CleanSpace industrial days

Managing the end of life (Passivation for managing the spacecraft's end-of-life)

DEFENCE AND SPACE

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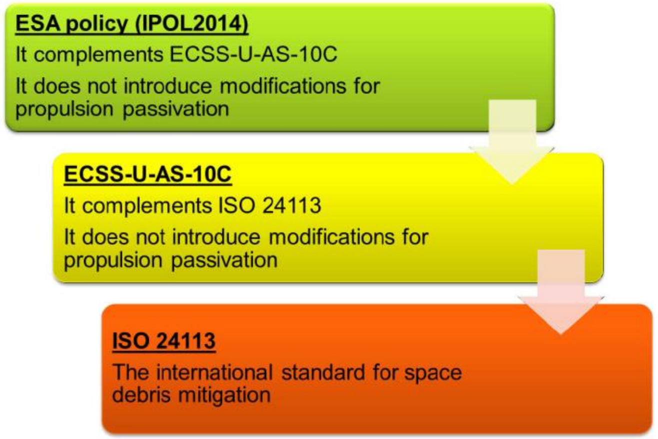
Introduction : recall of the Passivation requirements

The objective of the passivation is to ***deplete or make safe*** all remaining on-board energy at the end of mission to minimize risk of explosion in orbit during the disposal phase due to self-explosion (increase of T°) or due to hypervelocity impacts with microdebris/micrometeorites.

- No remaining pressurized elements
- No energy in battery
- No rotating parts

  (and also no RF emissions)



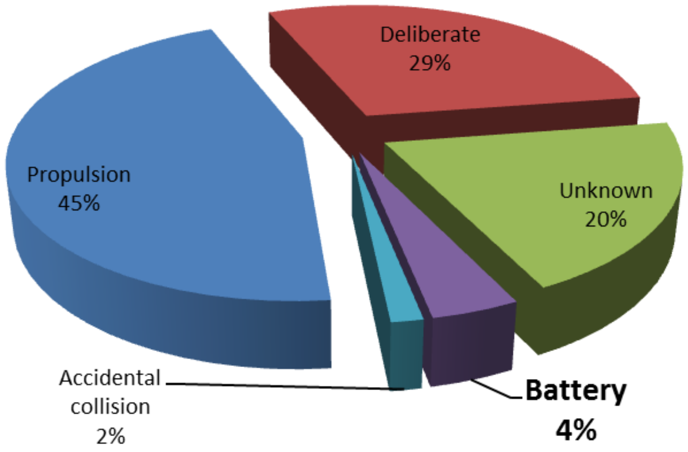
Need for high **probability of successful disposal operations** > 0.9

- Tendency = increase of this value due to increase of global space traffic

Note : passivation is not mandatory for LEO missions with controlled re-entries, because duration of uncontrolled phase is only ½ orbit

Electrical Passivation | Context and past studies

Causes of known satellite breakups until 2008.
Source: US Space Surveillance Network (SSN)



Why are we talking about Battery Passivation?

Main objective: avoid **space debris** generation

- **Assessing various passivation strategies.**
- **Understanding battery behaviour at End-of-Life under extreme conditions through testing.**

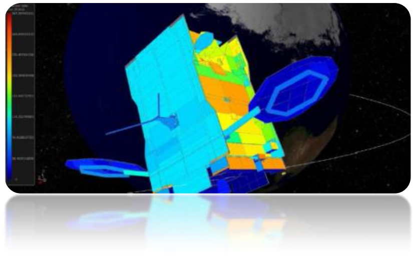
CNES Passivation/Fin de vie du sous-système de puissance

ESA GSTP Spacecraft Power System Passivation

CNES Battery Passivation regarding LOS constraints

2012 → 2013 → 2014 → 2015 → 2016 → 2017 → 2018 → 2019

2008: French law LOS (Loi d'Opérations Spatiales) applicable to satellites launched after 2020



ESA TRP Battery Passivation

CNES ABSL End-of-Life

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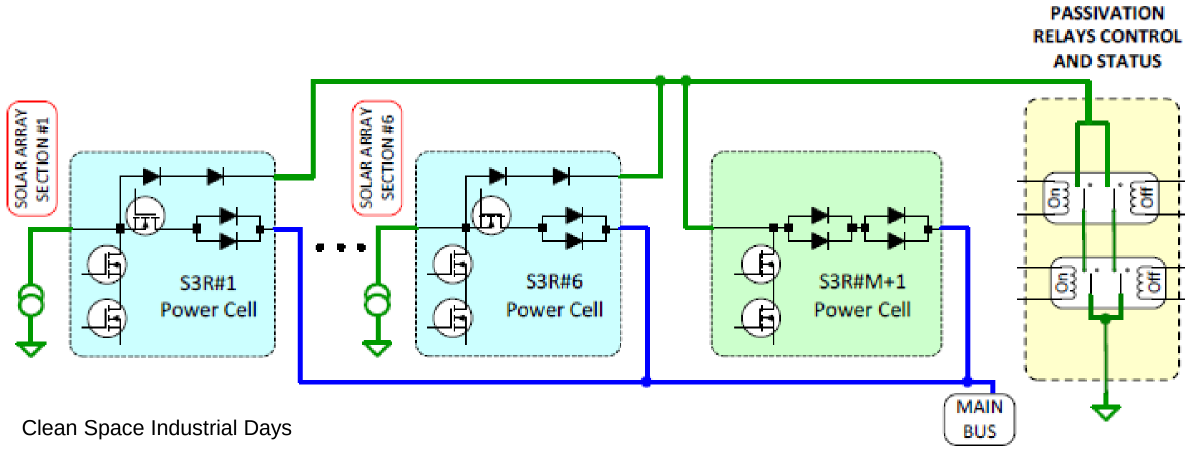
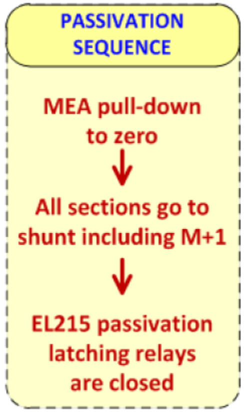
Electrical Passivation | Overall strategy for LEO, medium power satellite

- LEO satellite electrical passivation principles were defined with CNES in a dedicated study performed in 2012 in the context of the French Space Operations Act (FSOA)

- It requires specific hardware that has been introduced in power conditioning products; overall principles are the following:
  - Disable the solar array power generation by an action in the power conditioning unit (reversible actions):
    - On direct energy transfer (DET) system, the passivation is performed using relays that are shunting the solar array power, using dedicated commands
    - On maximal power point tracker (MPPT) system, the passivation is performed switching OFF the DCDC conversion path, using dedicated commands
  - The battery is therefore discharged by the spacecraft power consumption up to hardware under voltage detection threshold (set close to 0% battery state of charge)
  - The battery progressively discharge to zero Volt under remaining current leakage in the power system.





Electrical Passivation | Overall strategy for GEO satellite

- Geostationary orbit satellite electrical passivation principles are leveraging the existing capabilities of electrical power system hardware to perform the passivation

- Overall principles are the following:
    - Discharge the battery through balancing system up to minimal operational voltage of the battery (close to 0% state of charge)
    - The battery charge sections are disabled in a way they cannot recharge the battery
    - The solar array can still supply the main power bus, in particular power conditioning unit, data-handling system converter and telecommand receiver; nevertheless the EEPROM have been cleared up during the software passivation to avoid system restart
    - The battery progressively discharge to zero Volt under remaining current leakage in the battery passivation system.

Electrical Passivation | Overview of performed activities and conclusions

- Study performed with ESA on ***GSTP Spacecraft Power System Passivation at End of Mission***:
  Several passivation strategies have been identified and system environment has been assessed
  - Battery temperature was assessed for different satellites conditions → **maximal expected probable maximal temperature the range of +130°C**
  - Tests were performed on EEE (diodes, Mosfet, relays) involved in passivation functions to evaluate the long term behavior → **there is no parameter drift or weakness invalidating the passivation solution designs**

- Study performed with ESA in collaboration with ABSL/SAFT/CEA on ***TRP Battery Passivation*** studying state of the art of electrochemical cells under different test conditions:
  - Several test have been performed in various abuse conditions (short circuit, overcharge, high temperature…)
  - Test have demonstrated a **better robustness of electrochemical cell to temperature at low state of charge**
  - On the state of the art of battery cell, **no thermal runway is observed for cell temperature lower than 140°C**.

- **These studies are validating Airbus passivation strategies**

- **Future battery and electrochemical cell technologies shall be assessed in abuse condition to confirm the validity of the strategy**

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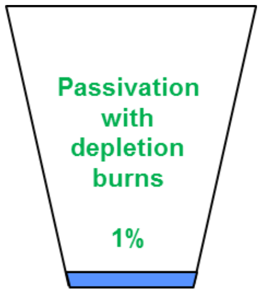
Propulsion passivation

Two solutions are used today :

Depletion burns through the thrusters

- Solution currently used for several existing product lines with chemical propulsion ➔ achievable final pressure very low (< 1 bar typically)
- Baseline for Xenon systems (for re-pressurization or for Electric propulsion) ➔ achievable final pressure very low (< a few bars, extremely low compared to burst pressure > 400 bars)



- ➢ Pro : no additional device (so no additional **complexity** and **risk** on the mission)
- ➢ Drawbacks : need for large set of units when done in Orbit Control Mode (limiting consequently the probability of success), and potentially long EOL operations

Use of specific passivation device

- Progressive implementation of dedicated passivation device in new product lines
  - on a case by case basis
  - selection is sometimes done by the Propulsion subsystem supplier (not by ADS)

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Passivation : way forward

Improving the passivation efficiency

Several adequate solutions are available or under development ➔ no real additional need identified

Improving the probability of success

Short term :

➔ Studying the possibility to passivate in more robust modes, with limited set of units (degraded modes, Safe mode)

Long term

➔ Studying the possibility of (more) autonomous passivation process

THANK YOU