Addressing DRACO mission phase A design challenges

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(a) Elecnor Deimos, (b) European Space Agency, (c) von Karman Institute for Fluid Dynamics, (d) R.Tech

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Contents

DRACO mission objectives

Space debris mitigation requirements → implies → Increased number of destructive re-entries → implies → De-risking strategy for people safety

Multi-disciplinary physics of destructive re-entry processes is poorly understood

DRACO is intended to:

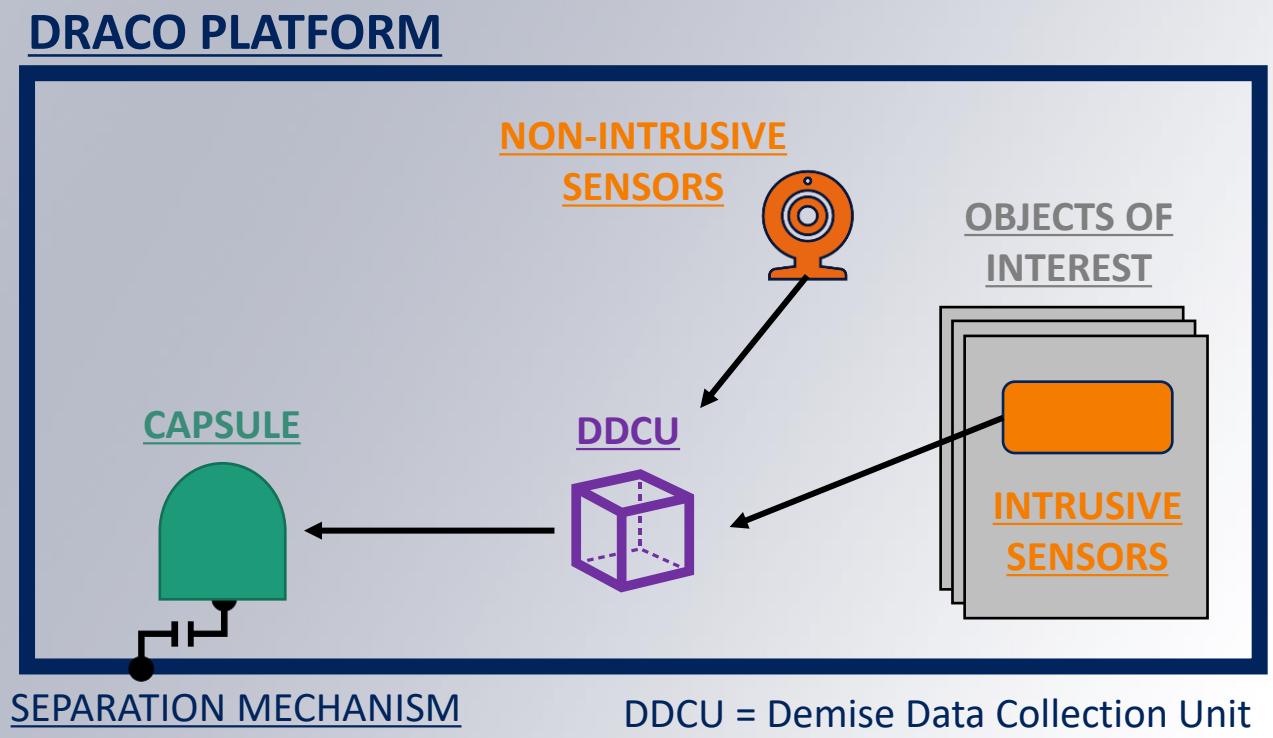
1) Validate space debris re-entry predictive models with in-flight data
2) Demonstrate fundamental understanding of re-entry break up and ablation behaviours (in view of Design 4 Demise strategies)
3) Verify on-ground demise testing with actual in-flight data

To design a **representative LEO platform** to record in-situ the break-up sequence and ablation process during a destructive re-entry.

Instrumented by a **device that collects data during the destructive re-entry** and transmit them.

System concept

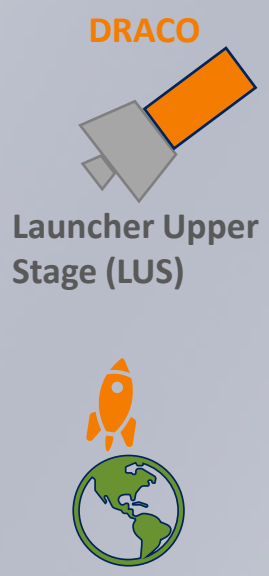
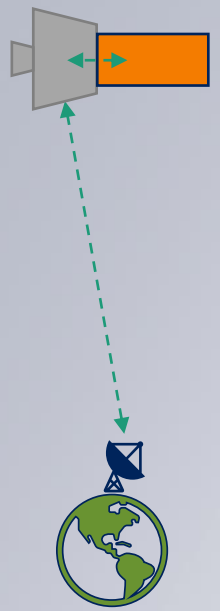
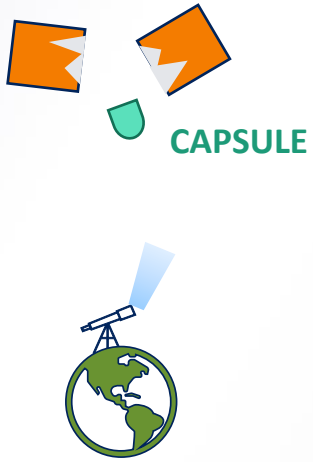
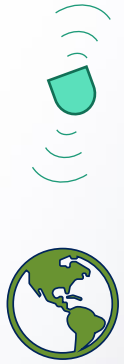
- Dry mass of **at least 100 kg**
- Wet mass of **maximum 200 kg**
→ Representative of LEO satellites



DDCU = Demise Data Collection Unit

- **Sensors** will measure temperatures, deformations, objects separation detection and qualitative imaging of the environment.
- Data **from sensors** collected by **DDCU** and transmitted to the **CAPSULE**.
- Objects of Interest (OoI) can be functional or non-functional. The **structure demise** will be studied too.
- The platform may be equipped with **additional functional components**.

Mission concept

1) LAUNCH	2) ORBITAL PHASE	3) SEPARATION	4) RE-ENTRY	5) FRAGMENTATION	6) DESCENT	7) FLOATING + RECOVERY (TBC)
	**Check-out** of DRACO (autonomous or by LUS) before release (TBC) 	DRACO **separates** from LUS after final re-entry manoeuvre 	At **120 km** start **data collection** of the destructive re-entry 	Break up and **release of the capsule** External observation campaign (TBC) 	**Data transmission** from the capsule to satellites and/or ground stations 	**Transmission up to 3h** while floating and recovery of the capsule (TBC) 

Re-entry external observation campaign

Driving Parameter	1. Ground-based	2. Airborne-based	3. Sea-based
Cost 46%	+ Low operational costs	- High cost, can be reduced by sharing the flight (may cause schedule conflicts)	- High cost, can be reduced by sharing the platform (may cause schedule conflicts)
	4	**2**	**2**
Trajectory Observation Flexibility 10%	- Constrained by ground infrastructure location **(e.g., can be problematic to observe the SPOUA region)** + Large aperture	- Constrained by air traffic control and political borders - Limited by maximum flight hours + High flexibility in reaching the observation point of interest	- Constrained by ship ports of call + Mid flexibility in reaching the observation point of interest
	3	**4**	**2**
Data Quality 16%	+ Large aperture and long focal length optics ensure improved spatial resolution	- Limited spatial resolution due to small window apertures (diffraction limit) - Image degradation due to plane vibrations induced to instruments	+ Long focal length optics can be used improving spatial resolution - Suffer the sea perturbations and ship-motor induced vibrations, a gyro-stabilized system is needed
	4	**2**	**3**
Sky Visibility 28%	- Weather influences the visibility (clouds, moisture) - Suffer atmospheric effects (long atmospheric paths)	+ Can operate above cloud level, improving visibility	- Weather influences the visibility (clouds, moisture) - Suffer atmospheric effects (long atmospheric paths)
	3	**5**	**3**
NORMALIZED RANKING VALUE	**40%**	**33%**	**27%**

Criteria weights are computed using the Analytic Hierarchy Process

Sensors selection

Temperatures → **Thermistors**

+ very high accuracy
- limited temperature range

→ EXCLUDED

Temperatures → **Thermocouples**

+ good accuracy
+ extended temperature range
+ high TRL

→ BASELINED

Deformations → **Strain Gauges**

+ Micro-dimensions
+ Acceptable max temperature
  → may need TPS

→ BASELINED

Objects separation → **Joint contact switches**

+ Micro-dimensions
– Low max temperature

→ Further study needed

However, some objects may separate before reaching that temperature → Better to protect the underlying structure of OoI or to keep the scenario representativeness ?

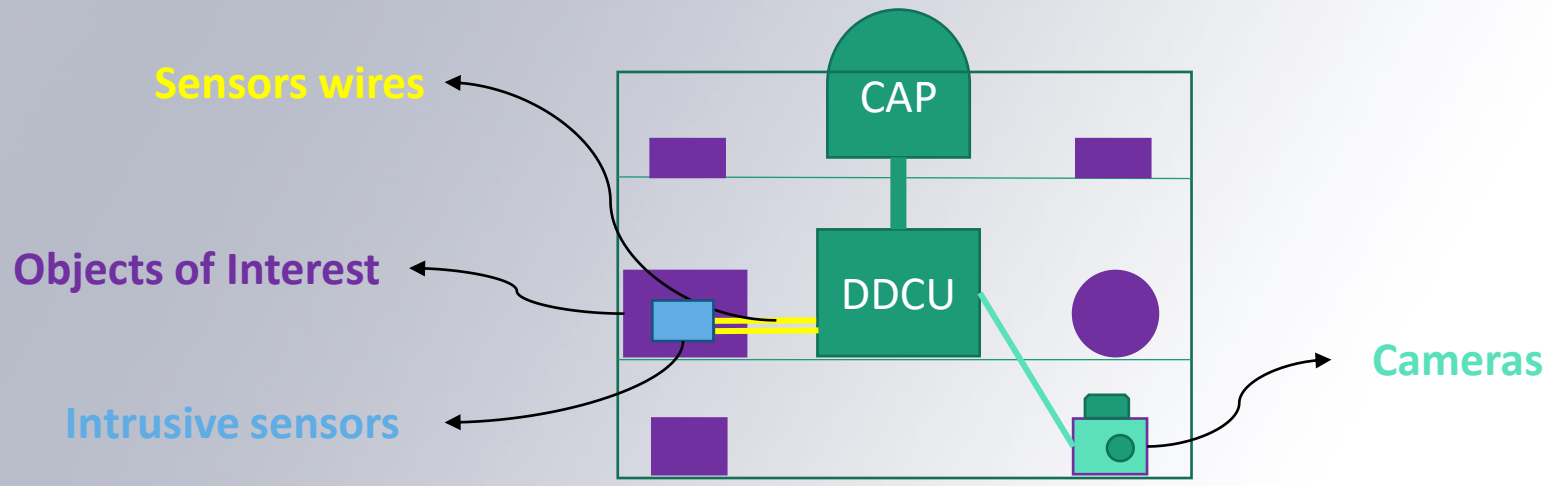
Qualitative imaging of the environment → **IR cameras**

+ Can measure high temperatures
– Limited operational temperature (needs TPS)

→ Further study needed

Accelerations → **Capsule IMU**

Spacecraft configuration



Capsule on top (with thermal protection) → “easier” capsule release

Design challenges:

- DDCU and DDCU-capsule connection need thermal protection
- Temperature reached by wires outside the “box with TPS” and so the reached one at DDCU interface
- Cameras (and its harness) TPS

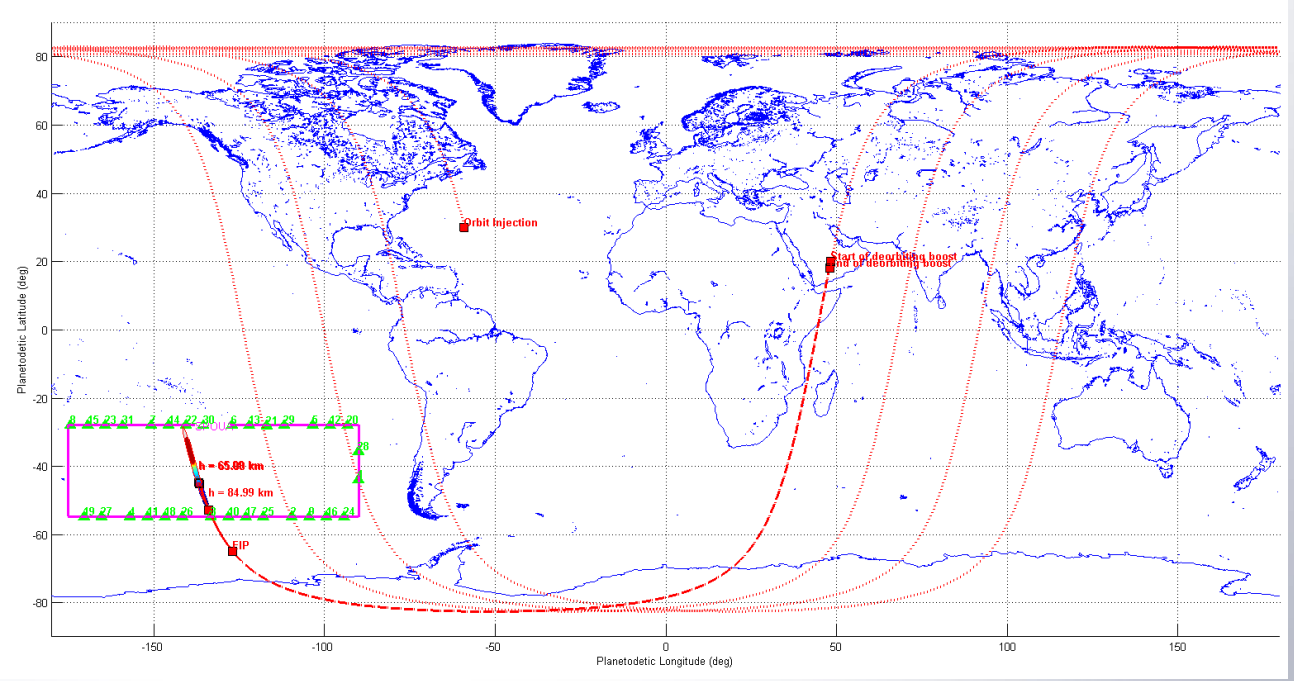
Preliminary mission analysis

A de-orbit maneuver from a typical VEGA target orbit (SSO @ 500 km) with AVUM+ allows to target entry conditions in the range of interest for DRACO.

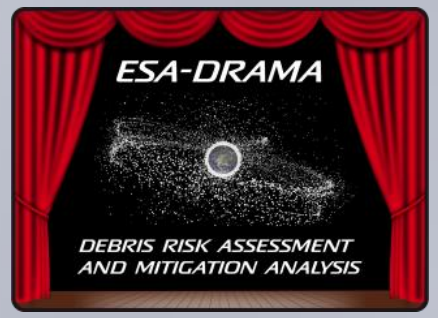
The **mission depends on the Launcher schedule** (e.g., VEGA-C or other micro-launchers).

31 opportunities identified, 7 opportunities selected as potential solutions for re-entry analysis:

- **#3: short mission, 5.8 hrs after injection →**
- #4: short mission, 7.5 hrs after injection
- #6: mid-short mission, 16.5 hrs after injection
- #15: mid-long mission, 43.3 hrs after injection
- **#21: long mission, 63.8 hrs after injection**
- **#27: long mission, 80 hrs after injection**
- #28: long mission, 86 hrs after injection



Objects of Interest selection



DRAMA and **PAMPERO** are adopted to **study the demisability of DRACO and to support the selection and the accommodation of the Objects of Interest**.

Available Mass for OoI: 40 kg

Available Volume: all the empty space of the three floors

Object	Criticality	Reason
Battery	LOW	Cells have steel can / large number of cells
Electronics Card	MEDIUM	High GFRP failure temperature
Fill & Drain Valve	HIGH	Titanium part
Gyroscope	HIGH	Titanium housing
Magnetorquer	LOW	Magnetic core (higher melting point than steel)
Propellant Tank	HIGH	Titanium material
Reaction Wheel Shaft	MEDIUM	Steel material; multiple objects
Reaction Wheel Flywheel	HIGH	Steel material; multiple objects
Solar Array	LOW	Low ballistic coefficient
Structural Panels	LOW	Low ballistic coefficient (demise in component based model)
Mirrors (Zerodur)	MEDIUM	Zerodur material
Mirrors (SiC)	HIGH	Ceramic material
Thrusters	MEDIUM	Inconel material
Optical payload fixings	HIGH	Invar / titanium materials
Solar Array Drive Mechanism	HIGH	Steel central shaft
Star Tracker	HIGH	Internal titanium parts
Lenses	HIGH	Silica material

Classification of space-debris critical components in terms of ground risk has been subject of several investigations in the literature.

This list constitutes the baseline for the OoI under consideration for DRACO

Objects → functional or dummy according to the platform

Objects → conventional or demisable

J. Beck, I. Holbrough, J. Merrifield, M. Spel, J-M Papy, D. Briot, S. Bianchi, E. Minisci: Probabilistic assessment of spacecraft demise (PADRE): Final Report, Issue 1 (2020)

Objects of Interest selection

Criteria for the OoI selection:

Scientific return based on the number and variety of objects, their representativeness for small satellites, and the presence of D4D objects.

Costs score inversely proportional to the number of objects; it depends also on the market (choosing from European markets increase this number) and the choice to have multiple objects for the same item.

Compatibility of the OoIs with the sensors (also if the objects can be easily measured by the sensors) and positioning with respect to the cameras.

- Propellant tanks
- Reaction wheels
- Magnetorquers
- SADMs & solar panels
- Star trackers
- Batteries
- Mirrors
- Gyroscopes
- Demisable joints and inserts

Location of OoI is decided to ease their presence in the FOV of cameras and ensure its demise is properly monitored.

DRACO mission challenges

Only Medium and High Exposure ones here reported

DDCU loss due to destructive re-entry before completion of data transfer to the capsule

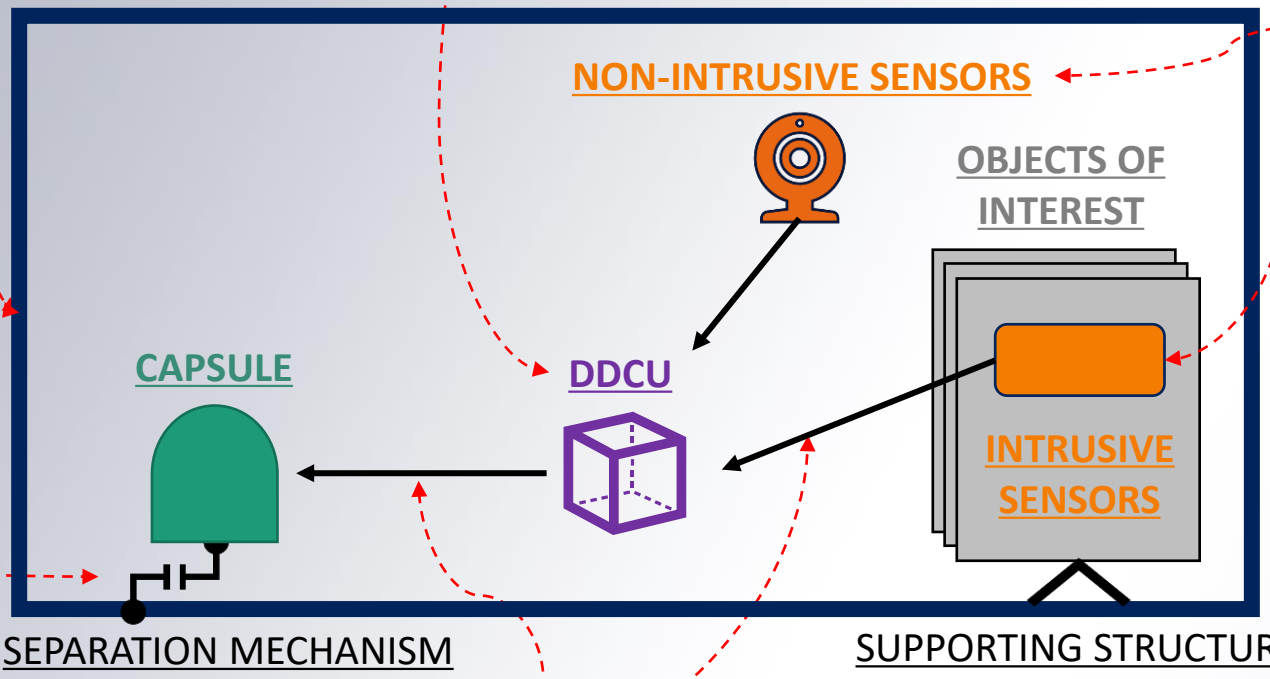
Re-entry angle shallower or steeper than the one requested due to LUS propulsion/AOCS and/or separation mechanism malfunction.

Sensors malfunction due to destructive environment

Small envelope available for harness routing along the platform decks and panels compatible with a reduced exposure to high temperatures

Loss of sensor data due to early demise of the underlying structure or of the unit/sensor harness.

Separation mechanism damage due to the environment, interfering with capsule release.



Loss of connections between measuring devices and DDCU, and between DDCU and capsule.

Mission way forward and conclusions

Mission level

- Effect of LUS **injection accuracy** on the demisability behaviour, both attitude (e.g., tumbling) and positioning

System level

- **OoI iterative selection and accommodation**, including **D4D components** (e.g., joints, magnetorquers, tanks, RWs, SADM, etc.)
- **Sensors distribution** over OoI and structure, **cameras placement and thermal protection**
- Consolidation of internal structure material to **exclude early termination of the scientific window**
- **Thermal protection system** for DDCU and harness
- **Capsule release mechanism** design

Thank you for the attention!

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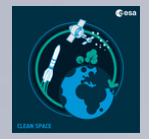

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