The Horizon 2020 ReDSHIFT Project: 3D printing of demisable spacecraft

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Clean Space Industrial Days
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THE REDSHIFT CONSORTIUM

Great Britain:

- **University of Southampton**
- **Belstead Ltd.**
- **PHS Space Ltd.**

Luxemburg:

- **LUX Space**

Spain:

- Deimos Space
- Elecnor Deimos Satellite Systems

Germany:

- Technical University of Braunschweig
- Deutschen Zentrums für Luft- und Raumfahrt
- University of Cologne

Italy:

- IFAC-CNR (coordinator)
- Università di Padova
- Politecnico di Milano

Greece:

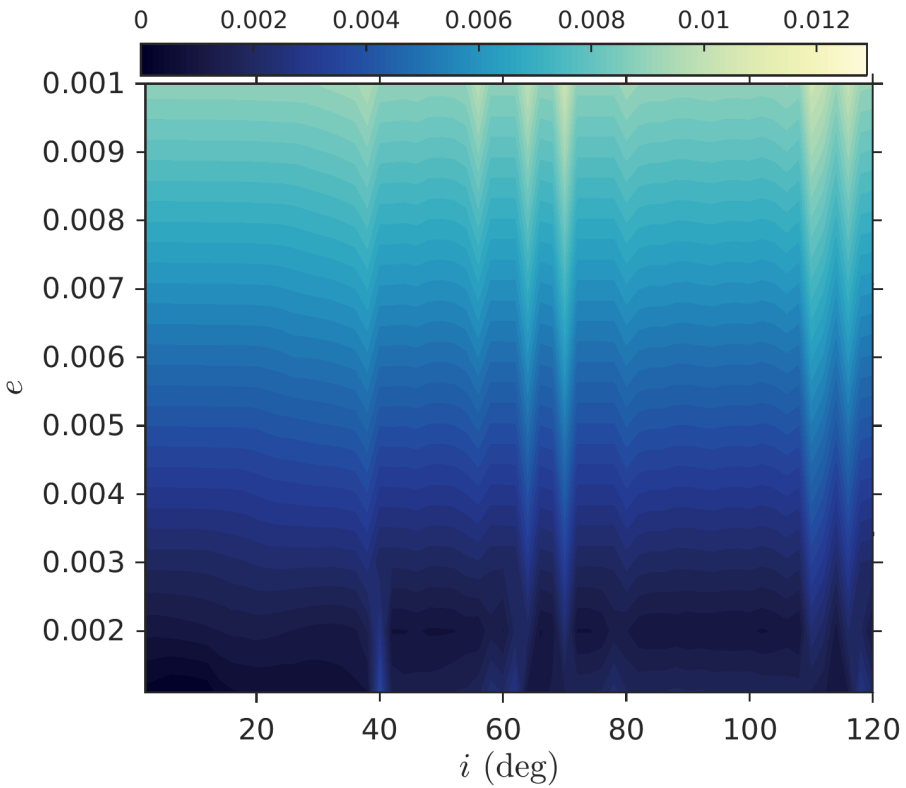
- University of Thessaloniki

ReDSHIFT: MITIGATION FROM THE CRADLE TO THE GRAVE

- Simulations: Simulate the evolution of the current space environment with standard procedures and, later on, with the proposed advanced procedures.
- Astrodynamics: a "cartography" of the phase space in the Earth vicinity will be performed looking for de-orbiting highways (coupled with non-standard propulsion means) using modern celestial mechanics and astrodynamics tools.
- 3D-printing: produce and test prototypes of small spacecraft (or part of) with novel solutions (protection, design-for-demise,....) based on the theoretical findings.
- Legal framework: propose advances to the current mitigation guidelines on the basis of the results obtained.

MAXIMUM ECCENTRICITY MAPS

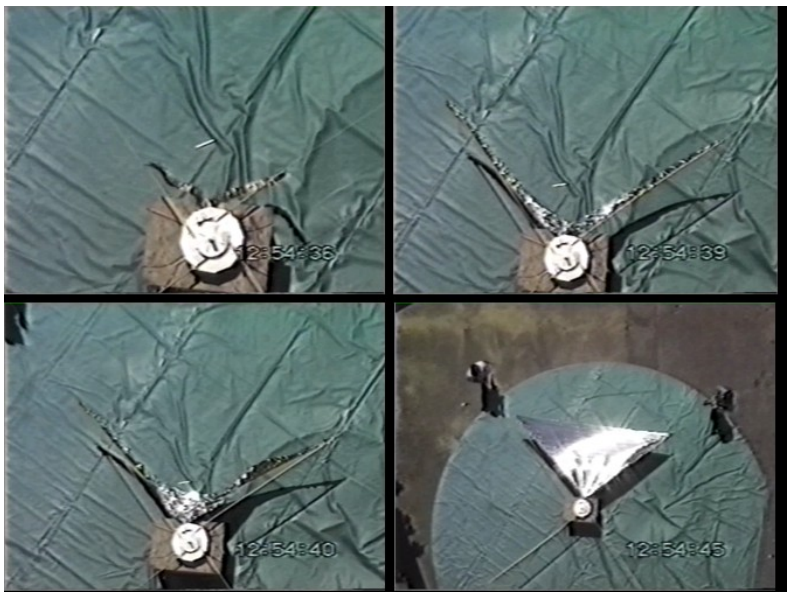
Initial orbits: $a = R_\oplus + 1560$ km, $\Omega = 90°$, $\omega = 0°$

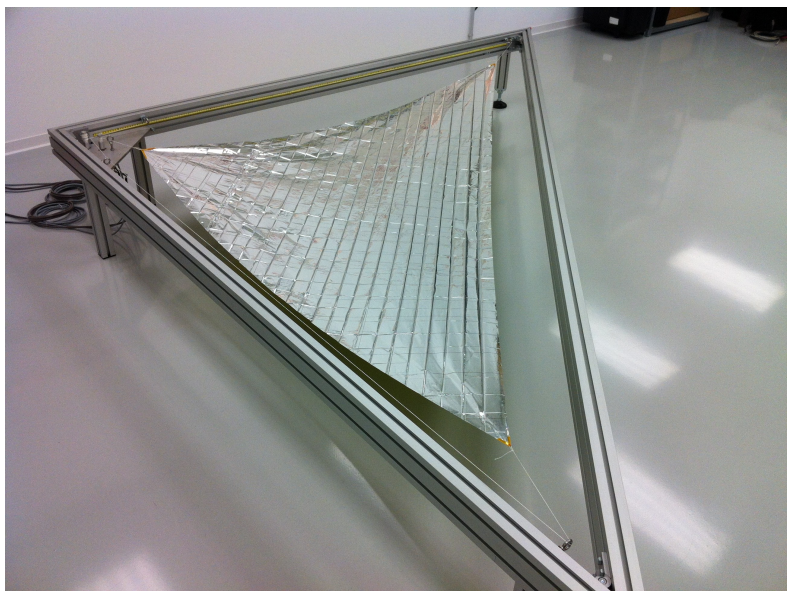


$C_R(A/m) = 0.012$ m^2/kg

AREA AUGMENTATION DEVICES

The possibility to exploit area augmentation devices is explored, by integrating the orbits also objects with $A/m = 1$ m^2/kg.





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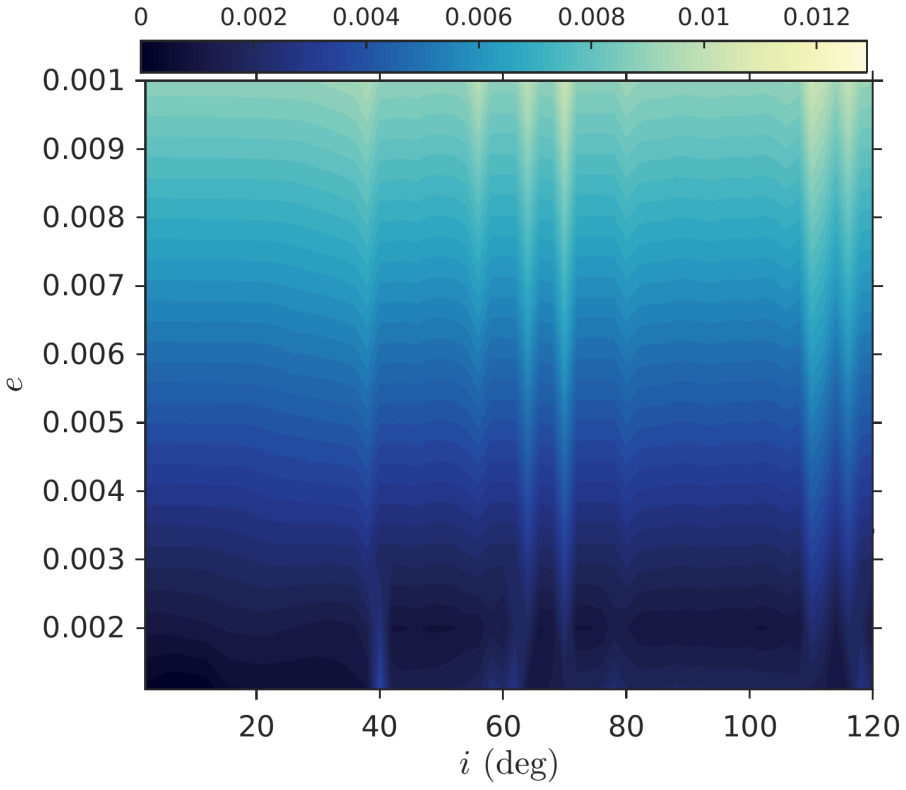

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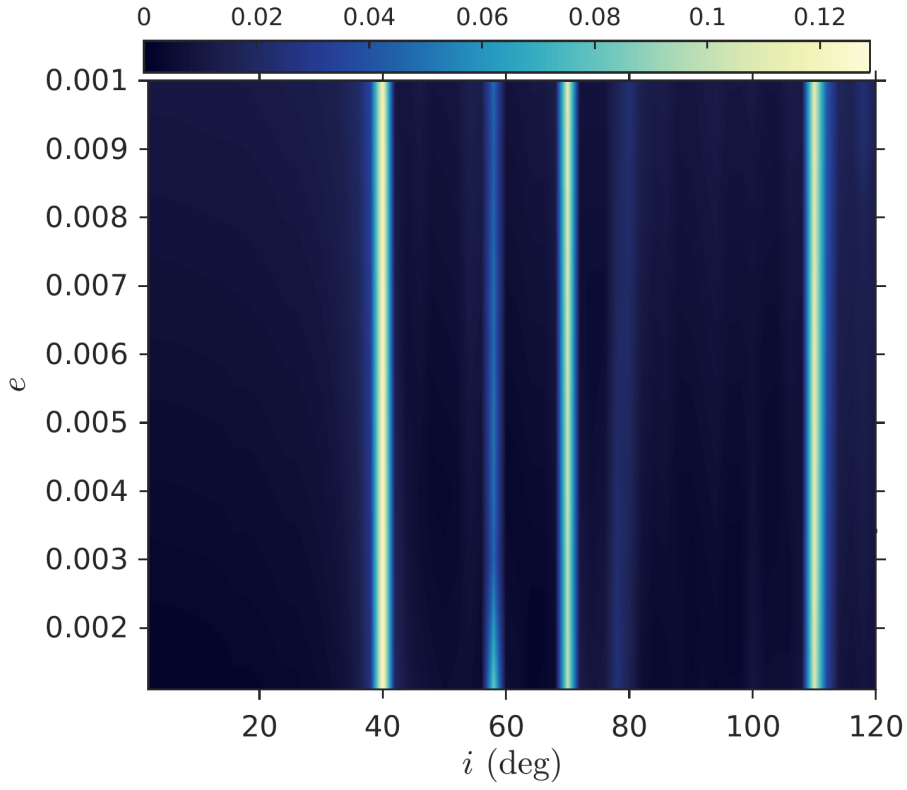
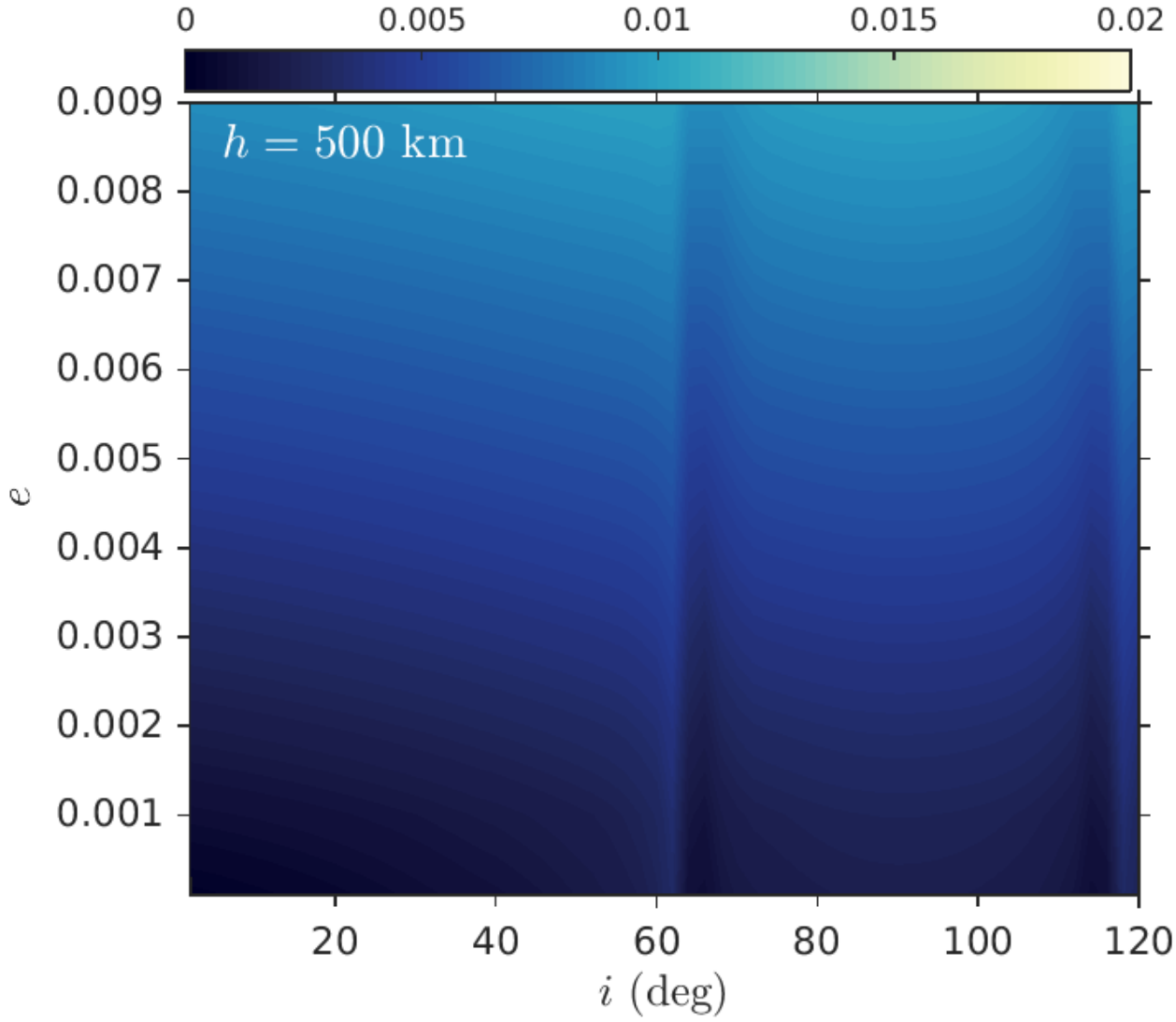


$C_R(A/m) = 1$ m^2 /kg

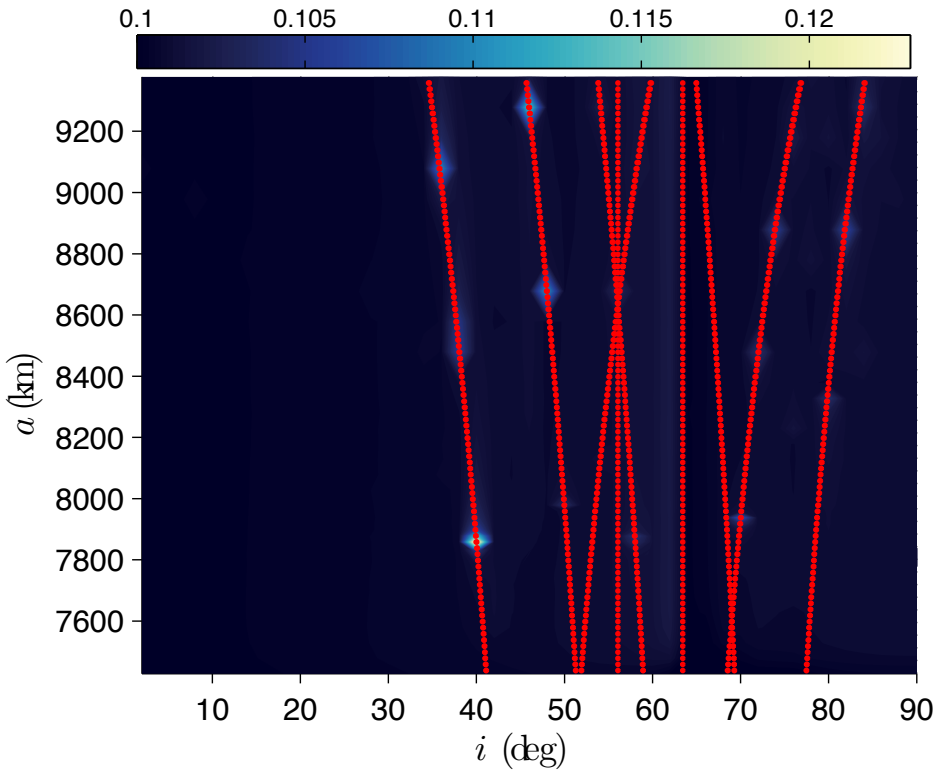
i vs *e*: MEM CONTOUR MAPS FOR EPOCH 2020



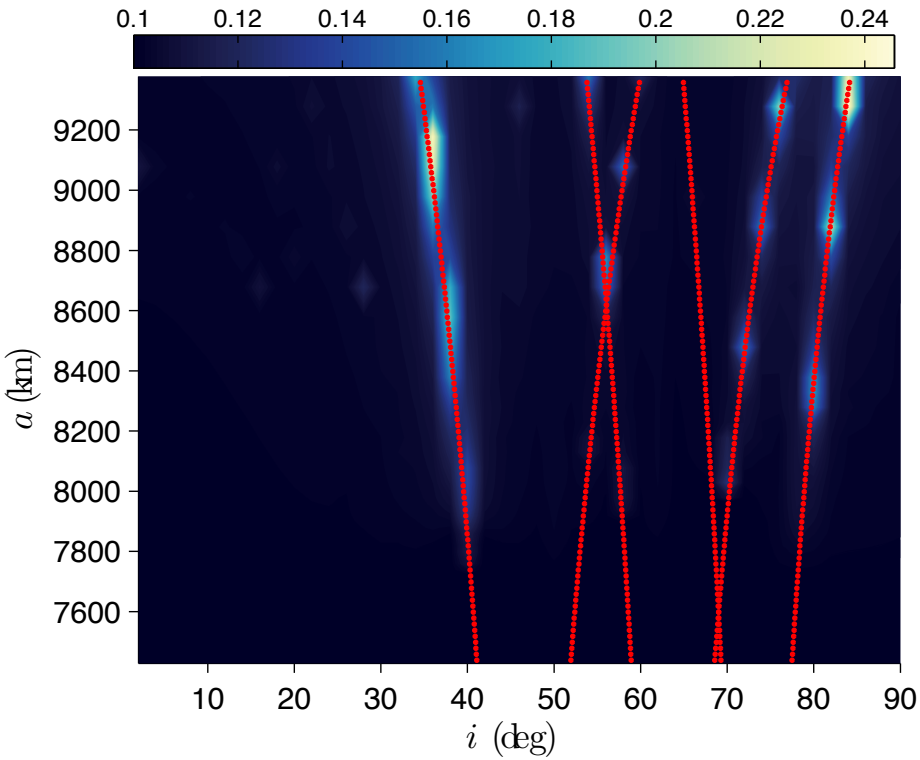
MAXIMUM ECCENTRICITY AND RESONANCES

$e = 0.1, \Omega = 0°, \omega = 0°$

Epoch 2018, $C_R(A/m) = 0.024\ \mathrm{m}^2/\mathrm{kg}$

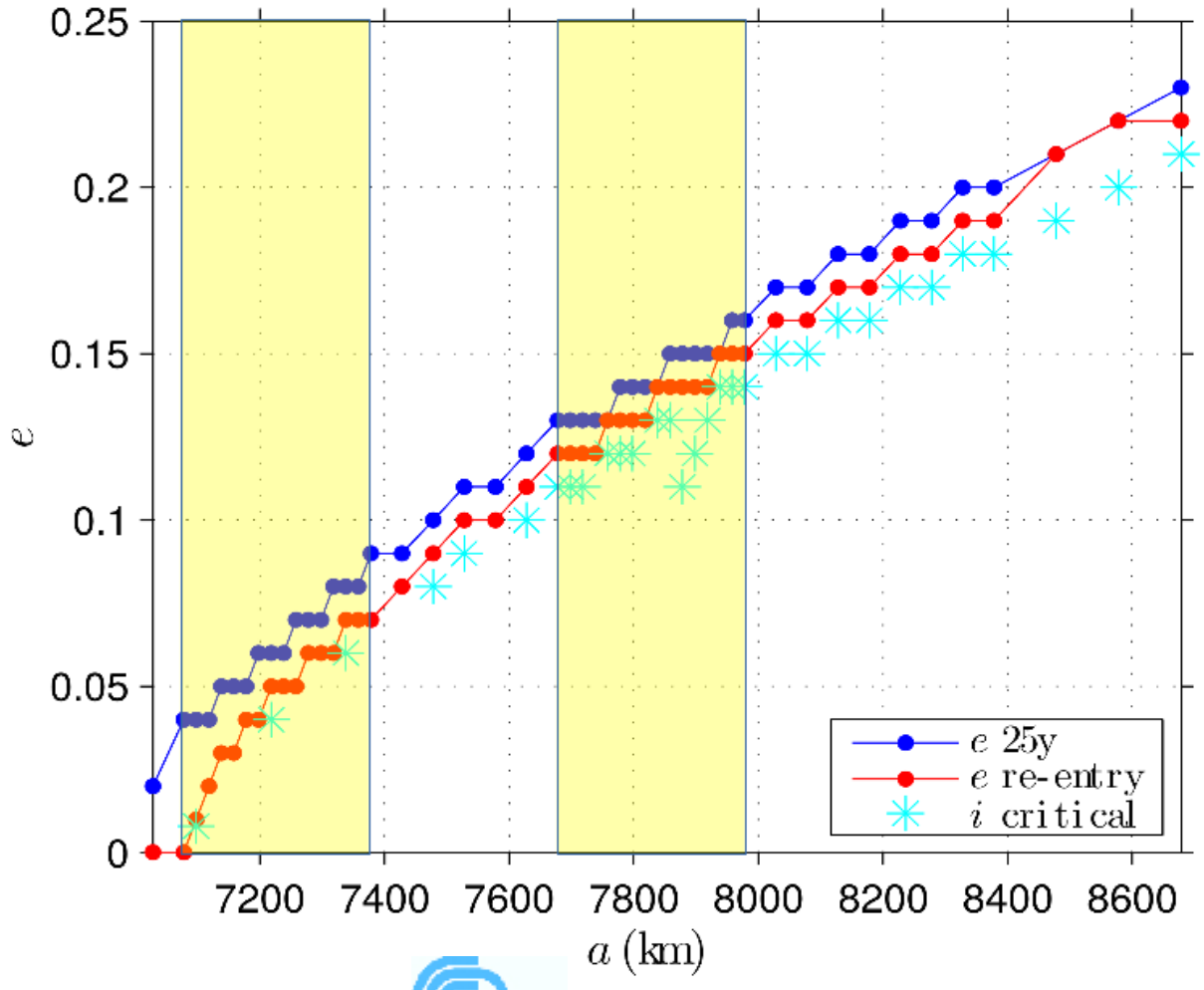


Epoch 2020, $C_R(A/m) = 1\ \mathrm{m}^2/\mathrm{kg}$



RE-ENTRY ECCENTRICITIES

(A/m) = 0.012 m^2 /kg, $\Omega = 180°$, $\omega = 0°$, Epoch: 2020



3D PRINTING: REDSHIFT STRUCTURAL MODEL

- 8U-cubesat
- 226.30 × 226.30 × 227.00 mm
- compatible with the Additive Manufacturing system at the University of Southampton.

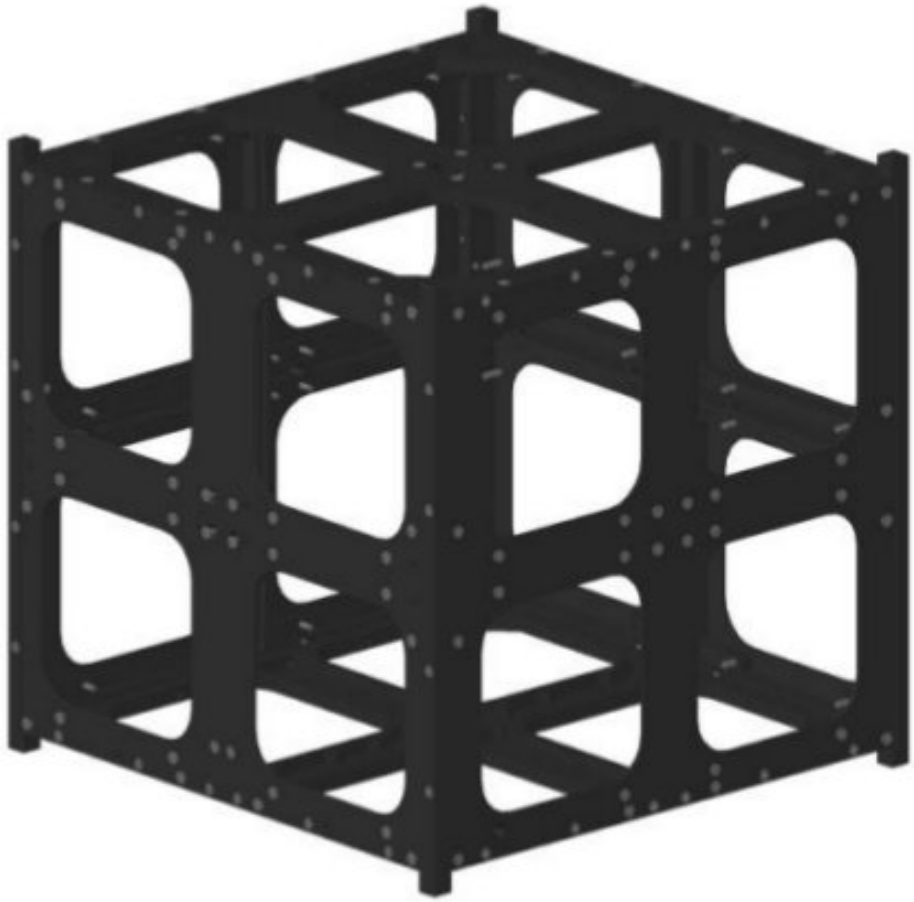


Image by EDSS

3D PRINTING: REDSHIFT STRUCTURAL MODEL

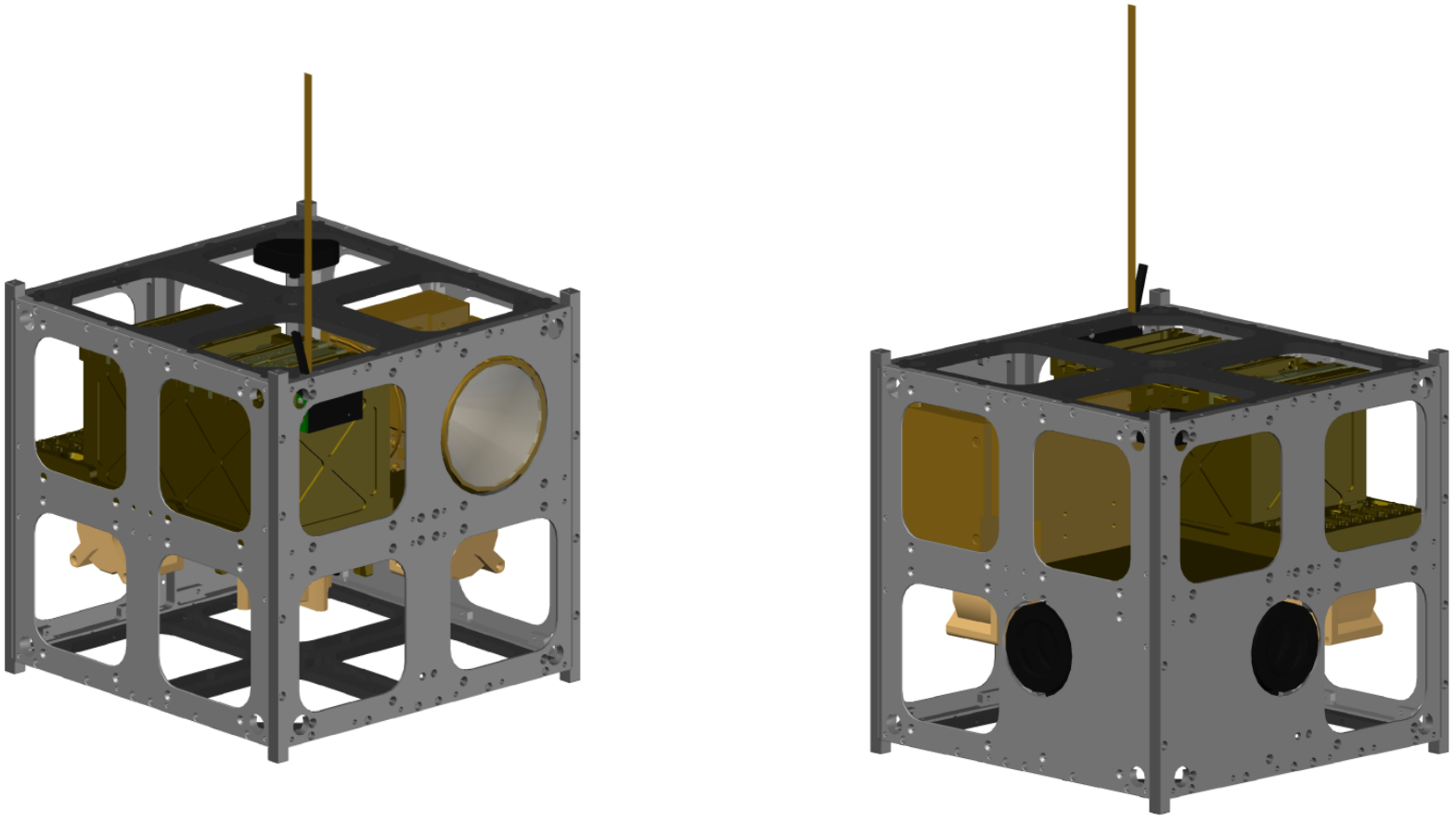


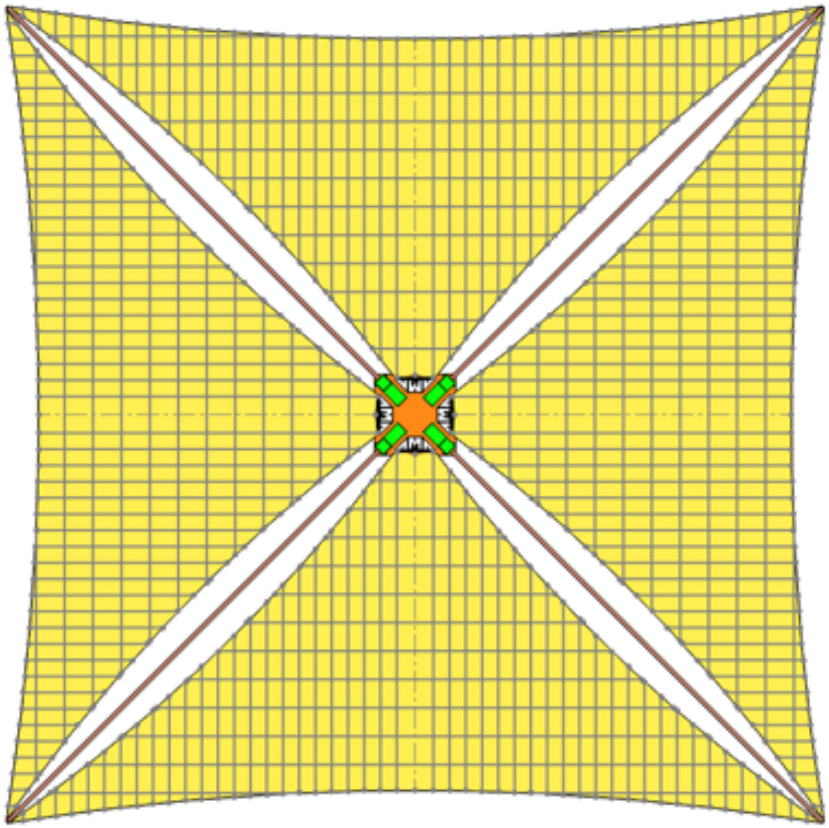
Image courtesy of EDSS

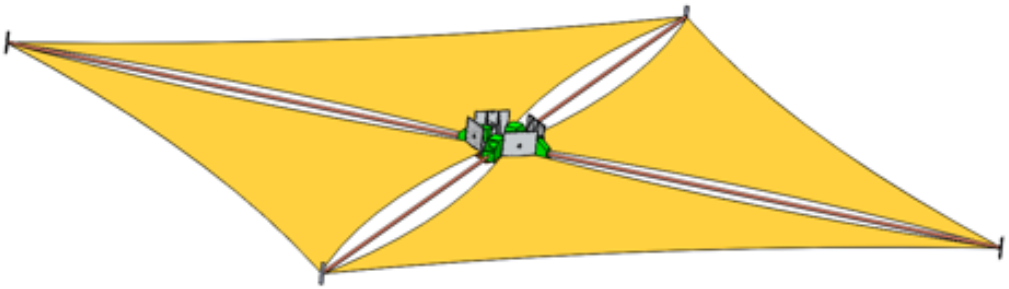
3D PRINTING: REDSHIFT STRUCTURAL MODEL

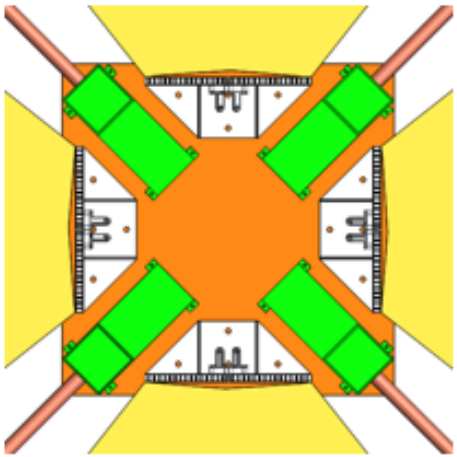
- CAD model and manufacturing drawings completed by EDSS
- 3 different models with different number of components and materials
- A number of features will be tested on these models:
  - Shielding
  - Controlled Break Up
  - Design for Demise (D4D)
- Different tests will also be performed on them:
  - D4D, in heated wind tunnel at DLR, Germany;
  - Impact, with hypervelocity gas guns at CISAS, Italy;
  - Radiation tests at INFN, Italy.
  - Vibrational test at EDSS, Spain.

REDSHIFT: 3D PRINTING FOR SAIL

Square planar drag sail module with sail deployed (LuxSpace)







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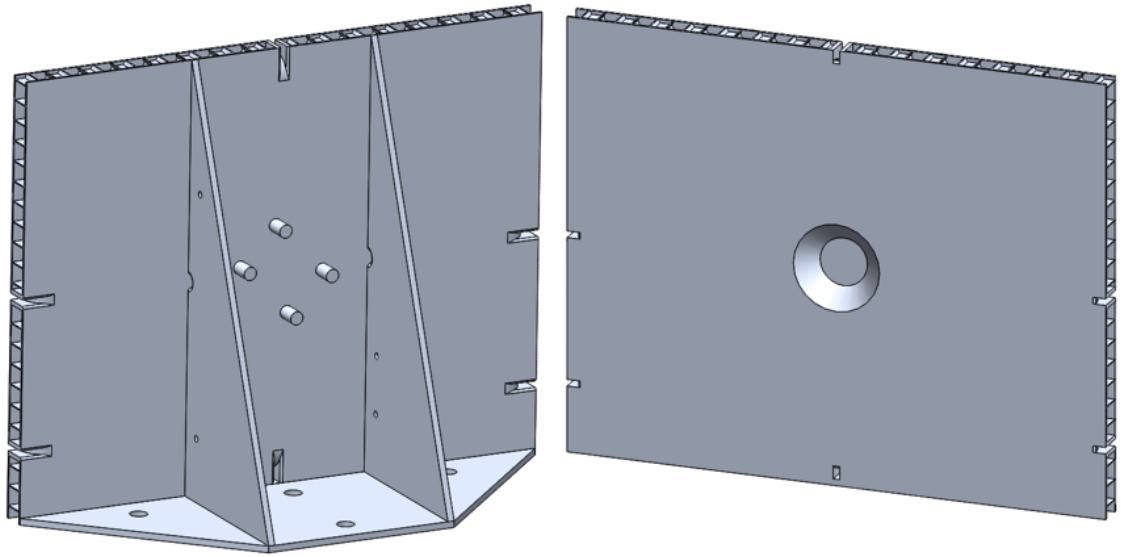
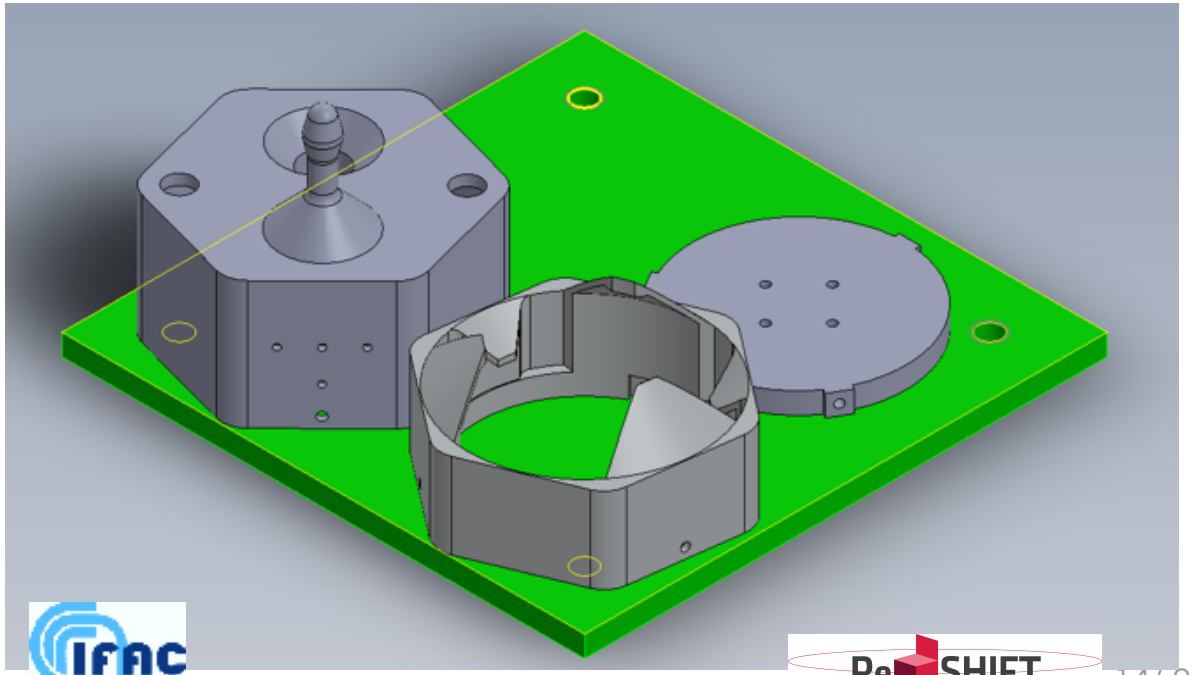


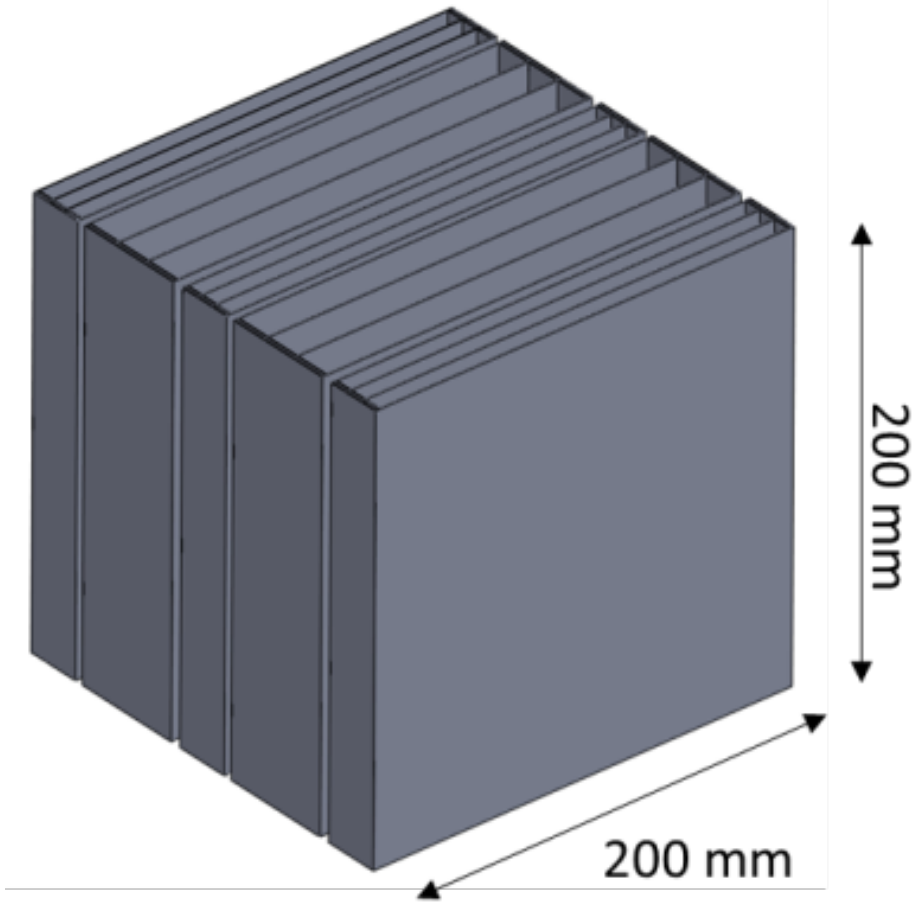
- Sail container

- Attach assembly mechanisms on 3D printing plate



REDSHIFT: 3D PRINTING FOR SHIELDING

Multi-shock panel: structure panel comprising four equally-spaced aluminum bumper layers

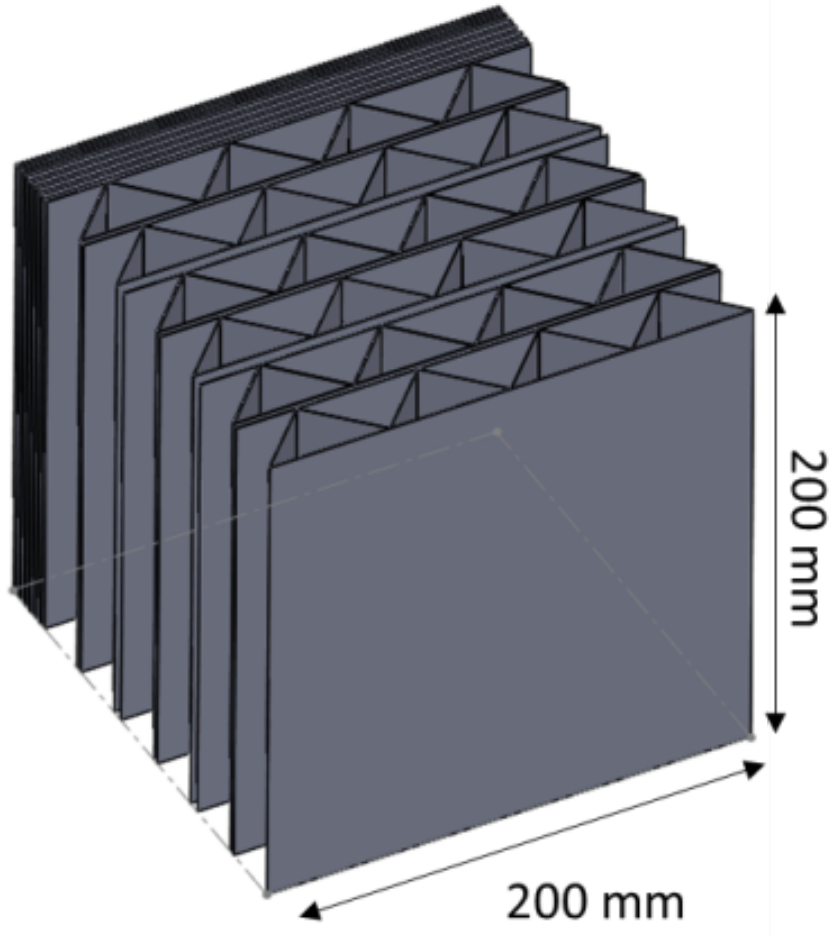


- Material is Al alloy
- Thickness: $0.25 \div 1.00$ mm

PHSSpace & UniPD

REDSHIFT: 3D PRINTING FOR SHIELDING

Single corrugated panel: structure panel comprising outer bumper layers sandwiching a corrugated core bumper layer



- Material is Al alloy
- Thickness: $0.25 \div 1.00$ mm

REDSHIFT: D4D WORK

Theoretical analysis work being performed on a wide range of aspects:

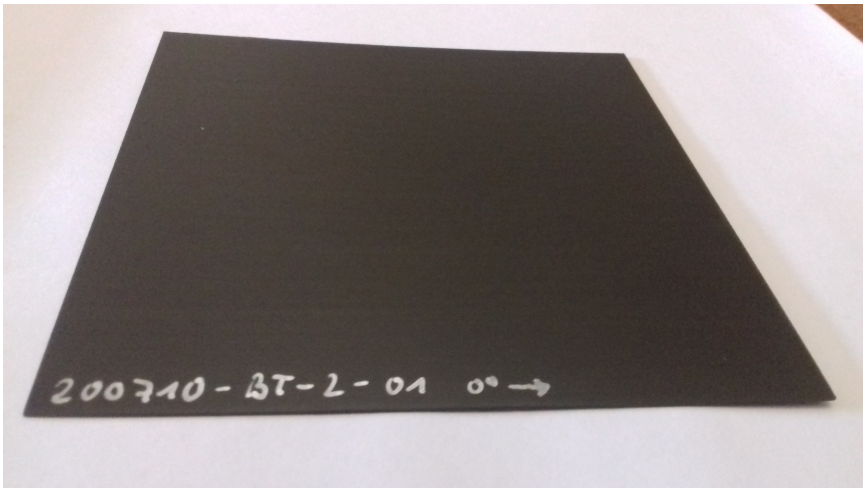
- Synergies with re-entry highways
- Impact of drag sails on demise
- Propellant tanks fragmentation effects
- Reaction wheel demise analysis
- Assessment of sandwich panel demise
- Impact of 3D printing on demise

Complemented by dedicated test campaigns.

REDSHIFT: D4D WORK

Key test objects:

- Aluminum shear testing & Comparison with 3D printed material
- CFRP material shear testing and fibre bend/break testing
- Sandwich panels demise testing
  - Comparison with 3D printed cores
- Insert removal tests
  - Comparison with integrated 3D printed insert



INVENT material, CFRP M55J fibres with EX1515 cyanate ester resin

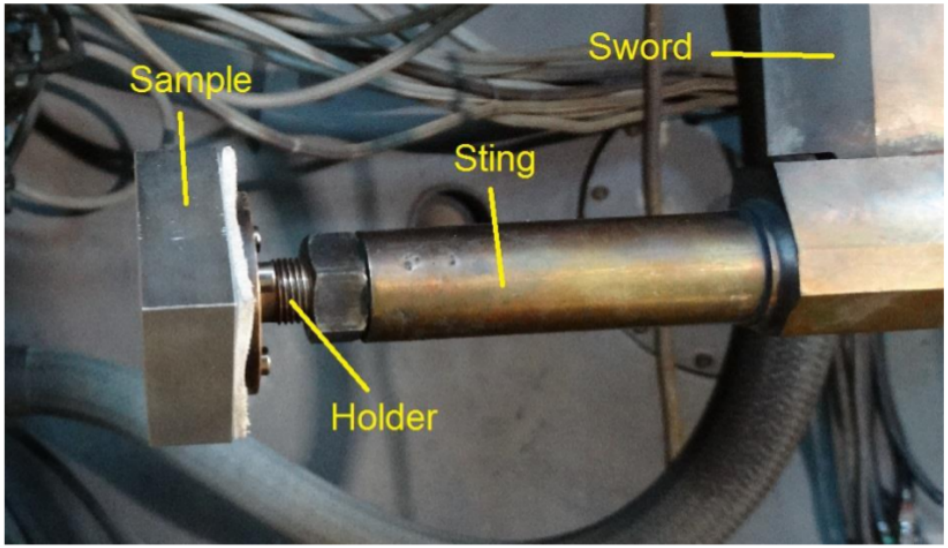
20mm aluminum honeycomb, CFRP facesheets as above

REDSHIFT: D4D - KEY TEST OBJECTS: CUBESAT

Complex Object Testing: CubeSat

- EnduroSat Structure, integration by EDSS
- DLR will replace the dummy cards with a range of electronics GFRP cards for the tests.

REDSHIFT: D4D - CUBESAT: DLR TUNNEL SETUP



The *L2K sting* interface consists on M16-1.5 (fine) threaded hole.

Sample holder can be made of common grade A2 stainless steel (EN 1.4301 / AISI 304).

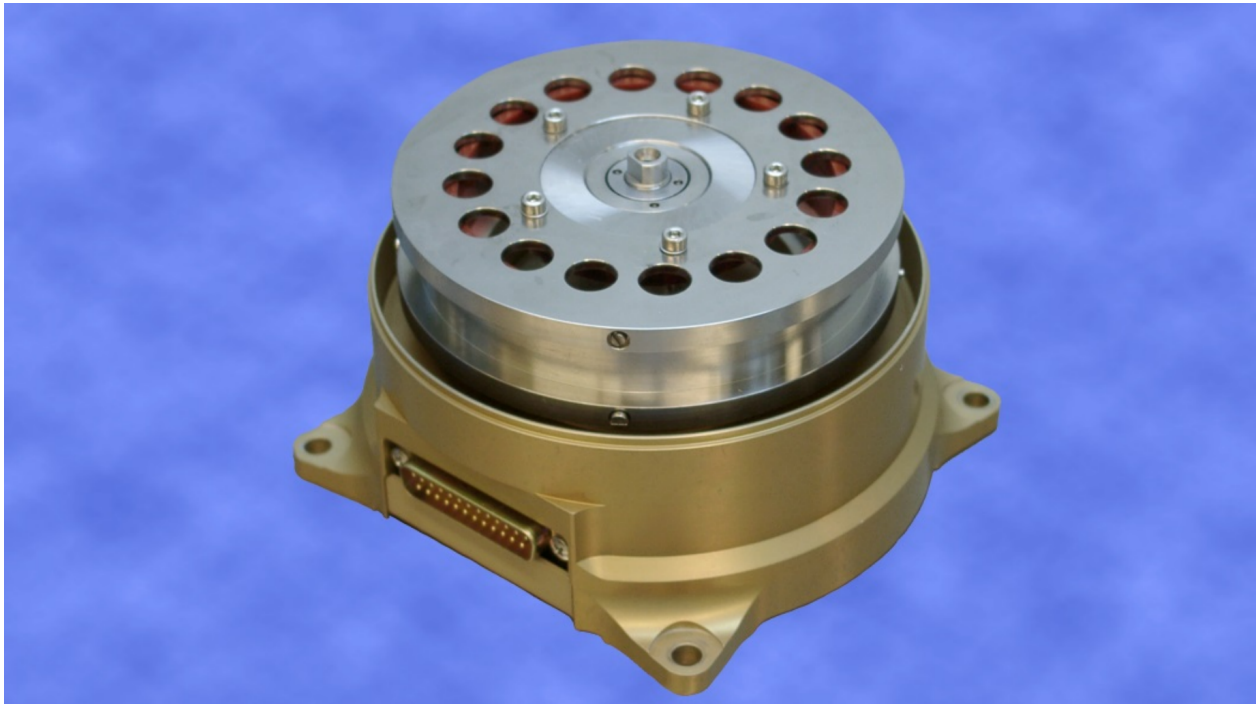
Test conditions:

- Heat flux: 50-100 kW/m2
- Temperature: 500-900˚C

REDSHIFT: D4D - KEY TEST OBJECTS

Complex Object Testing: Reaction wheel from Rockwell Collins

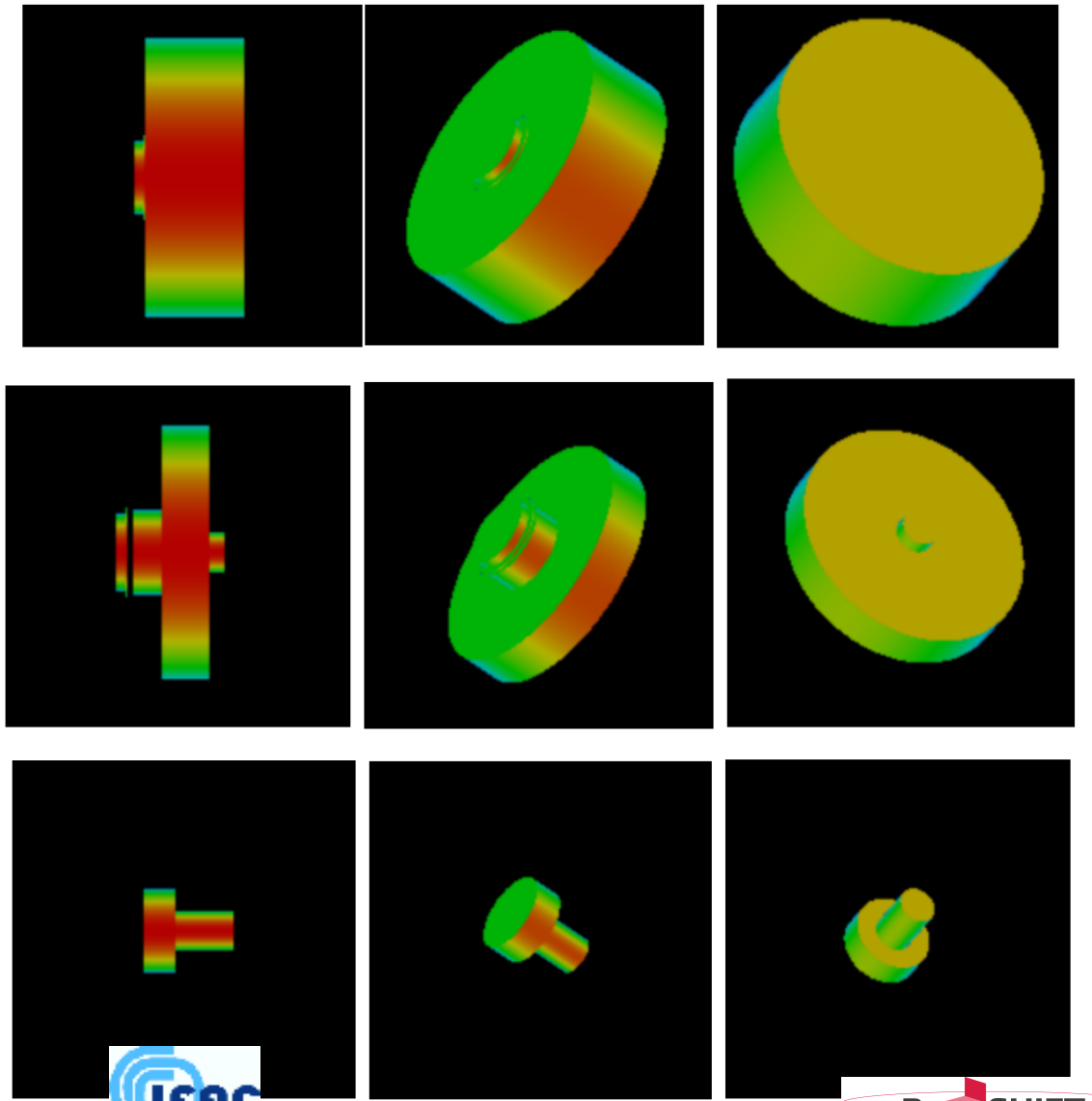
- Aim is to do two tests:
  1. one at low flux to assess fragmentation
  2. one at higher flux on the surviving steel parts.



D4D - Reaction wheel D4D modelling

Contours are heat flux (Lees model)

- First row: full wheel
- Second row: covers removed (top and bottom)
- Bottom row: ball bearing unit and motor stator



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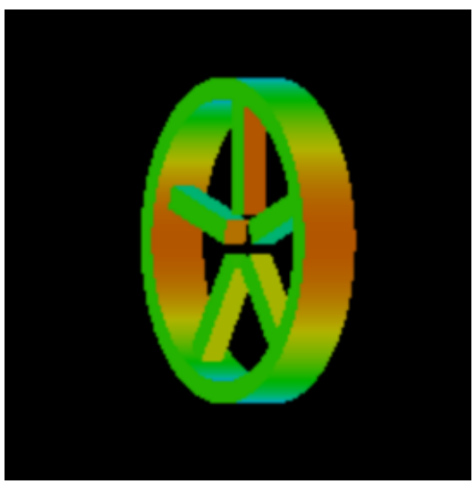

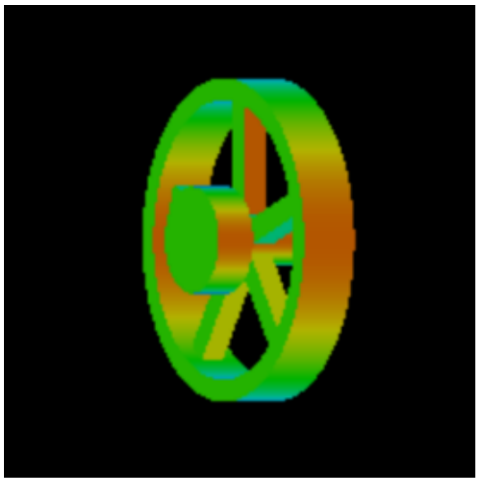
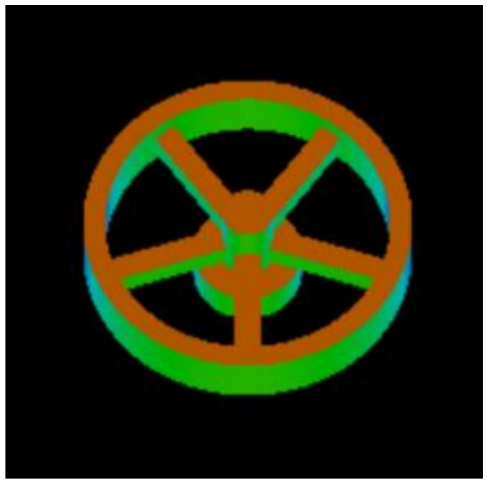

Conclusions and future work

- The astrodynamics part is almost completed
- The software implementing the flux analysis and the *de-orbiting highways* concept, along with the maneuvers, is prototyped and under final revision.
- A web-version of the software, including also the parts related to design and protection, will be publicly available at the project web-site (http://redshift-h2020.eu/)
- The 3D printing facilities are (nearly)ready to start producing the samples
- The first D4D tests are starting in the next weeks
- The impact tests will start as soon as the 3D printed samples will be delivered

ACKNOWLEDGMENTS

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(http://redshift-h2020.eu/).

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