Clean Space Industrial Days

Electrical Passivation

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AIRBUS DEFENCE & SPACE

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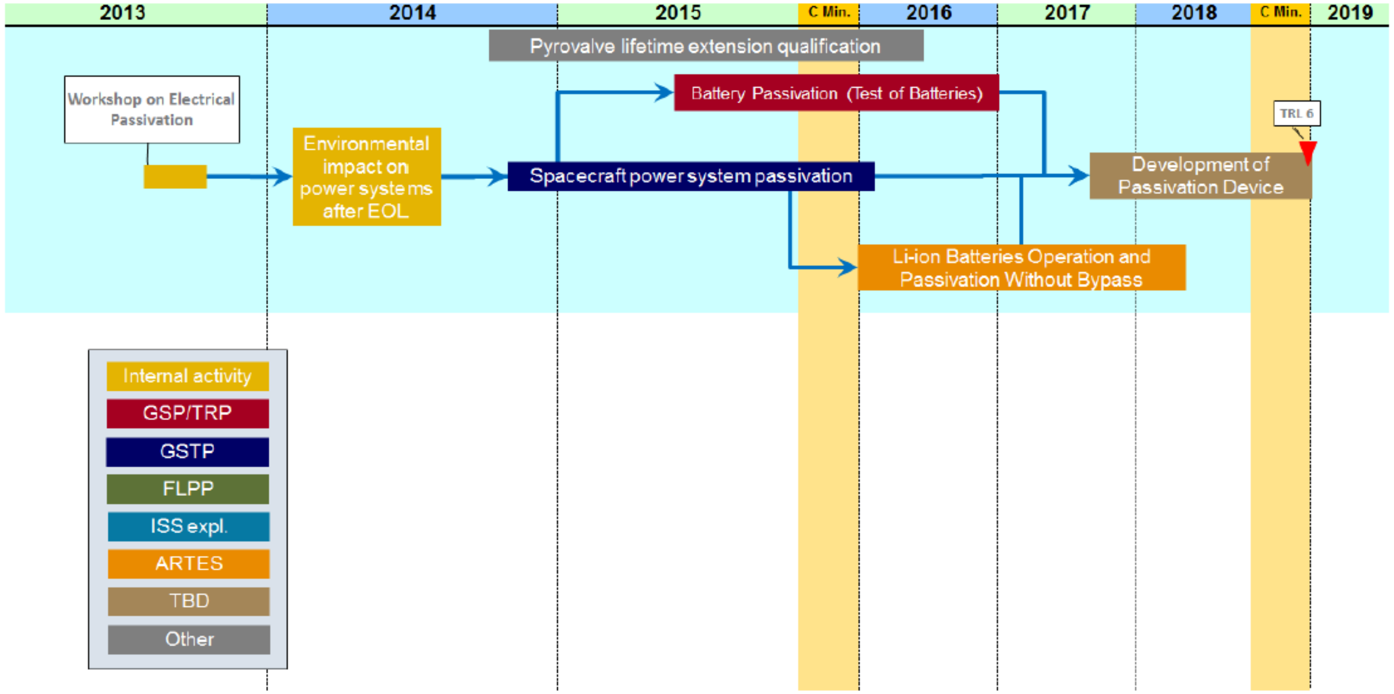
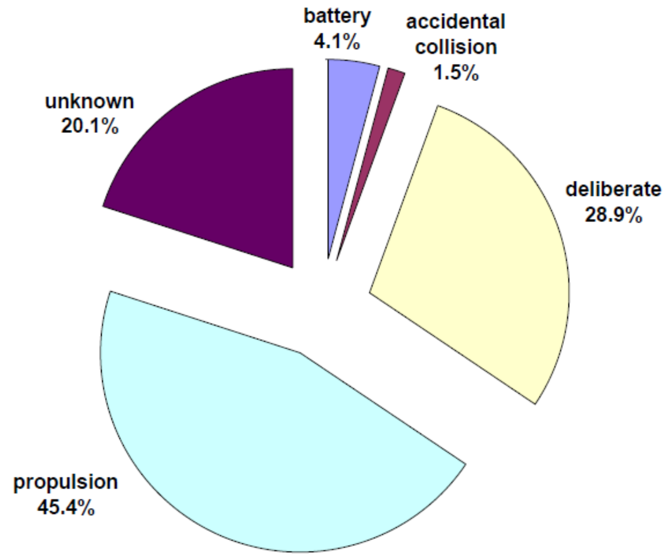
Introduction to Electrical Passivation

- <u>Clean Space's Power Passivation Roadmap:</u>





Causes of known satellite breakups until 2008

Artist's illustration of a Defense Meteorological Satellite Program (DMSP) military weather spacecraft

<u>Airbus DS has been involved since the very beginning:</u>

- Attended the **Workshop on Electrical Passivation**
- Attended the **Final Presentation of the Environmental Impact after EOL**
- Sub-contractor in the **GSTP study**
- Prime-contractor in the **TRP study**
- Involved in the Batch 3 of the **CleanSat Building Blocks**

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Introduction to Electrical Passivation

The goal of electrical passivation is:

To deplete or make safe all stored energy on board of a space system after the end of the operational phase.

According to the different regulations the following points can be derived from the most restraining specifications:

- The **battery shall be fully discharged**, or at least placed in a state that guarantees the absence of debris generation,
- The **energy from the solar generator shall neither be transmitted to the batteries** nor to any active equipment.
- **No time constraint to reach a stable state is specified.** The operations will however be as reduced in time as possible.

Constraints and requirements applicable to Electrical Passivation (proposed by Airbus DS):

- **During the mission lifetime: no accidental activation of the Passivation.**
  - Reliability of non-passivation: **0.9999**
  - **SPF free**
- During the disposal phase:
  - Reliability of passivation:**0.99**
  - No SPF requirement
- Once passivated:
  - Reliability of keeping the EPS passivated during 25 years or more: **0.95**
  - No SPF requirement
- **Reversibility** is not always possible (depends on the solution) but it **would be nice to have**.

R&D studies: CNES study with TAS-F (2012)

Objective of the Study:

To propose different solutions regrading the Electrical Passivation to be in compliance with the French law (LOS) before 2020.

- Trade-off and analysis of different solutions.

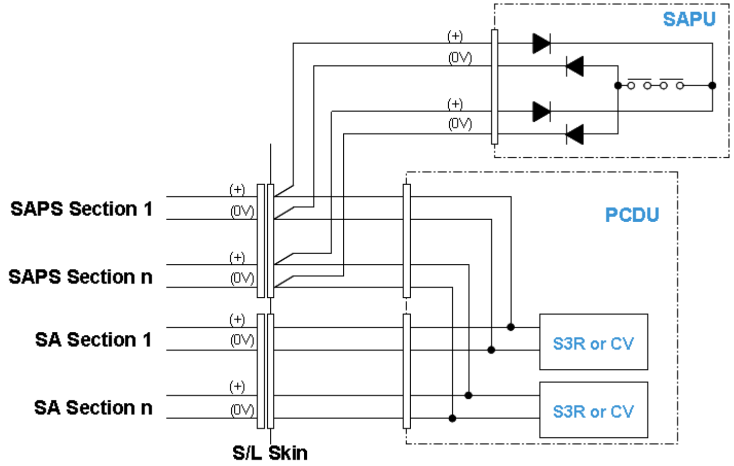
- Four were selected as the most interesting:

  - **SA short circuit in external box (SAPE):** well suited for LEO platforms with little number of SA sections, and without modification of the product lines. But new equipment.

  - **Bus short circuit:** preferred solution for LEO platforms, very constrained in terms of accommodation, and with a lot of SA sections. *All other « non-mechanical » solution is questionable over a 100 year lifetime (radiation).*

  - **Switch (Mosfet) in series inside the PCDU to inhibit the SA current transfer to the bus:** Only for MPPT Buck and Buck Boost topologies because MOSFET in series

  - **SA harness cutting device:** Interesting for all PF. Implementation and Space qualification to be studied.



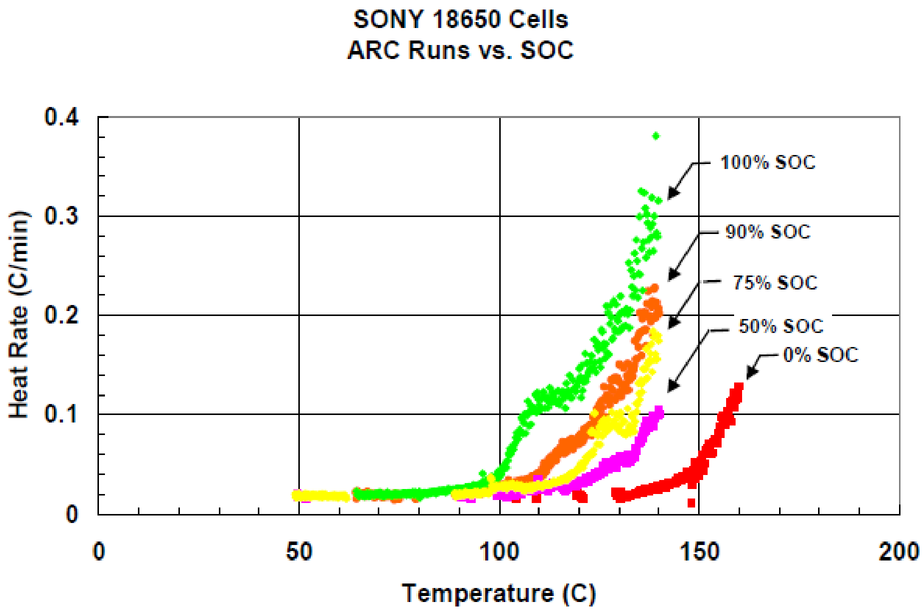
R&D studies: GSTP: Spacecraft Power System Passivation with RUAG (2014)

Objective of the Study:

To study, implement and evaluate the most adequate means to ensure a proper and reliable spacecraft power system passivation at end of mission.

The study carried on by RUAG and Airbus DS about the main parameters that impact the battery's safety:

- **Temperature:** higher temperatures increase the risk of a thermal runaway to a potential explosion and generation of debris. In fact, if the energy contained in the cell is very high, the leak-before-burst strategy may not be sufficient to avoid the explosion.
- **State of Charge (SoC):** the higher the SoC, the higher the risk of triggering a thermal runaway at lower temperatures.
- **Radiation:** high levels of radiation may modify the chemical compounds of the cell but the impact on thermal runaway is not yet clear enough.
- **Aging:** cycled cells show higher thermal stability than new cells, which gives an advantage to EoL satellites with regard to BoL.



Simulation of worst Environmental conditions after 40 years:

Max Battery Temp :	**+200°C**
Max Battery Radiation dose:	**57 Mrad**

R&D studies: TRP: Battery Passivation with ABSL/SAFT/CEA (2016)

Objective of the Study:

To test Li-Ion battery cells and modules under extreme conditions encountered after spacecraft disposal in order to assess their safety.

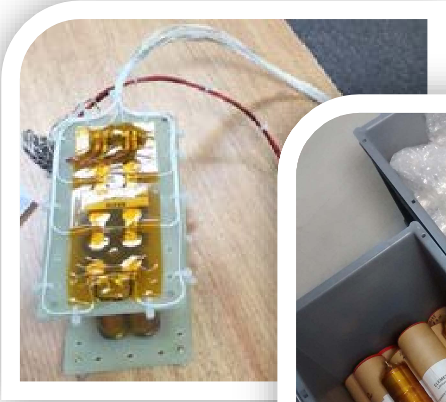
Cells to be tested:

- **SAFT:** VES16, VES140 and VES180.
- **ABSL:** 18650 HC/HCM and NL

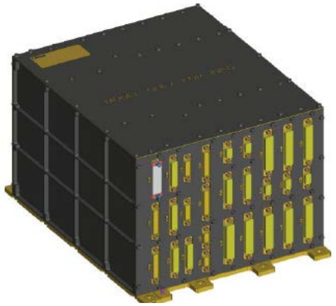
The tests that are going to be performed use the GSTP simulation results and include:

- **External / Internal short-circuits**
- **Overcharge / overdischarge**
- **High temperature and Thermal Runaway**
- **Micrometeoroids**

The goal is **to assess the impact of radiation, vacuum, aging and SOC on the battery safety.**



Mission applications: Astrobus Platform

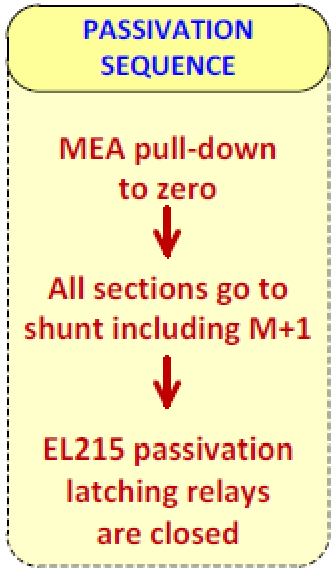


Astrobus XS (Myriade platform): no new missions foreseen.

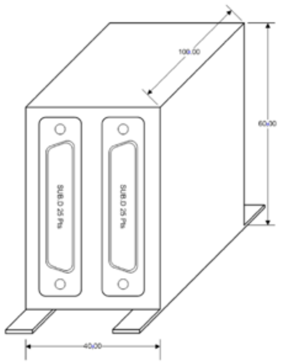
Astrobus S (Myriade Evolutions platform): development of the new PCDU with an electrical passivation feature included: **short-circuit of the Solar Arrays thank to relays**.

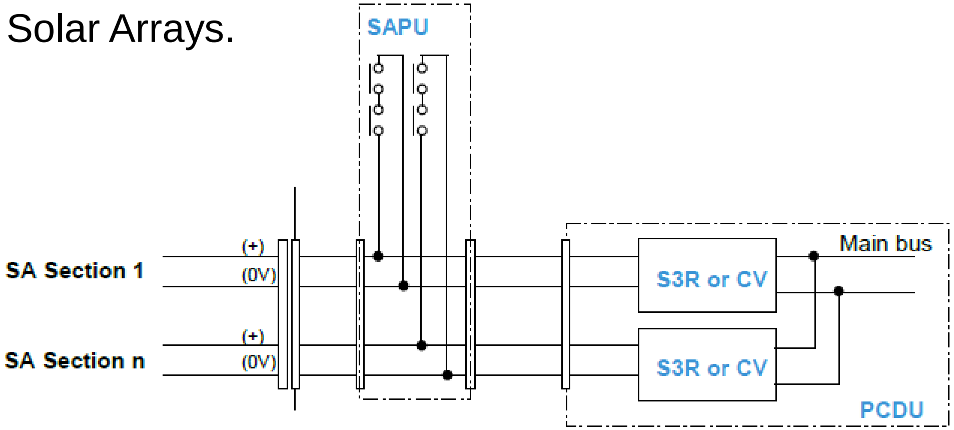
Astrobus M/L (or AS250): no current passivation feature. The roadmap is to use an extended version of the PCDU Myriade Evolutions with the same feature.

Astrobus XL (or AS400): no current passivation feature. It is foreseen to include it in the product line inside the PCDU in order **to isolate the Solar Arrays thanks to the SAR mosfets for internal protection**.



It is important to be noted that Airbus DS has already a back-up solution with the **SAPE (Solar Array Passivation Equipment)** to short-circuit the Solar Arrays.





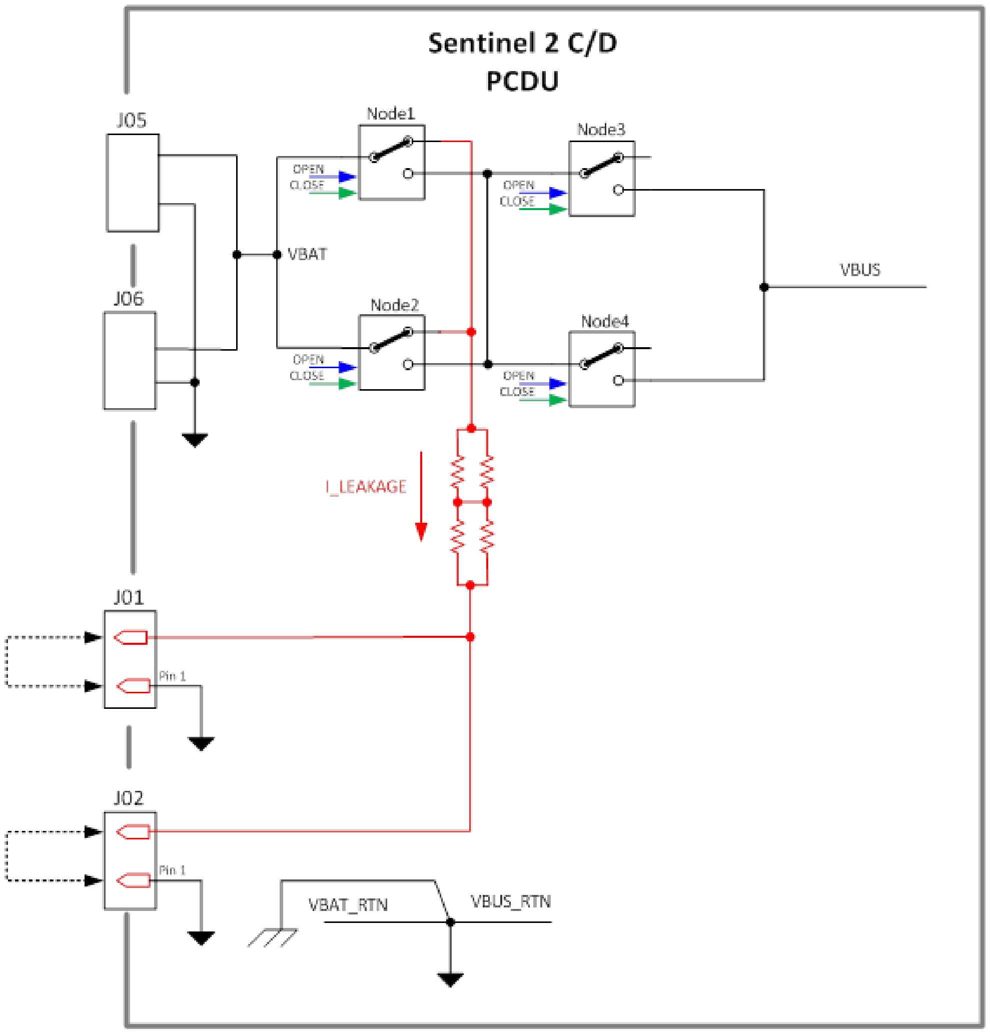
ESA missions: Sentinel 2 / Jason-CS and BioMass

Both missions will use, after several trade-offs, the same solution:

Modify the PCDU to disconnect the Battery at the end of the mission

<u>Characteristics:</u>

- Requires to implement leakage path and OFF command of the relays in flight.
- Does not passivate solar generation
- Not reversible



Conclusions

- **We start to know more about the environmental conditions of the spacecraft after disposal** and 40 years in orbit thanks to our simulations (GSTP).

- **We will soon have precise information about the battery safety for all the qualified cell models from SAFT and ABSL for the later conditions**. We will then be able **to assess the probability of a battery break-up** and the potential **generation of debris** (TRP).

- As it can be observed, **there is no a unique solution for electrical passivation**. RUAG and Airbus DS are preparing **a catalogue (or a tool box) with some of the possible options**, its advantages, drawbacks and potential showstoppers.