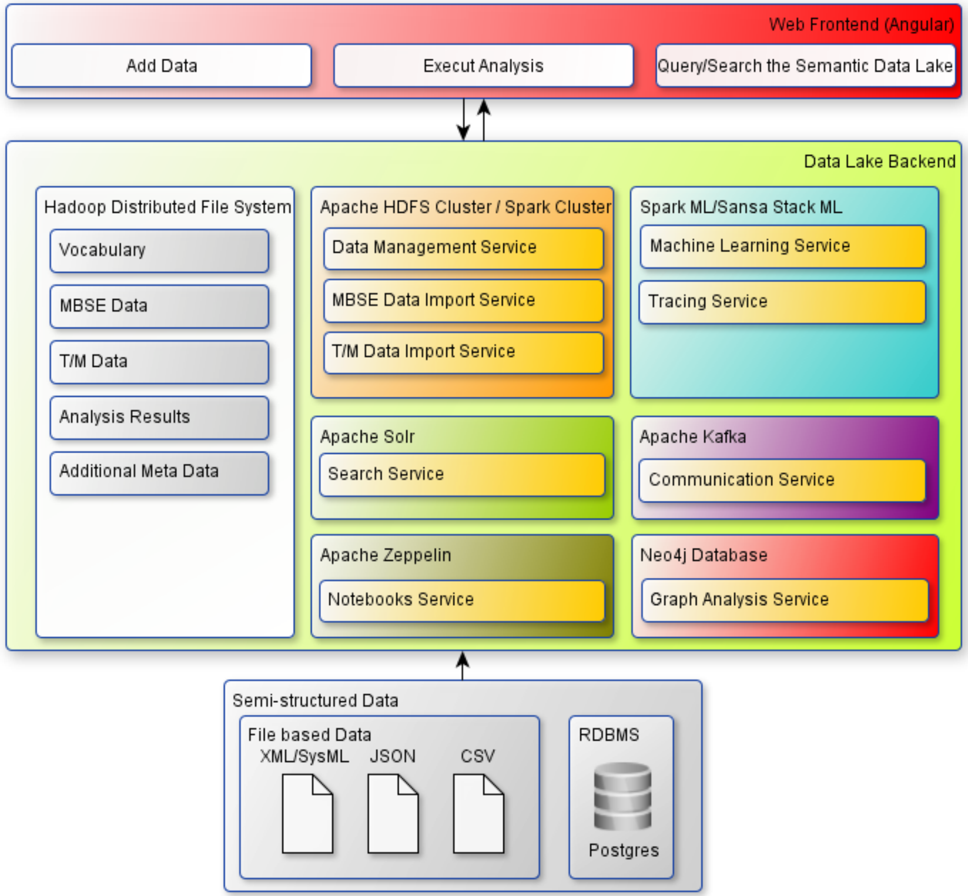






Architecture

- BigData Europe platform as blueprint
- Modern micro-service based approach, scalability and performance will be evaluates
- HDFS as storage
- Established Open-Source components
  - Apache Spark, Solr, Zeppelin, Kafka
  - Spark and Sansa – and/or Python ML Libraries
  - Neo4J and Cypher as Graph Analytics tool
- Angular based Web Frontend
- Deployed as Docker stack



Outlook

- Extendibility documentation is part of the project
  - Find a suitable mission and datasets for 2 nd validation in different activity
  - Extend MachineLearning capabilities and integrated existing approaches
- Apply MachineLearning to trace detection
  - Using MBSE2DL traced dataset as training model
- Add additional artefacts to DataLake, e.g.:
  - Ticketing Data
  - Additional aspects of SysML model, e.g. functional models
- Align with OSMOSE results / Space Ontology