AIRBUS Space Battery Heritage Powering the Future

Space Power Workshop 2025

ALLENBACH Kévin

AIRBUS

SPACE BATTERY PRODUCTS | AGENDA

[Airbus Amber]

1. Who we Are and What we Do
2. Our Products and our Heritage
3. Data Science for Ageing Modeling
4. What is next?

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SPACE BATTERY PRODUCTS | WHO ARE WE ?

[Airbus Amber]

AIRBUS > AIRBUS DEFENCE & SPACE > SPACE SYSTEMS > SPACE SYSTEMS ENGINEERING > OPTICAL, MICROWAVE & ELECTRICAL SYSTEMS > **ADVANCED ELECTRICAL PRODUCTS & BATTERY**

Europe's **number 1** Defence and Space company

More than **35 000 people** employed **worldwide,** including in the USA

One single entity active all along the Space value chain

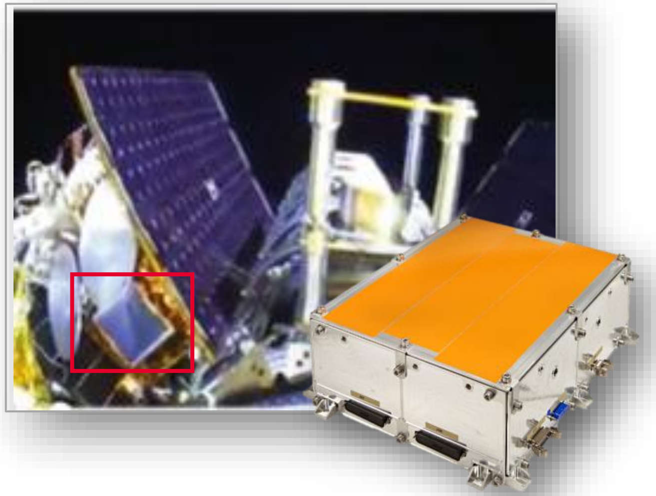
- Satellite manufacturing
- Launchers equipment
- Launchers & launch services
- Ground segment
- Satellite operations (services)
- Earth observation / Telecoms

PIONNEERING ON BATTERY DEVELOPMENT

- **Dedicated department for Battery Development** since **2002**
- **More than 20 years heritage with the Lithium-Ion (Li-Ion) technology** – 1st satellite with Li-ion battery launched in **2004** and still in-orbit!
- **New strategy** deployed in **2016:**

~ ***100 employees***, *based in Toulouse*, ***France***

From BUY…		To MAKE…
• Dedicated cells for Space • External supply • Airbus as "integrator"	→ • Costs • Mass • Obsolescence	• COTS cells • End-to-End battery products



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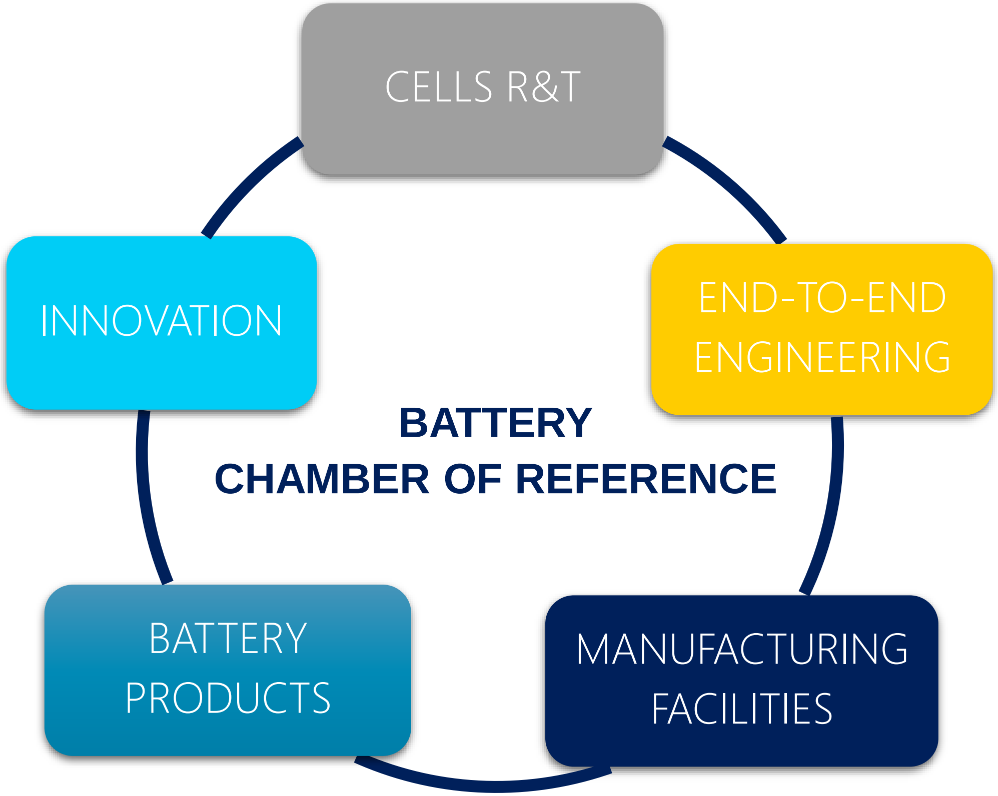
3 MAIN MISSIONS

Battery Chamber of Reference for AIRBUS Group

End-To-End Battery H/W products to internal/external customers **for Space, Aeronautics** and **Military** applications

Pushing **innovation** to **decrease cost & leadtime** at system level



Space Systems

Military / Air Systems

Unmaned Aerial Systems

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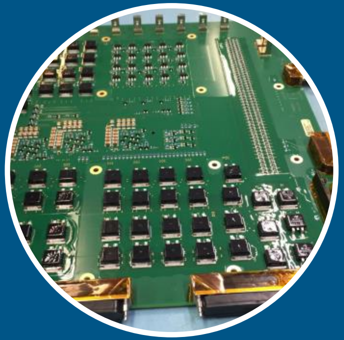
SKILLS

CELLS

Continuous electrochemical cell technology screening and testing

BATTERY DESIGN

- Mechanical and thermal design and simulations
- Electrical design and simulations

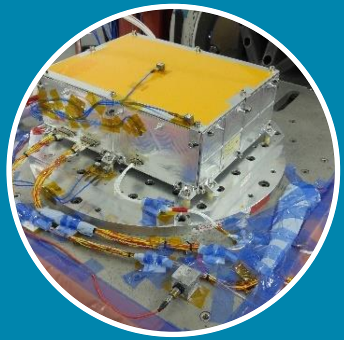


BATTERY MANAGEMENT SYSTEM

- Hardware ECSS / DO254
- Software ECSS / DO178
- Algorithms & Modelling

MANUFACTURING

- Fast prototyping
- Serial production (BAL)



TESTING

- Environmental ECSS / DO160 (thermal, mechanical)
- Electrical & Safety ECSS / DO311

END-TO-END

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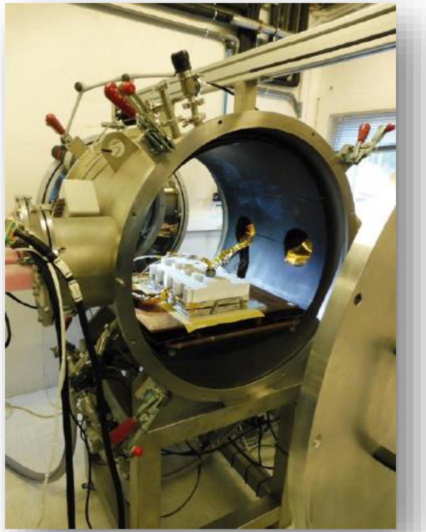
ELECTRICAL LAB

> 300 cells tests channels	**20 thermal chambers** -70 to +200°C
2 vacuum chambers	**Abusive test facilities** Fire and explosion proof equipment for cells and battery tests
1 EMC chamber ESD tests with electrostatic discharge Electromagnetic compatibility test on Space equipments	

- EMC/ESD
- ELECTRICAL CHARACTERIZATION
- SAFETY TEST
- LIFE TEST



BATTERY ASSEMBLY LINE

- Operated and qualified since **2019**
- About **500m²** in **ISO5 cleanroom**
- **Lean 6-Sigma**, automated process
- More than **1300 modules** manufactured

4 MAIN PRODUCT LINES

BASED ON AIRBUS HERITAGE

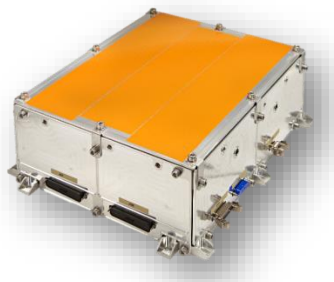
SCAN ME TO KNOW MORE!

AIRBUS BATTERY KEY FEATURES

- COTS Li-ion cells qualified for Space, well established supply line (LTA)
- Industrial design & modularity
- Optimized lead-times
- Competitive REC prices while keeping a high level of reliability
- Not submitted to export licenses

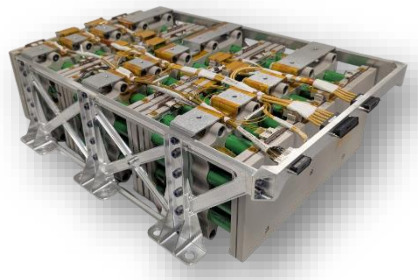
LEO CONSTELLATIONS

STELLAR-BATT



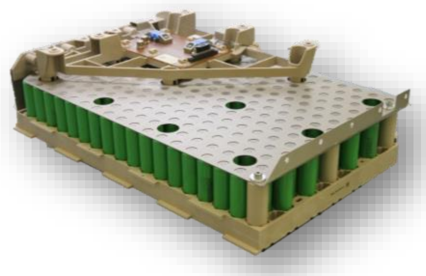
LEO OPTICAL/RADAR MISSIONS

ASTRO-BATT



GEO/MEO TELECOMMUNICATION AND NAVIGATION

COSMO-BATT



LAUNCHERS

LAUNCHER-BATT

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SPACE BATTERY PRODUCTS | KEY FIGURES

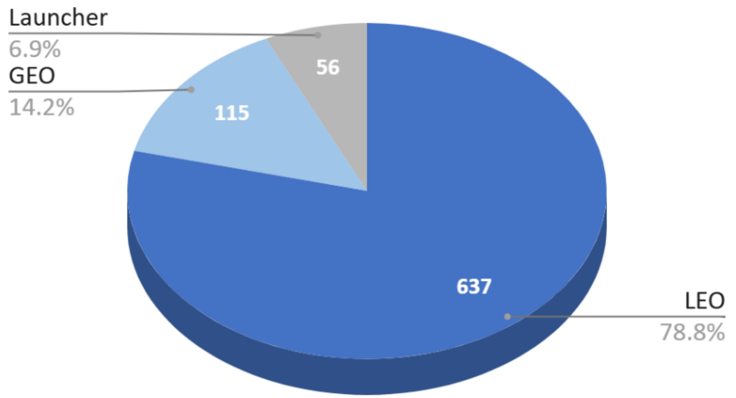
[Airbus Amber]

28 Different battery programs

> 2000 Ordered battery modules

> 1300 Manufactured battery modules

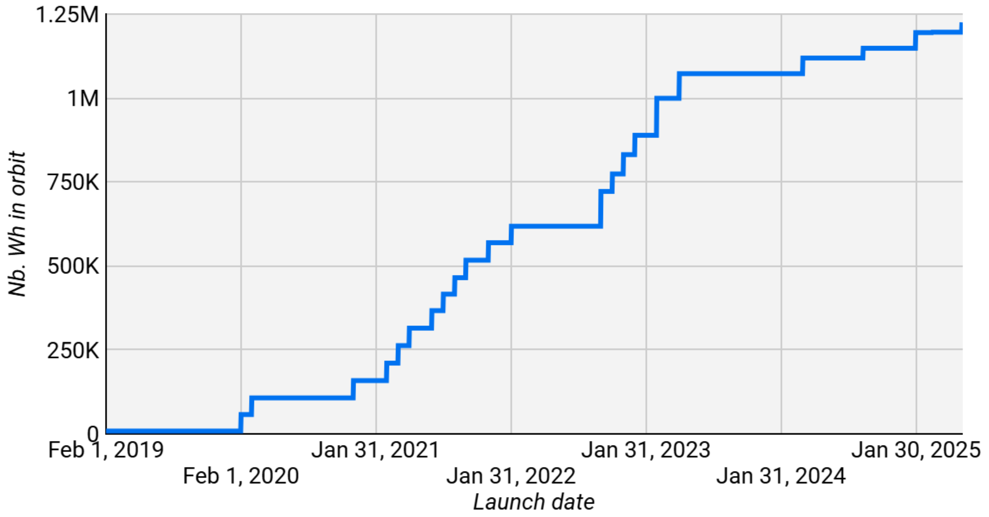
> **800** battery modules **in orbit**



> **180k** COTS cells used, equivalent to **2,1MWh**

> **110k** COTS cells in orbit, equivalent to **1,2MWh**

> 95 Billion cell hours of successful space operation with **no reported failure**



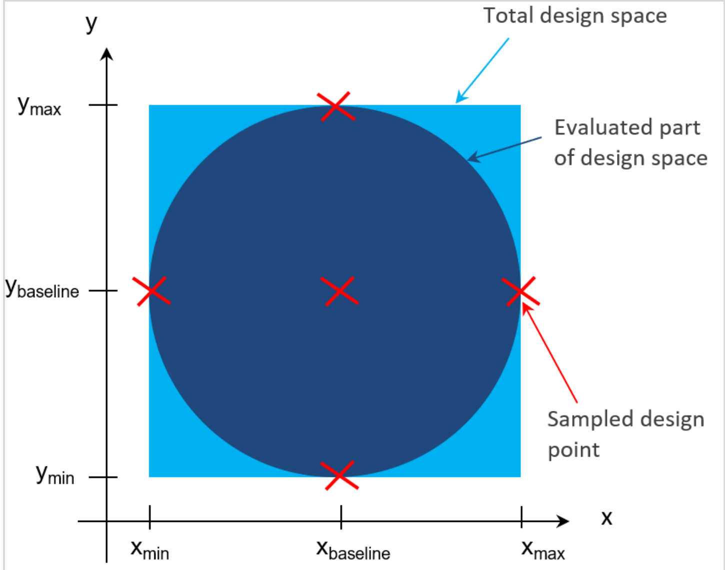
OUR KNOW-HOW | DATA SCIENCE FOR AGEING MODELING

Parameter
Temperature
DoD
EoCV
C-rate
D-rate

- Several parameters have an impact on **battery degradation**
- **Previous methodology -** 1 baseline test with set conditions, other tests with change of a single parameter with extrema values

Issues: "curse of dimensionality"

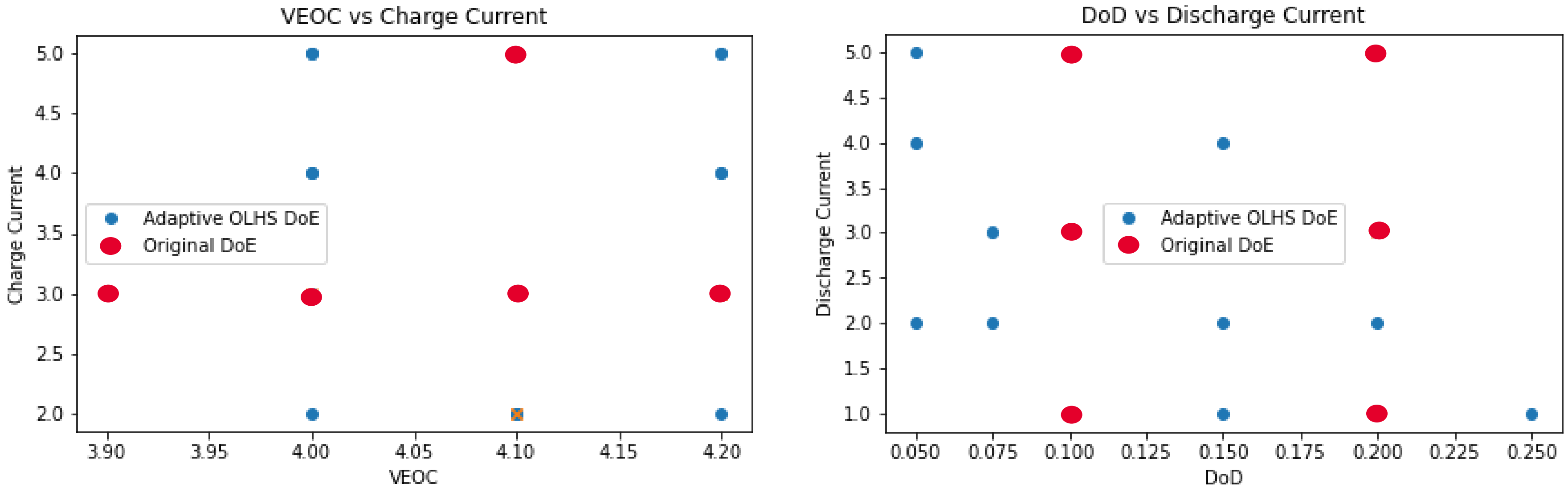
- Individual impact taken into account but not the **interaction** between the parameters
- **Inability** to efficiently sample the design space in high dimensionality (n>3)



→ Necessity to deploy another approach

- Establishment of a **Design of Experiment**, providing an optimized sampling of the design space

- Choice of Optimized Latin Hypercube Sampling (**OLHS**) method, adaptative to take into account existing data

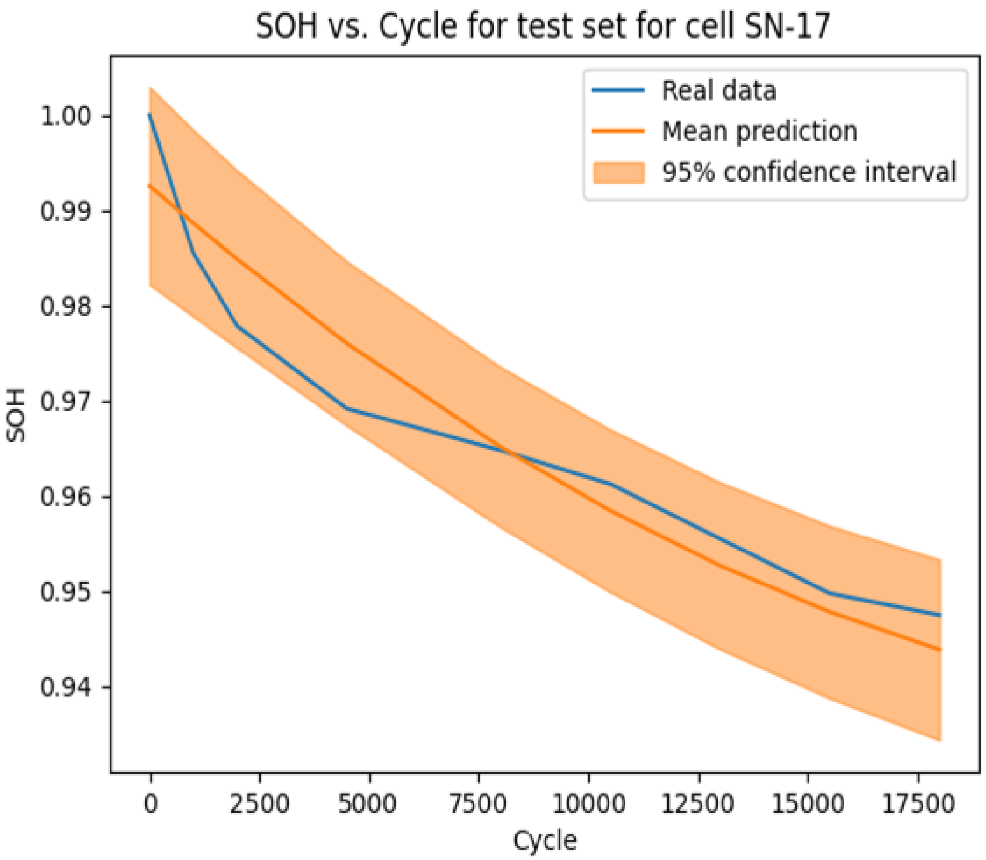


Example of test matrix deployed

OUR KNOW-HOW | DATA SCIENCE FOR AGEING MODELING

[Airbus Amber]

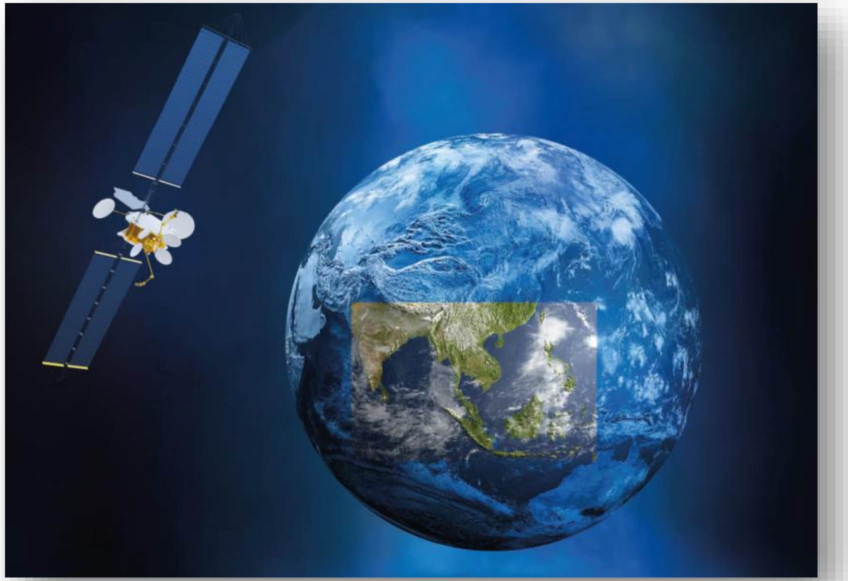
- Data issued from the tests are used to develop **accurate prediction models** for battery ageing using **Machine Learning** processes.



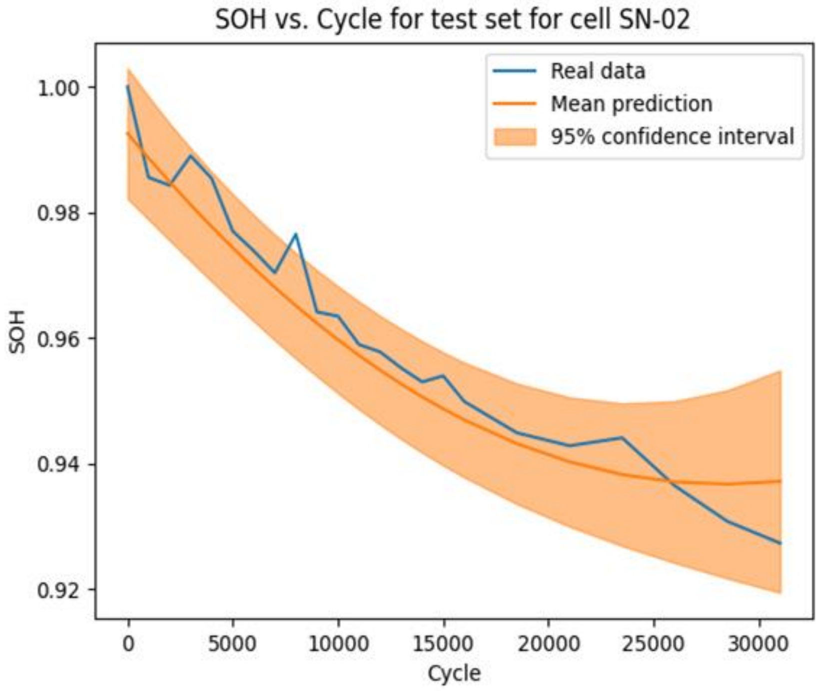
Example of prediction results

OUR KNOW-HOW | DATA SCIENCE FOR AGEING MODELING

- Use case example: increase of a **battery** lifetime in orbit of **30%**
  - Lower margin as more accurate model
  - Updated ageing assessment based on customer refined mission requirements (DoD, D-rate, temperatures) and Airbus prediction model, leading to the possibility to increase the mission of **30%**



- Limitations:
  - Analysis are limited to a defined range of values
  - Accuracy of the results decreases when getting closer to the boundaries of the design space
  - Accuracy of the results decreases at a given number of cycles if only a limited amount of tests have reached such values
  - Knee prediction only if numerous tests reach it



Example of prediction results

[Airbus Amber]

- On-going study with the University of Michigan with an **electrochemical model** coupled to **machine learning**

UNIVERSITY OF MICHIGAN

DATA DRIVEN → **PHYSICS INFORMED**

- Refined model with limited number of tests
- Modelisation of the knee point

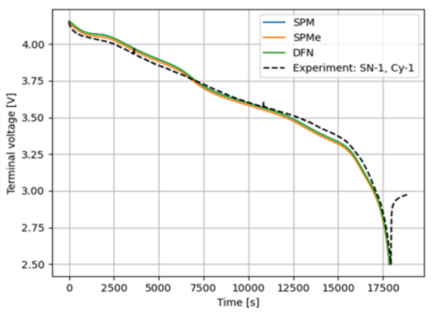
ADS calendar & cycling tests

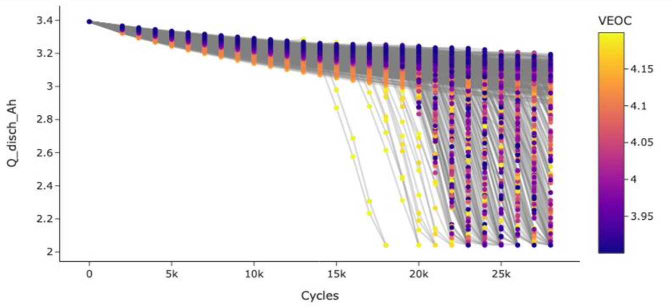
Parametrize

Electrochemical Model
SPM + Electrolyte
PyBaMM

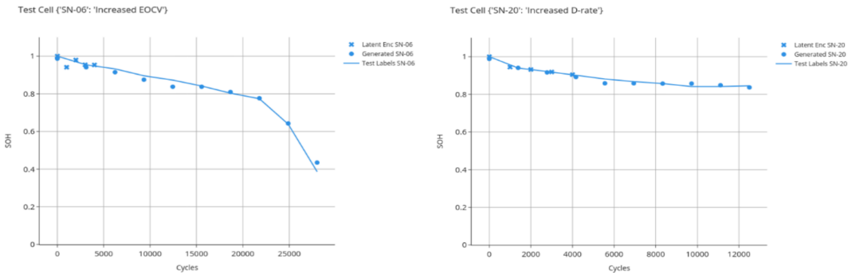
Datas for deep learning

Neural ODE Model





Enlarge DOE by data generation



Generate Prediction

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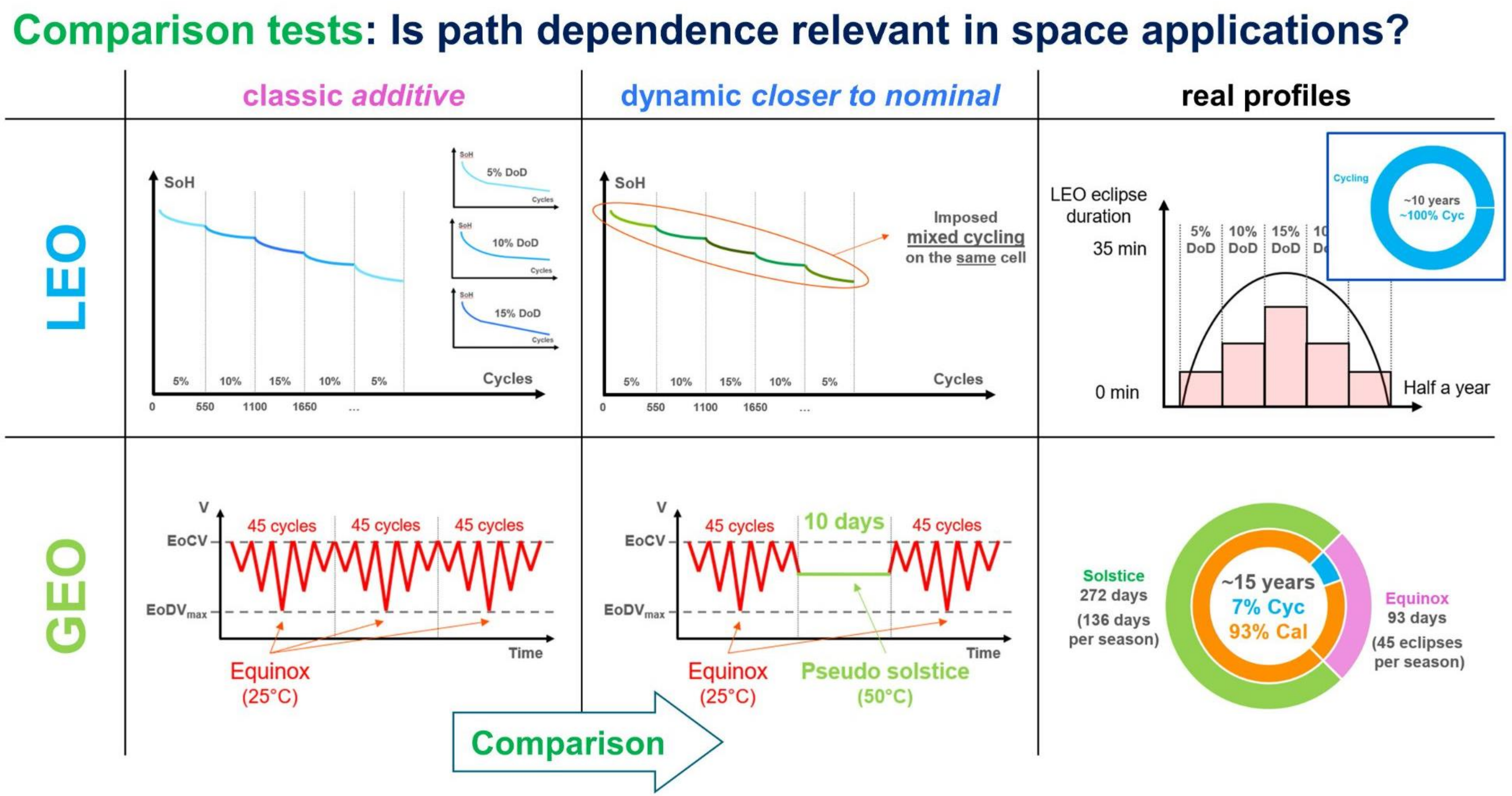
[Airbus Amber]

- On-going analysis of « **Path Dependency** » impact on battery ageing



First results end 2025 – impacts confirmed on first results

Refined ageing model ➔ lowest margins

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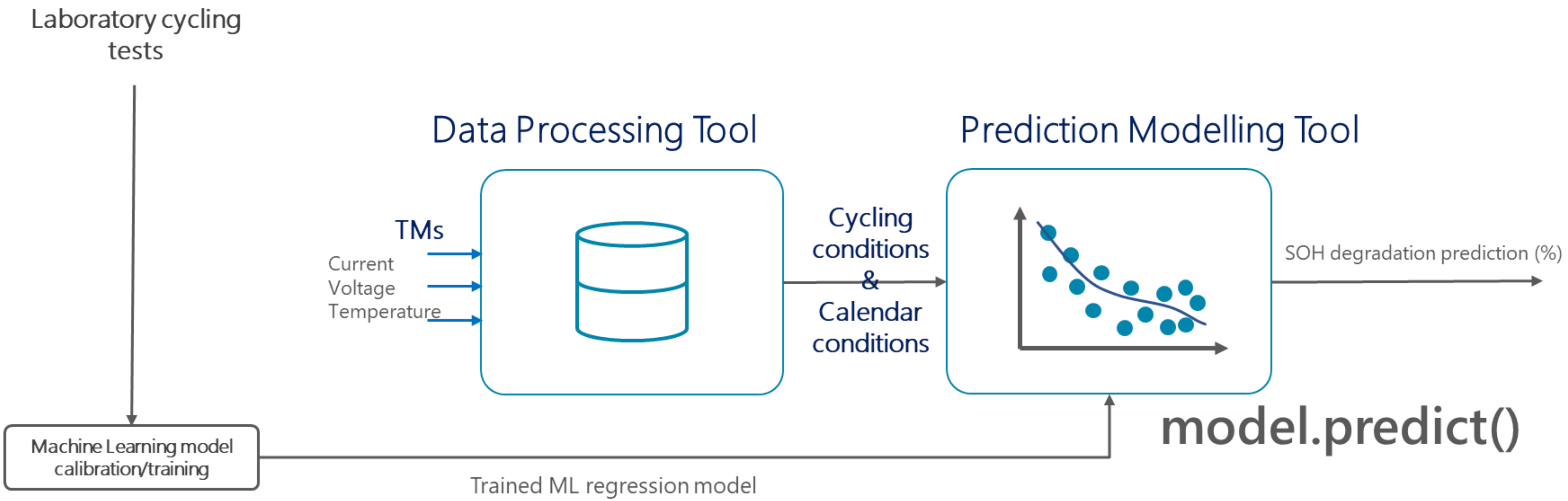
- Possibility to offer an **Ageing Prediction Tool As a Service** – enabling the customers to estimate batter degradation in EOL based on in-orbit telemetries or new use assumptions



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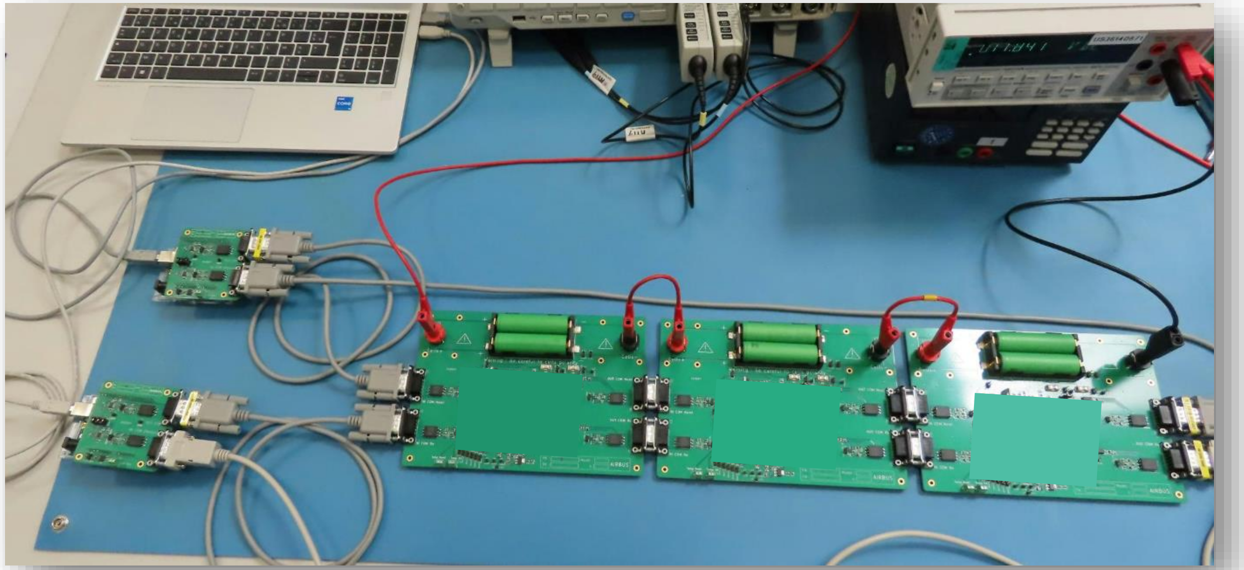
- **Intelligent Battery** – on-going study (TRL4) considering the development of a generic electronic concept, with **embedded battery SoC and SoH estimators**; while reducing the battery interfaces to its strict minimum with digital bus CAN



Proof of Concept

SPACE BATTERY PRODUCTS | KEY CONTACTS

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Thank you

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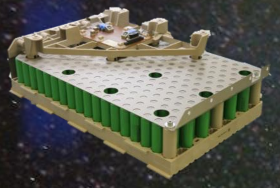
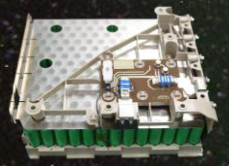
SPACE BATTERY PRODUCTS | OUR PROGRAMS



EUROSTAR NEO battery
> 160 FM modules manufactured
> 115 modules in orbit



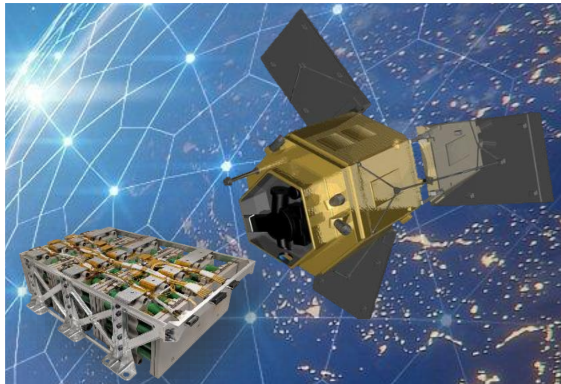
ONESAT battery
> 75 FM modules manufactured

GALILEO battery
> 75 FM modules manufactured

GEO/MEO Telecom and Nav.

OneWeb battery
> 630 modules in orbit

LEO Constellations



FORUM battery
Delivery beg. 2025

LEO Satellites

ARIANE 6 battery
> 120 FM modules manufactured
> 50 FM modules launched

Launchers

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COTS CELLS STRATEGY

WE MAKE THEM SAFE !

1 CELLS SCOUTING

Continuous search for the best-performing cells on the market

All over the world, from start-up to giga factories

2 CELLS QUALIFICATION

Once selected, the cells undergo different tests to ensure their qualification for given Space application

Space Qualification Test Plan approved by major Space stakeholders, including ESA

3 CELLS MODELING AND AGEING

Use of Design Of Experiment and in-orbit data to map batteries behaviors and build ageing models

4 CELLS LAT (Lot Acceptance Test)

Cells are ordered by batches. Each production batch is submitted to a LAT in order to validate its use in production

5 100% FM CELLS TESTINGS

Each individual cells is electrically tested before its introduction on the Battery Assembly Line

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SPACE BATTERY PRODUCTS | CYCLING TESTS STATUS

[Airbus Amber]

Cycle conditions	Number of cycles reached	Equivalent years in LEO
5% DoD, C/2	110 000	19,6
10% DoD, C/3	52 000	9,3
10% DoD, C/5	43 500	7,8
20% DoD, C/5	24 500	4,4

- 65 GEO cycling seasons performed, equivalent to 32,5 years orbit

LEO ageing prediction|Correlation analysis

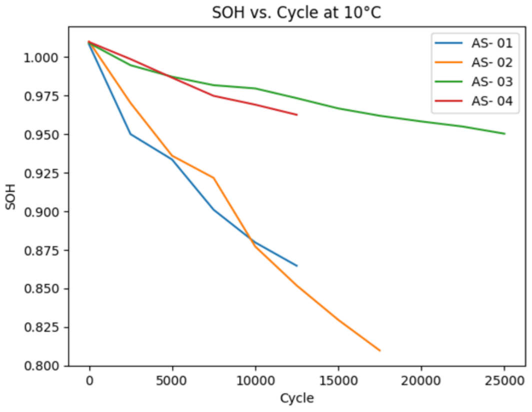
	Pearson	Pearson Partial	Spearman	Distance	Distance Partial
EOCV	-0.289680	-0.075383	-0.251482	0.092885	0.092656
DOD	-0.204948	-0.227383	-0.188036	0.057393	0.030135
D-rate	-0.512555	-0.471910	-0.396014	0.257865	0.242829
C-rate	-0.369771	-0.267153	-0.253111	0.150043	0.125070
Temperature	-0.060803	-0.009500	-0.191724	0.062747	0.050226
Cycles	-0.415048	-0.704111	-0.637155	0.307995	0.305183

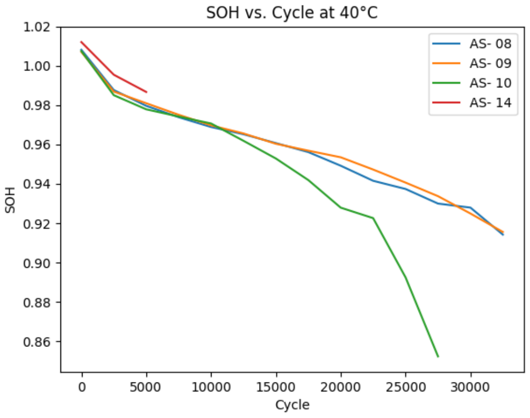
- Linear correlation for cycle number => expected
- No linear correlation for temperature
- All coefficients are negative: higher values for parameters means lower SOH

- Least monotonic for DOD & Temperature

- Lower general dependency for DOD, Temperature and EOCV

- Temperature correlation difficult to highlight
- Maybe due to lack of enough data at 10 & 40°C ?

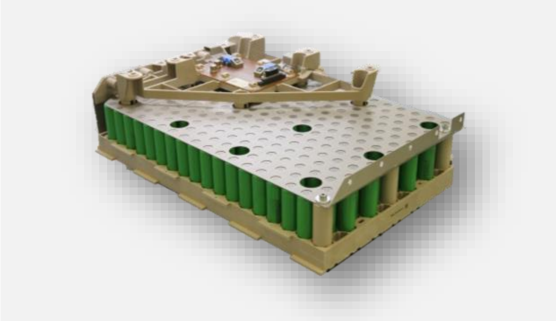




SPACE BATTERY PRODUCTS | PRODUCT LINES

GEO/MEO TELECOM AND NAV. BATTERIES

COSMO-BATT



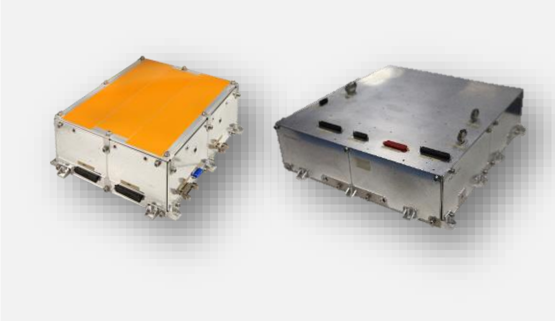
3 types of modules:

- **Small (-S)** – max. EoCV 4,2V, 550 to 960Wh
- **Medium (-M)** - max. EoCV 4,2V, 1100 to 2100Wh
- **Large (-L)** – max. EoCV 4,2V, 2200 to 2900Wh

Passive balancing system, normal and forced mode, voltage and temperature telemetries

LEO CONSTELLATIONS BATTERIES

STELLAR-BATT



2 types of modules:

- **Small (-S) –** Max. EoCV 37,8V, 1685Wh
- **Large (-L) –** Max. EoCV 37,8V, from 900 to 3600Wh

Passive balancing, timer, power switch ON/OFF, shunt current measurement, voltage and temperature telemetries, heaters

EEE automotive COTS components

LEO OPTICAL/RADAR SATELLITES BATTERIES

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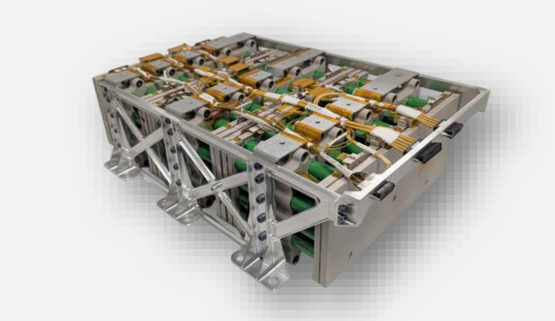

3 voltage configurations:

- **30V** – max. EoCV 33,6V, 3600Wh (-S) or 5400Wh (-L)
- **50V** - max. EoCV 50,4V, 5400Wh
- **100V** – max. EoCV 100,8V, 5400Wh

Passive balancing system, voltage and temperature telemetries

LAUNCHERS BATTERIES

LAUNCHER-BATT

2 types of modules:

- **Small (-S)** – max. EoCV 33,6V, 260Wh
- **Large (-L)** – max. EoCV 63V, 1620Wh

Embedded fuses for safety