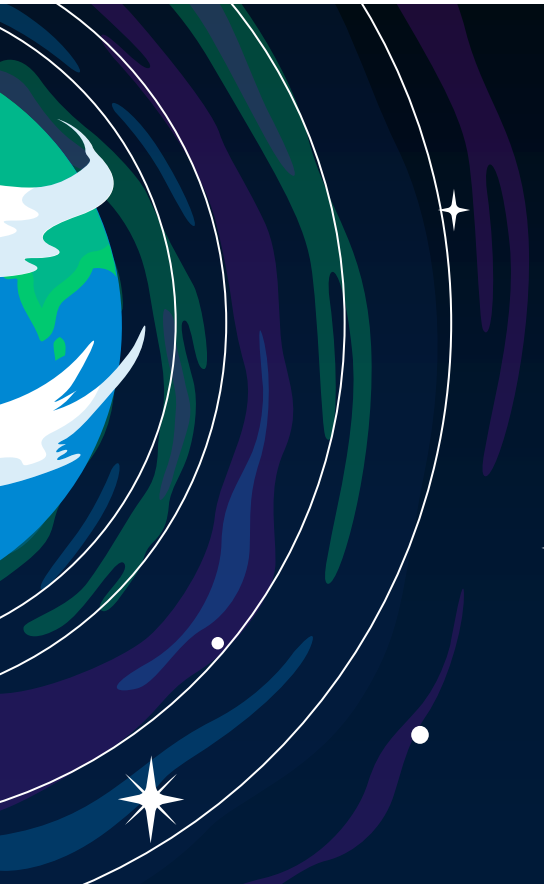
SPACEO

esa BUSINESS INCUBATION CENTRE Portugal



Advancements in Inflatable Drag Devices for Satellite De-Orbiting

ESA ESTEC 19-10-23

About SPACEO

SPACEO is a spin-off of Eptune Engineering a company working in Wind and Space markets.

The company was funded by Aerospace and Aeronautics engineers, with experience on the space market.

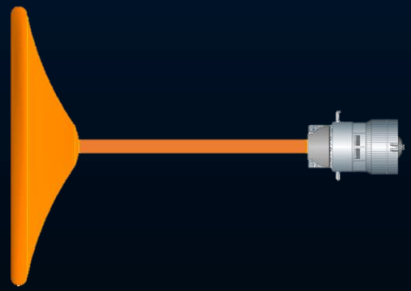
SPACEO was founded in 2023 with an important focus on solving the clean space problem.

The company was recently selected for ESA Business Incubation and is about to sign a pre-seed investment for the largest national venture capital, Portugal Ventures.

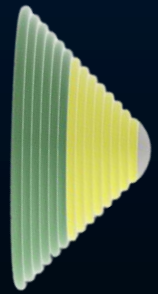
Previous Activities

ISAA- Inflatable systems for aerobraking and aerocapture

In this ESA project was studied the possibility of applying inflatable drag devices to perform aerobraking and aerocapture maneuvers on Mars and Venus, the project was focused on mission analysis and conceptual design of the inflatable drag systems.



Aerobraking - Trailing Ballute

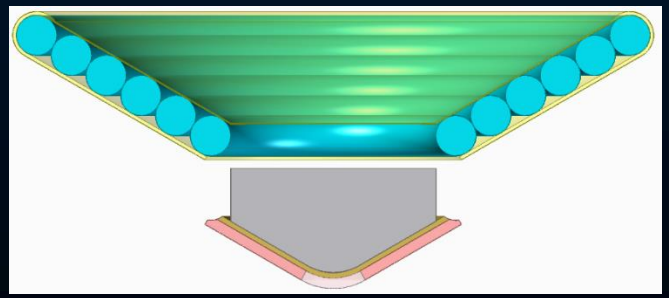


Aerocapture - Cocoon Ballute

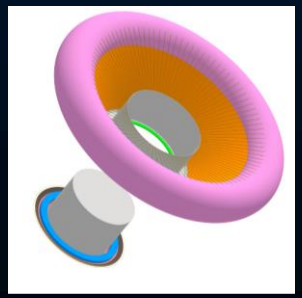
Previous Activities

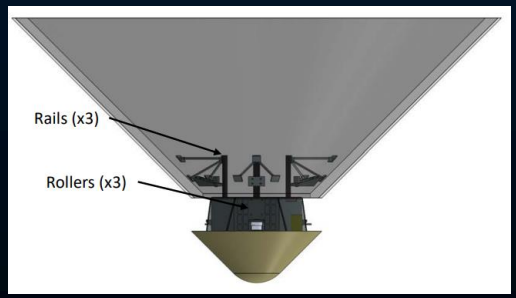
ADAM – Aerocapture Demonstrator at Mars

Mission architecture definition, technology assessment and preliminary requirements specifications of an aerocapture demonstration mission to Mars using single-event drag modulation aerocapture.



Stand alone – 400 kg





Piggyback – 100 kg

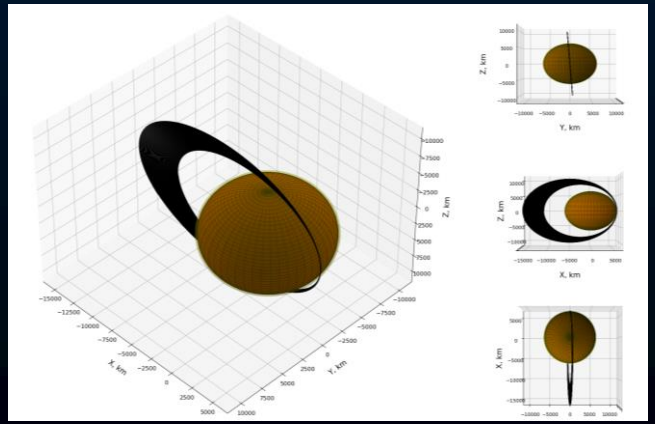
Vorticity FLUID GRAVITY ENGINEERING LTD

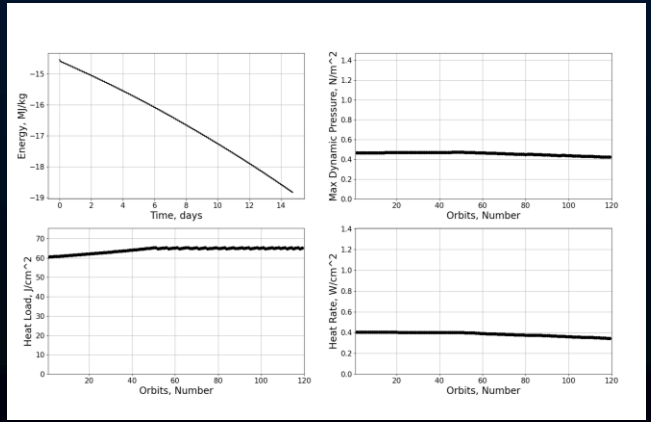
SPACEO

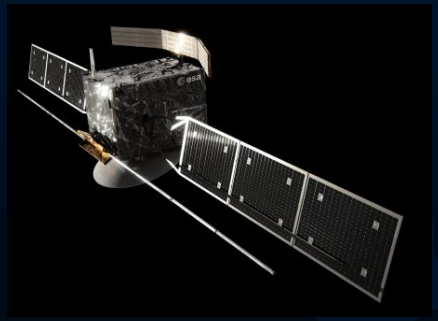
Previous Activities

Engineering Services

Support on MLI requirements definition. Orbital analysis of various scenarios of Envision aerobraking maneuver.



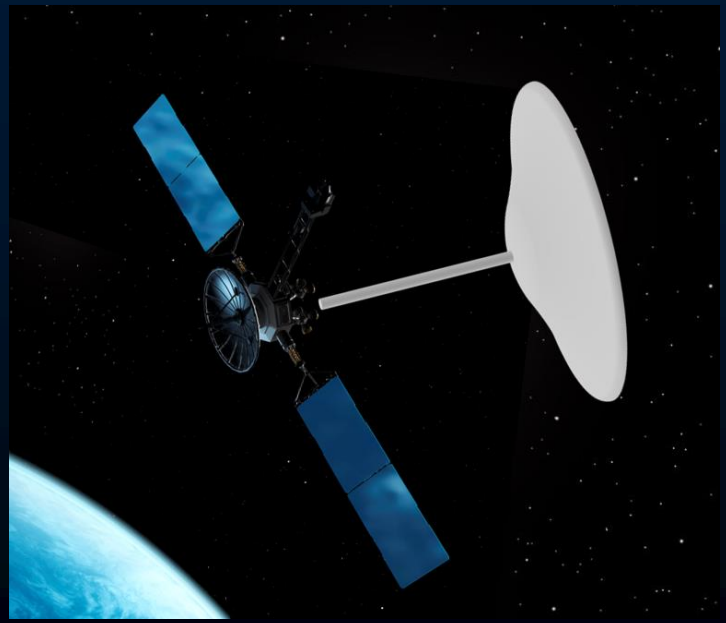




beyond gravity

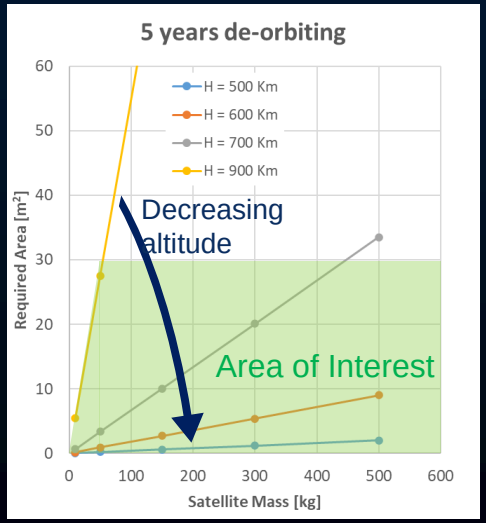
Problem

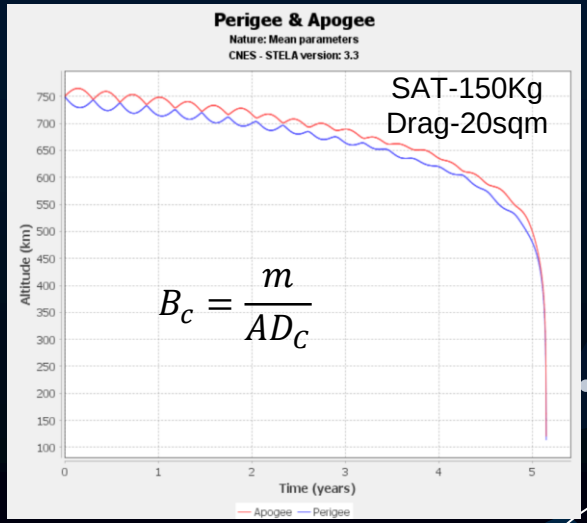
Solution → Inflatable Drag Device



Orbital Analysis

Circular and elliptical orbits were analyzed



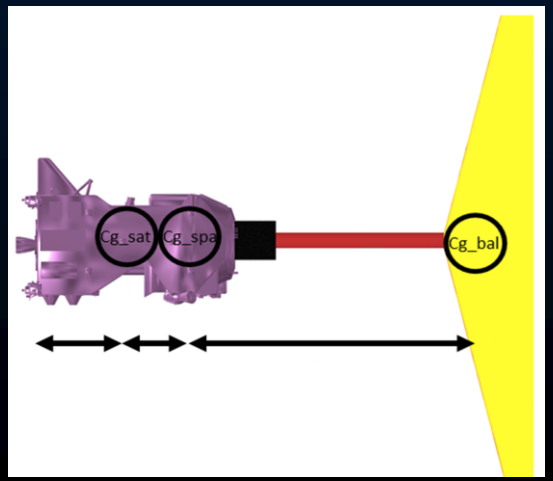


Decelerator design

Identification of possible designs.

Determination of preferred solution.

Flight control assessment.

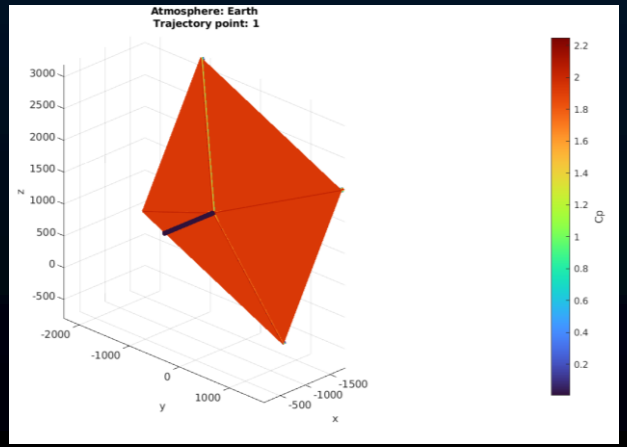


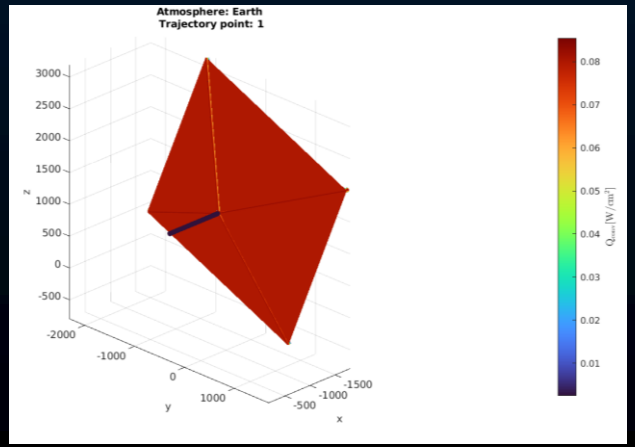
Geometry	Figure	Characteristics
Tension Cone		Drag Coefficient 1.64
Multi-Stacked Toroid		Drag Coefficient 1.6
Inflatable Rim&Spar		Drag Coefficient 1.6
Torus		Drag Coefficient 1.4
Spheric		Drag Coefficient 1.3
Planar Lentil		Drag Coefficient 1.31

Product development

Aerodynamic and thermal analysis was performed.

Altitude	Speed [km/s]	Cp	Cd
750km	7	2.02	1.95
500km	7.11	1.85	1.79
350km	7.22	1.81	1.75
150km	7.32	1.75	1.69



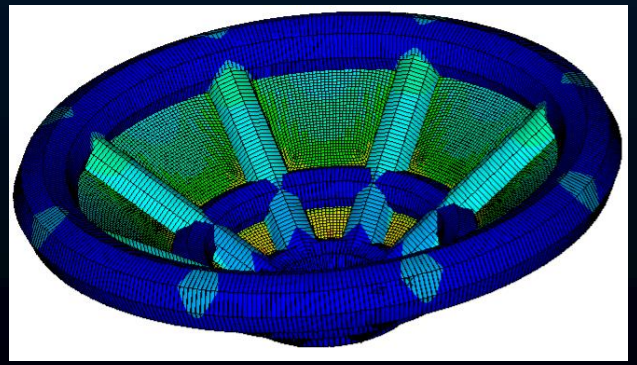


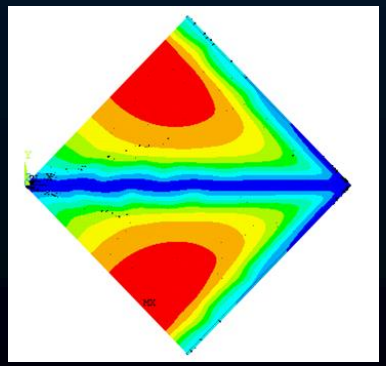
Product development

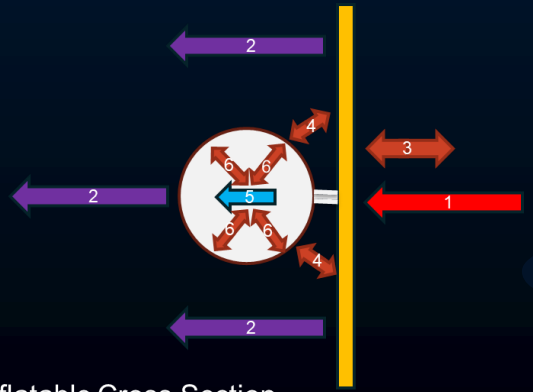
It were created an internal database and sizing methodologies.

Analytical and FEM tools were developed and validated by test.

Initial thermal characterization of the maneuver was performed.







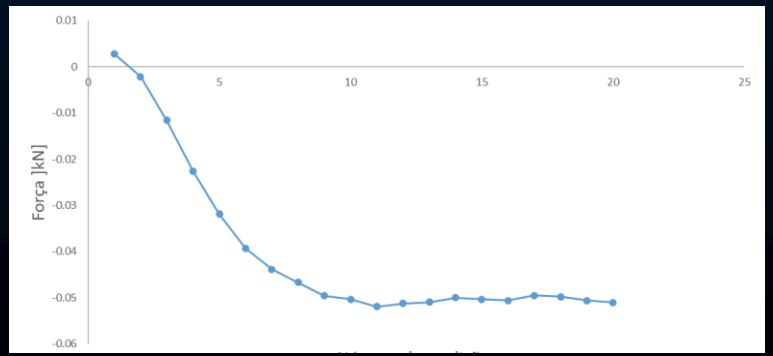
Inflatable Cross Section

Product development

Sizing inflatable deployable structures is not a straightforward task.

Large number of sizing methodologies.

Beams and torus were tested to determine and improve the analytical sizing tools.



Eq.	Equation
Brazier	$\frac{2\sqrt{2}}{9}\frac{\pi E r t^2}{\sqrt{1-v^2}}$
Wood	$\frac{2\sqrt{2}}{9}\pi E r t^2\sqrt{\frac{1}{1-v^2}+4\frac{p}{E}\left(\frac{r}{t}\right)^3}$
Baruch	$\frac{2\sqrt{2}}{9}\pi r t^2\sqrt{\frac{E_x E_\theta}{1-v_{x\vartheta}v_{\theta x}}}$
Stein	$\pi p r^3$
Zender	$\pi p r^3+\frac{\pi E r t^2}{2\sqrt{3(1-v^2)}}$
Wielgosz	$\frac{\pi}{4}\pi p r^3$

Materials & Processes

The testing campaign focused on:

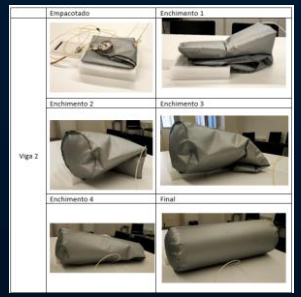
- Material properties.
- Sewing thread material and Tex nº and sewing pitch.
- Bonding of dissimilar materials.
- Blader welding .

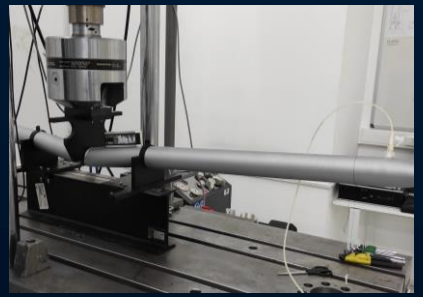
Inflatable Structures

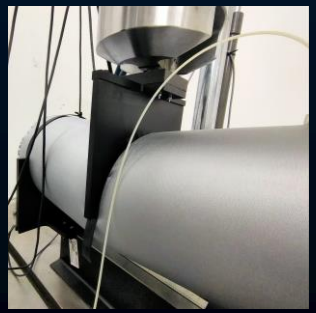
Beams and toroidal structures were produced and tested.

Key takeaway was the correlation with moment of collapse, determination of wrinkling onset and strength stabilization.

Deployment tests were performed .



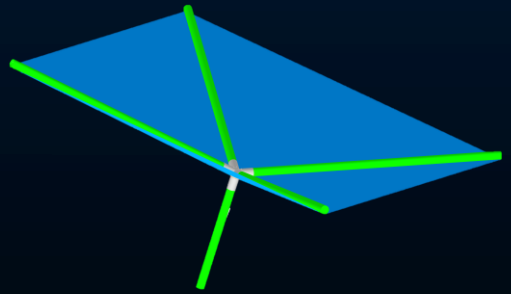




De-orbit Sail Prototype

To prove that a simple design can be easily produced and very cost competitive we developed and produced a 9m^2 prototype of an inflatable drag device.

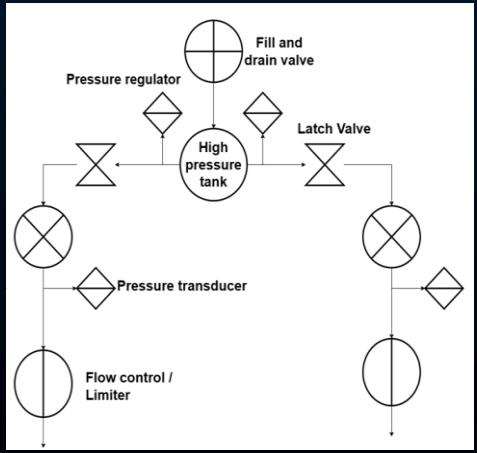
This prototype allowed the testing of the complete production processes, structural resistance and stiffness.



Inflation System

Tank or cold gas generators can be used as sources of inflation gas

For now, we have not yet finally decided on what is the best solution.



Product Development Challenges

One of our concerns are the damages that the sail or the inflatable can have during end-of-life mission phase.

Impact and damage energy levels need to be researched further.

Rigidification technologies are under study.

Diameter [cm]	Ntotal [m/2 / year]	Volume [m3]	Mass [Kg]	Energy [J]	Ntotal/10m 2/5 year	Ntotal/ 10m3
0.02	1.5E+00	4.2E-12	1.2E-08	1.15	14.9	74.5
0.03	4.7E-01	1.4E-11	4.0E-08	3.88	4.73	23.65
0.05	1.1E-01	6.5E-11	1.8E-07	17.96	1.09	5.45
0.07	4.1E-02	1.8E-10	5.0E-07	49.28	0.407	2.035
0.1	1.4E-02	5.2E-10	1.5E-06	143.68	0.143	0.715

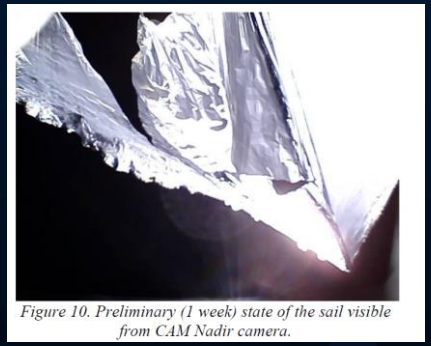


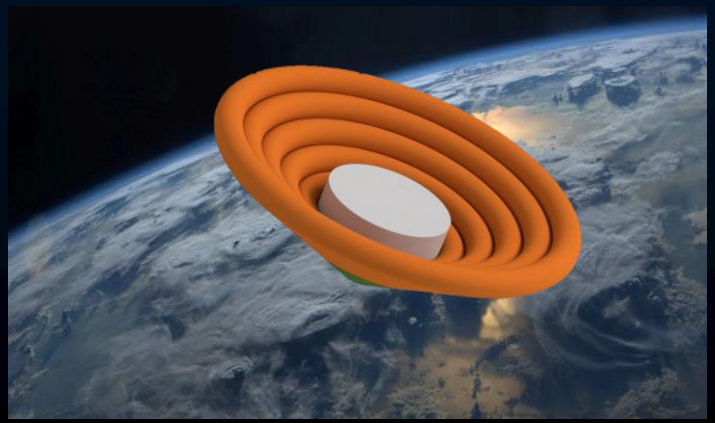
Figure 10. Preliminary (1 week) state of the sail visible from CAM Nadir camera.

Future

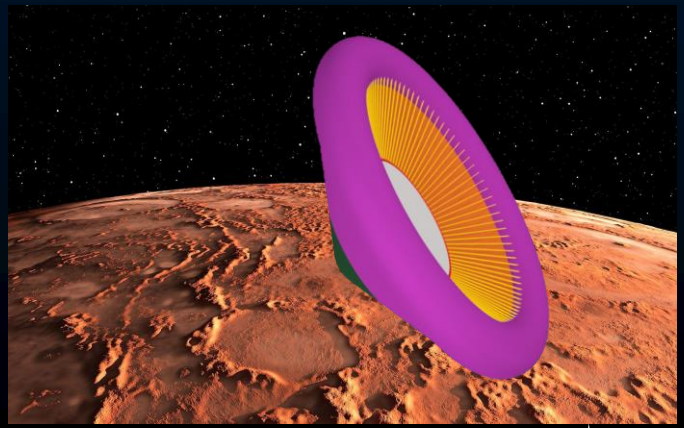
Have an in-orbit demonstration of an inflatable decelerator for clean space .

Keep progressing in other fronts:

Decelerator for recovery of space assets



Decelerator for aerocapture & EDL



Questions?

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