Introducing the European Reconfigurable Battery Unplugging System (EReBUS)

a Step Towards Sustainable End-of-Life Management for Small-Satellites Constellations

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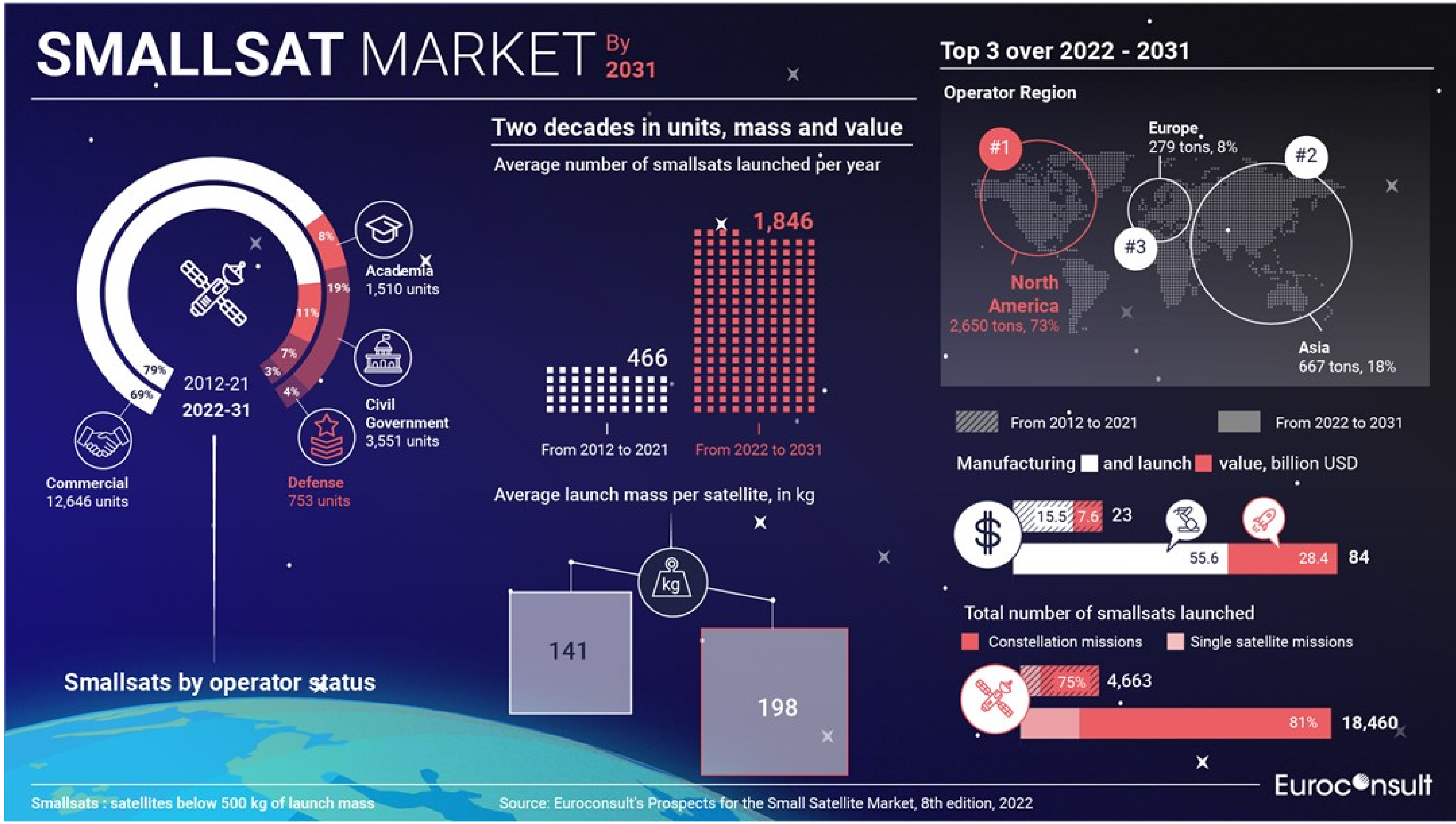
Credits: ASI/NASA

The Future of Space Missions

Growing trend for smallsats towards longer and more complex missions, even **constellations**.

Average of **one ton** of small satellites per day over the next decade.

Need for robust and **reliable passivation systems** to safely and efficiently manage the increasing number of satellites reaching their **End-of-Life**.



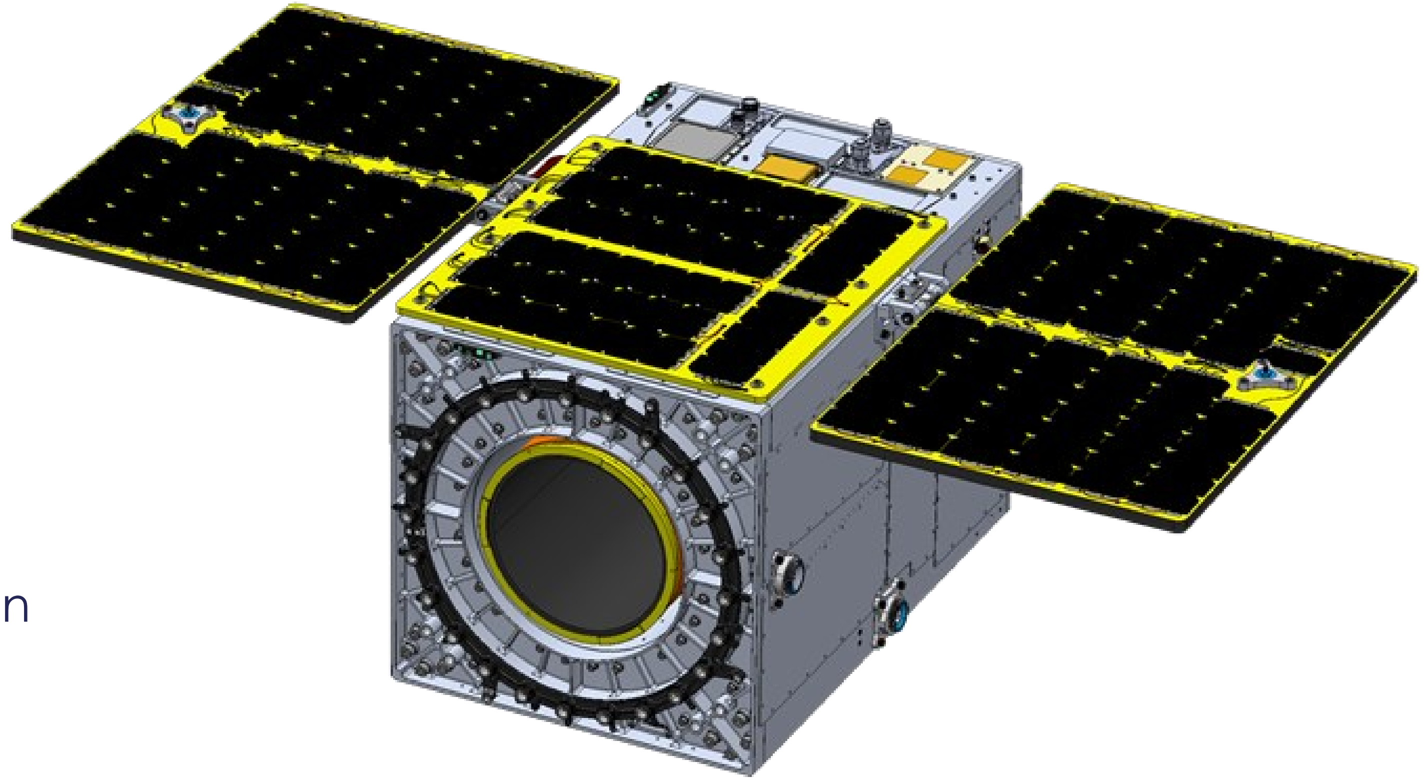
Need for Passivation

Primary objective of passivation:

- Minimize **residual energy**
- Decrease risk of explosions
- Reduce the generation of debris

Main passivation measures:

- Propellant tanks emptying
- Reaction wheels cessation of operation
- **Batteries discharge**



EReBUS Project

Develop and test a passivation method for **Li-ion battery cells** to be integrated into small satellites and CubeSats.

Ensure compliance with the **Space Debris Mitigation** requirement for passivation, without introducing any additional risk during normal satellite operations.

Developed within the framework of the **ESA ARTES** activity 4F.137: ESA TEC-EP, in a collaboration between Argotec (IT) and ABSL-EnerSys (UK).

State-of-the-Art and Trade-offs

Passivation techniques:

- Solar Panels isolation → risk of battery's over-discharge
- Battery isolation → does not guarantee passivation
- **Battery isolation and discharge**

Passivation devices:

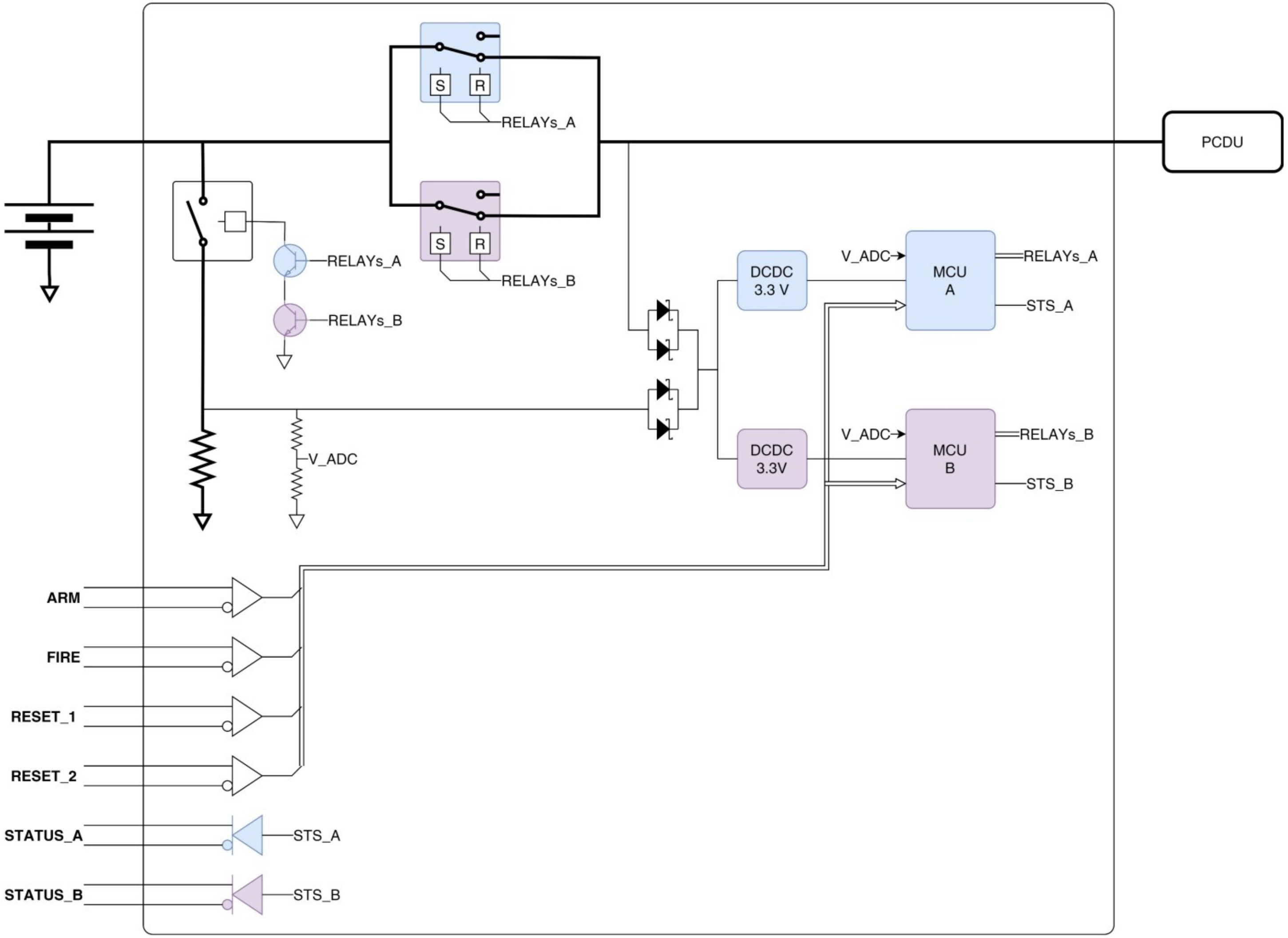
- Bypass switches → only for low voltage lines, non-testable
- Cable cutter → utilizes pyrotechnic explosives, unsafe, non-testable
- Fuse → complex circuit to activate, non-testable
- Solid-state switch → low volume, high power, constantly powered, susceptible to radiation
- **Relay** → radiation resistance, low power consumption, large volume

Passivation Device Architecture

The architecture **prioritizes mission assurance** while guaranteeing successful battery disconnection and passivation.

Key components have been **redundantly** integrated into the passivation device.

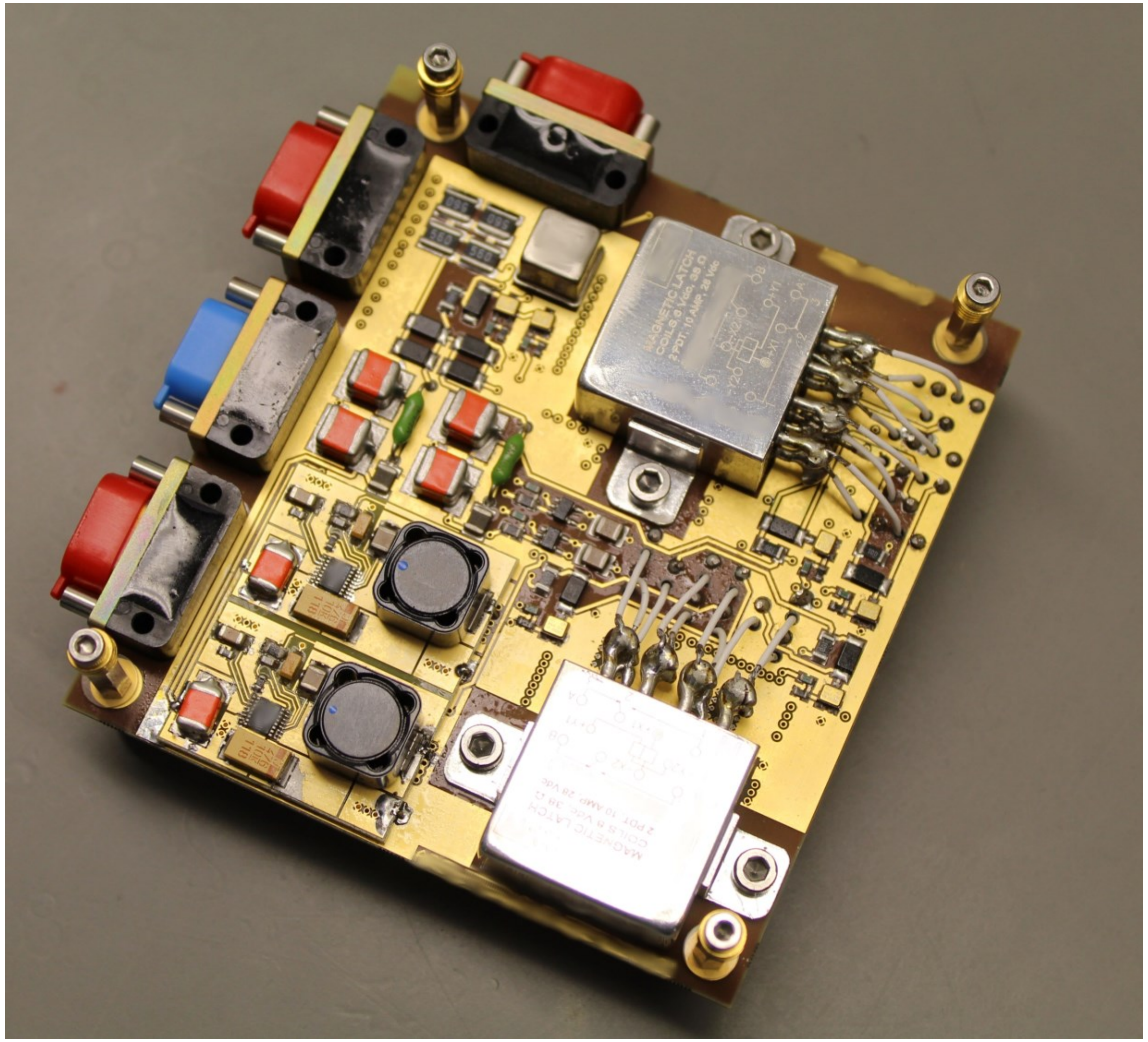
Effective and safe passivation of the battery, mitigating the risk of residual energy and contributing to the overall **compliance** with space debris mitigation regulations.



Passivation Device Features

Electronics main features:

- Compact form factor (PC/104 dimensions)
- Lightweight (160g)
- Compatible with state-of-the-art cells
- Microcontroller-based
- Use of selected radiation hardened parts
- Cost-compatible with CubeSats
- Validated up to 155W (34V or 8A)



Battery's Selection

Evaluation criteria:

- Energy density
- Capacity
- Cycling performance
- Operating temperature range
- Safety features
- Cost

Selected cells:

- COTS LEO cells
- COTS MEO/GEO cells

Characterization tests performed on cells:

- Over-discharge
- Over-temperature

Life Test

Accelerated cycles to replicate EoL conditions

Partial LEO cells cycling:

- Rate: C/2
- DoD: 20%
- EoCV: 4.1V
- Cycles: 10000

Severe LEO cells cycling:

- Rate: C/2
- DoD: 100%
- EoCV: 4.2V
- Cycles: 1860

Partial GEO cells cycling:

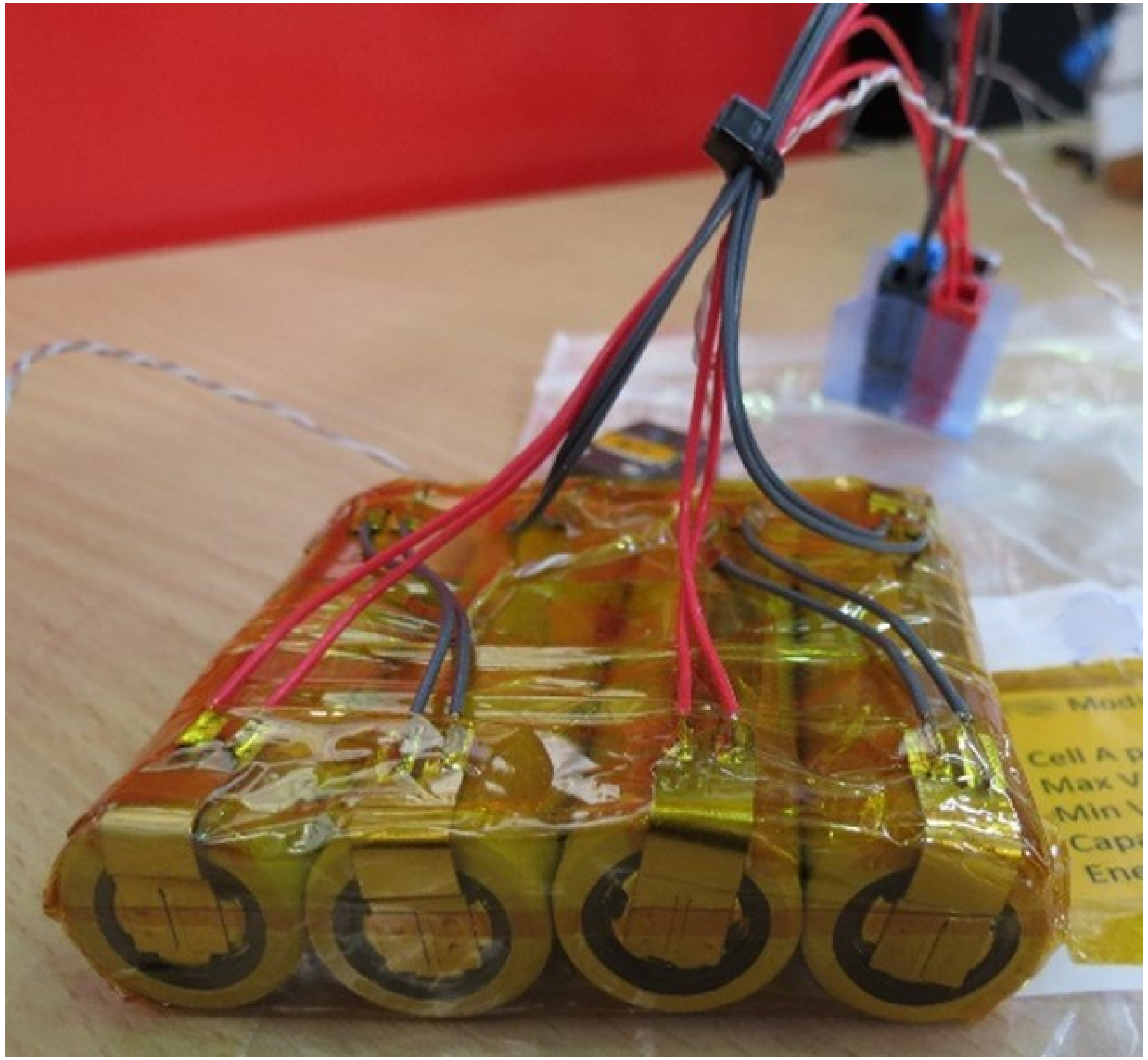
- Rate: C/2 discharge, C/5 charge
- DoD: 40%
- EoCV: 4.1V
- Cycles: 2600

Severe GEO cells cycling:

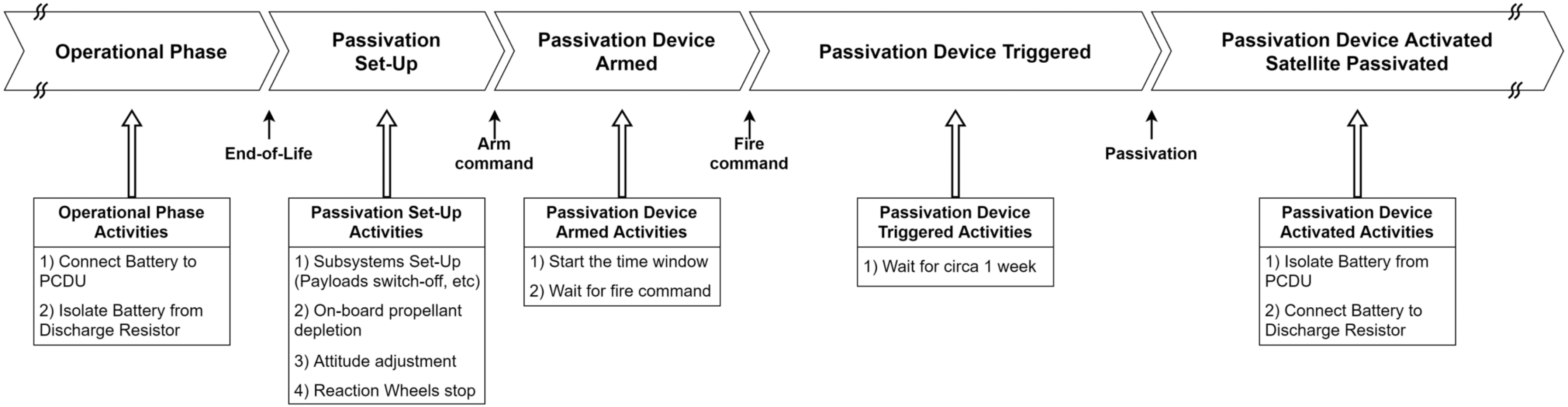
- Rate: C/2 discharge, C/5 charge
- DoD: 100%
- EoCV: 4.2V
- Cycles: 1300

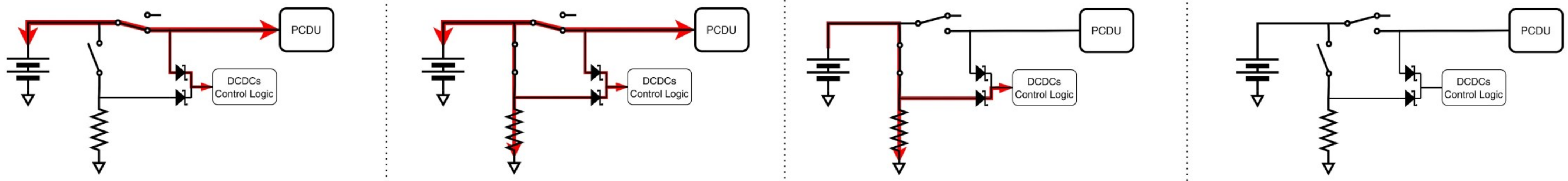
Battery Assembly

For each cell type a **2s2p** pack has been assembled for integration and testing with the electronics



Passivation Sequence



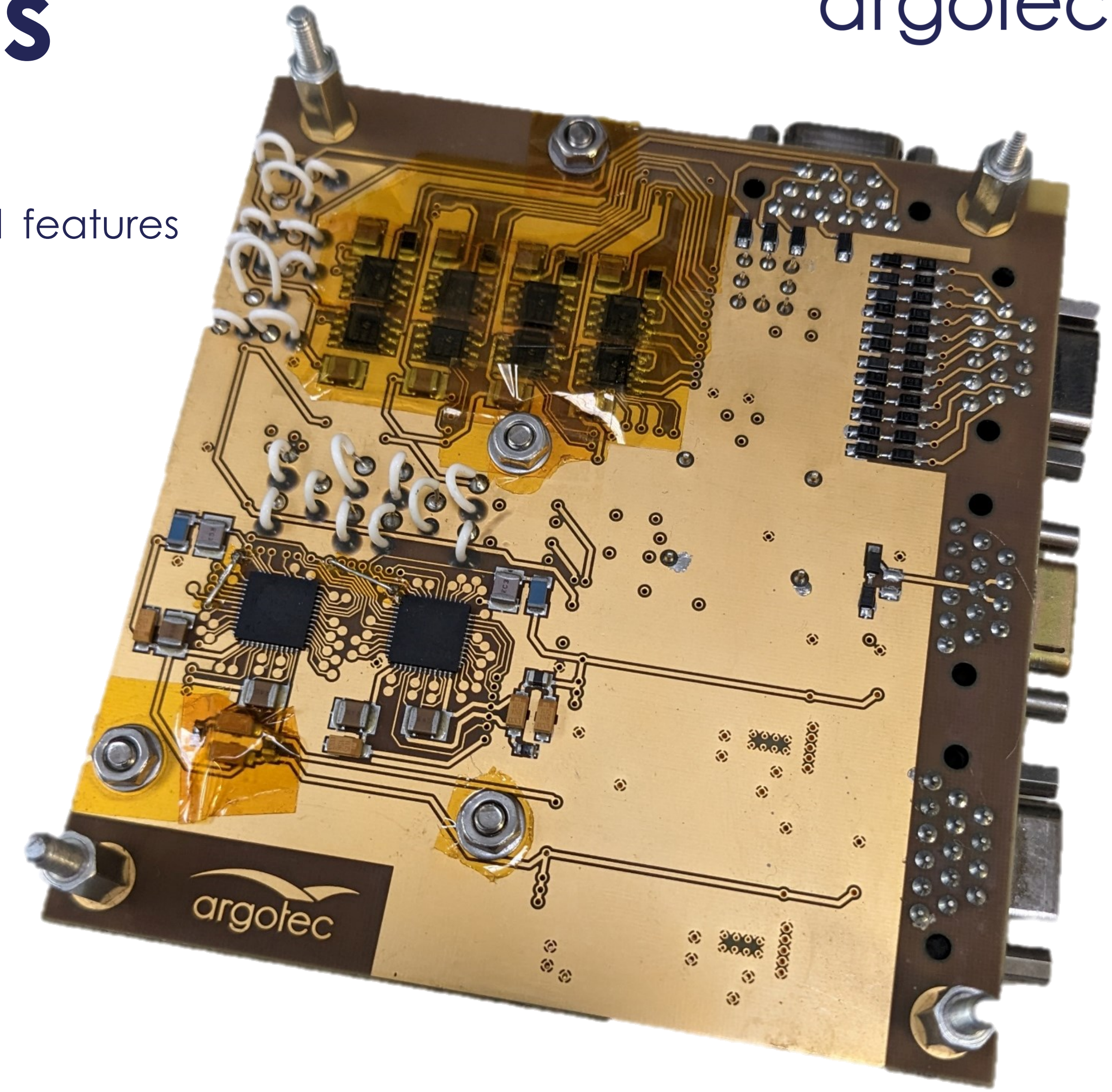


1) SATELLITE OPERATIONAL PHASE | **2) OPERATIONAL PHASE TO PASSIVATION PHASE** | **3) PASSIVATION PHASE** | **4) SAFE DISPOSAL**

Additional Features

Thanks to the **microcontroller** the following additional features are achieved:

- Double activation command
- Abort command
- Status telemetry
- Satellite's watchdog
- Autonomous End-of-Mission procedure

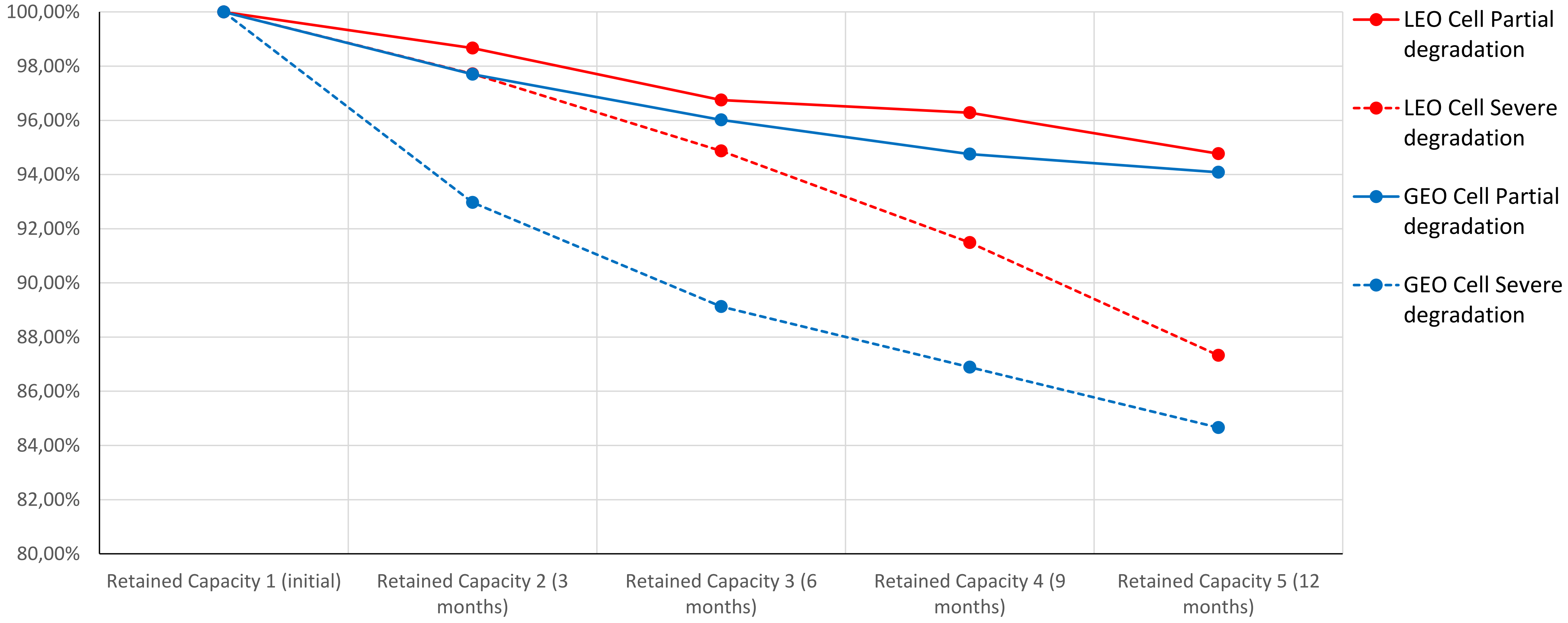


Results: Guidelines

Set of rules developed to allow safe and reliable passivation:

1. Discharge to **0% SoC**, avoid over discharge
2. Avoid high temperatures
3. Prevent recharging of the battery
4. Passivation device shall survive **25 years** at least
5. Critical circuits sections shall be redundant
6. Passivation device shall allow to abort the sequence and restore functionality

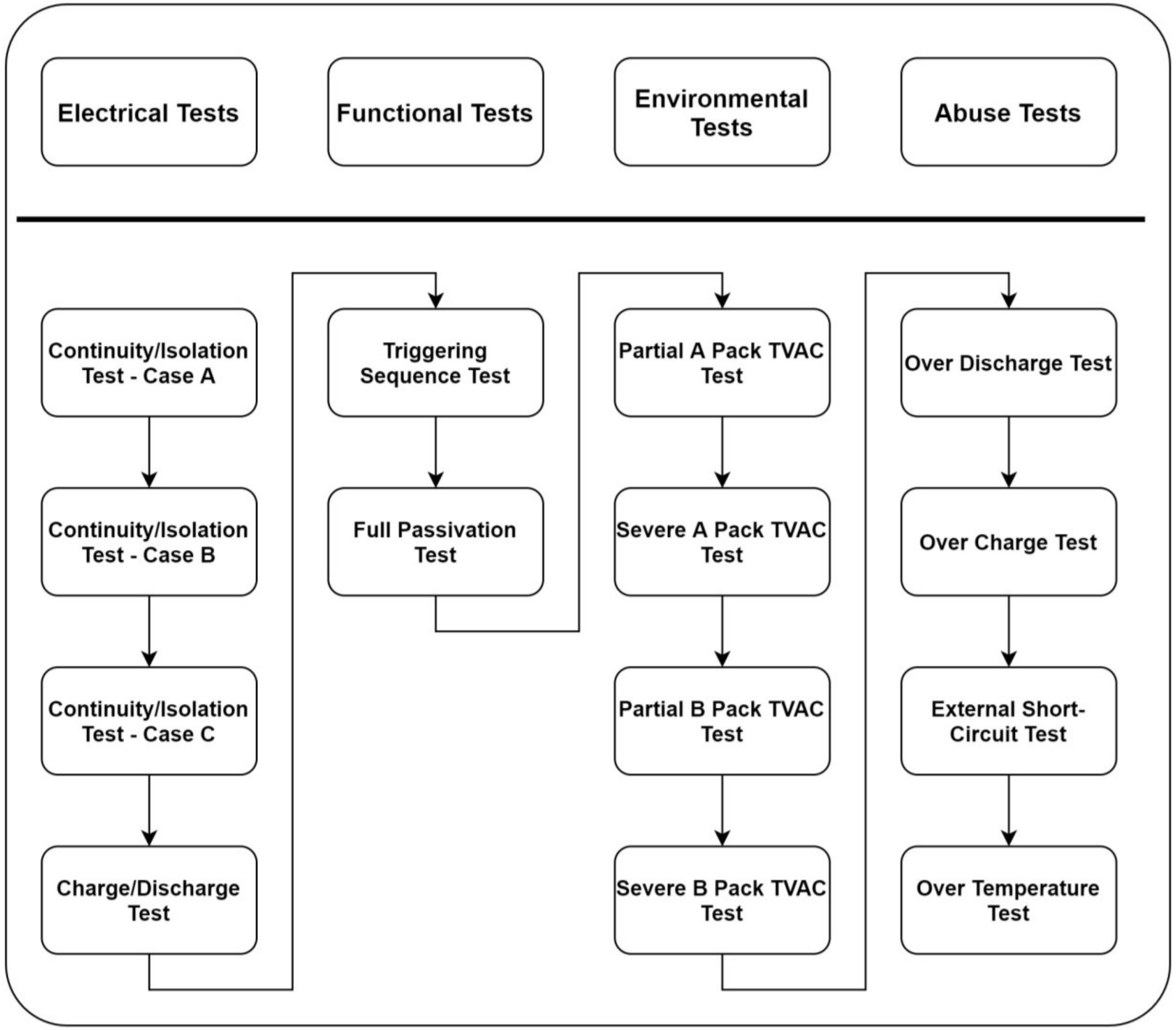
Results: Battery Capacity



Results: Test Campaign

Campaign performed on the electronics integrated with battery packs:

- Electrical → Validated isolation
- Functional → Verified passivation
- Environmental → Thermal vacuum between **-40°C and +60°C**
- Abuse → Evaluated safety mechanisms



Next Steps

The **EReBUS project reached its goals**, identifying passivation needs, characterizing the behavior of modern Li-ion cells and delivering a prototype for the passivation device capable to operate in real-world condition. Next steps include:

- Development of a proper Qualification Model, finalizing flight design
- Selection of maiden flight (**partners are welcome!**)
- In-orbit demonstration of performance and functionalities

Argotec is committed at supporting the development of next-gen constellation: the production of EReBUS devices will happen all-in-house in our new Space Park

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THANK YOU