ADAM GOES EDEN

Anomalieerkennung zur Risikominimierung in bioregenerativen Lebenserhaltungssystemen

Ferdinand Rewicki – DLR Institute of Data Science Jena

German Aerospace Center (DLR)
At a glance

- DLR is the research and technology centre of the Federal Republic of Germany for aeronautics and space as well as energy, transport, security and defence
- German Space Agency for the realisation of German space activities
- Projektträger oversee funding programmes, support knowledge transfer
- National and international cooperations
- Supporter for industry, authorities, administrations, public stakeholders

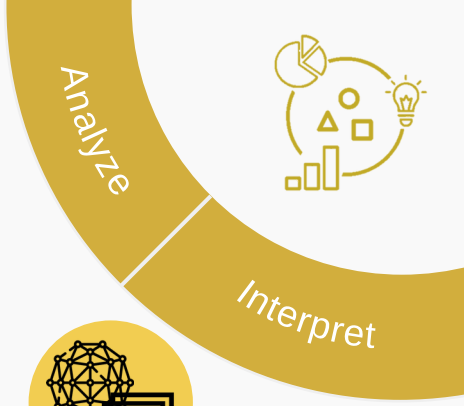
DLR Institute of Data Science

DATA ACQUISITION & MOBILISATION

DATA MANAGEMENT & ENRICHMENT

DATA ANALYSIS & INTELLIGENCE

Research focuses
Data Analysis and Intelligence



Anomaly detection in time series
Detection and classification of abnormal behavior or outliers in time-based data

Adaptation of large language models
Fine-tuning, pruning, knowledge distillation, etc. for the development of state-of-the-art AI models for DLR applications

Knowledge-integrating data analysis
Combination of domain-specific knowledge and rule-based algorithms for data analysis

Image and point cloud analysis
Pattern recognition and information generation from 2D and 3D data

Causal inference
Data-based analysis of cause-and-effect relationships and attribution

Explainability and uncertainty estimation in AI systems
Increasing confidence and traceability in machine learning predictions

Hybrid quantum-high performance computing
Combination of quantum machine learning and high-performance computing for anomaly detection

Human Factors and Transfer
Increasing technology acceptance through co-creation, persuasive technology, Acceptance-by-Design, etc.

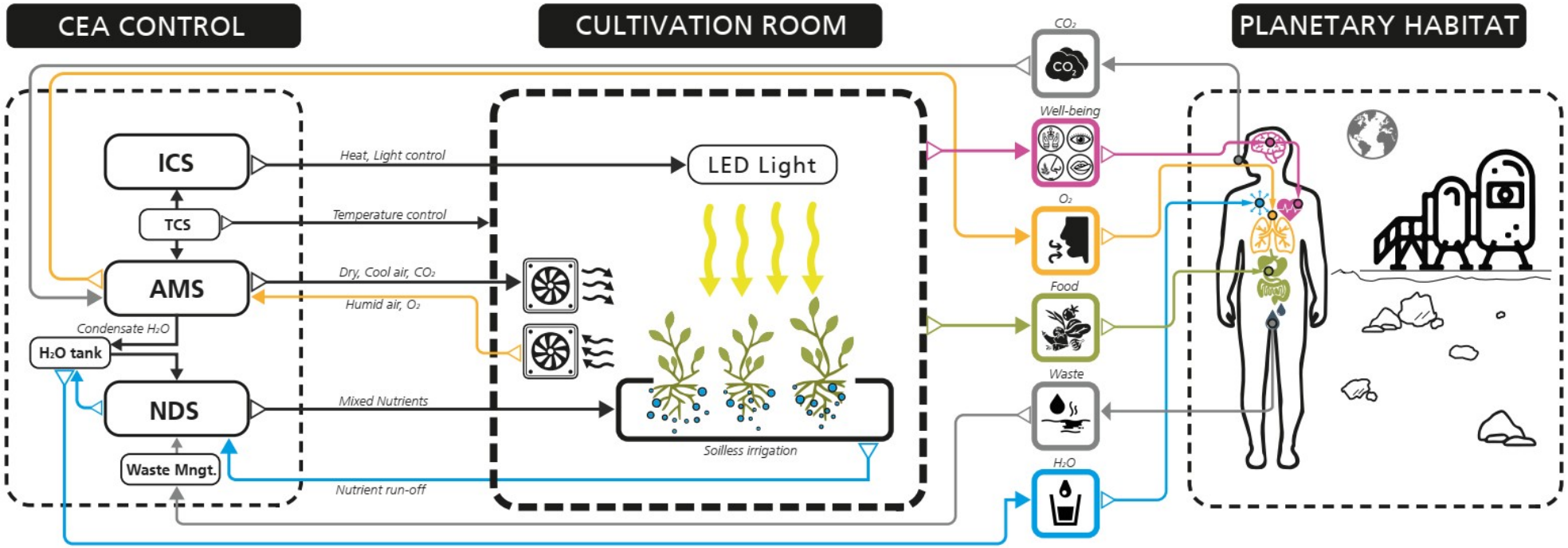
Agenda

1. The EDEN Program
2. Time Series Anomaly Detection
3. Anomaly Type Classification
4. ADAM Subsystem
5. Outlook

1. THE EDEN INITIATIVE

Image source: ESA/DLR

Bio-regenerative Life Support



- *Input:* CO2-rich air (respiration), water (recycled grey water), nutrients, light
- *Output:* O2-rich air, water (dissolved in air as RH), nutritious biomass, mental well-being
- *Goal:* Creating a symbiosis between plants and humans

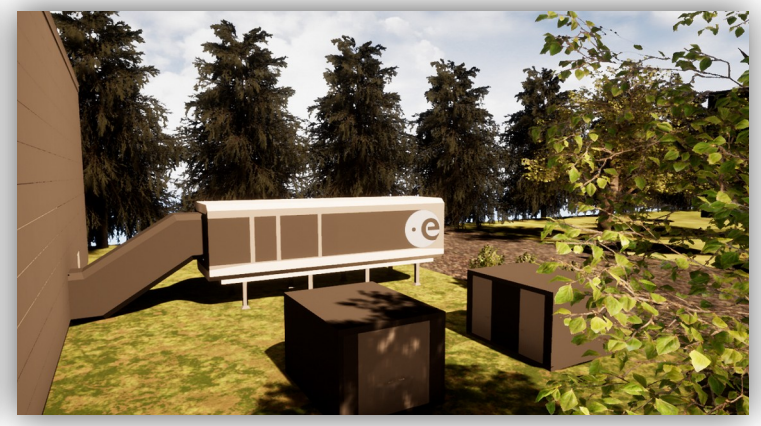
Our Research Projects

EDEN ISS & LUNA, LAM-GTD

EDEN ISS

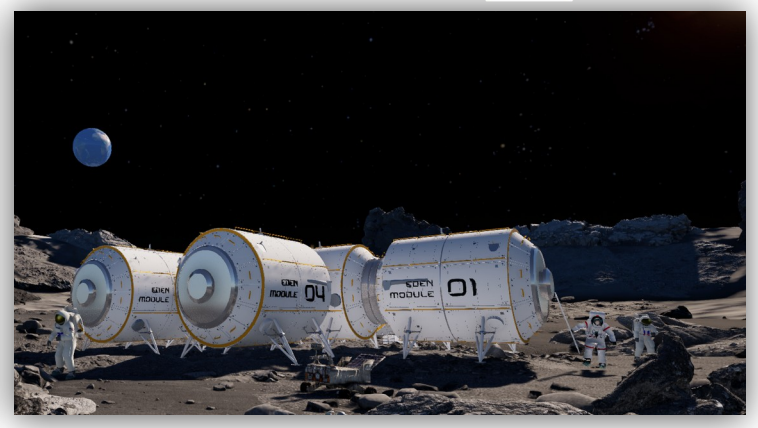
A container-sized plant cultivation test facility in Antarctica.
The system was built to demonstrate and validate key technologies and procedures necessary for safe food production within a (semi-) closed system.

EDEN LUNA



Life extension of the EDEN ISS system with fully redesigned subsystems and a refurbished container. Attached to the LUNA analog facility in Cologne, end-to-end operated by and DLR/ESA employees & astronauts.

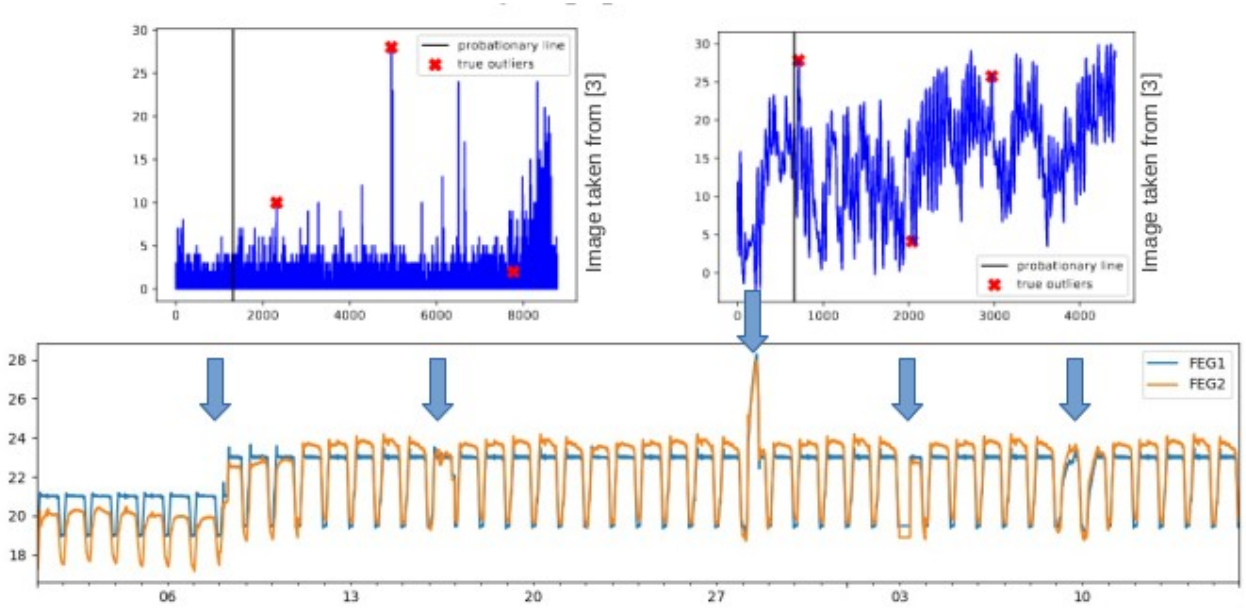
LAM-GTD



LAM is the attempt to take BLSS one step closer to space. It is a cargo module which turns into a lunar greenhouse once it reaches the Moon. The GTD is developed with space standards and requirements in mind, but operated on Earth.

2. ANOMALY DETECTION IN TIME SERIES

Anomaly Detection in Time Series



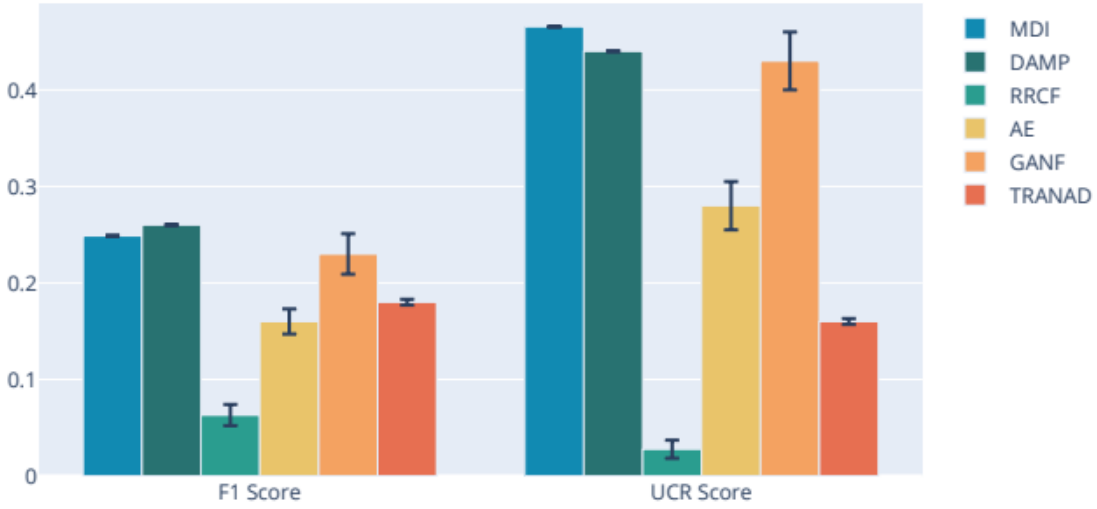
Input Data
Univariate
Multivariate

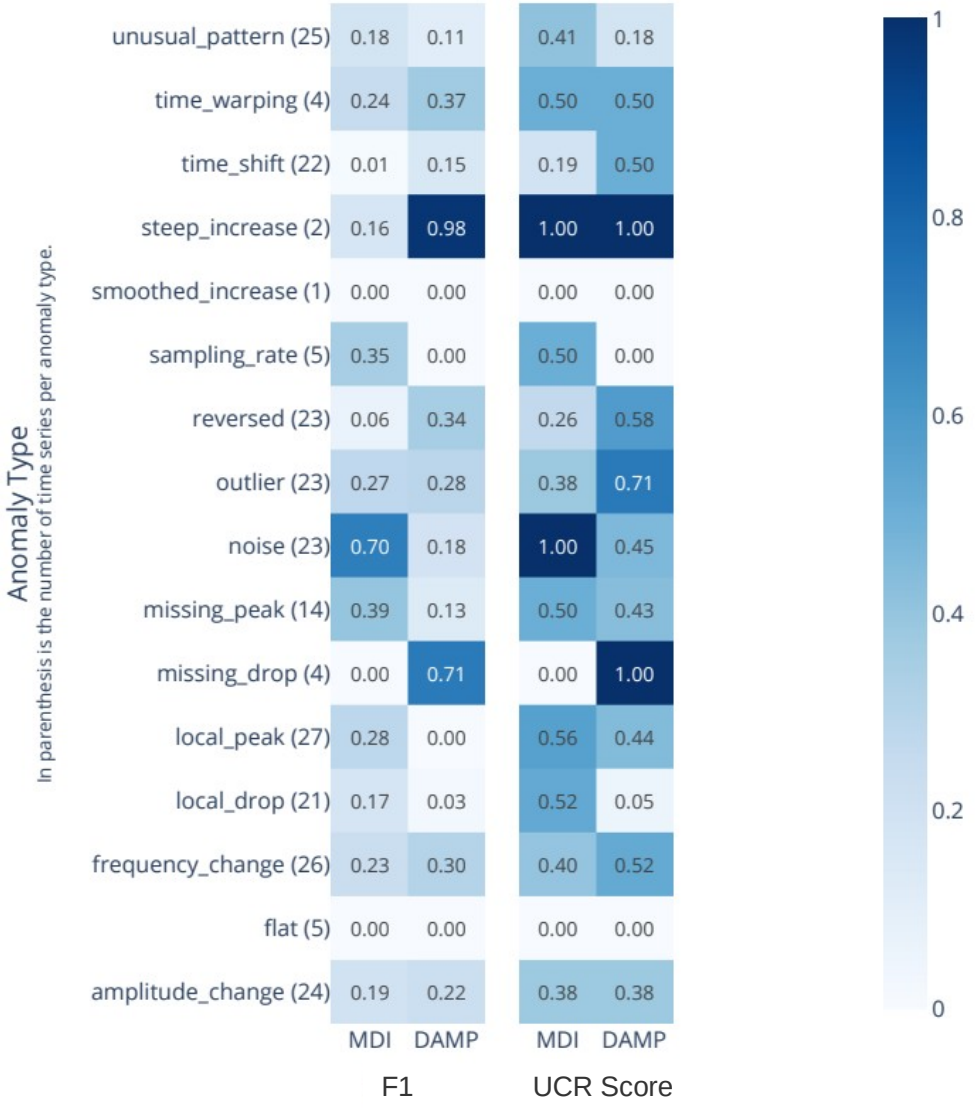
Method
Probabilistic
Reconstruction
Classification

Learning
Supervised
Semi-supervised
Self-supervised
Unsupervised

Anomaly Type
Point
Collective
Contextual

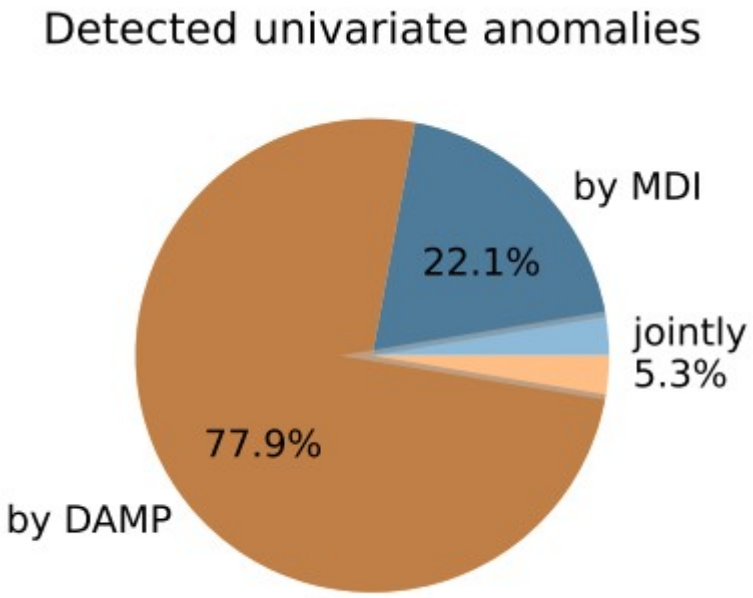
Anomaly Detection in Time Series

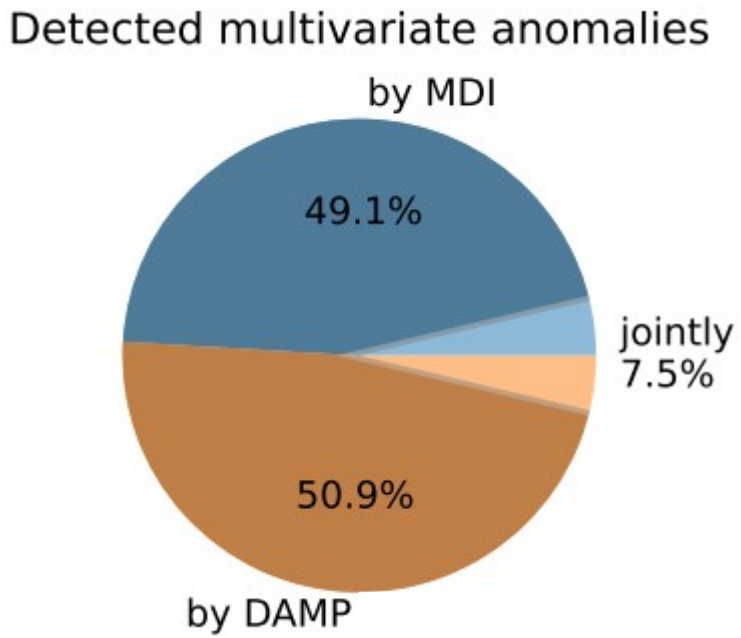




Rewicki, F., Denzler J., & Niebling, J.: "Is it worth it? Comparing six deep and classical methods for unsupervised anomaly detection in time series." Applied Sciences 13.3 (2023): 1778.

Anomaly Detection in Time Series

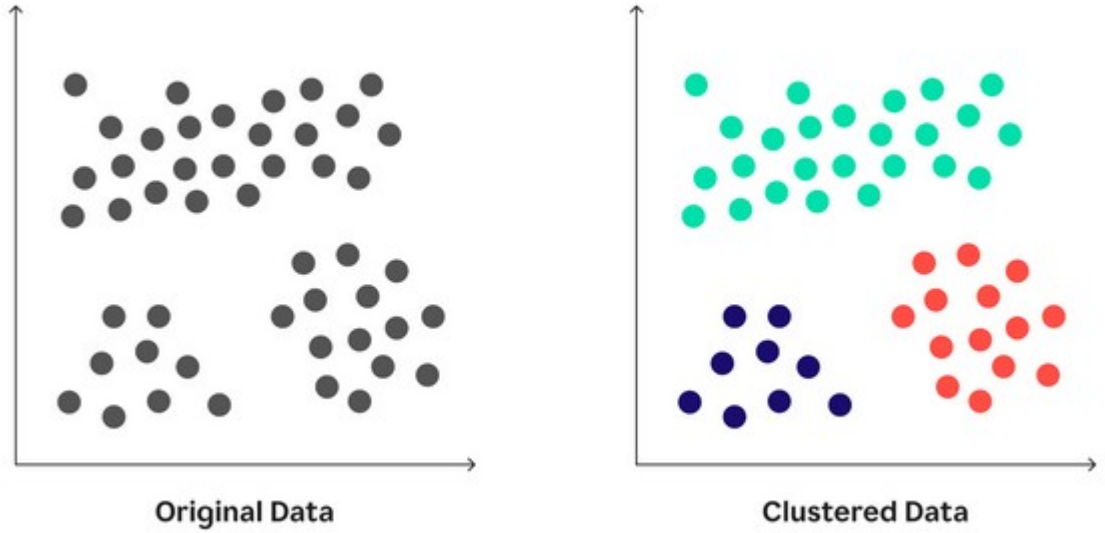




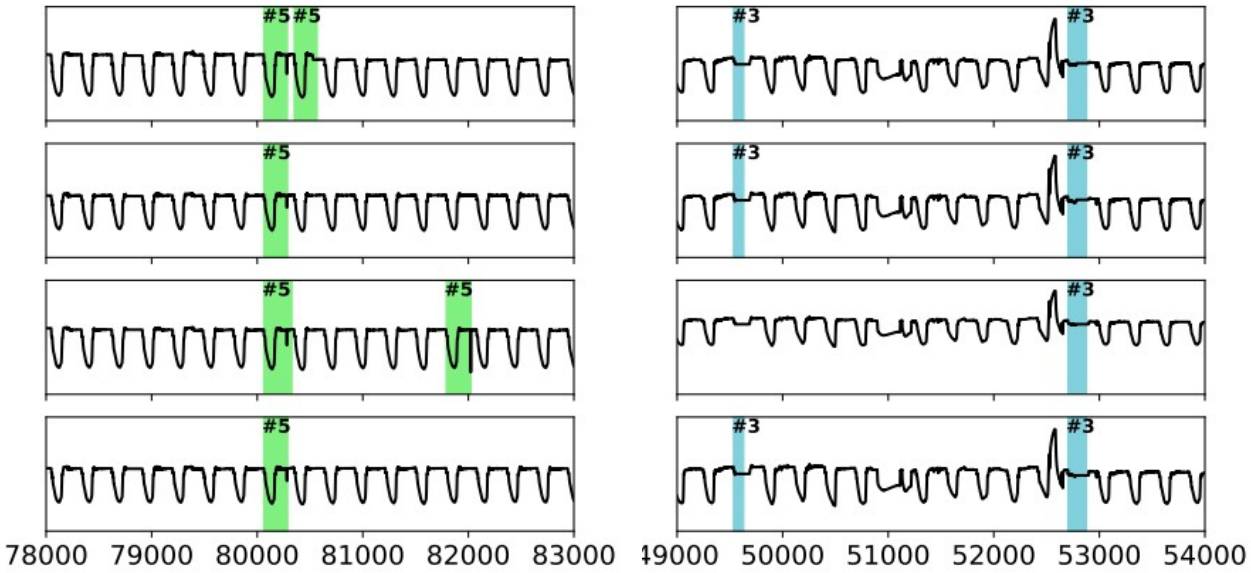
Rewicki, F., Gawlikowski J., Denzler J., & Niebling, J.: "Unraveling anomalies in time: Unsupervised discovery and isolation of anomalous behavior in bio-regenerative life support system telemetry.“, ECML-PKDD 2024,

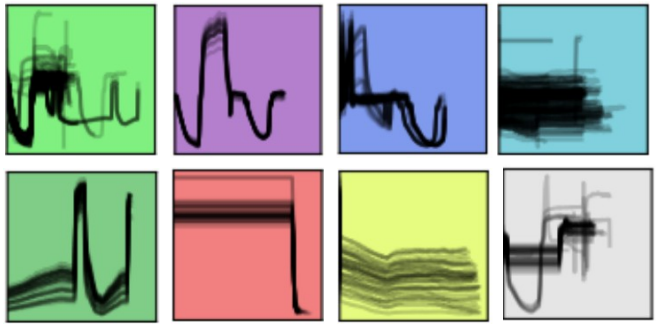
3. ANOMALY TYPE CLASSIFICATION

Time Series Clustering



Time Series Clustering





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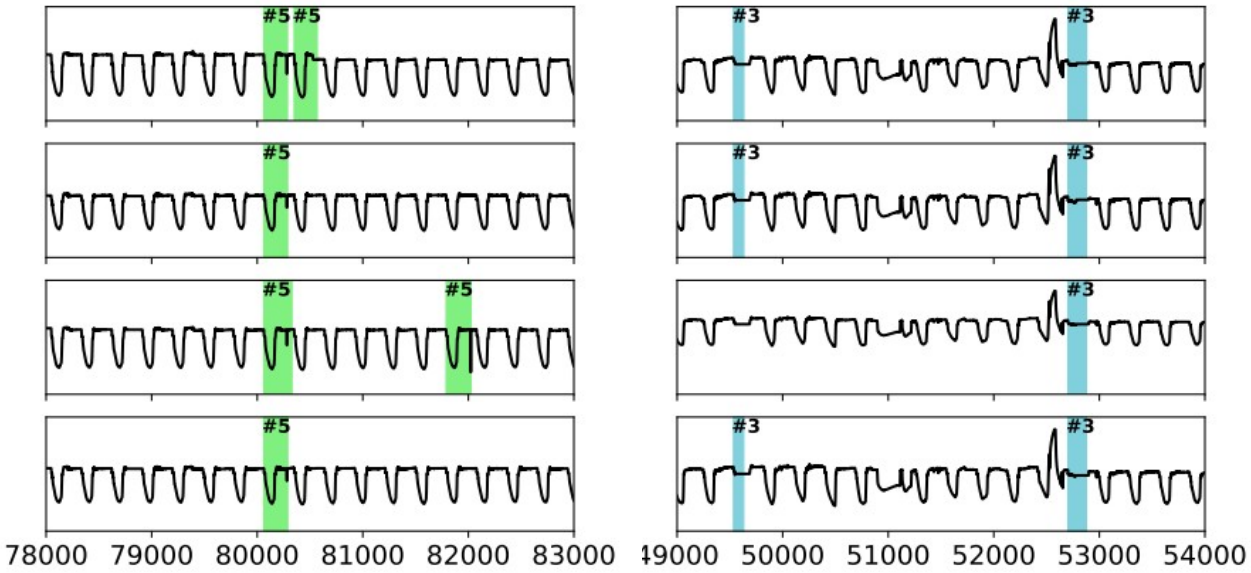

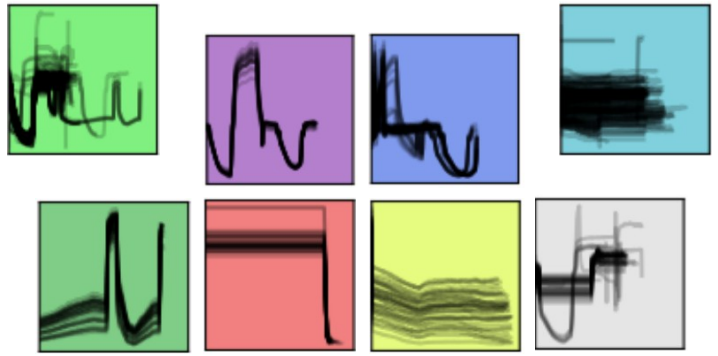

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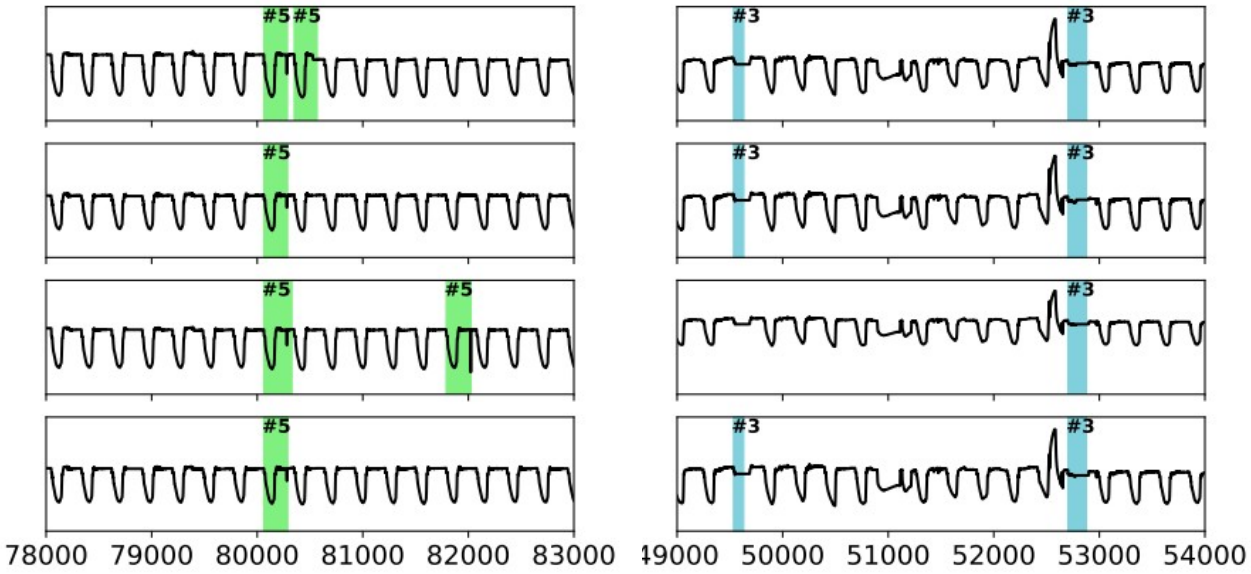
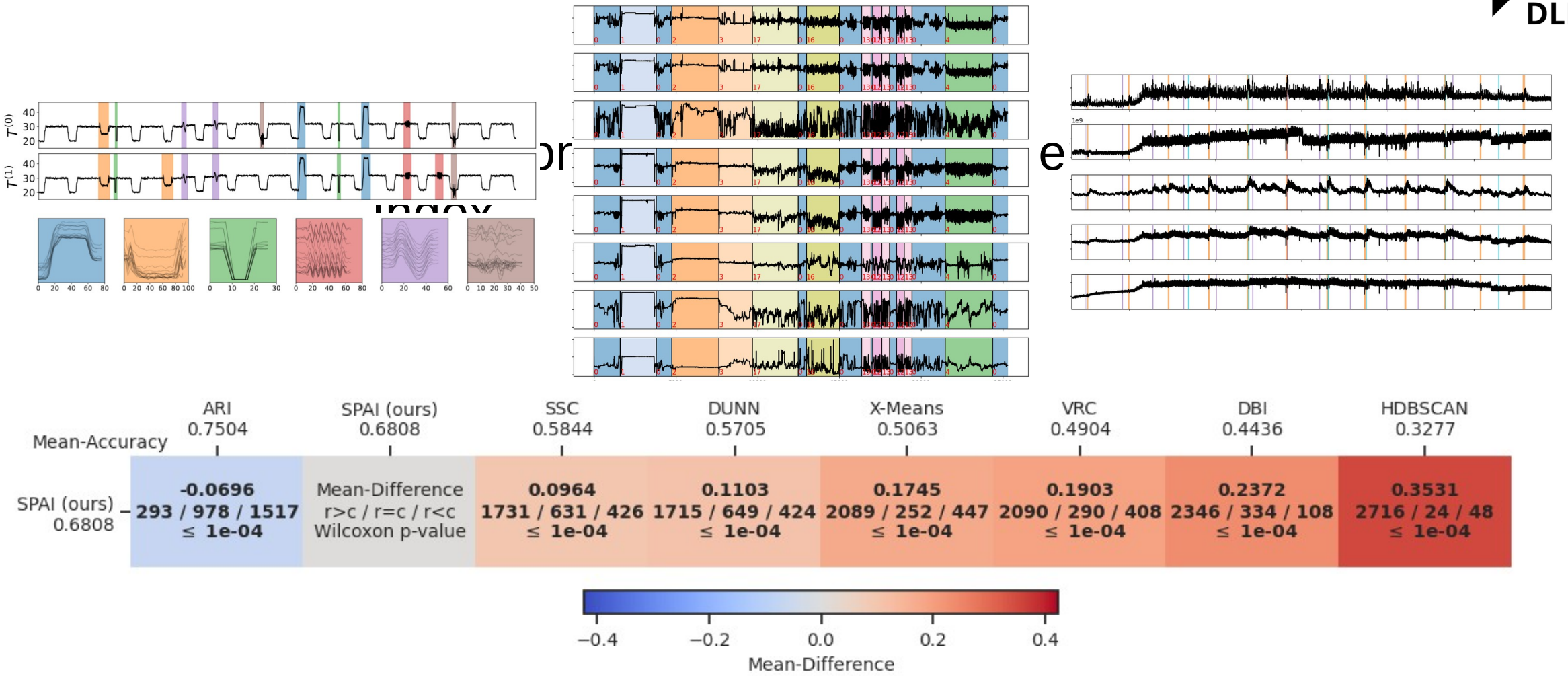


Synchronized Pattern Agreement Index

$$SPAI := \lambda \frac{|A_S^*|}{|A_S|} + (1-\lambda)\frac{K-1-n_{\mathbb{1}}}{K}$$

Time Series Clustering



Rewicki, F., Denzler J., & Niebling, J.: "Anomalous Agreement: How to find the Ideal Number of Anomaly Classes in Correlated, Multivariate Time Series Data“, AAAI (WS-AI4TS) 2025.

$$SPAI := \lambda \frac{|A_S^*|}{|A_S|} + (1-\lambda)\frac{K-1-n_{\mathbb{1}}}{K}$$

EDENluna

4. ADAM SUBSYSTEM

Michel Fabien Franke, Institute of Space Systems, 2024/09/04

ADAM Subsystem

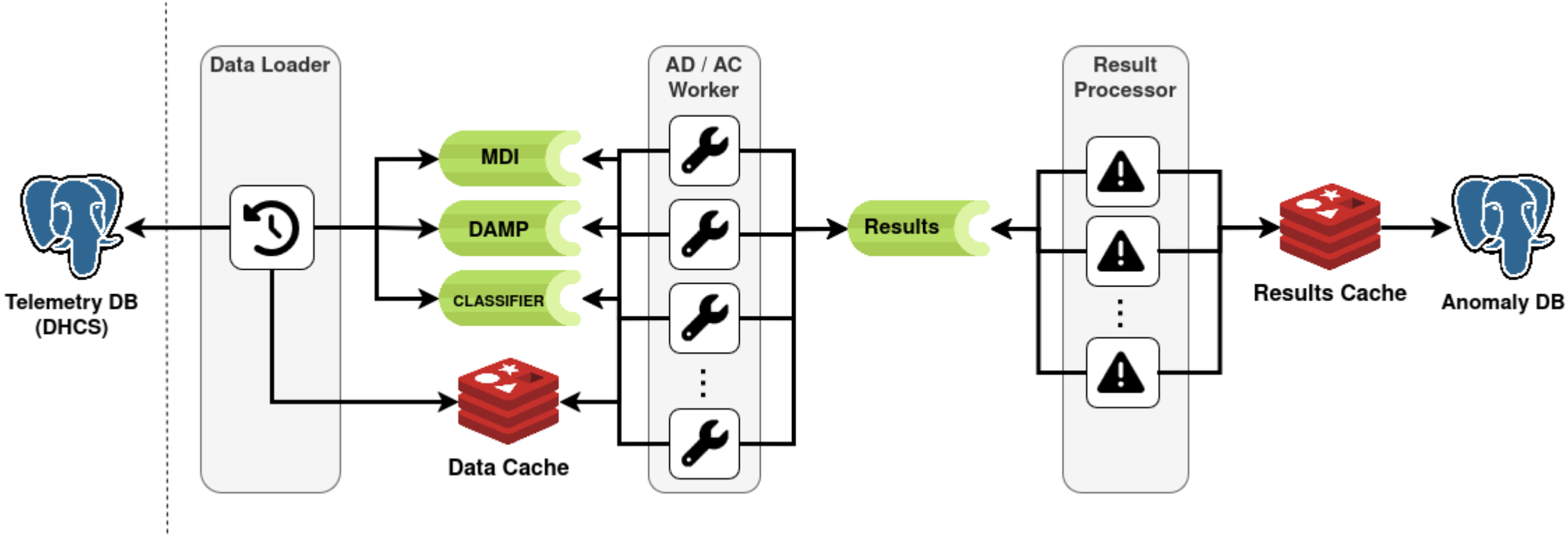
Functional Requirements

- Detect wide range of anomlaous behavior in telemetry data stream
- Classify recurring anomalous behavior
- Collect user annotations

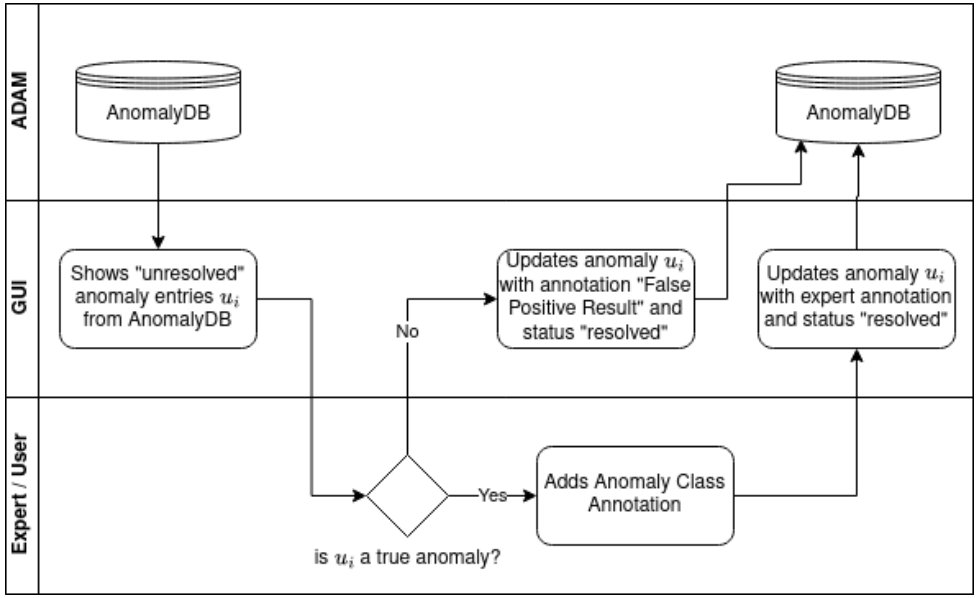
Technical Requirements

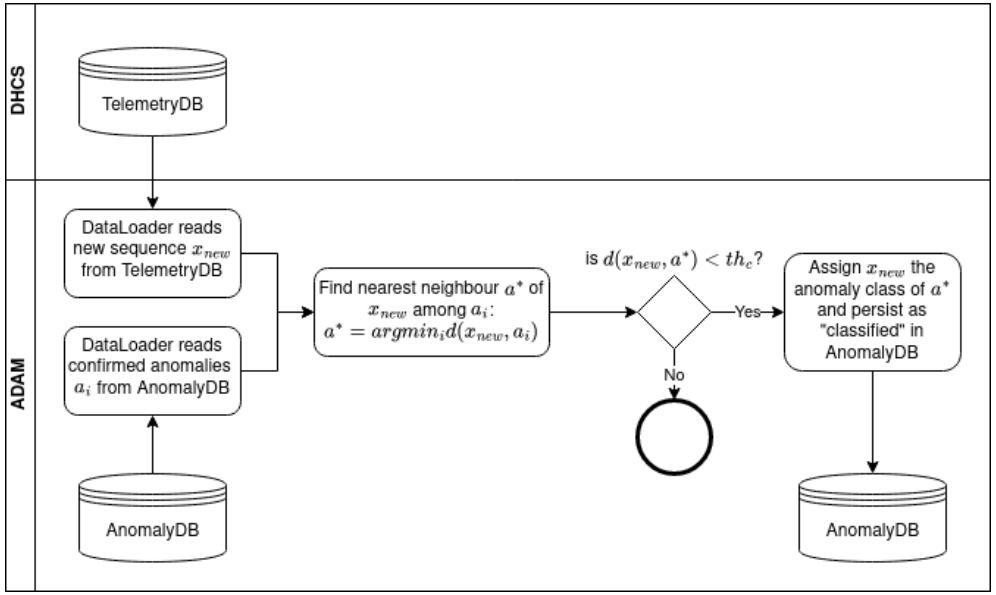
- Run on-premise inside Mission Control Center MCC
- Scale along available hardware and power budget
- GUI for inspection and annotation

ADAM Subsystem

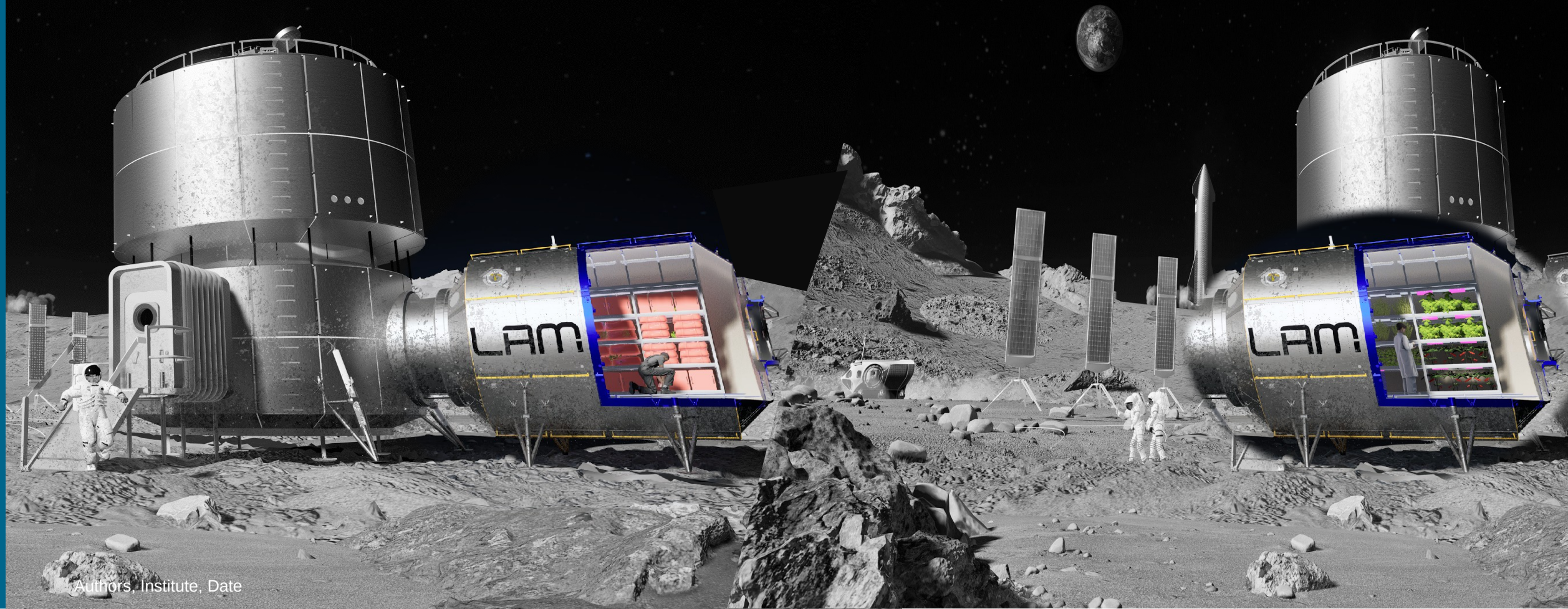


How it works – Annotation & Classification

- 



THANK YOU FOR YOUR ATTENTION!



Thank you for your attention

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Impressum

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