AEROTHERMODYNAMIC ANALYSIS OF INNOVATIVE HYPERSONIC DEPLOYABLE REENTRY CAPSULES

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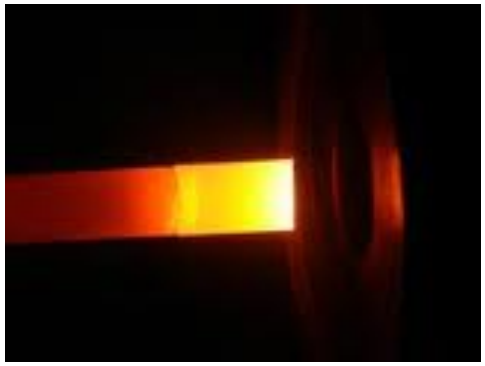
Hypersonic research activities at the University of Naples

- Theoretical and numerical research in hypersonic aerodynamics and aerothermodynamics
- Experimental study and characterization of thermal protection materials in plasma wind tunnel



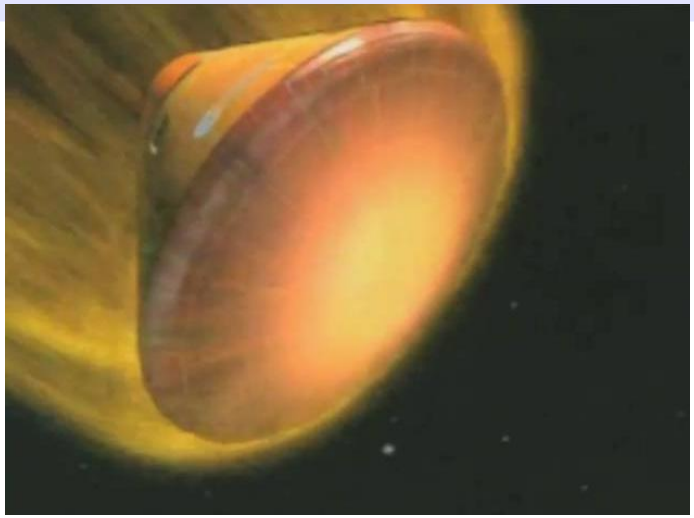
- Study and design of winged re-entry vehicles and future hypersonic spaceplanes

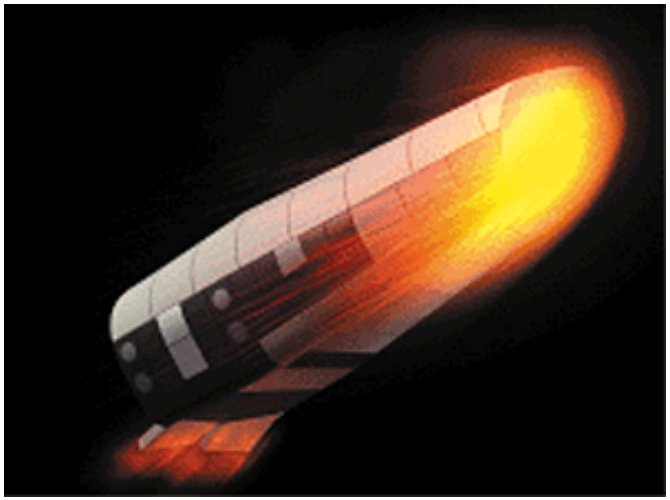
- Innovative re-entry capsules

Objectives of the presentation

- Show the main capabilities of deployable aero-brakes for Earth re-entry capsules
- Discuss aerothermodynamic and mission analyses of these re-entry systems
- Discuss some feasible missions offered by the system
- Introduce study and design of technological demonstrators for sub-orbital re-entry missions

Atmospheric reentry



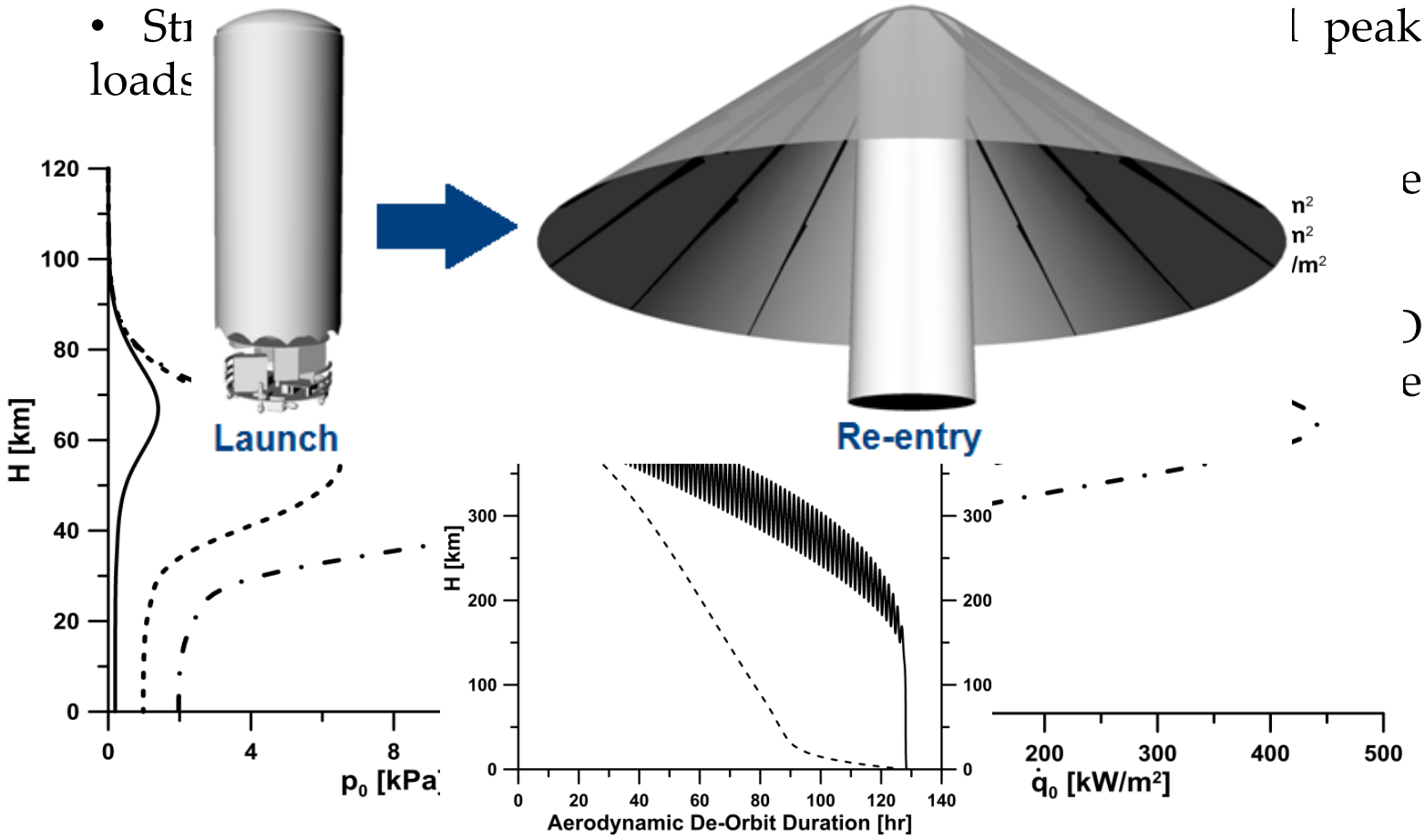


- Reentry energy: 150 times the enthalpy of fusion of iron; 7.5 times the explosive energy of TNT

- **Thermal Protection System (TPS) technology in 50 years of re-entry of capsules and blunt bodies**

Introduction to deployable reentry capsules

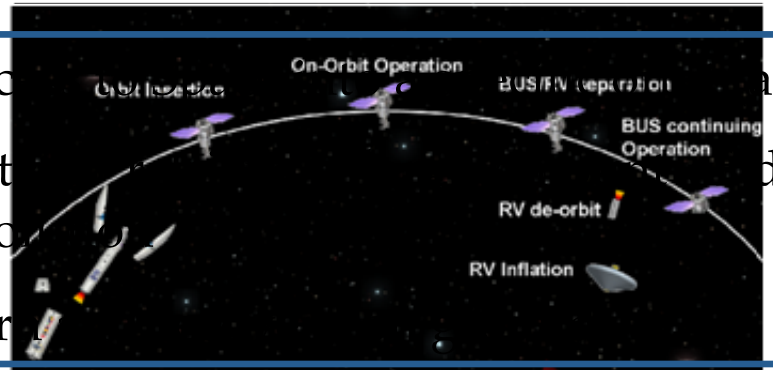
- **Why deployable re-entry capsules?**
  - Easy accommodation in launch vehicles in folded configuration
  - Sti l peak loads e

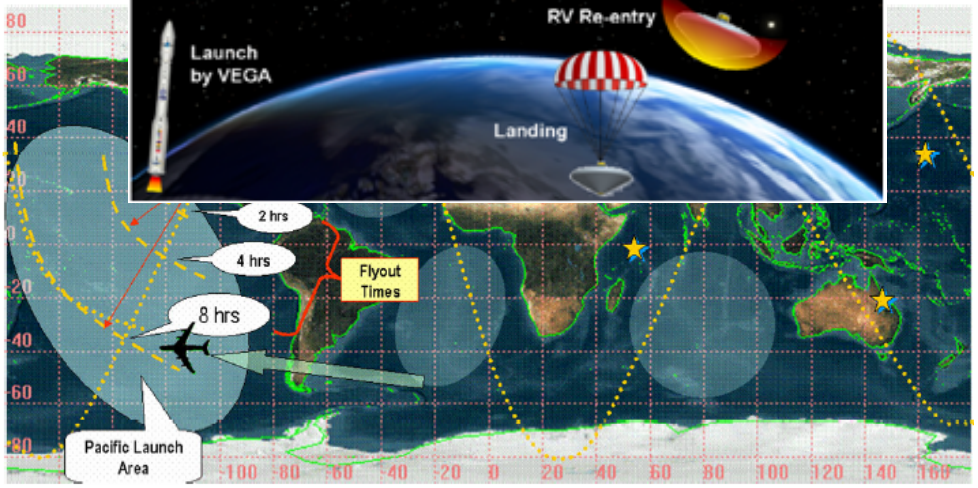


Possible missions

- **Potential orbital mission scenarios**
  - Space mailing to/from the ISS
  - Orbital scientific mission to/from LEO
  - Earth observation mission

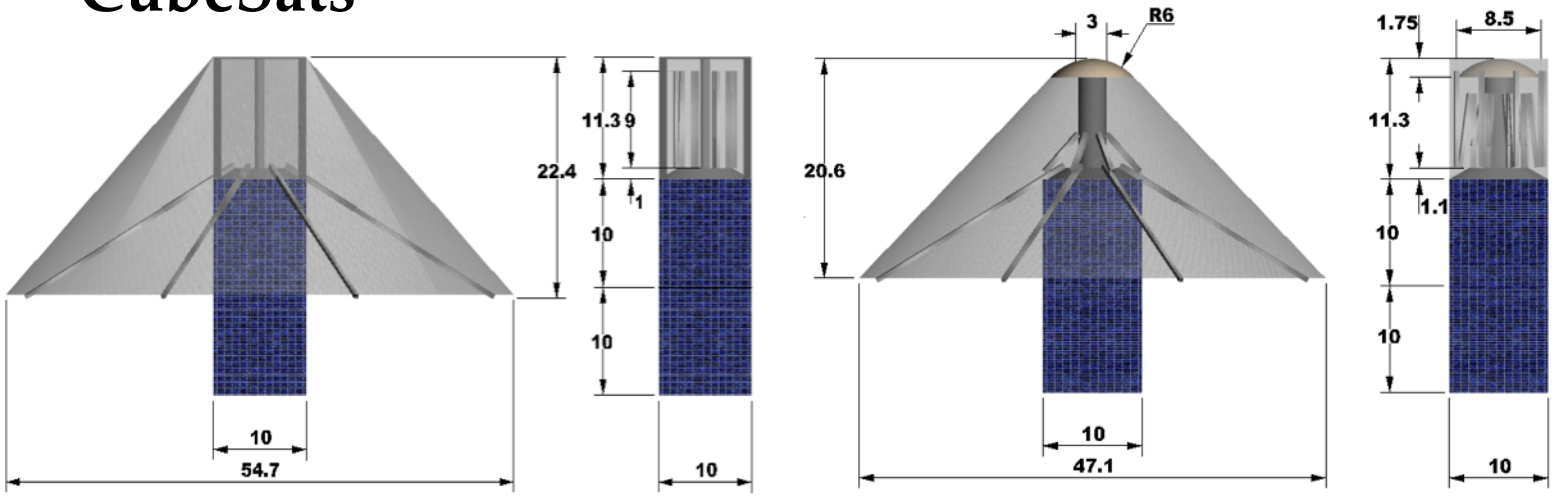
- Quick acc… …ir launch)
- Possibilit… …data at high spatial reso…
- Safe retur…





Space debris mitigation

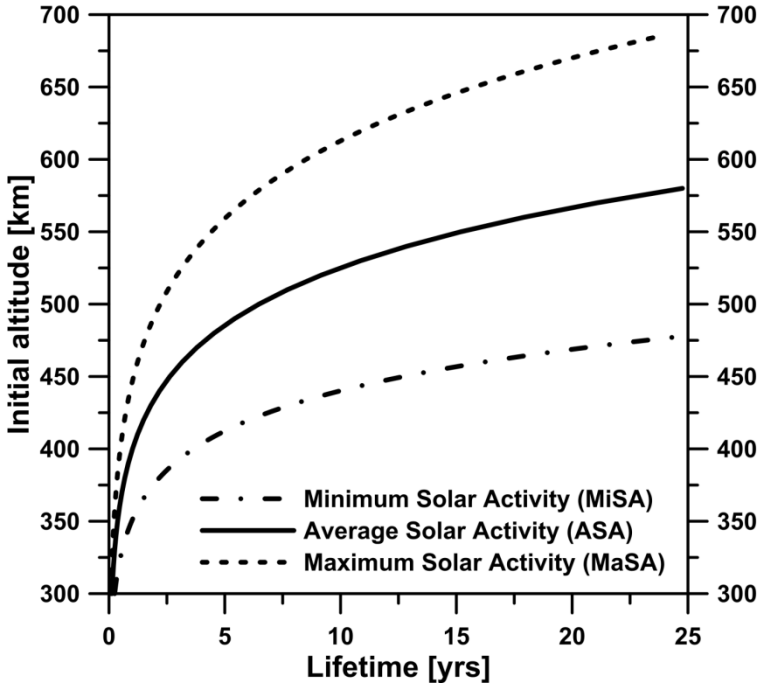
- **CubeSats**



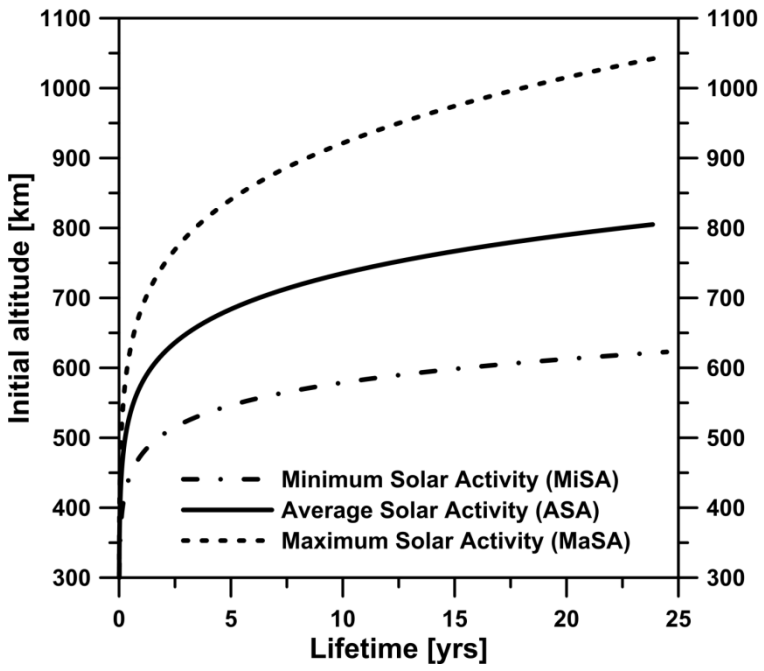
- Contrast the phenomenon of Space debris
- Match the 25 years requirement for orbital decay
- Enable orbit insertion at larger altitudes
- Possibility to recover payloads and data
  - Reduce costs reusing hardware and subsystems
  - Perform post-flight inspections and experimentations

Space debris mitigation

- **De-orbit trajectories**



Standard CubeSat

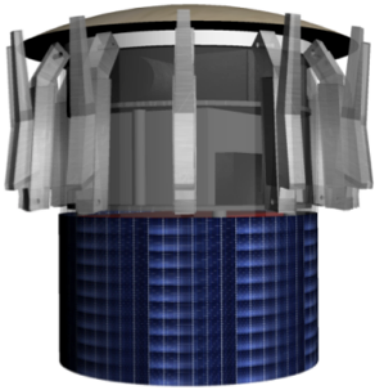


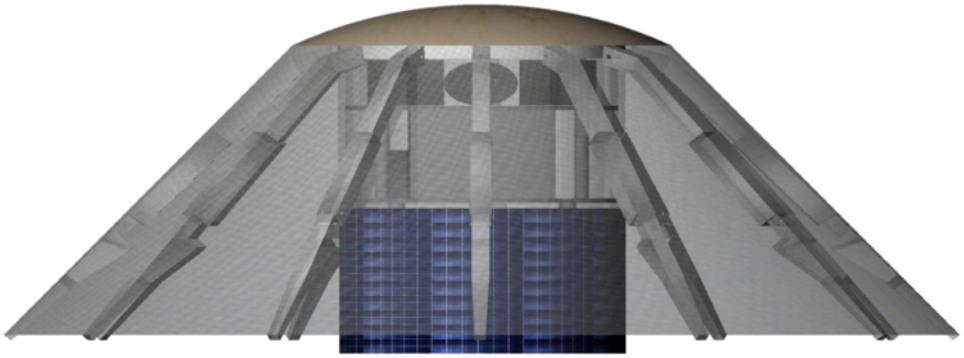
CubeSat with aerobraking system

- Possibility to increase the orbit altitude for orbital decay
- Significant reduction of the orbital decay lifetime

MISTRAL System

- **Air-launchable system (MISTRAL, Telespazio)**





- The orbital injection can be performed at relatively low altitude to reduce size, mass and cost

- The deployable aerobrake can allow the capsule to perform efficient manoeuvres in a relatively short time, with low risks and avoiding any propulsive boost

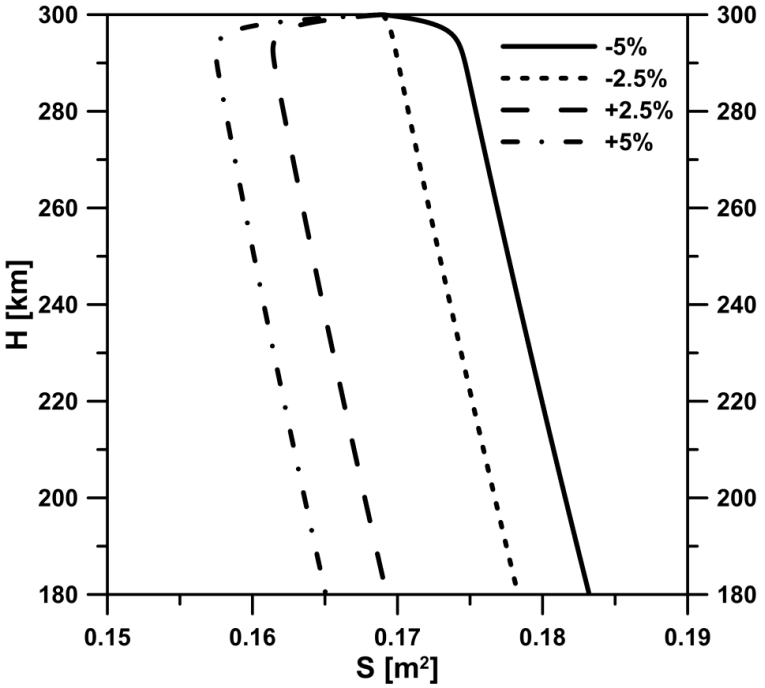
- A dedicated ground segment is under study

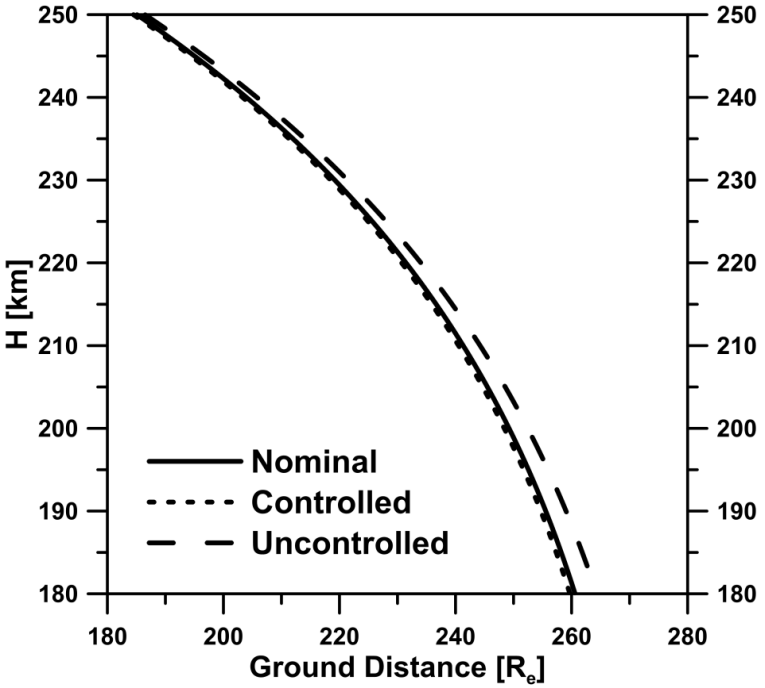
Aerodynamic de-orbit and re-entry

- **Aerodynamic control of de-orbit trajectories**

- The reference surface modulation can be exploited to cope with the off-nominal conditions along the de-orbit trajectory (e.g. air density uncertainties) to target the capsule towards the selected landing site

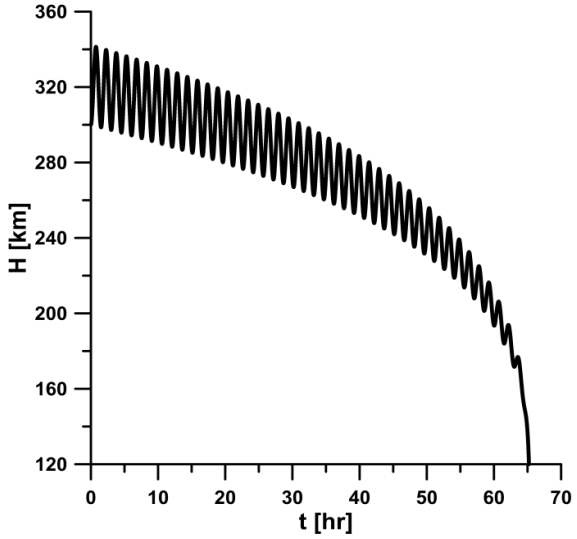
$$\Delta S = k_1 \cdot (H - H_{nom}) + k_2 \cdot (\lambda - \lambda_{nom})$$

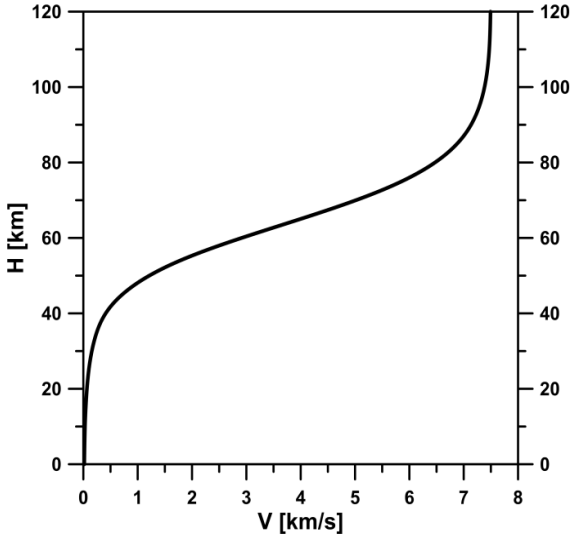


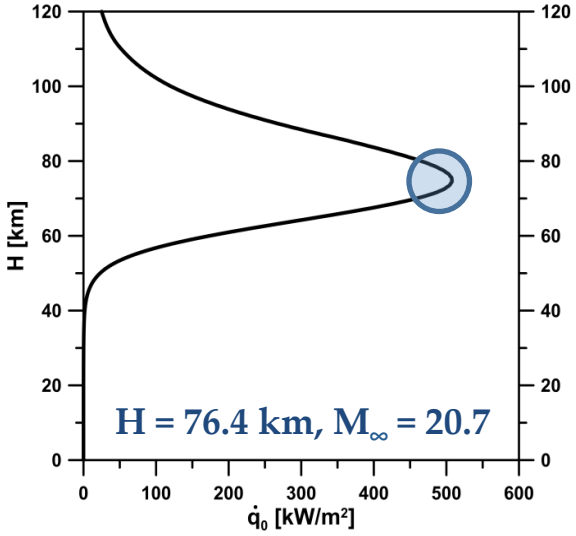


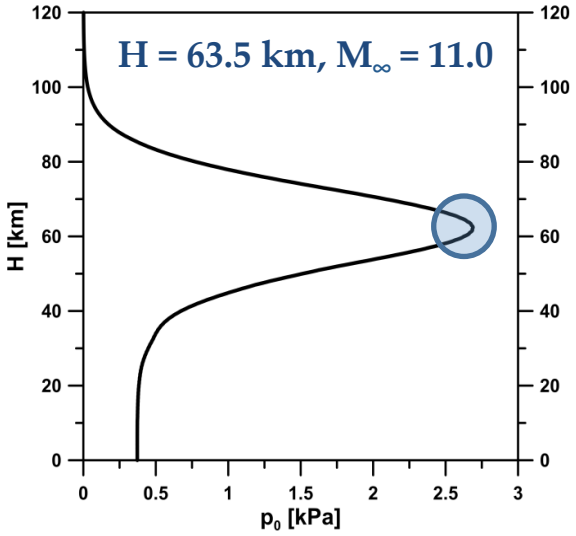
Aerodynamic de-orbit and re-entry

- **De-orbit and re-entry trajectories**



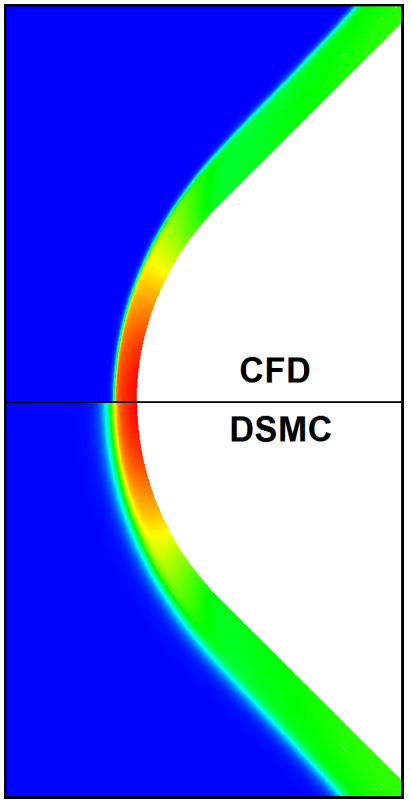


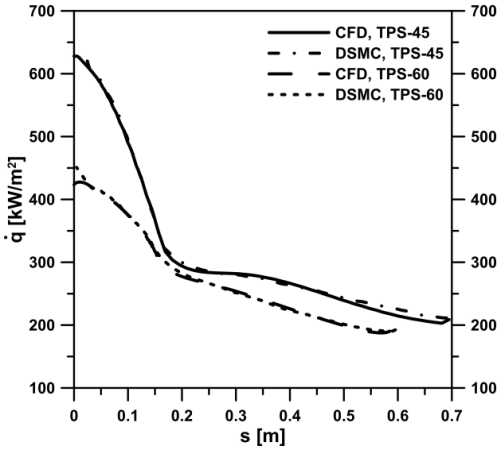


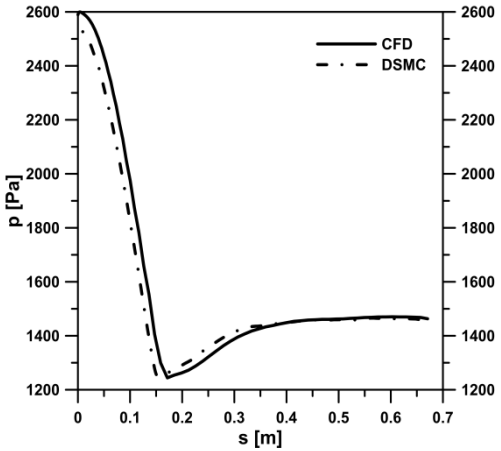


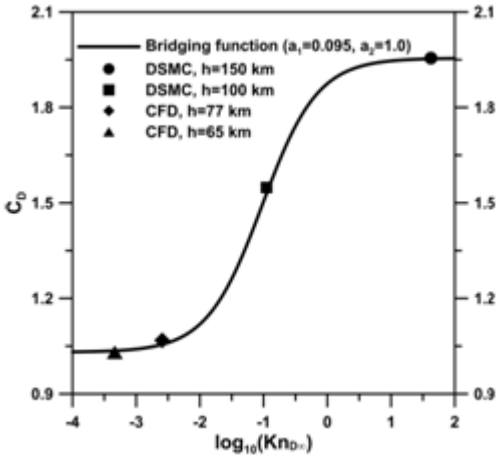
Aerothermodynamic analyses

- CFD and DSMC Aerothermodynamic analyses







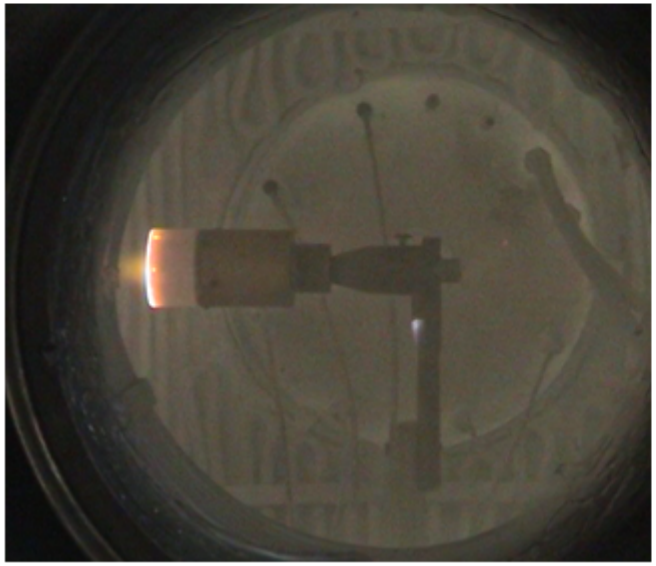


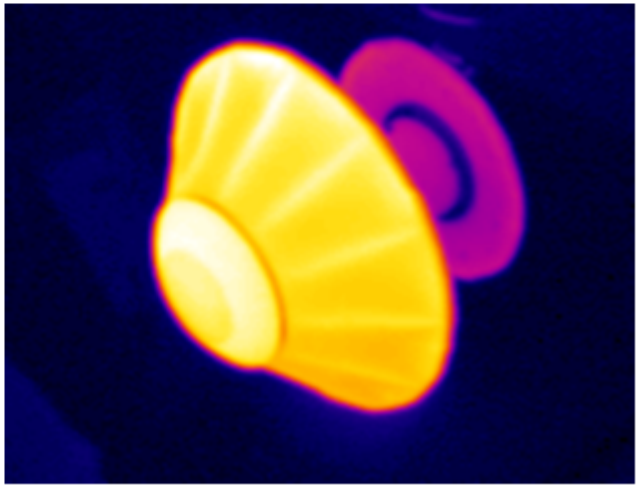
H [km]	M_∞ [-]	Re_∞ [-]
76.4	20.7	14165

TPS materials

Rescor 310 M is a ceramic foam with a maximum operative temperature of 1650°C

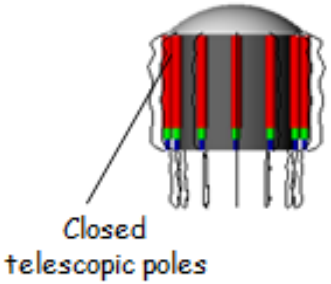
Nextel 312 woven fabric was able to withstand up to 1400°C in the Scirocco PWT

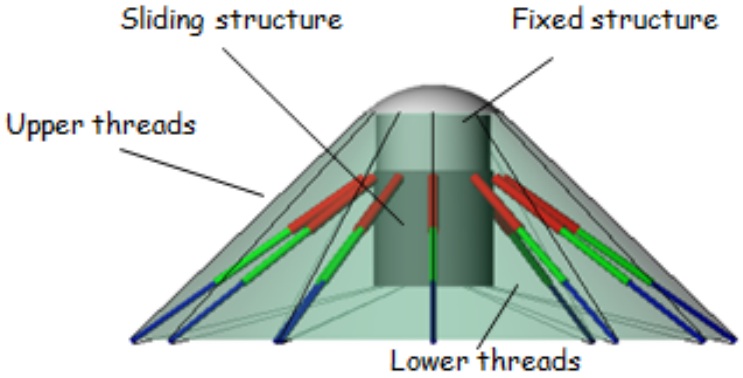


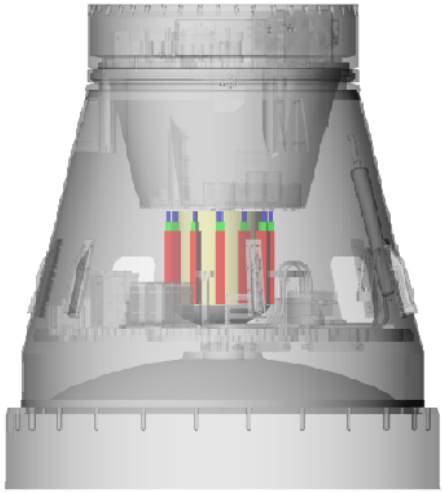


Sub-orbital technology demonstrator

- **Technology demonstrator for Maxus rocket (IRENE, ALI)**





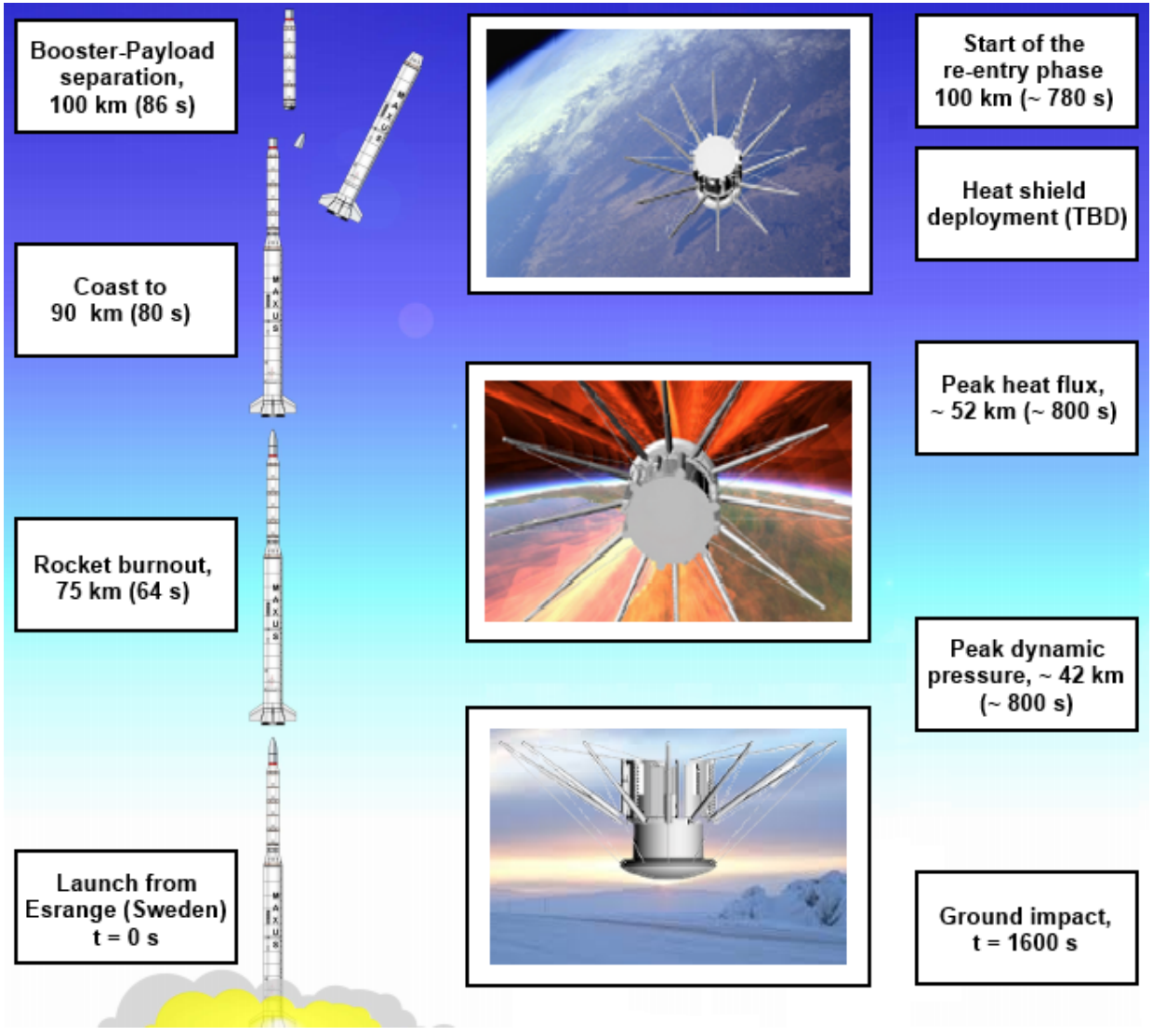


- Compatibility with Maxus interstage
- Total mass less than or equal to 15 kg
- Ballistic coefficient lower than 20 kg/m^2
- Automatic system for TPS deployment
- TPS able to withstand heat fluxes in the order of 300-350 kW/m^2

- Structure able to withstand mechanical loads in the launch phase & aerodynamic loads in the atmospheric re-entry phase

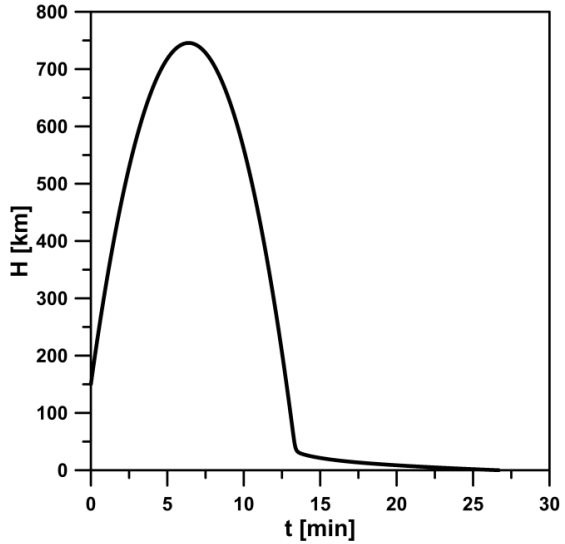
Sub-orbital re-entry mission

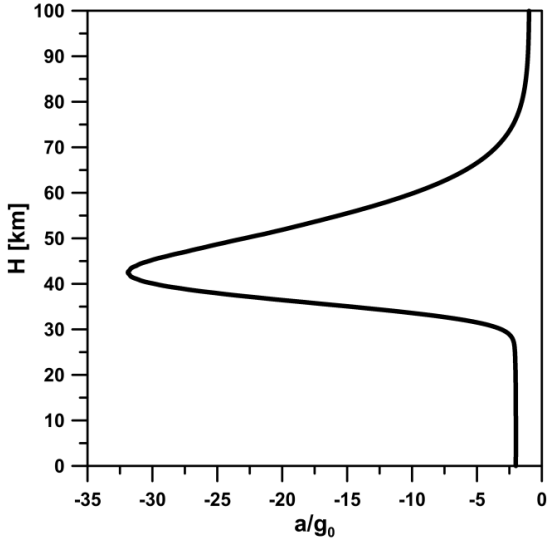
- **Technological demonstration mission**

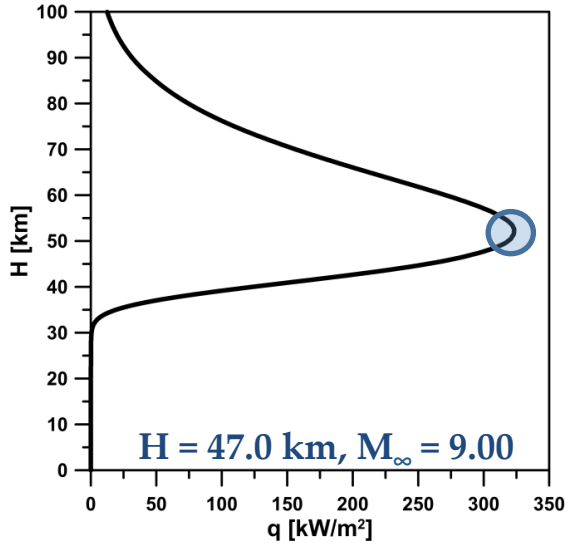


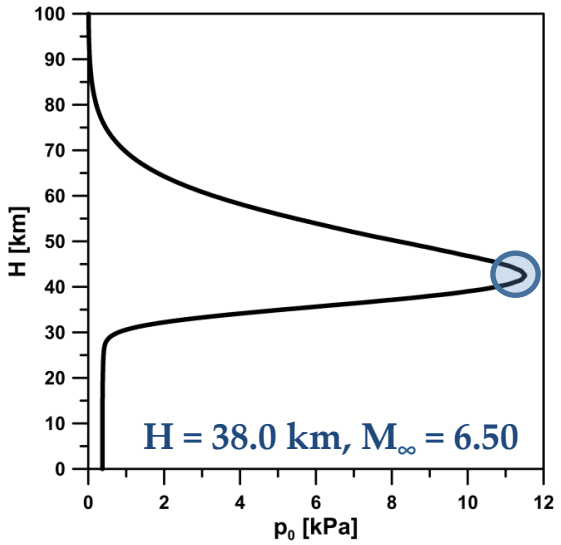
Computed trajectories

- **Suborbital re-entry trajectories**



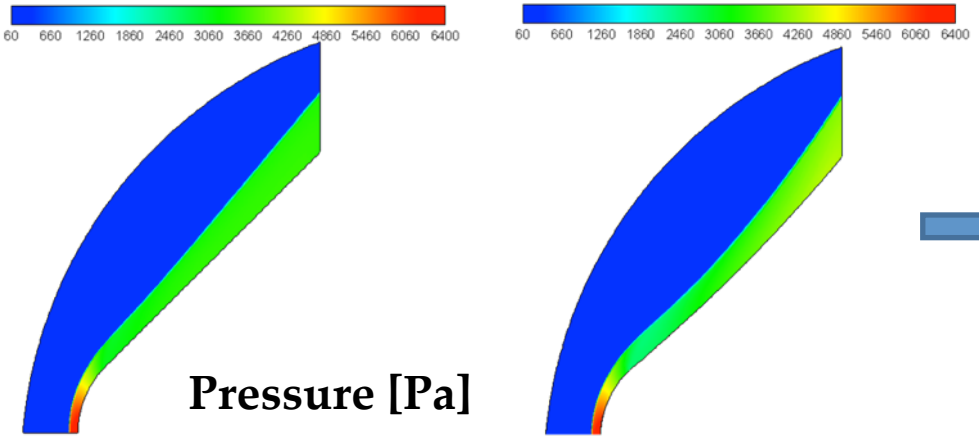




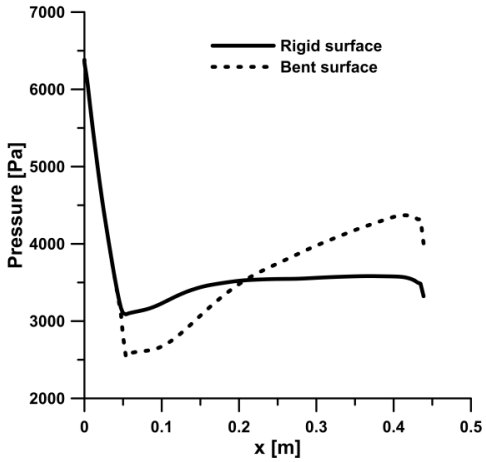


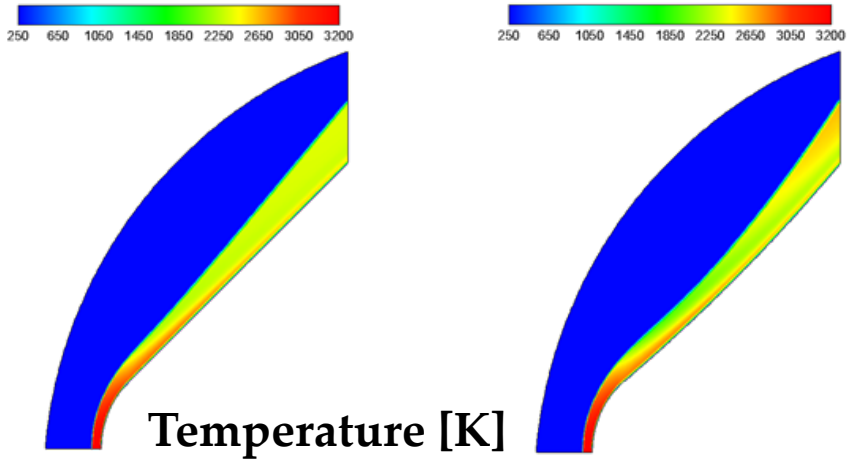
Aerothermodynamic analysis

- **CFD Aerothermodynamic analyses**
- Air can be considered in chemical equilibrium, due to the relatively low energy profile

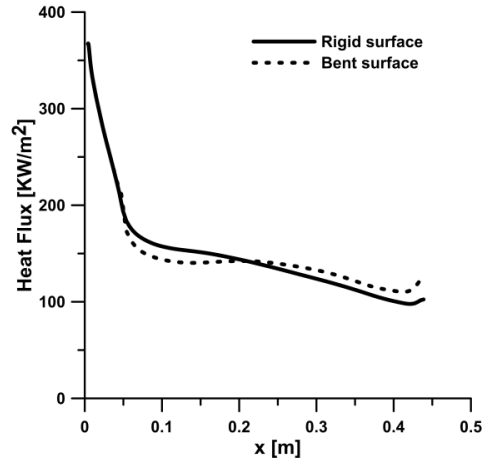


Pressure [Pa]



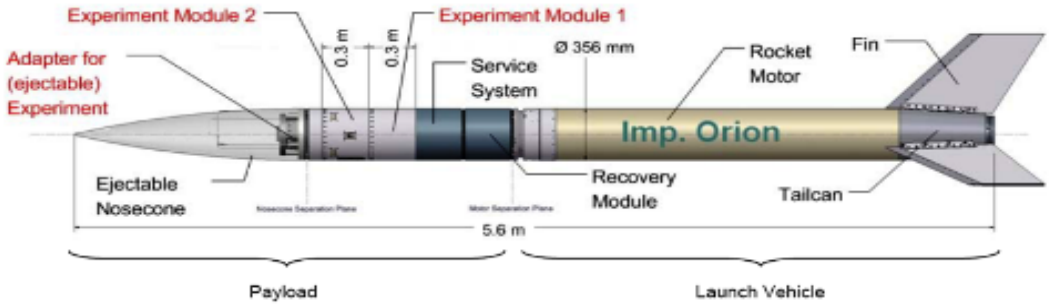


Temperature [K]

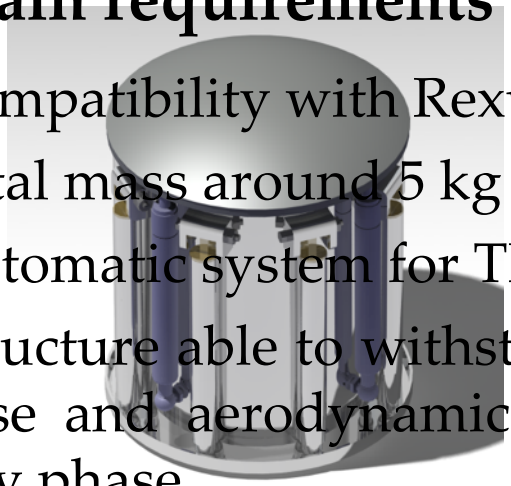


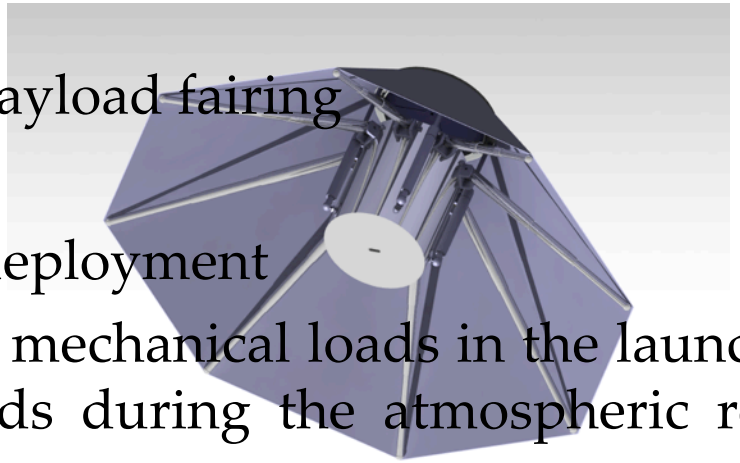
Rexus project

- **Technology demonstration mission for Rexus**
- Launch from Kiruna within the Rexus fairing



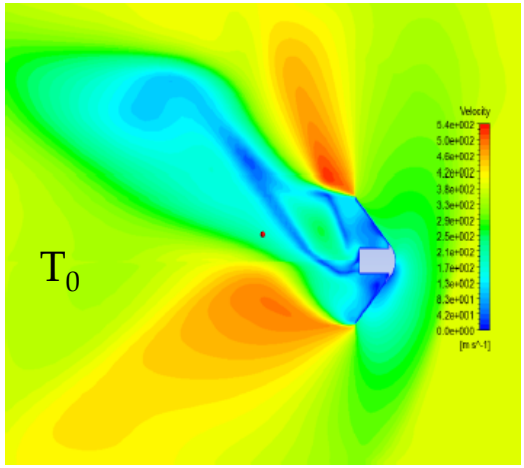
- Ejection from the rocket fairing after the nosecone fairing ejection and before the rocket de-spinning
- Landing and recovery
- Aerobrake deployment during descending parabola
- **Main requirements**
- Compatibility with Rexus payload fairing
- Total mass around 5 kg
- Automatic system for TPS deployment
- Structure able to withstand mechanical loads in the launch phase and aerodynamic loads during the atmospheric re-entry phase

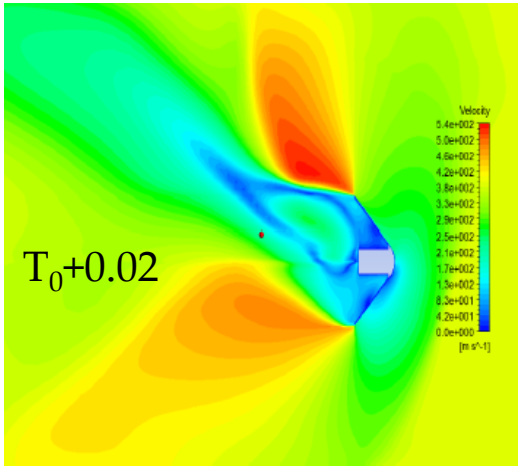


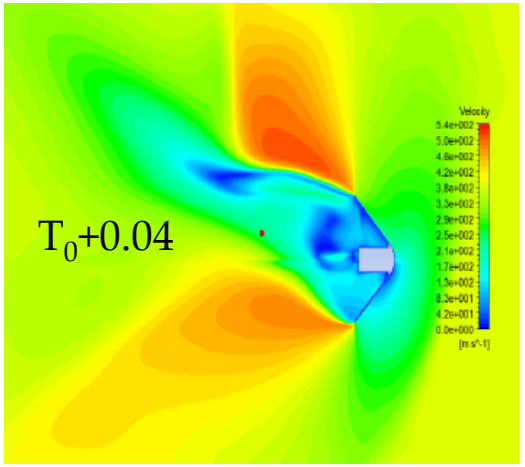


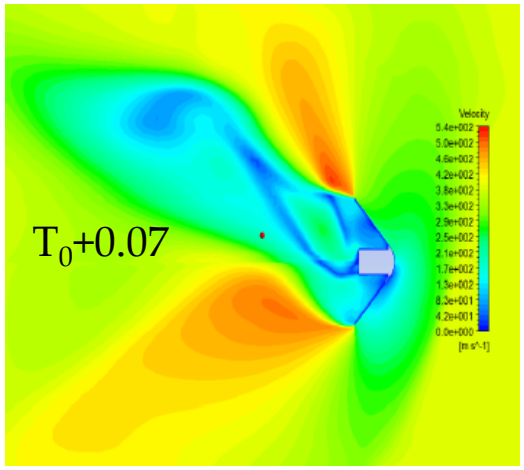
Technology demonstrator

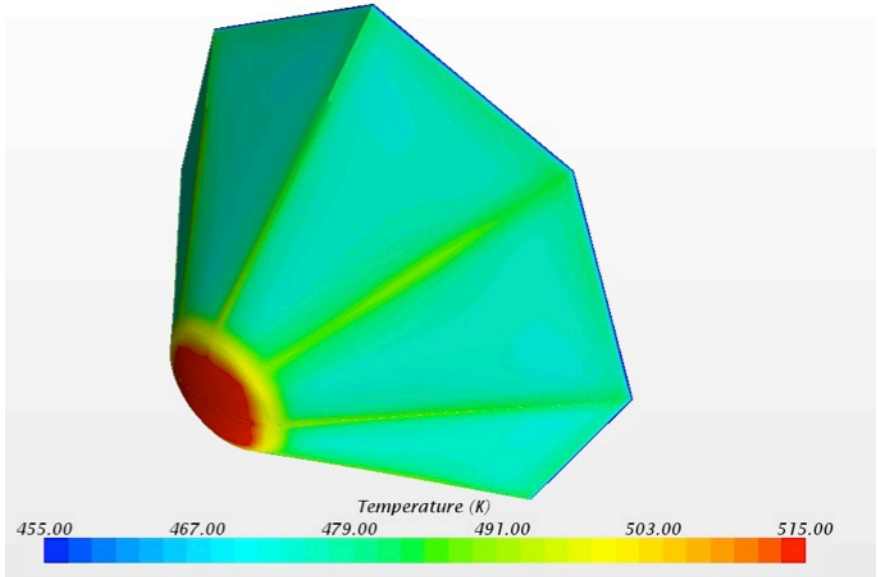
- **CFD Aerodynamic and aerothermodynamic analyses**



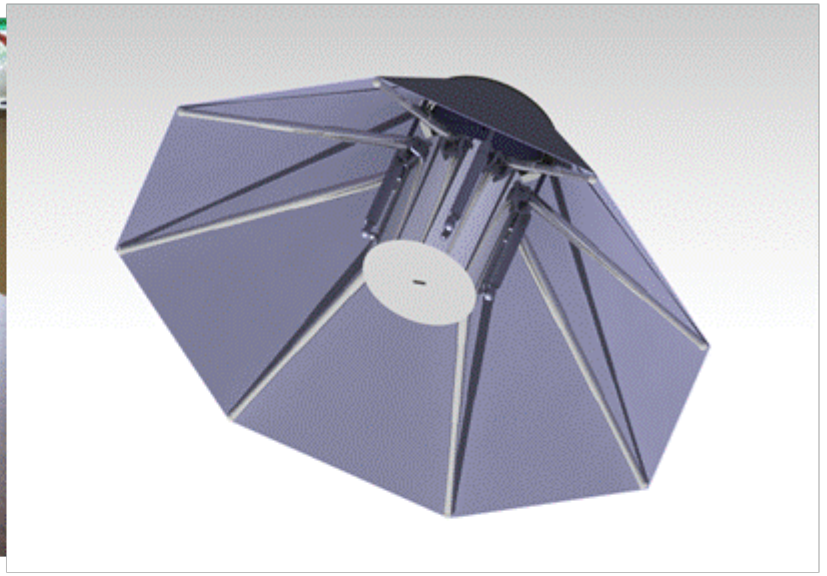


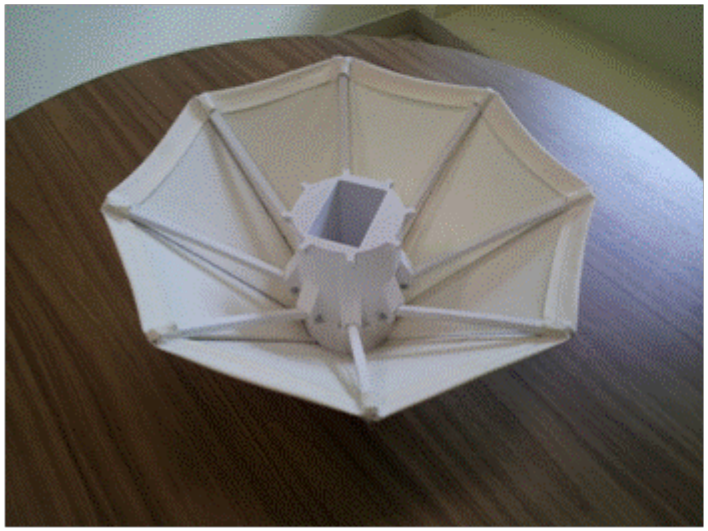


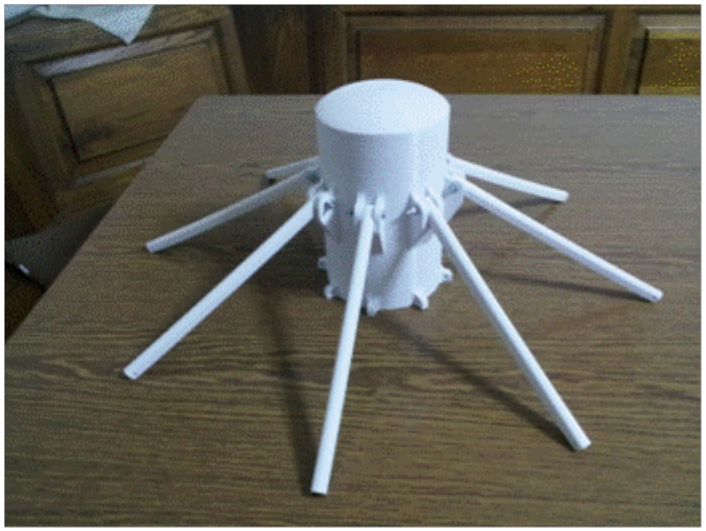




Scaled model







Conclusions

- Different possibilities for orbital re-entry and for suborbital demonstrators
- A new method for the aerodynamic control of a variable geometry umbrella-like structure has been proposed
- Evaluation of the aerothermodynamic conditions and materials identification
- Results will be applied in future research projects