System impacts of propulsion passivation

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Disclaimer:

This presentation summarizes the overall outcome of the performed studies in a general manner. Details can be found in the corresponding GSP documentation.

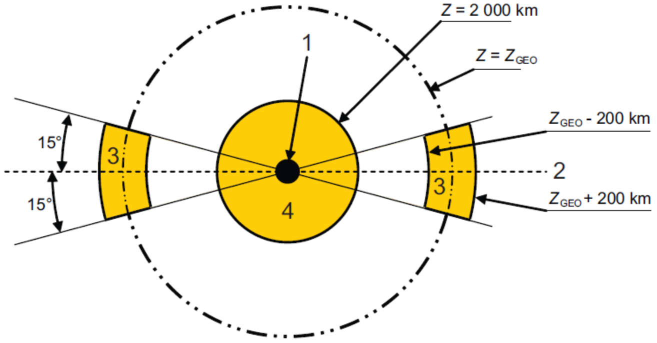
General intend of the study

General approach for all standards (ECSS-U-AS-10C with ISO24113, Space Debris Mitigation Policy for Agency Projects (2008), …) is the passivation of the space element. Listed requirements of ISO24113 are

3.4 Actions performed by a spacecraft or launch vehicle orbital stage to permanently reduce its chance of accidental break-up and to achieve its required long-term clearance of the protected regions → ACTIONS TO BE DONE

6.2.2.2 The determination of accidental break-up probability shall quantitatively consider all known failure modes for the release of stored energy, excluding those from external sources such as impacts with space debris and meteoroids. → NO EXTERNAL IMPACT

6.2.2.3 During the disposal phase, a spacecraft or launch vehicle orbital stage shall permanently deplete or make safe all remaining on-board sources of stored energy in a controlled sequence. → CONTROLLED SEQUENCE



Source: ISO24113:2011-Second edition

General intend of the study

Action plan is therefore needed to perform the controlled sequence to make safe or deplete all stored energy on board. ESA Space Debris Mitigation states

- Passivation is the depletion of all stored energy on board a space element. ESA Space Debris Mitigation states that the passivation is the *"Action to permanently deplete or make safe all on-board sources of stored energy in a controlled way in order to prevent break-ups"*
- Annex B is highlighting within the vulnerability analysis the need to assess micrometeoroids and debris impact *"The probability of an accidental break-up due to an impact or collision against an orbiting object is always not negligible. "*

→ High level requirements for passivation are defined!

→ What is the safe-state for the chemical propulsion system? What is a controlled way?

General intend of the study

Assessment on system prime level to investigate the corresponding needs for the subsystem chemical propulsion to passivate the spacecraft

a. What is the status of the S/C at EOL?
b. What risks are seen for this status?
c. What is needed in terms of equipment to reduce these risks?

Primes (OHB and Airbus) have investigated current platforms for their state and the associated risks. This includes the assessment of accidental breakup’s defined by ISO24113 as also the assessment of HVI.

References:

PPS-OSE-TN-0003_1A_TN3 System impacts of Propulsion Passivation Final Report – OHB

PPAS_finalreport_ESYS.TCN.PPAS.ADST.00051issue2 – Airbus

Propulsion Characteristics of ESA running missions - ESA

Systems used for the investigation

Several systems currently flying, under manufacturing or development were used for the assessment of critical aspects for the passivation (to indicate the thermal constraints, the sizes of the tanks, the residuals and the accommodation of the tanks). These systems consist of

- Monopropulsion system
    - PMD and diaphragm tanks
    - Different orbit heights for thermal impact assessment
    - Blowdown as also pressure regulated system
    - Different accommodation scheme for the tanks
- Cold gas system
    - Assessment of criticality of higher pressure

Systems used for the investigation

- Bipropulsion system with pressure regulation system
  - With or without PMD
  - Three different sizing cases for the fuel loading

→ Assessment of expected residuals is possible

→ Assessment of different passivation approaches (pressurant and propellant) possible

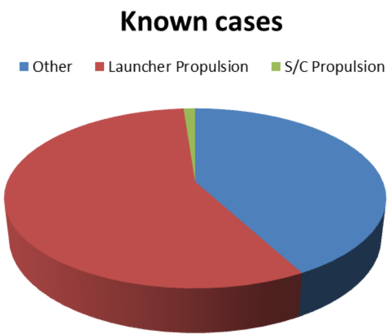
→ Assessment of impacts for cold gas systems

→ Assessment of pressures within the tanks during disposal phase

Primes also used their systems currently in development for the study to have even more reliable figures for the information needed

Critical aspects for chemical propulsion systems

Review of accidental break-ups has revealed that propulsion system is somehow "inherently safe" (usage of as much propellant as possible, passivation of the pressurisation system due to usage of pyrovalves, …). This is based on the number of breakup's due to spacecraft propulsion.



In the studies, the pressure levels at EOL for the systems were assessed and compared to the limitations of the system itself. Residuals for the systems were assessed or assumed.

Propellants are also assessed w.r.t. their potential thermal impact on the tank system. For the monopropulsion system, the consideration of decomposition is leading to a temperature increase and possible high temperatures within the tank.

Residuals and pressure increase

Residuals are in the order of a few percent

Hydrazine slightly higher indicated, around 3% for the cases assessed

Bipropulsion systems are in the order of 1%

Temperature increase of the residuals and decomposition of the propellants assessed. Pressures in tank can rise up to

- → Monopropulsion systems up to 35bar, still below the burst pressure of the tank
- → Bipropulsion systems up to 15bar and therefore still below MEOP of the tank

→ Main risk of these pressures are in combination with particle impacts!

→ Second main risk is the thermal runaway of the propellant inside the tank!

Main critical risk - HVI

Assessment done for different particle sizes and time in orbit

- Larger particles (more than 10mm diameter) are critical and leading in every case to an explosion of the tank due to the rapid decomposition of the remaining propellant. Nevertheless, risk is considered low due to low impact probability.
- Smaller particles are not leading to high risk. The probability of an explosion is only given for high temperatures within the tank.

→ Even if risk is small, remaining questions (which temperatures are reached for which time in orbit, experimental verification of the used approaches) are to be addressed in the future.

Propulsion passivation strategies

Current propulsion passivation strategies without special hardware:

- Passivation of the monopropulsion system by using the thruster in endless mode. Open question is still the usage of the thruster during passivation and the qualification of the thruster in this pressure regime.

- Bipropulsion system is used until telemetry is indicating bubble ingestion in the thruster. Remaining tank pressure are in the order of a few bars (up to 3 bar, remaining residuals).

- Pressure regulation system and therefore pressure within the helium tanks is currently not passivated.

Development plans

Passivation of the system is seen as critical aspect

- Impact of REACH on Pyrovalves
- Impact of limited life-time of the pyrovalve squibs

Corresponding development needs are addressed for the propellant and the pressurant side of the space propulsion system. For the monopropulsion system

- Qualification of the RCT's for the low inlet pressure range (assuming safe-mode usage during depletion phase)
- Qualification of a passivation device like a pyrovalve for longer mission lifetimes and without impact of REACH

Needs for bipropulsion systems:

- Most promising solution is usage of an electronic pressure regulator to deplete all stored energy (including helium) with increased performance.

Conclusion

- Chemical propulsion system is not one of the most critical items. Nevertheless, passivation is seen needed due to the risk of high velocity impacts and thermal runaway
    - Open questions and points are addressed and highlighted.
- Way forward for the passivation of the spacecraft is provided and feasible. Critical areas for the spacecraft system are identified.
    - Research opportunities are identified
- Development needs and opportunities for improvement of the overall chemical propulsion system are summarised.
    - Technological developments and corresponding roadmaps are available

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Questions?