Zero Debris Platform Study
Clean Space Industry Days 2026

ESA & Airbus, July 2026

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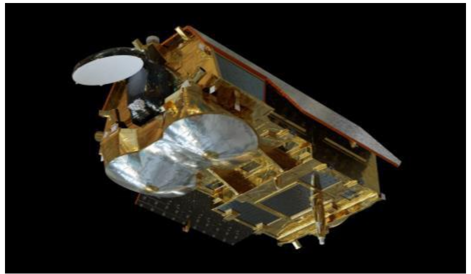
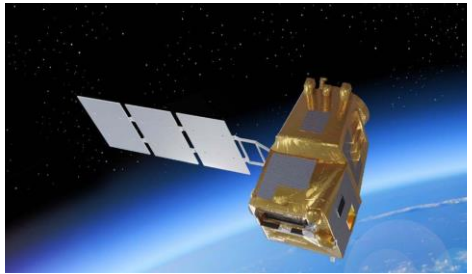
Objectives

- **Activity** based objectives:
    1. Identify and analyse **design drivers** and perform **trade-offs** to define technological solutions
    2. Pass a System Requirement Review (SRR)
    3. Identify and evaluate technology **developments** with potential **suppliers**.
    4. Define a **roadmap** for the ZD Platform evolution and technology development.

- **Technical** objectives:
    1. Understand drivers and solutions to reach a **fully demisable platform** design.
    2. **Modular implementation of controlled re-entry**: Identify and leverage development approaches and technologies to allow late implementation of a controlled re-entry.
    3. System **resilience**: How to anticipate and prevent failure to perform disposal due to internal, or external causes.
    4. **Mitigatory** operations and design: Understand which operations can still be performed to mitigate the risk (of unsuccessful disposal or to the environment) in case a **failure** occurs. To prevent **break-up risk** during mission lifetime and during the disposal phase.
    5. Preparation for **removal**: To identify and trade-off solution to prepare the satellite for removal

Study cases





	Cristal	LSTM	Sentinel-6C Hybrid
Real mission	Yes	Yes	No
Payload	Radar	Optical	Radar
Re-entry	Controlled	Controlled	Uncontrolled
Propulsion	Chemical	Chemical	Electric
Mass	1700 kg	1200 kg	1700 kg
Orbit type	Drifting polar orbit (92°)	SSO (98 deg)	Inclined (66 deg)
Orbit altitude	690 km	650 km	1336 km
ECSS applicable	Yes	Yes	Yes
Applicable SDM regulations	ESA policy	ESA policy	ESA policy
Export control constraints	No (EU dual use)	No (EU dual use)	No (EU dual use)
Market type (institutional/commercial)	Institutional	Institutional	Institutional

Introduction to requirements analysis and gaps identification

- A number of **requirements** from the SRD have been identified as challenging or have significant design impact on large LEO platforms. The most important ones are listed and discussed in following slides.

- **Gaps** have been identified to become compliant to the ZD SRD and meet the Zero Debris objectives:
  - The majority of the identified gaps are "**Knowledge gaps**". These can be closed by further fundamental R&D.
  - "**Definition gap**" are those where definitions or requirements are ambiguous. These need to be addressed by the agency. Industry can support.
  - "**Means gap**" are those which can be closed by technology development (at LSI or supplier).

- The following slides summarize those gaps which have significant impact on the PF or for other reason are considered important for outcomes of the study.

Summary of challenging requirements

Req. ID	Topic	Impact on PF design
ZDS-050 **ZDA-470**	Accidental **break-up probability**	**Blocking for orbits with high MMOD density** Current assumptions and methodology yields clear NC for typical orbits. Linked to GAP-3 and 5
ZDS-110 **ZDS-111**	**Probability of successful passivation**	**Major impact,** through to the end of life of at least 0,99 (TBC). Linked to GAP-12
ZDS-131	**Avoid debris generation**	**Impact unknown** It is not possible to verify this requirement for the time being because of the lack of tools and methodology to assess fragmentation Linked to GAP-3 and 4
ZDS-370	**Probability of successful self-disposal**	**Impact on design cannot be defined** without knowledge of **MMOD impact** consequences and agreed methodology Linked to GAP-3
ZDS-490	**Fully demisable platform**	With technologies and means, as of today, **it is not possible to show fully demisable platform** Linked to GAP-6 and 7

Requirements gaps

GAP-ID	Description	Gap type
GAP-3	To understand **efficiency of shielding solutions** and robustness of equipment against MMOD, HVI testing is needed to develop BLEs for a wider range of situations /configurations /shielding solutions	Knowledge gap
GAP-4	There are **no means to model fragmentation** following MMOD impact.	Knowledge gap
GAP-5	It is necessary to **characterize what kind of MMOD collision leads to break-up**. It is defined for the purpose of the study that break-up is same as catastrophic collision. Term needs to be defined by ECSS.	Definition gap
GAP-6	Tools for **realistic (and probabilistic) analysis of re-entry are needed. The assumptions for the analysis** need to be standardised. Modelling is observed having major impact on the analysis results. This applies for material models and how the model is constructed.	Means gap
GAP-7	**Demisable ECSS qualified units** with flight heritage is are not available.	Technology gap
GAP-12	**Safe level** in context of passivation of different units is not clearly defined. Clarification at ZD-SRD WS: A safe level of passivation is reached when any remaining stored energy cannot be expected to cause an accidental **break-up**.	Means gap Knowledge gap

General recommendation: Simplify requirements and focus on root objectives, not design solutions. E.g. passivation, residual orbit lifetime, disposal/passivation reliability, break-up risk etc. all have the same root objective to not generate additional debris.

Design driver analysis: Break-up risks

- The break-up risk during the operational lifetime due to MMOD collision for a mission like Cristal is exceeding the 10^{-3} threshold (ZDS-050)
  - Rather than putting the mission into question, there are several ways to move forward:
    - **Question the requirement**
    - **Question the methodology**
    - **Question the guidelines**
- A similar situation also applies to the **break-up risk during the disposal phase**

Design driver analysis: Vulnerability analysis

- A solid foundation is available from **manned spaceflight** when it comes to general methodologies and tools.
- However specificities of **uninhabited satellites lack heritage**.

- The vulnerability assessment is strongly dependent on the modelling of the different equipment exposed to MMOD impacts and on the associated BLEs (Ballistic Limit Equations).
- In order to progress on this topic, it is necessary to establish a more extensive **BLE** database and more detailed **guidelines** (e.g. should perforation of a housing be considered a failure, or can we be more detailed).
- It is also necessary to ensure that the **suppliers** produce adequate **information** about the characteristics of the material composing the equipment housing and geometries which is not necessarily available in the documentation delivered today.

Design driver analysis: Fragmentation analysis

- **Requirement** should be defined clearly (quantify fragmentation in the context)

- There is **lack of tools and methodologies** to perform fragmentation analyses (generation of ejecta)
- To provide the means to quantify / verify compliance it is necessary to:
    - Agree on the **tool framework** (can probably reuse a large part of the tools used for vulnerability analyses)
    - Define **modelling guidelines**
    - Establish **numerical models** for relevant configurations and materials (similar to BLEs for vulnerability analyses)

Design driver analysis: Demisability

- ➢ Demisability analysis based on detailed models confirms that platform with improved demisability is NOT fully demisable
- ➢ Due to the ongoing tool/data evolution there often are surprising results after updates, i.e. PCBs surviving re-entry

- ➢ For the demisability requirements ZDA-480/ZDS-490 **major gaps** have been identified in the methodology.
- ➢ Tools and methods are based on strong **simplifications** and **assumptions** which lead to high (and unquantifiable) **uncertainties**.
- ➢ Guidelines and tools leave a lot of room for interpretation or user error.

→A risk of wrong conclusions and overengineering.
→A risk of overlooking of actual problems.
→Very difficult to implement meaningful D4D and credibly demonstrate it achieves its goal in real life.

- ➢ Where **gaps** remain and cannot be avoided immediately, they should be clearly **acknowledged**
- ➢ Avoid stacking up **worst case assumptions**

Design driver analysis: Passivation

- The **probability of successful passivation requirement** ZDS-110 is applicable to all missions regardless of the re-entry strategy and sets a new very high threshold of **0,99** (TBC).

- Target can be reached by
  - Increasing **intrinsic reliability**
  - **Increasing redundancy** level of the equipment involved in passivation
  - Introduce additional equipment in the platform design

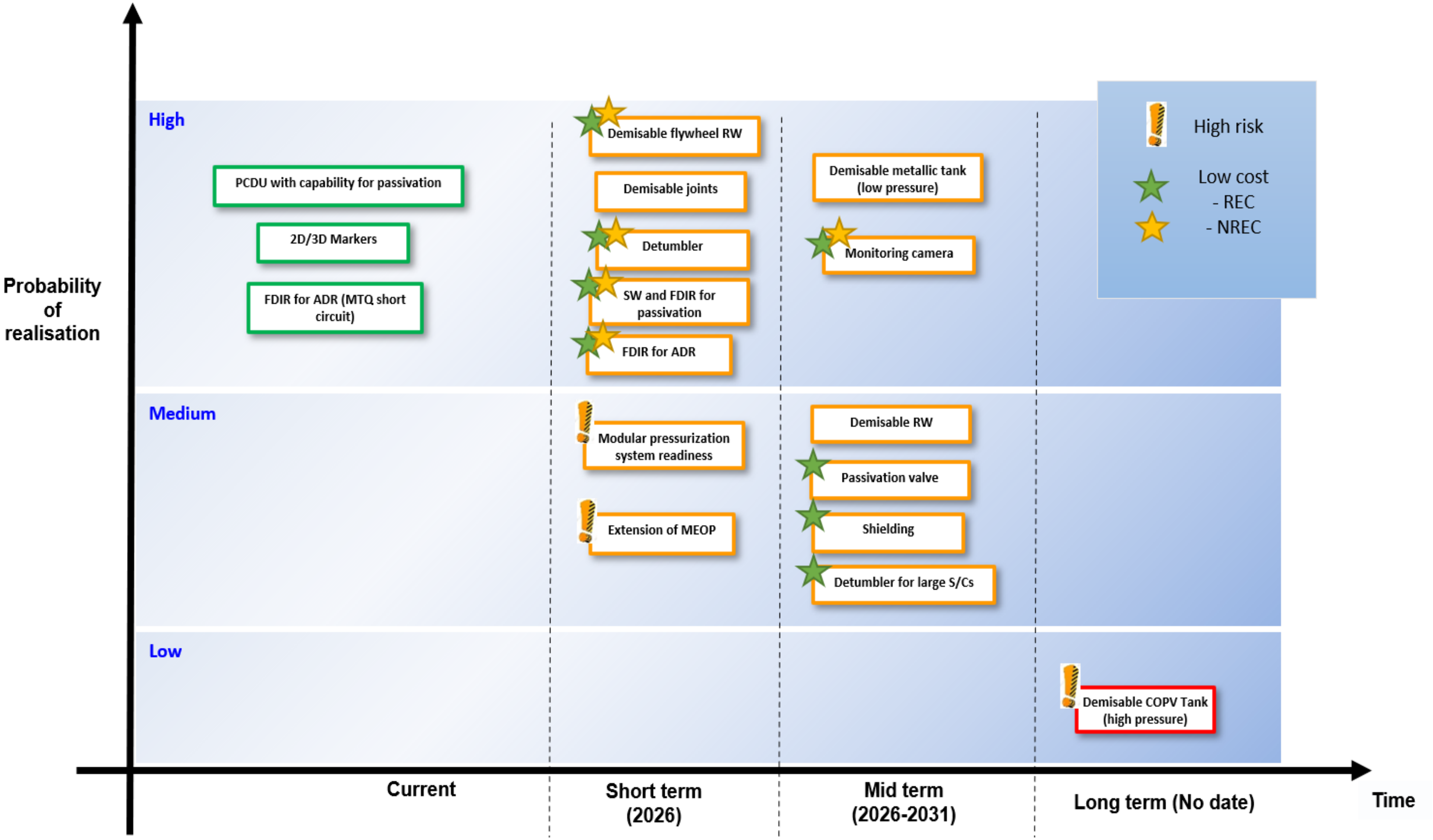
  → This can become a **major cost driver**

- For a **controlled re-entry**, it is proposed to take into account re-entry maneuver reliability

Identified required technologies to meet technical objectives

Technical objective	Technological solutions	Status
Fully Demisable Platform	Demisable equipment: Tank, HP tank, thrusters, RW, MTQ	Ongoing, priority on tanks and RWs
	Separation joints and separation technology	Requires detailed re-entry analysis
	Thermite implementation	Room for innovation
Modular implementation of controlled re-entry	Chemical propulsion - Scalable Tanks	To be taken into account in demisable tank development
	Chemical propulsion - (re-)Pressurisation	Re-design taking into account demisability
System resilience	Built-in monitoring devices, on-board algorithms, on-ground algorithms	To be further detailed
	Shielding	Early development
	Monitoring camera	Available solution to add observation & gather information
Mitigation operations and design	Fluidic passivation device	
Preparation for removal	Detumbler (medium & large)	Ready for in-orbit demonstration / design phase
	Detumbling function MTQ (Short circuit function as part of MTQ)	Feasible, no development at the moment

Platform evolution roadmap



Probability of realisation	Current	Short term (2026)	Mid term (2026-2031)	Long term (No date)
High	PCDU with capability for passivation 2D/3D Markers FDIR for ADR (MTQ short circuit)	★☆ Demisable flywheel RW Demisable joints ★☆ Detumbler ★☆ SW and FDIR for passivation ★☆ FDIR for ADR	Demisable metallic tank (low pressure) ★☆ Monitoring camera	
Medium		❗ Modular pressurization system readiness ❗ Extension of MEOP	Demisable RW ★ Passivation valve ★ Shielding ★ Detumbler for large S/Cs	
Low				❗ Demisable COPV Tank (high pressure)

Time

❗ High risk

Low cost
★ - REC
☆ - NREC

Conclusion: Technical objectives status

ID	Objective	Status
T-OBJ1	**Fully demisable platform** To understand drivers and solutions to reach a fully demisable platform design.	Not yet achieved and unrealistic to fully achieve
T-OBJ2	**Modular implementation of controlled re-entry** To provide the means to anticipate required changes in case a controlled re- entry which was not foreseen is needed. This change shall minimize impacts on mission design to have a robust platform design as soon as possible in thedevelopment phase.	Already Achieved
T-OBJ3	**System resilience** To understand how to detect and prevent failures to perform disposal due to internal (reliability, subsystem failure, loss of redundancy), or external causes (collision with non-trackable debris)	Partially achieved
T-OBJ4	**Mitigatory operations and design** In case a failure occurs, to understand which operations can still be performed to mitigate the risk (of unsuccessful disposal or to the environment) To prevent break-up risk during mission lifetime and during the disposal phase.	Partially achieved
T-OBJ5	**Preparation for removal** To identify and trade-off solution to prepare the satellite for removal	Already Achieved

DEFENCE AND SPACE

Thanks a lot for your attention! Questions?

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