DRACO mission phases A-B1 outcomes and way forward

Paolo Minacapilli[a], Saul Campo[a], Mercedes Pavia[a], Gabriele De Zaiacomo[a], Andreea Burlou[a], Santiago Molina[a], Angel Naranjo[a], Carmen Fuentes[a], Andrea Fabrizi[a], Andrea Pizzetti[a], Andrés Caparrós[a], Biagio D'Andrea[a], Guillermo Asensio[a], Guillermo Silva[a], Stijn Lemmens[b], Beatriz Jilete[b], Benjamin Bastida Virgili[b] , Simone del Monte[c], Amandine Denis[c], Bernd Helber[c] , Eddy Constant[d], Gauthier Brives[d], Martin Spel[d]

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

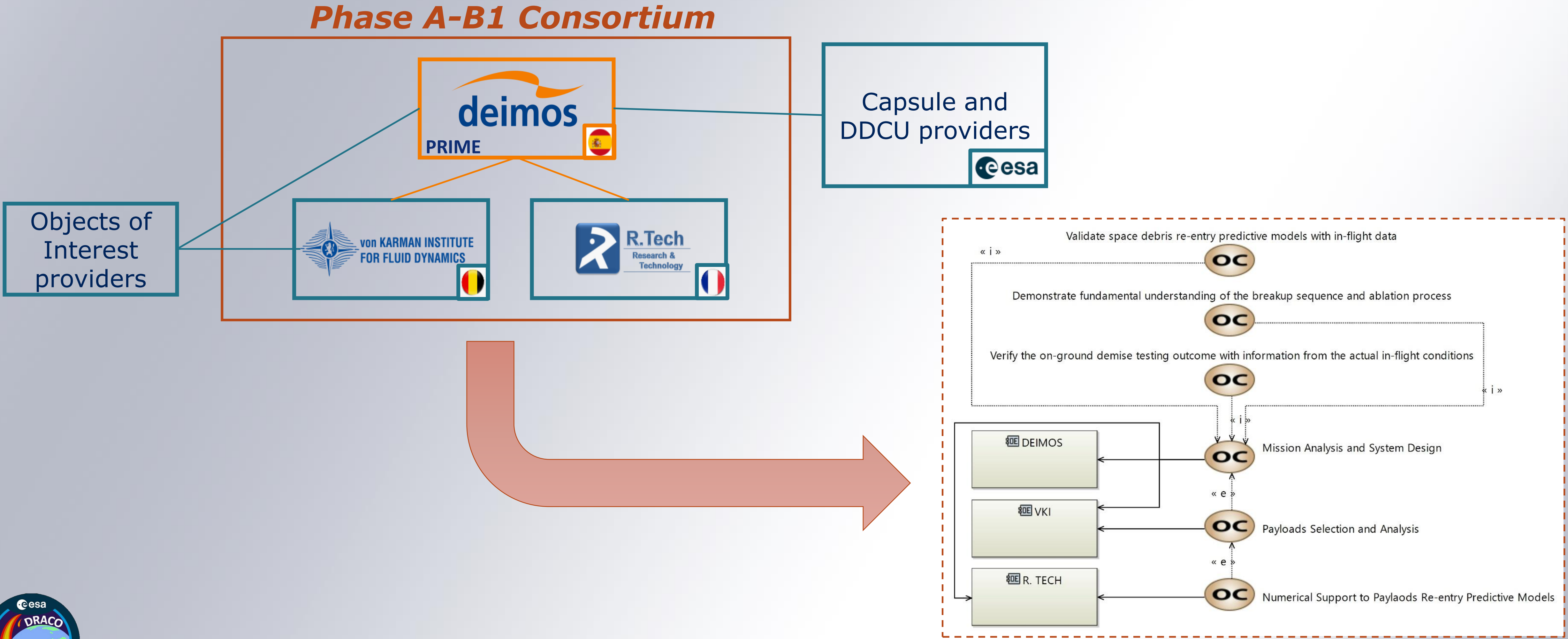
Clean Space Industry Days (CSID)
ESA-ESTEC, Noordwijk,
The Netherlands

16-19 October 2023

19th October 2023

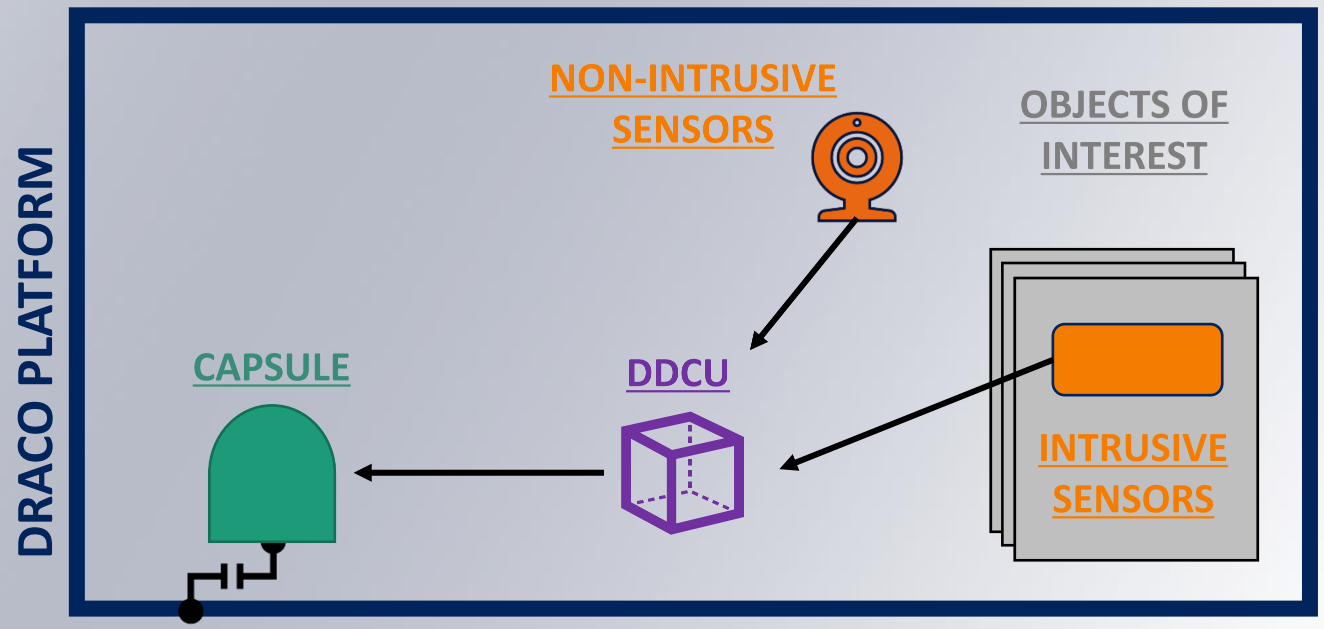
Contents

Project Framework and Consortium



19th October 2023

System Concept



DRACO PLATFORM

NON-INTRUSIVE SENSORS

OBJECTS OF INTEREST

CAPSULE

DDCU

INTRUSIVE SENSORS

SEPARATION MECHANISM

DDCU = Demise Data Collection Unit

Sensors data collected by DDCU and transmitted to the CAPSULE.

- Dry mass of **at least 100 kg**
- Wet mass of **maximum 200 kg**

→ Representative of LEO satellites

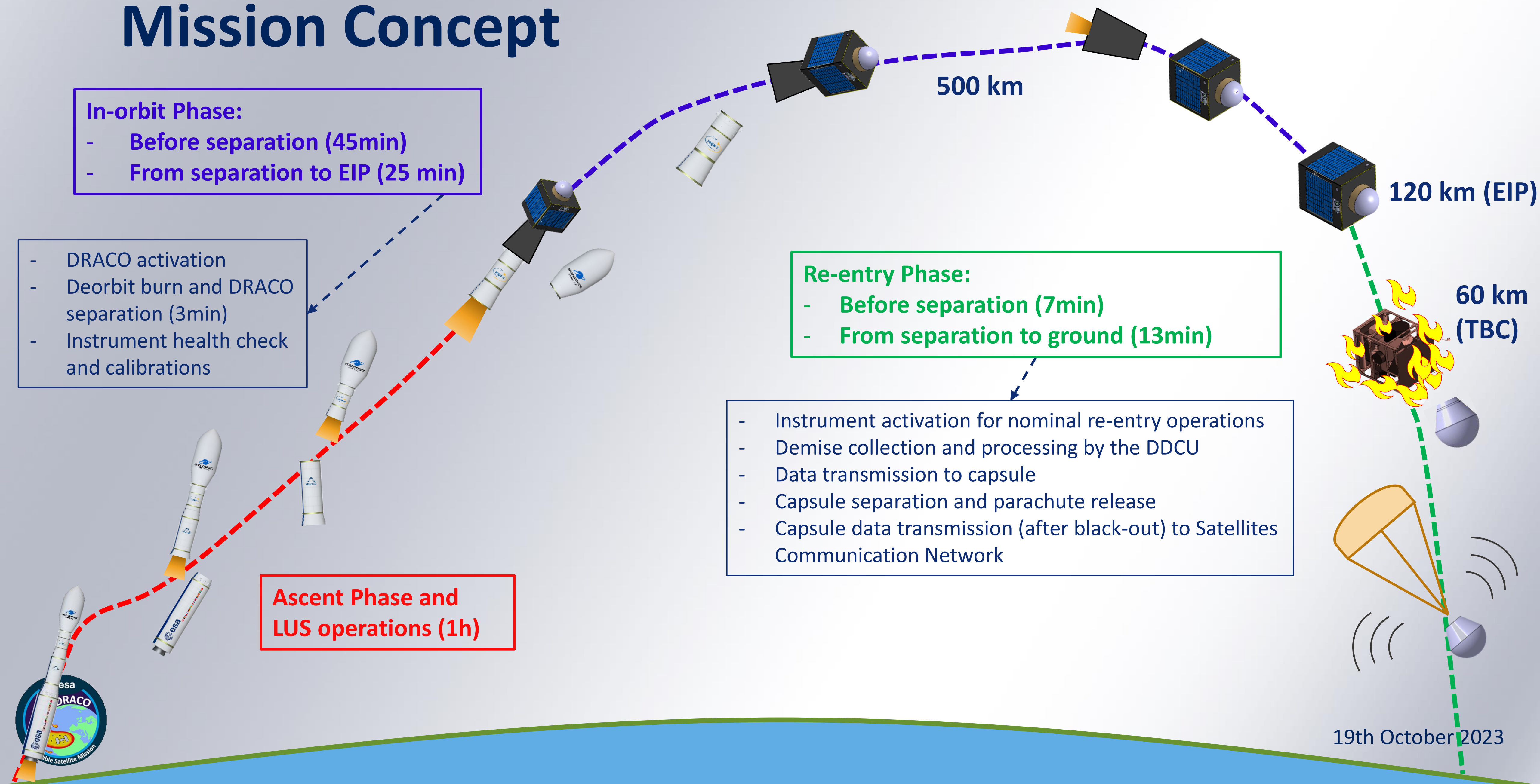
Instrument*: includes the capsule, the DDCU and the sensors (thermocouples, strain gauges, cameras).

Host platform: service module for the Instrument.

Objects of Interest (OoI): collection of components to be observed while demising during the destructive re-entry.

esa deimos von KARMAN INSTITUTE FOR FLUID DYNAMICS R.Tech Research & Technology

Mission Concept



In-orbit Phase:

- Before separation (45min)
- From separation to EIP (25 min)

- DRACO activation
- Deorbit burn and DRACO separation (3min)
- Instrument health check and calibrations

Re-entry Phase:

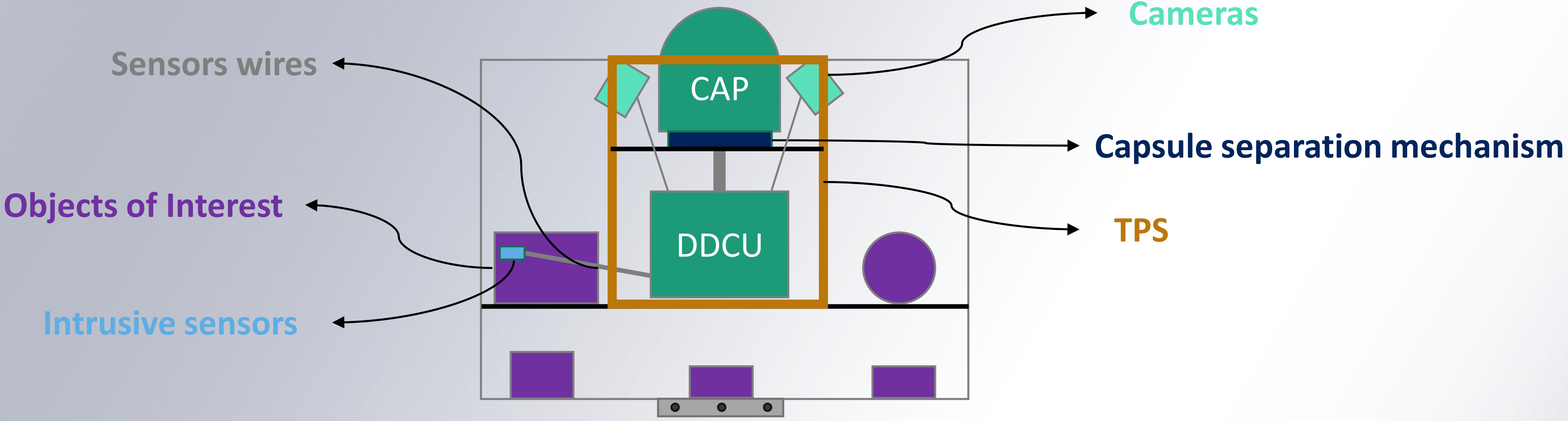
- Before separation (7min)
- From separation to ground (13min)

- Instrument activation for nominal re-entry operations
- Demise collection and processing by the DDCU
- Data transmission to capsule
- Capsule separation and parachute release
- Capsule data transmission (after black-out) to Satellites Communication Network

Ascent Phase and LUS operations (1h)

19th October 2023

Design Challenges



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

Components inside TPS box need to **survive to the re-entry**.

Design challenges:

- DDCU and DDCU-capsule connection need thermal protection
- Capsule separation mechanism shall survive the re-entry to guarantee safe capsule release
- Temperature reached by wires outside the "box with TPS" → need high temperature cables
- Cut-outs on TPS may cause its failure

Intrusive Sensors Selection

Temperatures	Thermistors	+ very high accuracy (± 0.05°C to ± 1.5°C) - limited temperature range (T_{max} 100°C)	→ Excluded
	Thermocouples	+ good accuracy (type K min. accuracy of 9.5°C) + extended temperature range (-200 + 1250 °C) + high TRL	→ Baselined
Deformations	Strain gauges	+ micro-dimensions + acceptable max temperature (~1300 K) →may need TPS	→ Baselined
Object separation	Micro contact switches	+ micro-dimensions - low max temperature (< 500 K) - switch lever operational difficulties	→ Excluded
	Thermocouples	+ already present TCs re-used (no extra data) + extended temperature range	→ Baselined
Acceleration	Capsule IMU	+ low cost, reduced size and weight, robustness and reliability - computing complexity (accumulations in errors in navigation)	→ Baselined

Optical Sensors Selection

Imaging of the environment

- Visual cameras
- Infrared cameras
- Plenoptic cameras

Considering CMOS:

\+ Low power consumption and costs

\- Low sensitivity

\- Re-entry at night

→ **Excluded**

\+ Can measure high temperatures

\- Limited operational temperatures → needs TPS

→ **Baselined, high FOV needed**

\+ Follow distancing objects with great definition

\+ No fixed focal point

\- Change focus after capturing

→ **Excluded**

Harness Thermal Protection

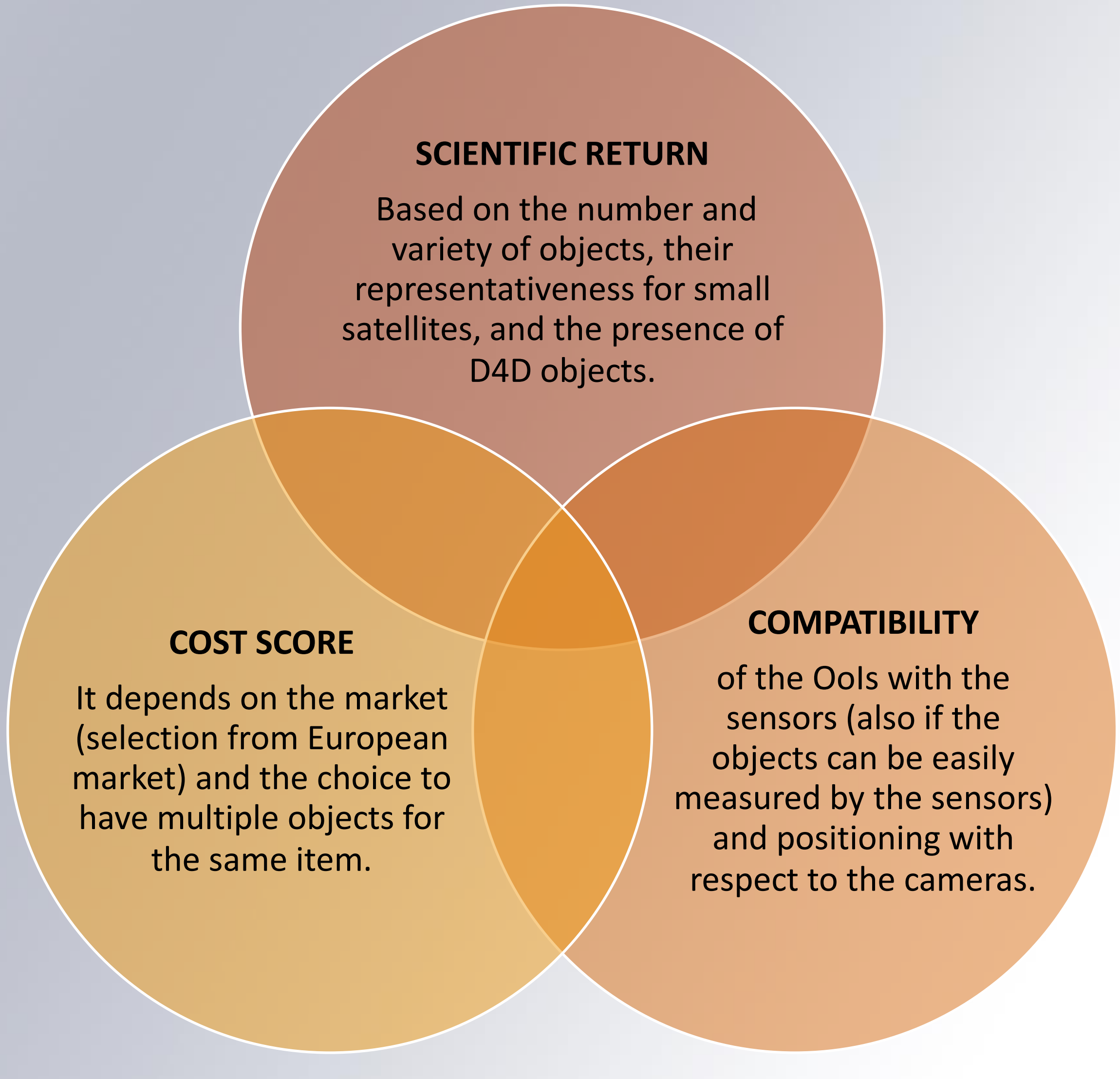
Sensors Harness → Extreme temperatures while on the re-entry. Compatibility with gauge and thermocouples diameters.

Capsule-DDCU Harness → Lower temperatures within the TPS, but high-temperature wiring could be used to increase the reliability of the system.

Harness Connectors → Thermal inertia will help keep the temperature of the connectors under an acceptable threshold thus allowing for standard market ones to be used (DDCU side, inside TPS box).

A **requirement for the temperature of connectors** is key, modelling the conduction heat transfer from wires outside the TPS box to connectors at DDCU side.

Objects of Interest Selection



SCIENTIFIC RETURN

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

COST SCORE

It depends on the market (selection from European market) and the choice to have multiple objects for the same item.

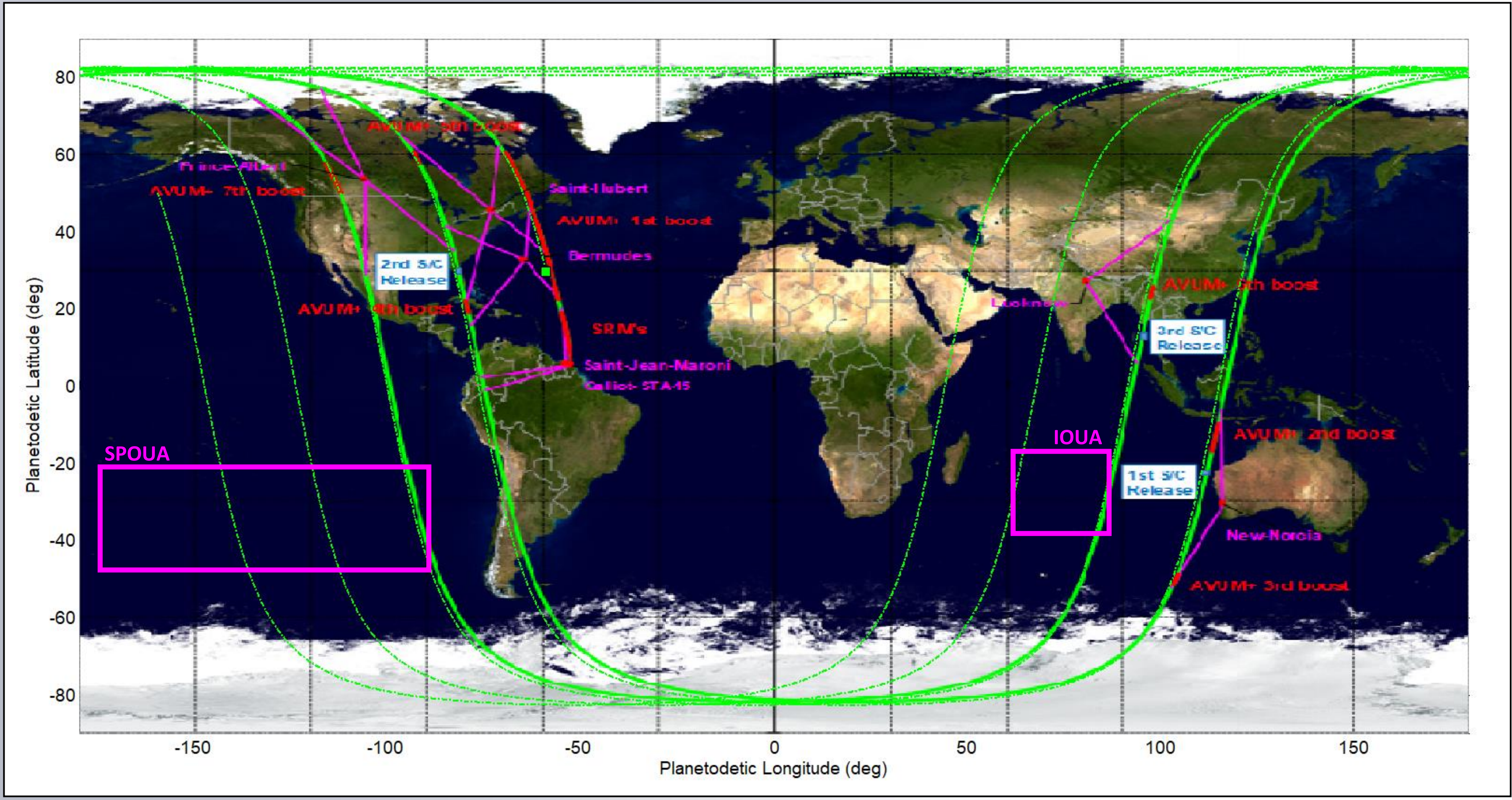
COMPATIBILITY

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

- Composite propellant tanks
- SADM
- Mirrors samples
- Magnetorquers (incl D4D)
- Reaction wheels (incl D4D)
- Star trackers
- Batteries
- Gyroscopes
- Host Structure
- …

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

Mission Analysis: orbital phase



Assuming VEGA-C mission profile for the preliminary mission analysis.

A reference orbital phase was propagated by DEIMOS to reproduce a typical VEGA-C mission (SSO @500 km).

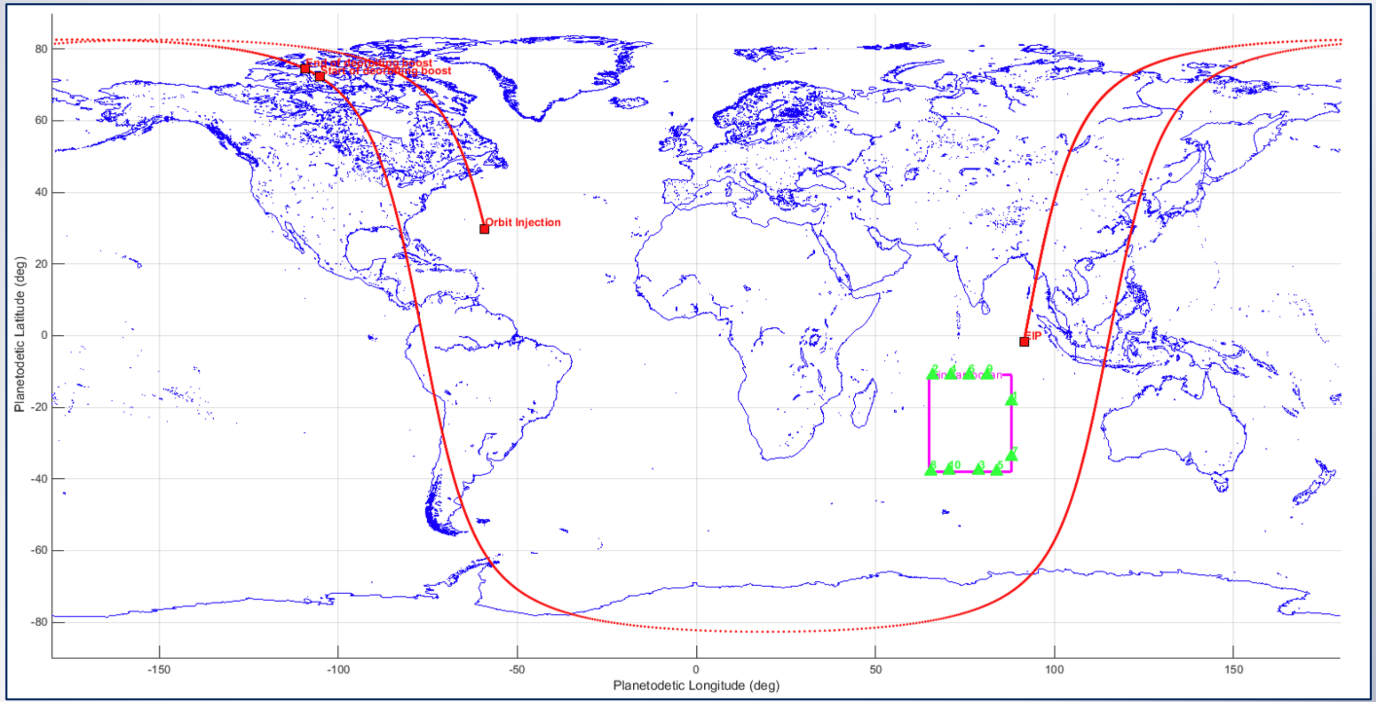
Unpopulated regions are identified as target disposal regions: SPOUA and IOUA.

Mission Analysis: re-entry orbit

Dependance on the selected launcher and associated mission profile

Baseline mission ground track → :

- Flight Path Angle (FPA) at Entry Interface Point (EIP) of -2.3° (guaranteed by AVUM)
- Indian Ocean re-entry

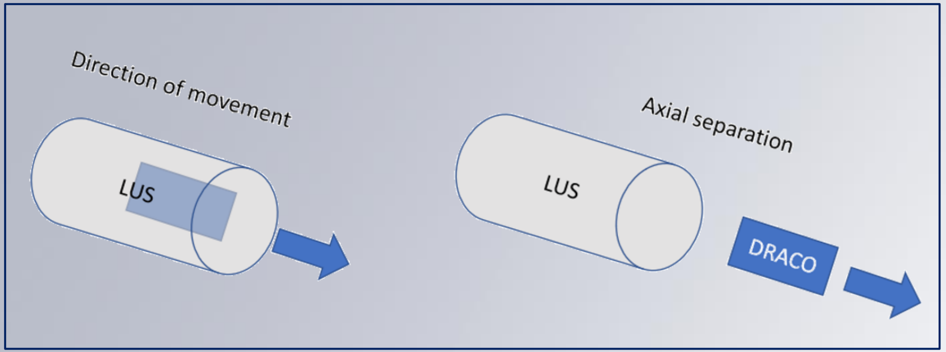


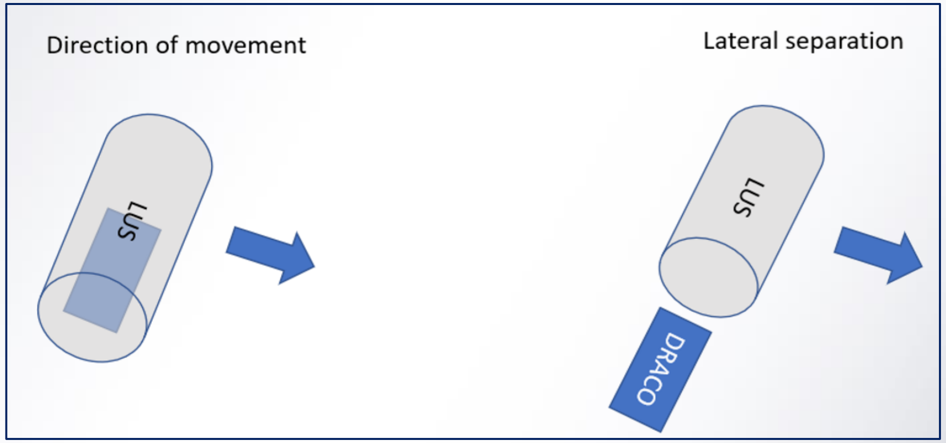
Backup options:

- FPA at EIP of -1.5° → shallower re-entry, more representative for uncontrolled re-entry
- SPOUA re-entry

Assessment of the Separation Manoeuvre

- A parametric analysis of the separation manoeuvre was run in order to support the definition of the DRACO's separation mechanism.
- Representative separation ΔV considered up to 1 m/s
- Two separation strategies: axial and lateral





The separation maneuver has a minor impact on the entry conditions:

- Negligible impact on the entry FPA, heading, and velocity.
- Changes in the EIP location in the order of tens of km.

19th October 2023

Re-entry Analysis: On-ground Casualty Risk

The re-entry simulation campaign consists of the following analysis:

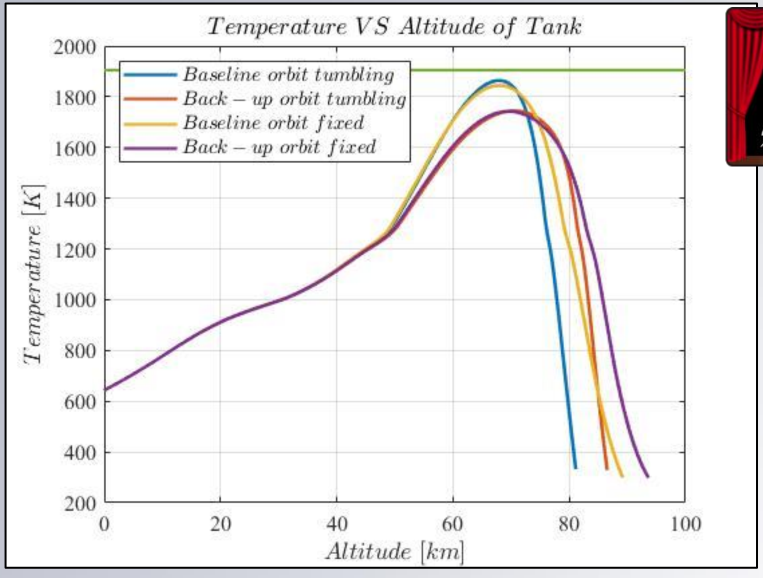
- Nominal entry conditions for the reference mission: controlled re-entry baseline and back-up case
  - The resulting **on-ground risk for the nominal controlled cases is 0**, since the surviving fragments are targeting an unpopulated area of the Indian Ocean.
- Dispersed entry conditions for the reference mission: controlled re-entry baseline and back-up case
  - The casualty and fatality risk associated with the **dispersed controlled re-entry is equal with 0** for all the cases.
- Non-nominal entry conditions: uncontrolled re-entry
  - For the uncontrolled re-entry case the **risk is 1.662x10-5 being compliant with the risk requirement of 10-4.**

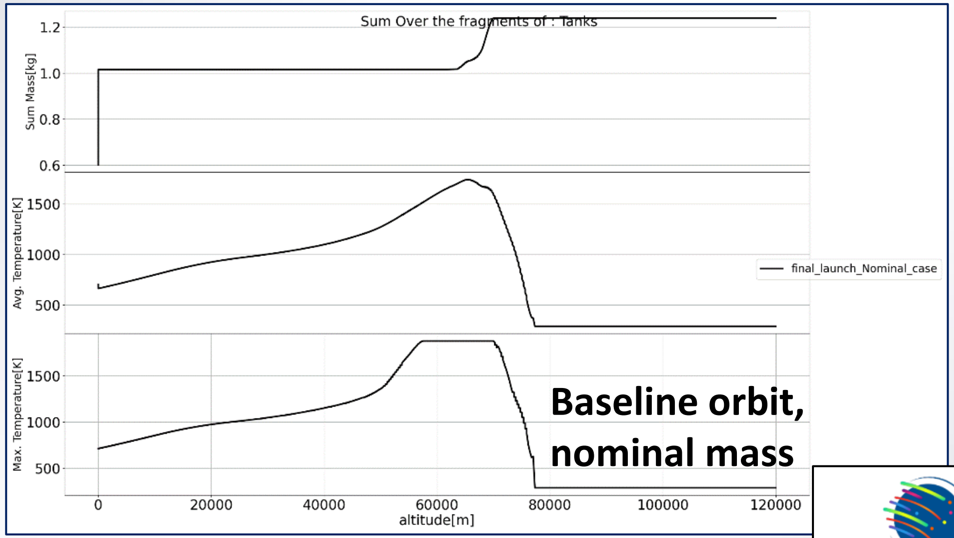
A preliminary mission robustness assessment was carried out to demonstrate that the potentially surviving fragments footprint does not extend over inhabited regions.

Simulations in DRAMA and PAMPERO

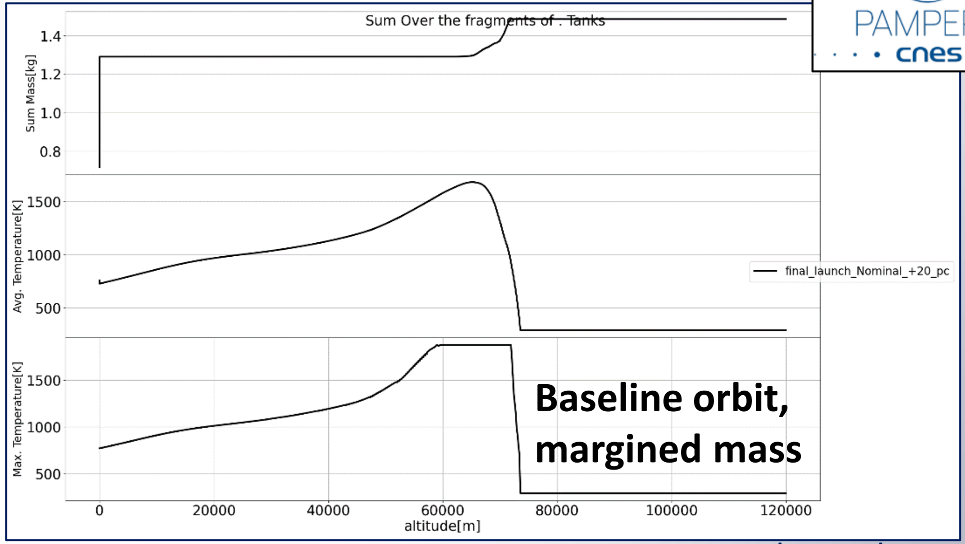
Evaluated the preliminary impact on the demisability of:

- Re-entry orbit and FPA at EIP
- Ballistic coefficient
- State at EIP (tumbling vs fixed attitude)
- Internal panels in titanium vs carbon-carbon vs aluminium
- Spacecraft configuration





Baseline orbit, nominal mass



Baseline orbit, margined mass

Mission way forward and conclusions

Mission level

- Effect of LUS **injection accuracy** on the demisability behavior, 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** design for Instrument survivability
- **Capsule release mechanism** design
- **Long Lead Items risk assessment**

Thank you for the attention!

DRACO mission phases A-B1 outcomes and way forward

Paolo Minacapilli[a], Saul Campo[a], Mercedes Pavia[a], Gabriele De Zaiacomo[a], Andreea Burlou[a], Santiago Molina[a], Angel Naranjo[a], Carmen Fuentes[a], Andrea Fabrizi[a], Andrea Pizzetti[a], Andrés Caparrós[a], Biagio D'Andrea[a], Guillermo Asensio[a], Guillermo Silva[a], Stijn Lemmens[b], Beatriz Jilete[b], Benjamin Bastida Virgili[b] , Simone del Monte[c], Amandine Denis[c], Bernd Helber[c] , Eddy Constant[d], Gauthier Brives[d], Martin Spel[d]

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

Clean Space Industry Days (CSID)
ESA-ESTEC, Noordwijk,
The Netherlands

16-19 October 2023

19th October 2023