Failure prognostics on large constellations with selected use of AI

CLEAN SPACE DAYS
ZERO DEBRIS FRAMEWORK

8th October 2024

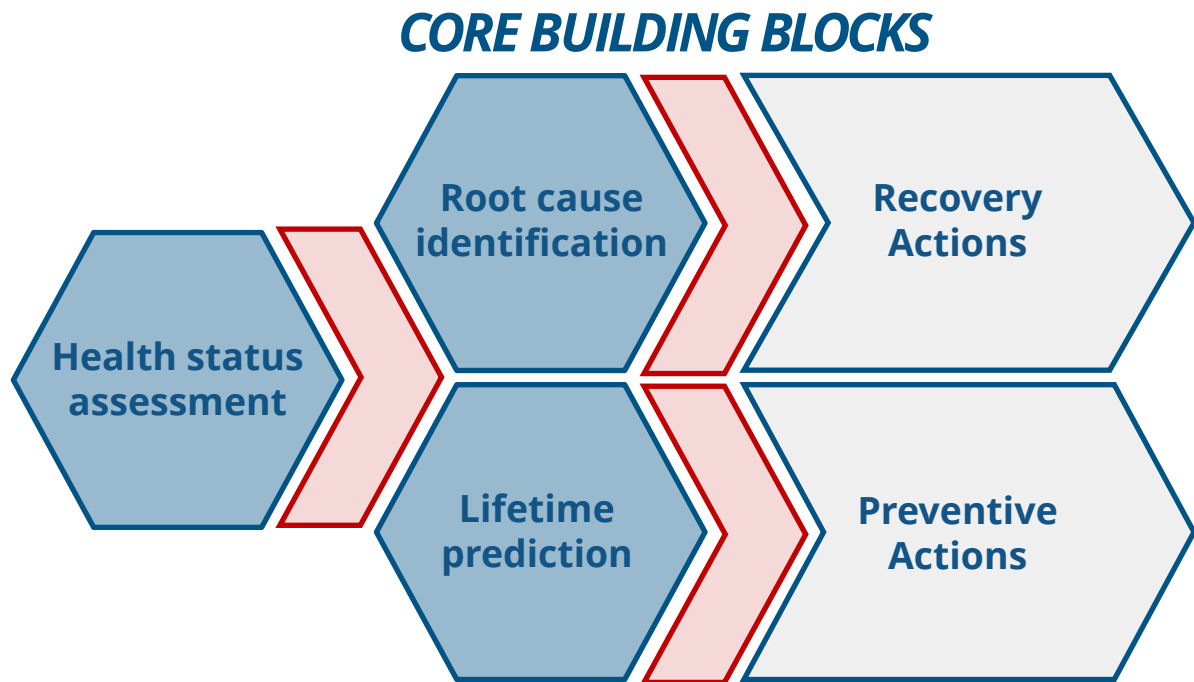Ing. Chiara Brighenti   TD – Controls & Diagnostics

Motivation

≫ Optimise **operations, maintenance** and **interaction** plans in fleets

≫ **Reduce risks of debris** and **downservices**

≫ **Speed up troubleshooting** to reduce reaction times

OUR GOAL IS TO PROVIDE SOLUTIONS **ENHANCING SAFETY AND RELIABILITY** OF SATELLITES
AND CONSTELLATIONS

Failure prognostics on large constellations with selected use of AI

SATE - Chiara Brighenti

≫ SATE ≪

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Clean Space Days 2024
8/10/2024

CLUE for predictive diagnostics

Modular and customised software solution with possibility of **on-board or ground** deployment.

It makes **selected use of AI** with general and reusable approach, rapid configuration and validation for the whole constellation.

CORE BUILDING BLOCKS

- Health status assessment
- Root cause identification
- Recovery Actions
- Lifetime prediction
- Preventive Actions

✓ **TRL 4** on-board space applications
  TRL 8 ground space applications

✓ TRL 4 in energy applications

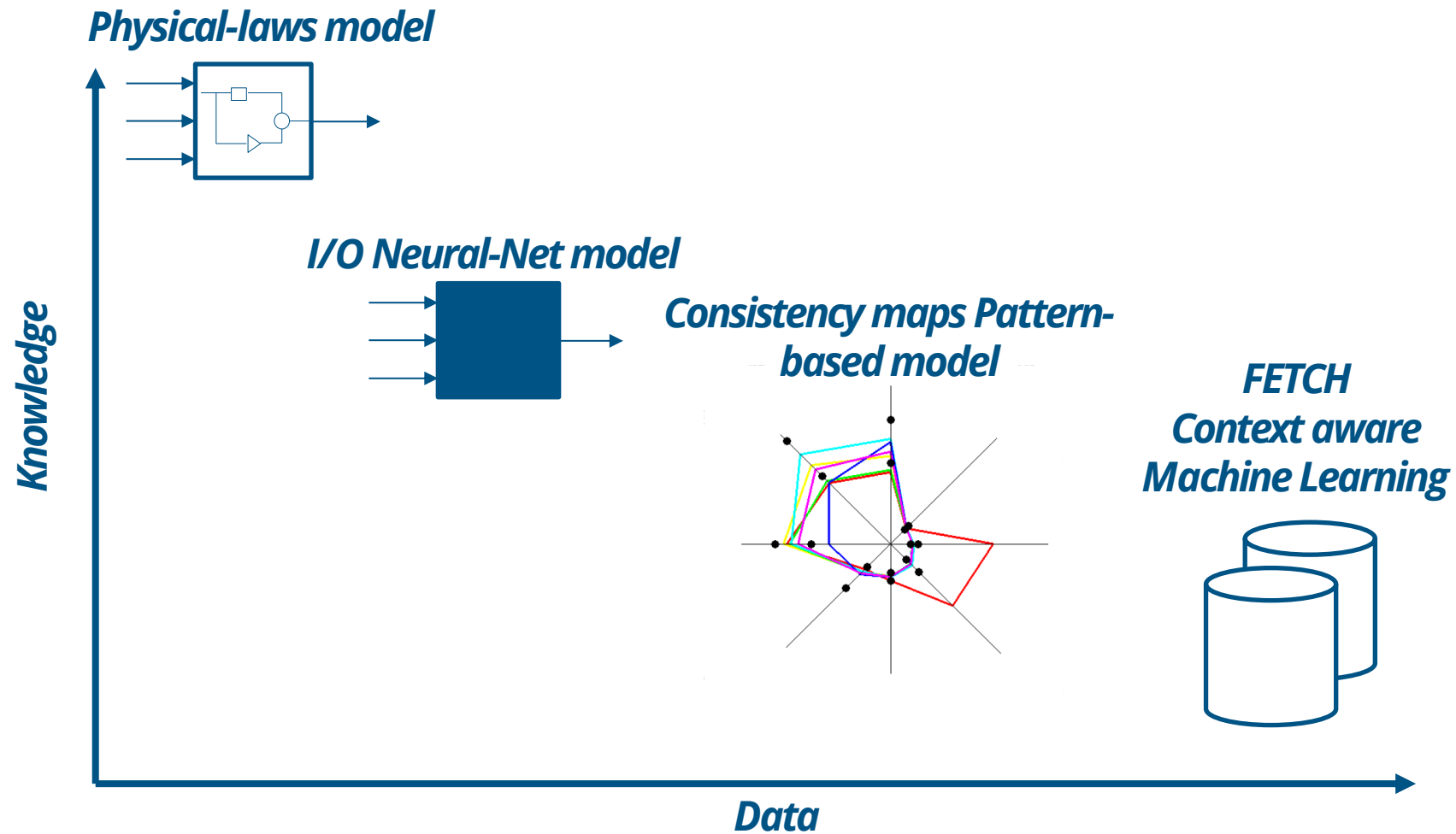✓ TRL 9 since 2021 in automotive applications
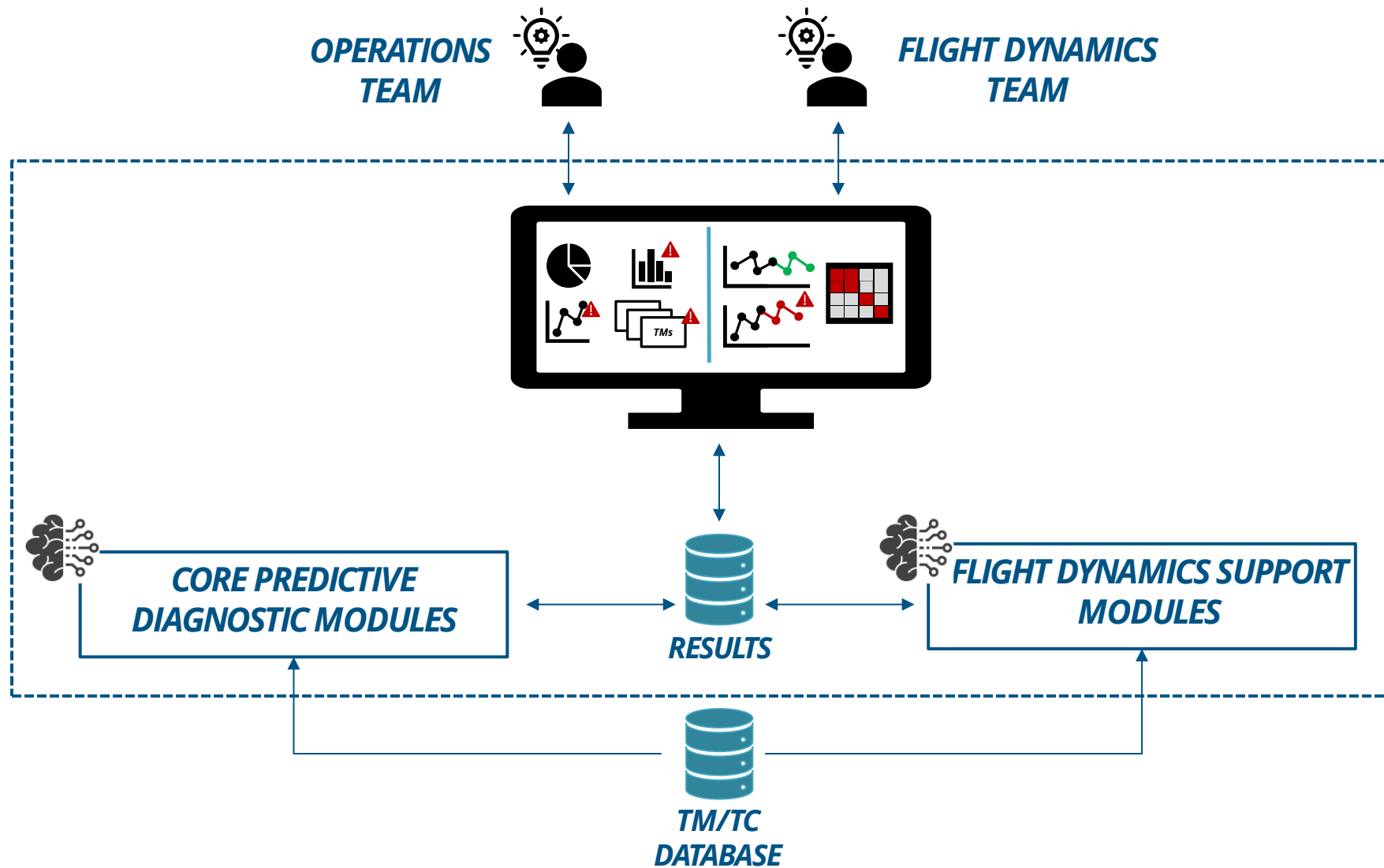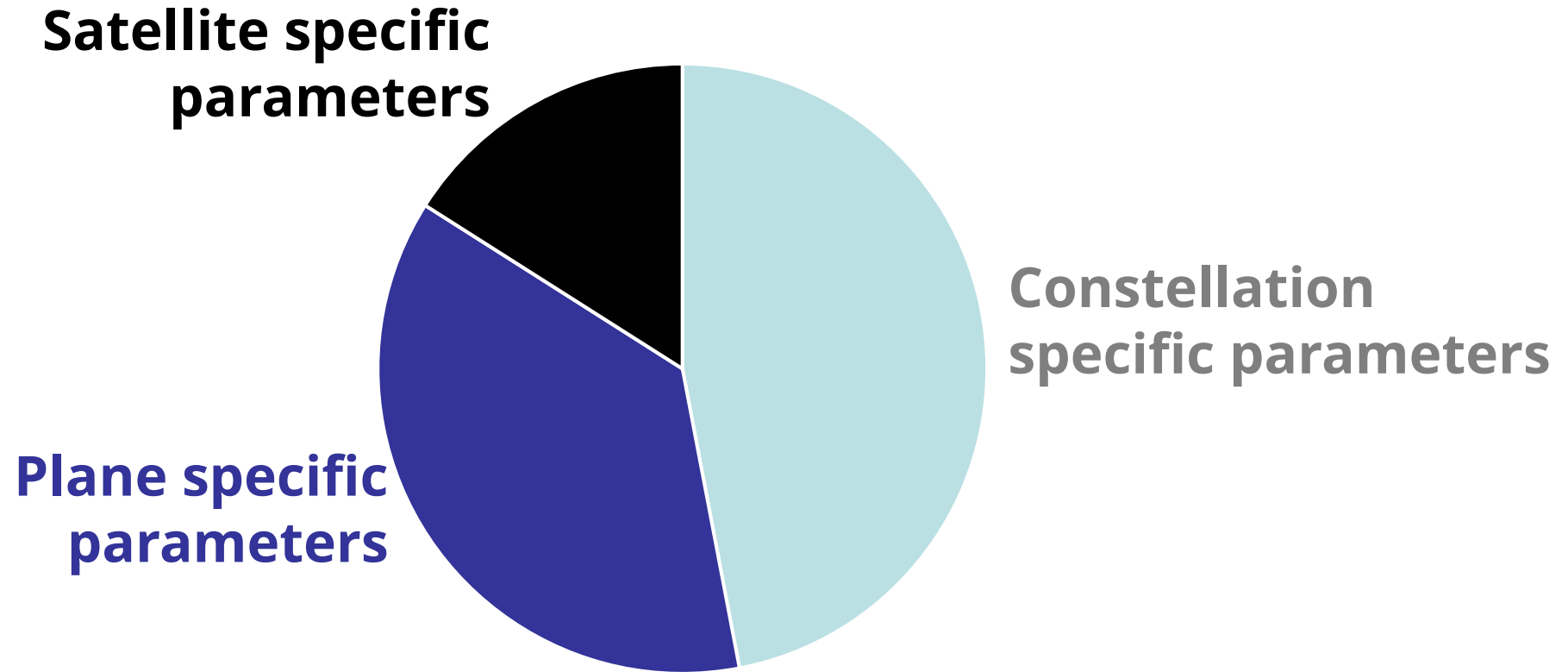
Ground deployment

Selected use of AI to tackle challenges

> AI based approach generality and **re-usability** in different application scenarios (different monitored subsystems, constellations-wise)

> On-board deployment with **limited computational resources**

> **Trustability**

> **Data availability** (especially under failure conditions) and **quality**

> Algorithms **robustness** to variety of nominal **contexts** and **ageing** conditions
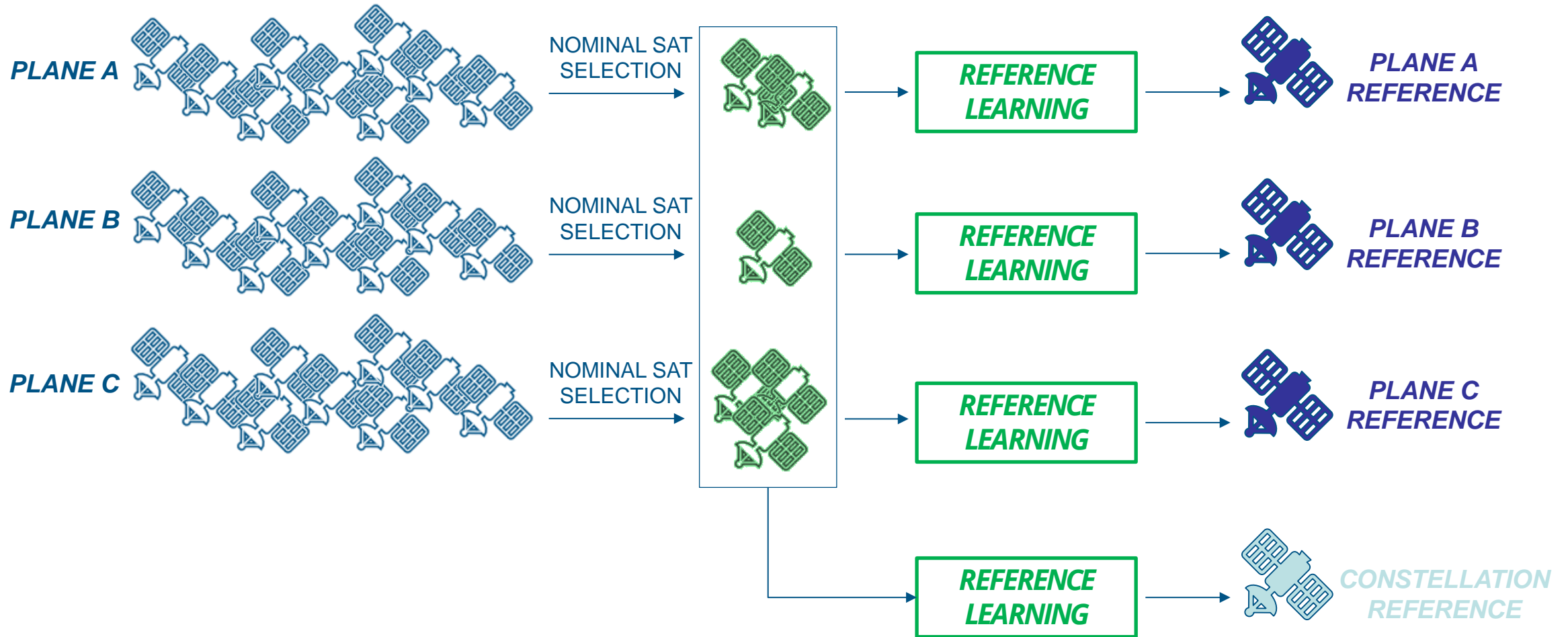
> **Reconfigurability**

Reference behaviour with selected use of AI

Physical-laws model

I/O Neural-Net model

Consistency maps Pattern-based model

**FETCH
Context aware
Machine Learning**

Knowledge

Data

Reference behaviour characterisation

Satellite specific parameters

Constellation specific parameters

Plane specific parameters

Reference models creation

Health status assessment

PLANE A

PLANE B

PLANE C

HEALTH STATUS CHECK

HEALTH STATUS CHECK

HEALTH STATUS CHECK

HEALTH STATUS CHECK

PLANE A REFERENCE

PLANE B REFERENCE

PLANE C REFERENCE

CONSTELLATION REFERENCE
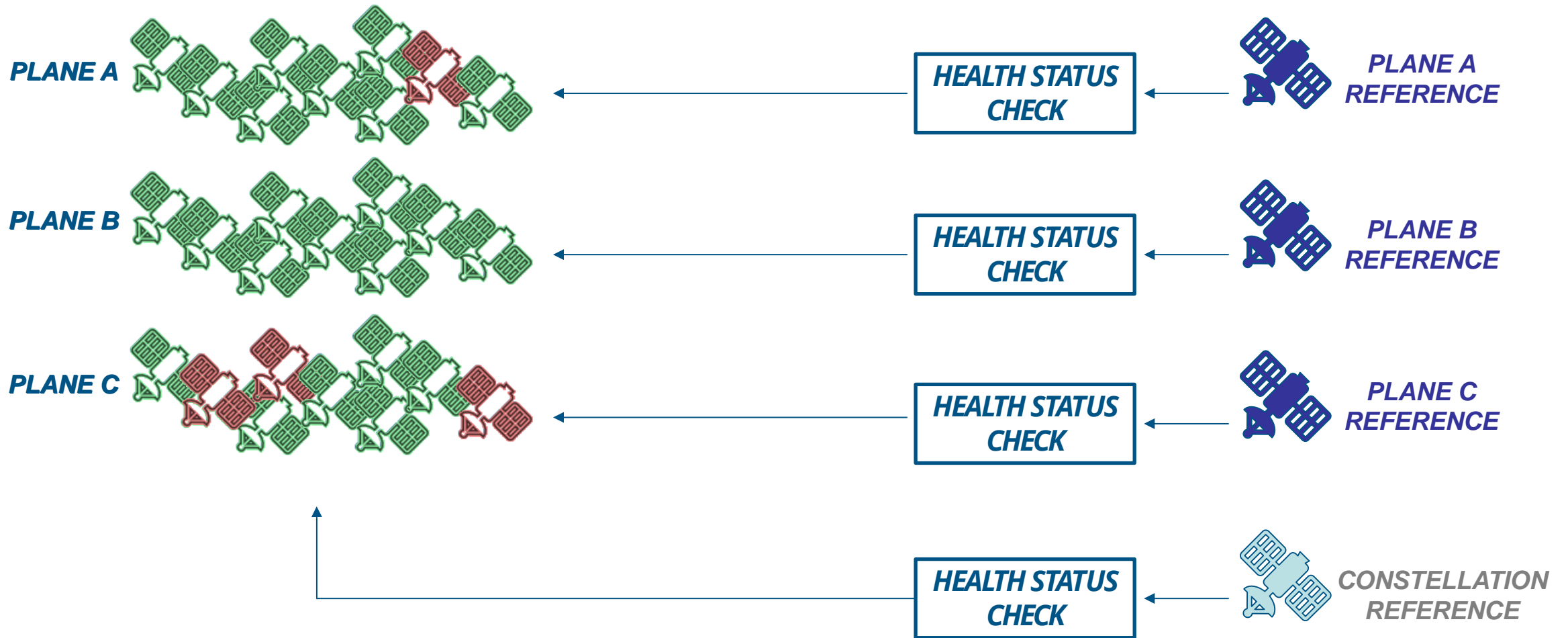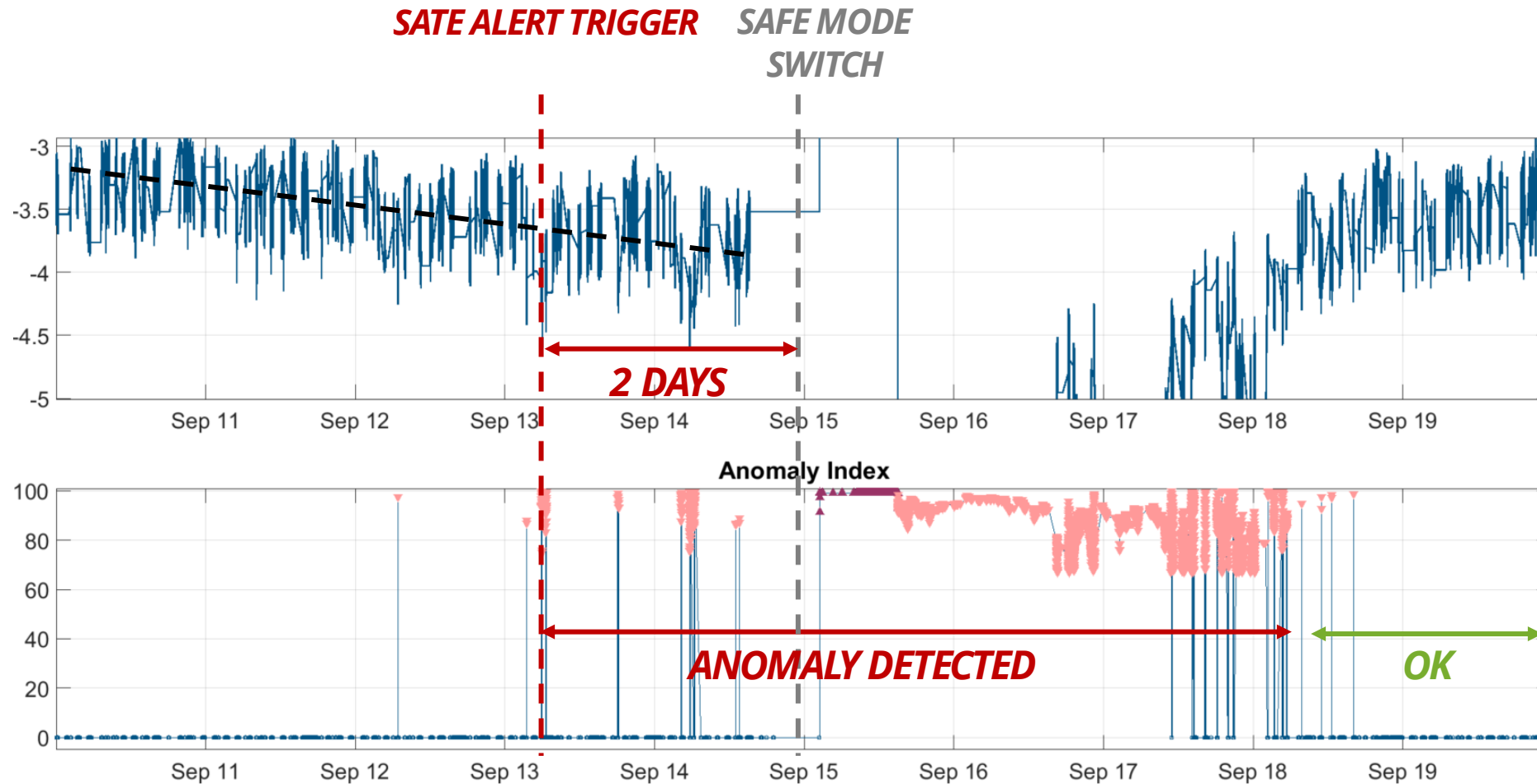
Success story from flying satellites – reaction wheels

Example of hidden reaction wheel degradation trend

Anomaly identified **almost 2 days before** safe mode

KPI measurement – simulated AOCS use case

Name	Meaning	Test outcome	Target
Precision positive condition	Among all CLUE alerts, how many are correct	**98.5%**	> 99%
Recall positive condition	Among all cases with off-nominal conditions how many are correctly identified by CLUE alert	**98.2%**	> 90%
Missed standard FDIR alerts wrt AI-FDIR correct alerts	Among all correct CLUE alerts how many are not detected by standard FDIR	**82.1%**	none
Early detection	Time interval between an alert by the CLUE system and a real component failure (excluding crash breaking events) or standard FDIR alert	**2 weeks to 2 months**	>10 hours
Fault Isolation accuracy	Among all CLUE alerts, how many are given with the correct failure mode information: mechanical (bearing) failure electronics failure, defective thermistor.	**99.6 %**	>99%
RUL estimate accuracy	Average accuracy of the prediction of a critical condition at alert set (excluding crash breaking events)	**77%**	>80%

Streamlined implementation path

Combining available data and domain knowledge towards service running in production constellation-wise

CUSTOMISED

VALIDATED

IN PRODUCTION

EXAMPLE SATS

VALIDATION SATS

WHOLE CONSTELLATION
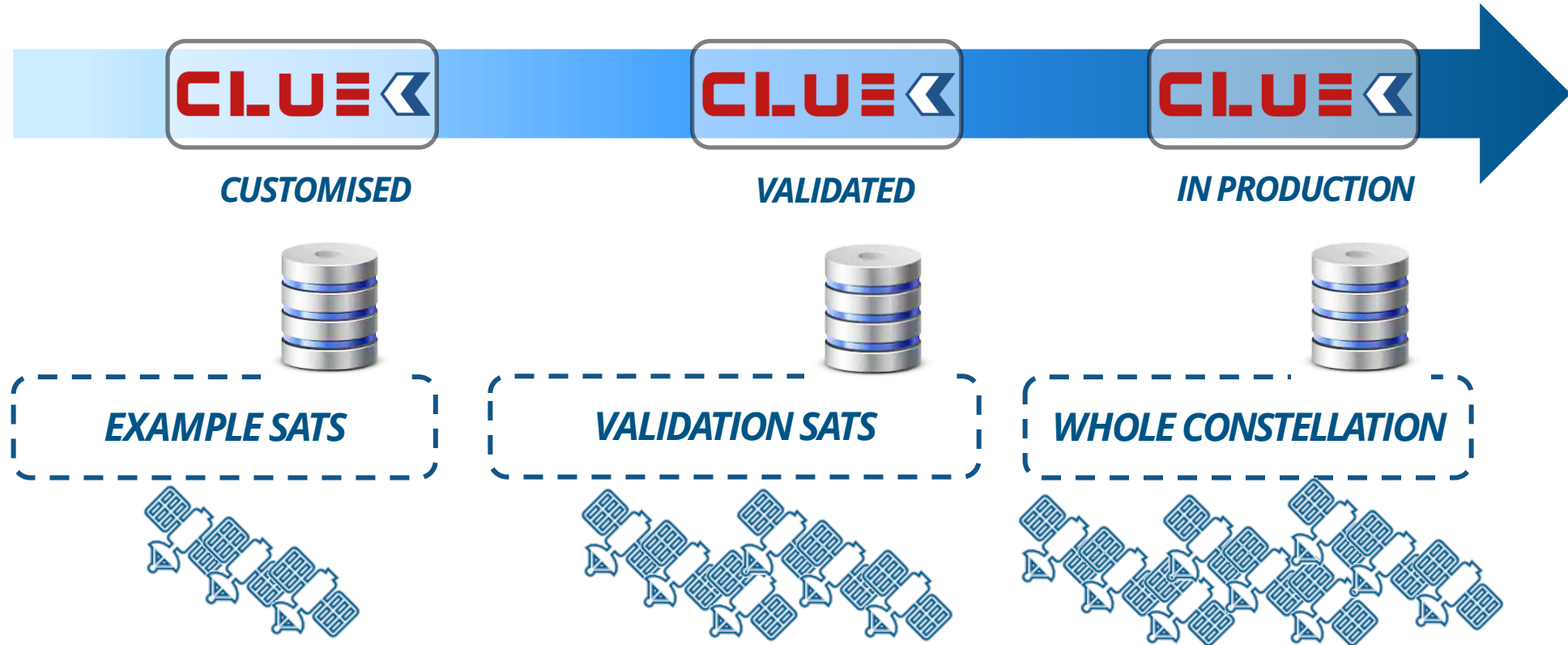
Next steps

- **Extensive validation** of the approach for large constellations in selected use cases

- Development of support modules for **troubleshooting** and **configuration management**

- Development of support modules for **flight dynamics tasks**

- Deploy the system for **operational demonstrations**

Engineering passion!

Travelling from sea depths
to outer space

with simulation and diagnostics since 1991

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