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In-orbit and Hypersonic Re-entry Control by Deployable Technologies

2nd International Symposium:
"Hypersonic Flight: from 100.000 to 400.000 ft"
Rome, Italy, 30th June-1st July 2016

ASSOCIAZIONE ARMA AERONAUTICA
CESMA
Centro Studi Militari Aeronautici Giulio Douhet

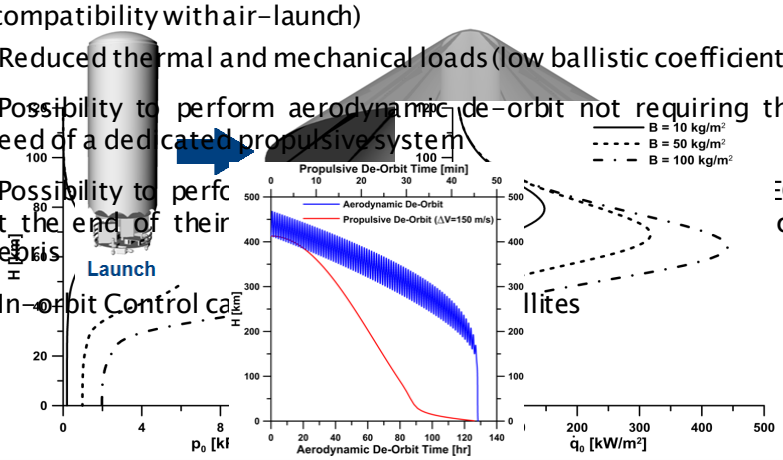
Outline

- ❑ Deployable aero-brakes technology main capabilities
- ❑ Possible missions offered by these systems
- ❑ Programmes and developments
- ❑ Conclusions

Introduction

Deployable re-entry capsules key features:

- Easy accommodation in launch vehicles in folded configuration (compatibility with air-launch)
- Reduced thermal and mechanical loads (low ballistic coefficient)
- Possibility to perform aerodynamic de-orbit not requiring the need of a dedicated propulsive system
- Possibility to perfc :O at the end of their ce debris
- In-orbit Control ca llites

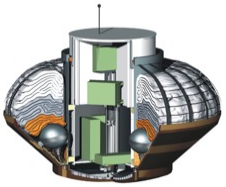


Possible missions

- **Recovery of small payloads** (mass of the order of a few kilograms and volume of the order of a few liters) **from the ISS**;
- **Scientific Space Missions** (study the effects of microgravity in the fields of physical and life sciences);
- **Probe Space Missions** to analyze the upper atmosphere over a very large area, even on a global scale in case of a polar orbit;
- **Earth Observation** Missions (possibility to reach the selected target as soon as possible and to safely retrieve data recorded on board);
- **Catch Debris** Missions (the satellite would chase the selected debris, capture it and finally re-enter the atmosphere activating the shield so to safely reach the selected target location);
- **Martian Missions** (futuristic), to transfer pieces of equipment on the Martian surface.

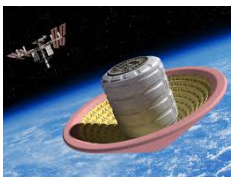
State-of art inflatable and deployable

IRDT



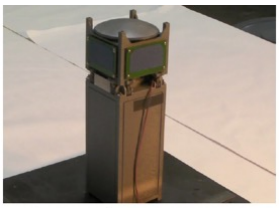
Successful launch in 2000

IRVE



Successful launch in 2003

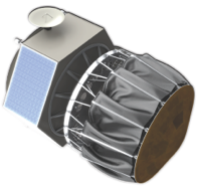
DRS

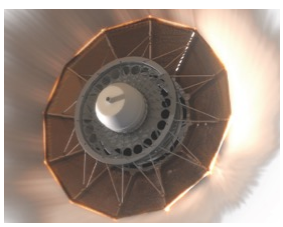


Patented in 2012

State-of art inflatable and deployable

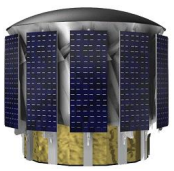
ADEPT

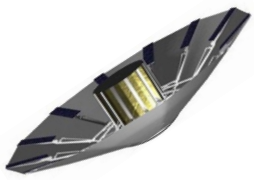




Transformable Entry System Technology

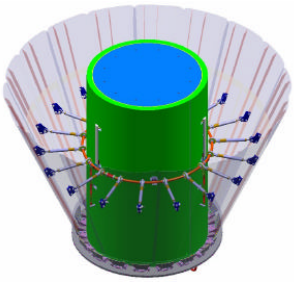
Bremsat





Designed in 1996

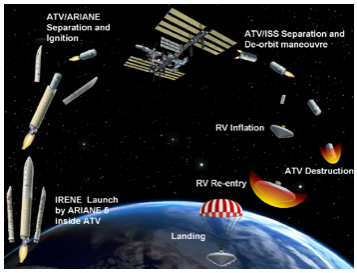
PARES

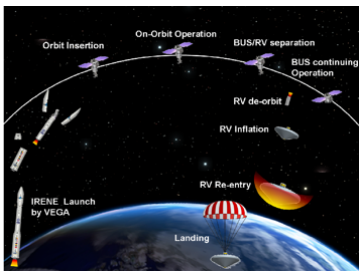


Designed since 2004

IRENE Technological Project

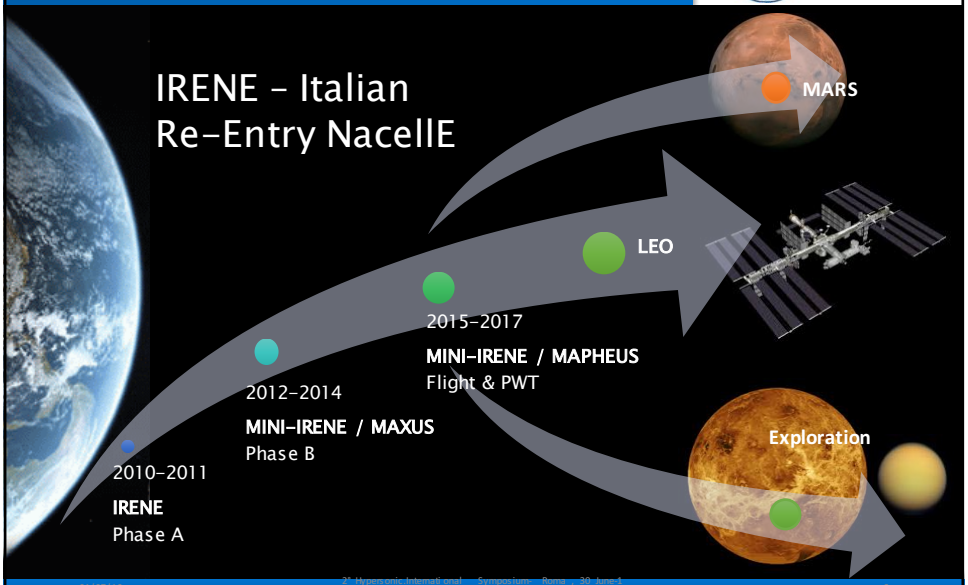
It is a programme of a SME consortium (ALI), coordinated scientifically by the University of Naples Federico II, which has the aim of developing a new deployable technology for atmospheric re-entry (for Earth or interplanetary missions).





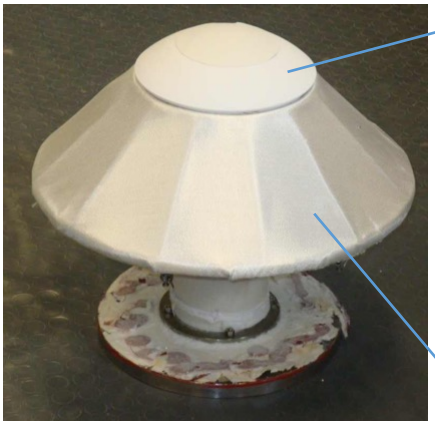
Mass [kg]	Payload [kg]	Max. Diameter [m]
130	40	3

IRENE Technological Project

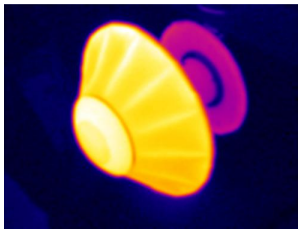


TPS Materials

Ground-test model for the experimental test performed in Scirocco in 2011



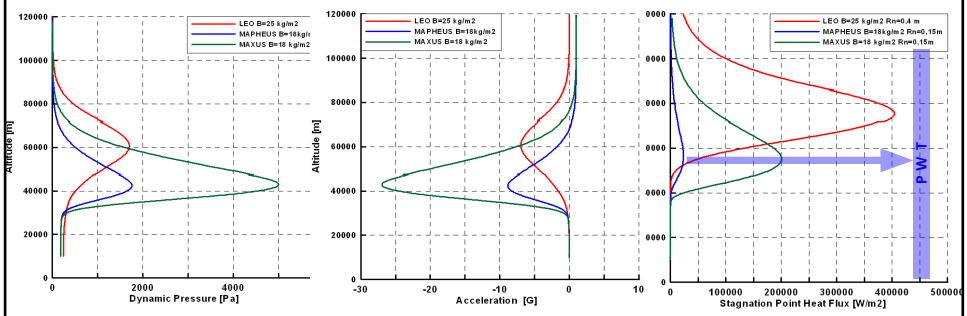
Rescor 310 M ceramic foam was able to withstand up to 1550°C



Nextel 312 Ceramic woven fabric was able to withstand up to 1350°C in the Scirocco PWT

Sub-orbital flight demonstrators

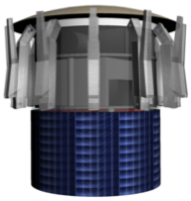
Re-entry profiles comparison (LEO, MAXUS, MAPHEUS)

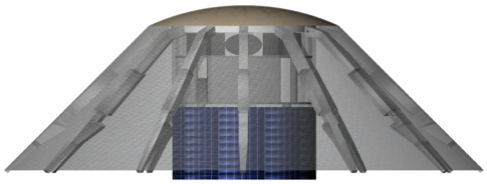


MISTRAL project: Aerospace District of Campania (DAC)

MISTRAL – MIcroSaTellite con capacità di Rientro AvioLanciato

It is an innovative microsatellite system proposed by DAC and studied by companies, universities and research centers in Campania (Prime contractor is Telespazio)

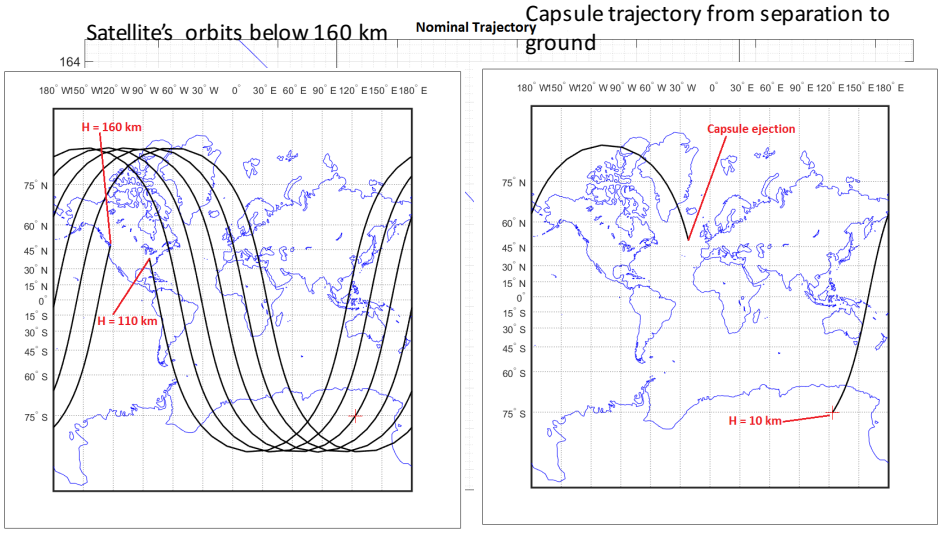




- It consist of a service module and a recoverable and deployable re-entry module
- The r… orbiting in orde…
- Fully …
- Air-Launch compatible to ensure Operational Responsiveness
- A dedicated ground segment is under study

Mass [kg]	Payload [kg]	Max. Diameter [m]
30-50	1-2	1

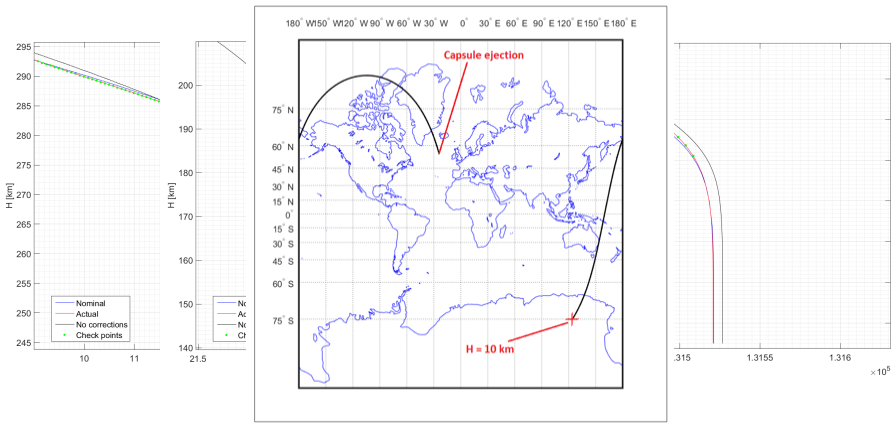
Controlled De-Orbiting



De-Orbiting

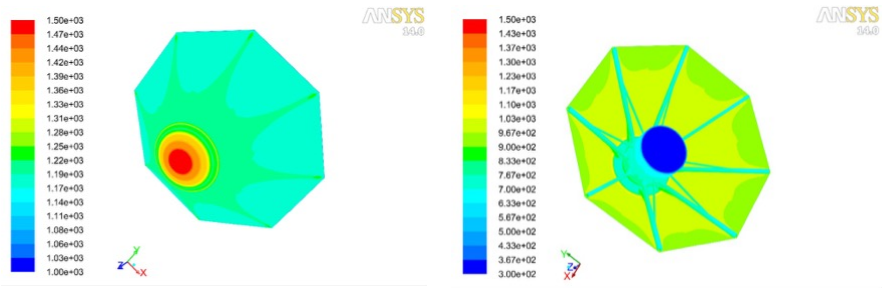
De-Orbiting control by aero-brake modulation

$$S = S_{ref} + k * (H_{eff} - H_{nom})$$



Hot reentry

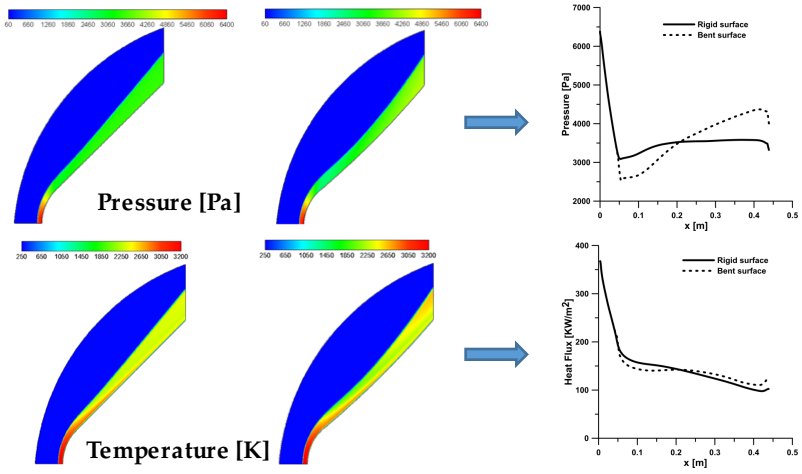
Re-entry module aerothermodynamics



Temperature distribution (°C) during a possible re-entry trajectory

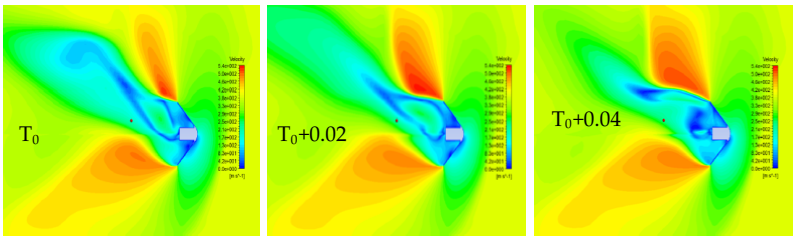
Aerothermodynamic analyses

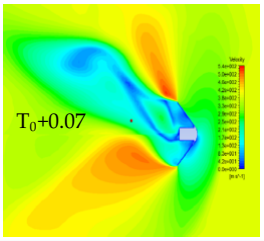
Air can be considered in chemical equilibrium, due to the relatively low energy profile



Aerodynamic and aeroelastic analyses

CFD Unsteady Aerodynamic analyses

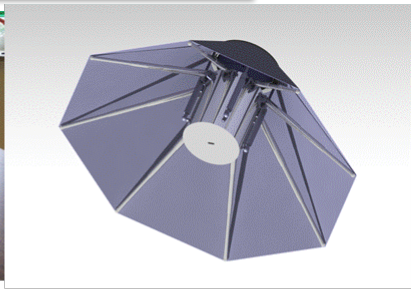
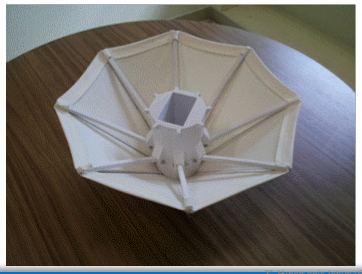
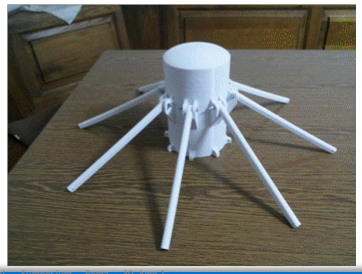




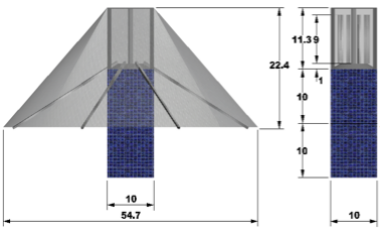
- Frequency: 14 Hz
- Amplitude:

p [Pa]	C_L [-]	C_D [-]	C_M [-]
≈ 80	≈ 0.020	≈ 0.015	≈ 0.040

3D-printed prototypes and aerodynamic models

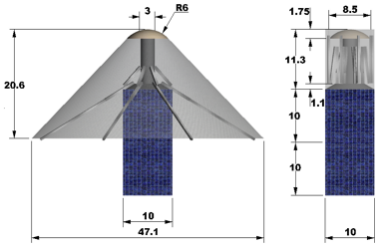





Other future applications: CubeSats



CubeSat End-Of-Life System (CELS)

- Reduce De-Orbit Lifetime (match the 25 years requirement);
- Contrast Space Debris with a passive aerobrake

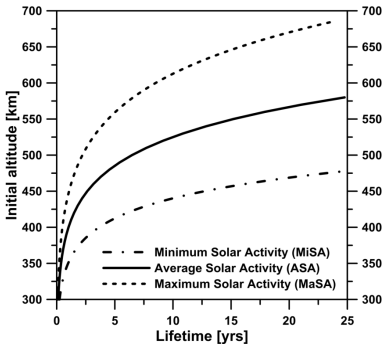


CubeSat De-Orbit & Recovery System (CDRS)

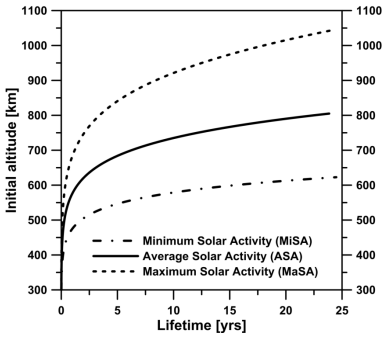
- Recover scientific/electronic payloads and data;
  - Reduce costs with reusable hardware and subsystems
  - Perform post-flight inspections and experimentations
- Control de-orbit and re-entry trajectories (modulating the aerodynamic drag), to reach the desired landing site

CubeSats

De-orbit trajectories



Standard CubeSat



CubeSat with aerobraking system

- Larger orbit altitudes possible
- Significant reduction of the orbital decay lifetime

Conclusions

- Deployable aero-brakes offer a wide variety of applications for both planetary re-entry and in-orbit control
- Different projects are under development in order to assess this new technology
- Numerical models and experimental activities allowed to understand aerothermodynamics for a range of different flight conditions and to identify TPS materials
- The possibility of a controlled de-orbiting has been shown
- Future developments include design of systems and subsystems for the different mission scenarios, including flight demonstrators, wind tunnel activities and drop tests