

# ADEO - Architectural Design and Testing of De-orbiting Subsystem (GSTP)

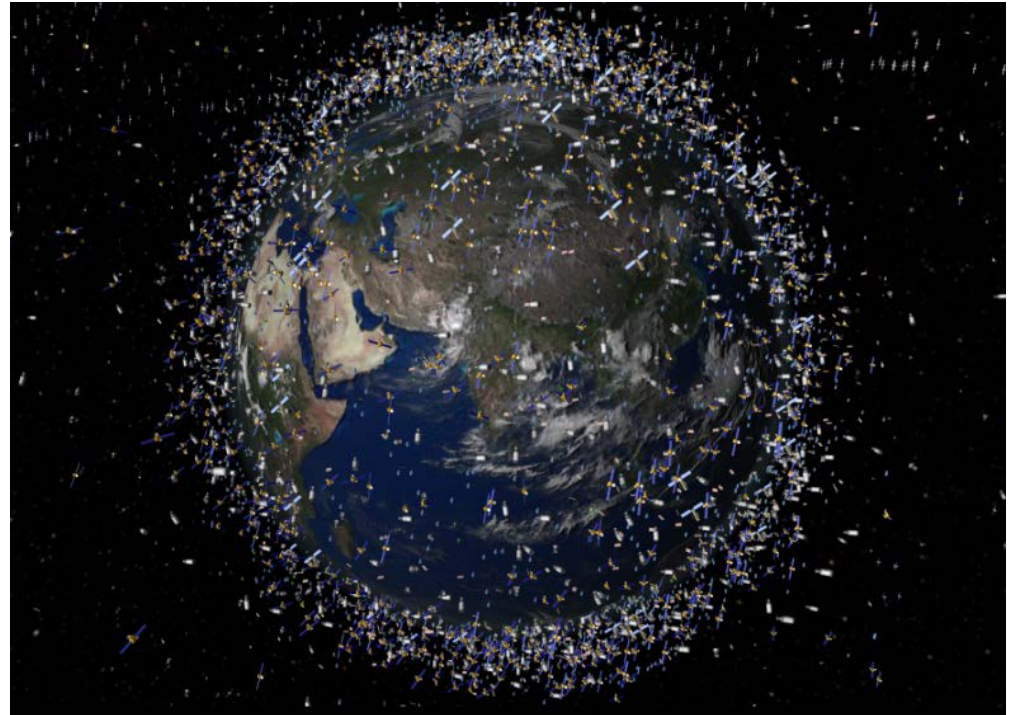
Clean Space Industrial Days (23. – 27.05.2016), ESA ESTEC

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Noordwijk | May 26<sup>th</sup> 2016

## Outline

- Objectives and Requirements
- Project Team
- Reference Mission
- Subsystem Design
- Analysis
- Breadboard Tests
- Demonstrator Test Campaign
- Conclusions



*Artist impression of space debris in LEO, source ESA*

## Objective

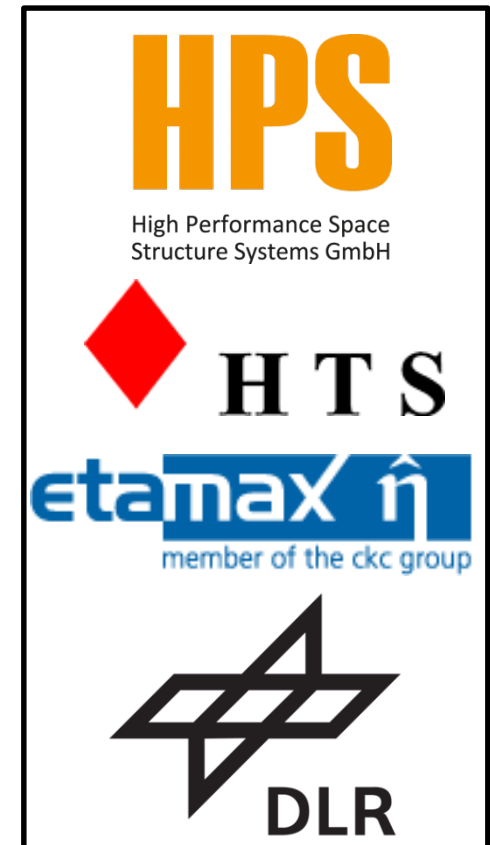
- **Design, manufacture and test a sub-system constituted by a boom and a membrane**
- **Used in LEO to augment the drag of small satellites (fit within VEGA envelope)**
- **De-orbiting period shall not exceed 25 years.**
- **High packaging density for low mass ratio**

## Requirements

- **Ultra-light weight**  
lower mass than propellant
- **Scalable**  
capability to simply enlarge the drag area
- **Generic**  
adaptable for multiple type of LEO missions
- **Passively stabilised**  
no active control system needed

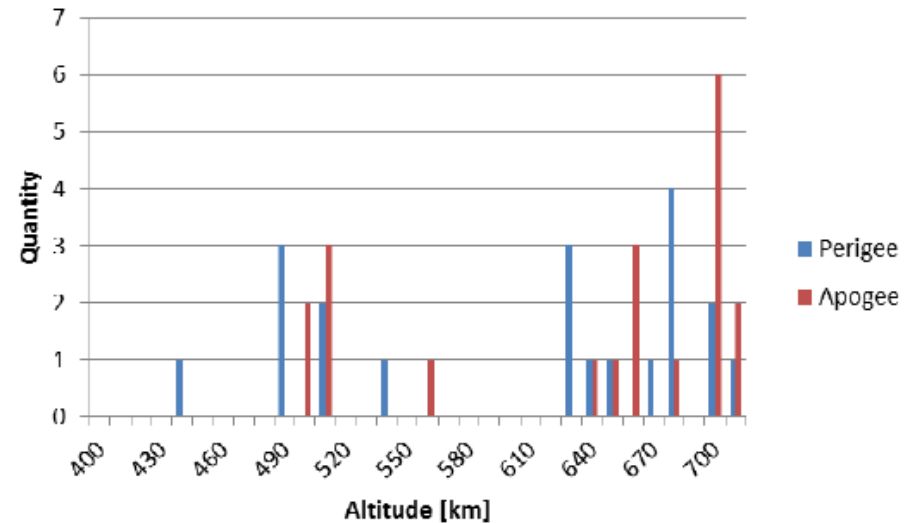
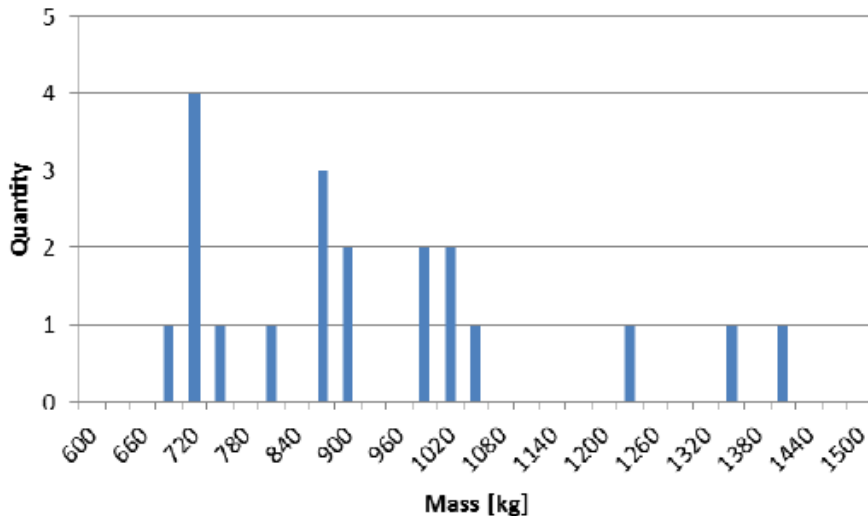
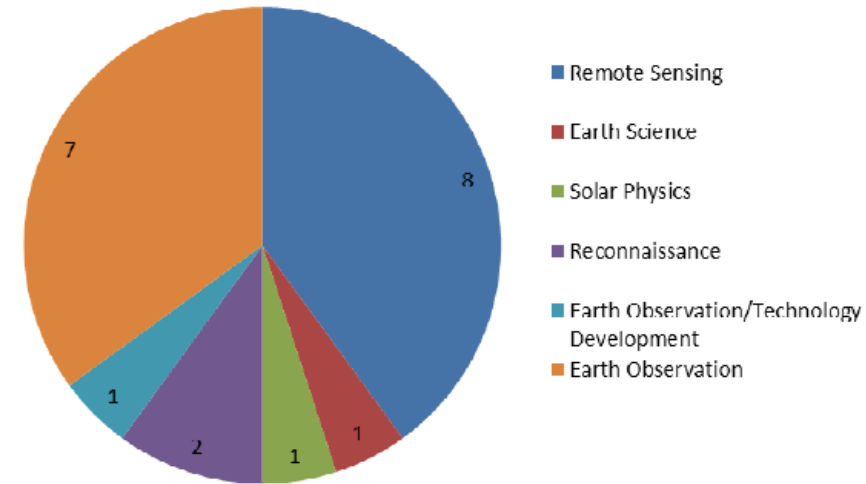
## The ADEO team

- **ESA**  
Customer
- **HPS (prime)**  
System Engineering, Subsystem Detailed Design, Analysis, Subsystem  
Assembly and Test
- **HTS**  
Mechanisms, Membrane (-> DEPLOYABLE MEMBRANE)
- **Etamax**  
Debris Modelling & Stabilisation Techniques
- **DLR Bremen**  
Reference Mission, Design Support, Testing
- **DLR Braunschweig**  
Deployable Boom Design & Manufacturing



# LEO Satellites Assessment

Criteria	Value	Remarks
Orbit period	<99min	Equivalent to a maximum mean orbit altitude of ~705km
Satellite launch mass	600kg < M < 1500kg	1500kg is maximum payload capability of VEGA launcher [AD4].
Users	No "Military"	Military satellites are not deemed likely application of a passive de-orbiting subsystem.
Purpose	No "Communications"	Large quantities of Iridium communication satellites bias the statistics.



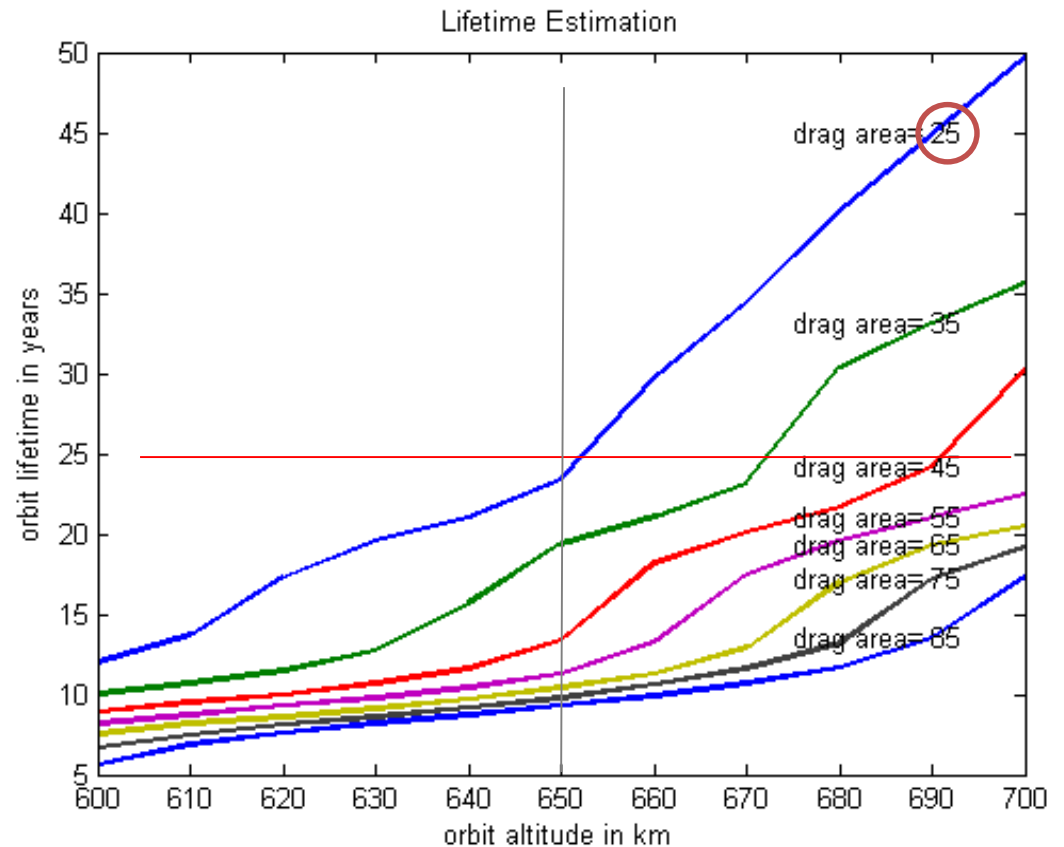
## Preliminary De-orbiting Analysis

- 1000kg satellite
- 650km orbit altitude
- Top Requirement:  
De-orbiting within max. 25yrs

→ 25m<sup>2</sup> drag area

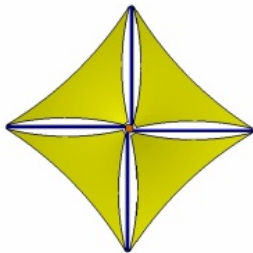
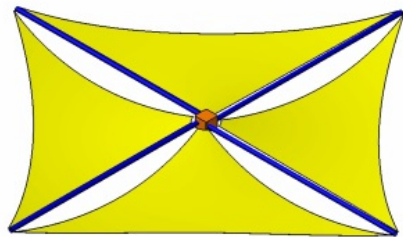
### Simulation:

- 2014 start solar activity
- >700km solar pressure is dominant

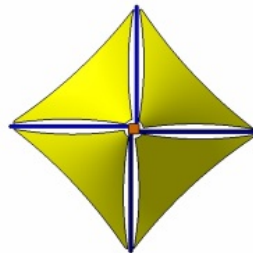
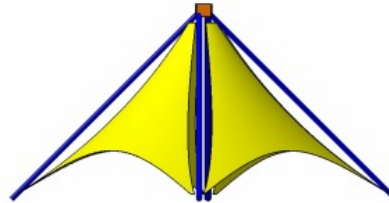
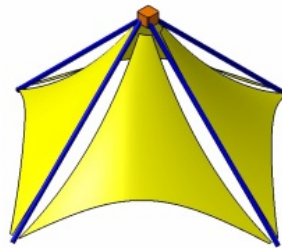


# Initial Concepts

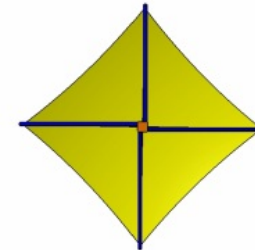
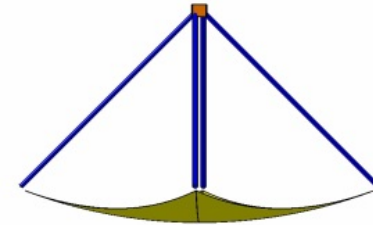
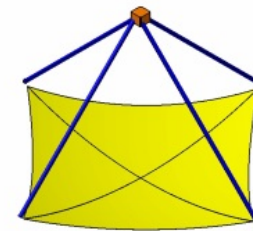
planar with slack



pyramidal



parachute



## ADEO Subsystem Design

S/S Size: 470 x 470 x 240 mm<sup>3</sup>

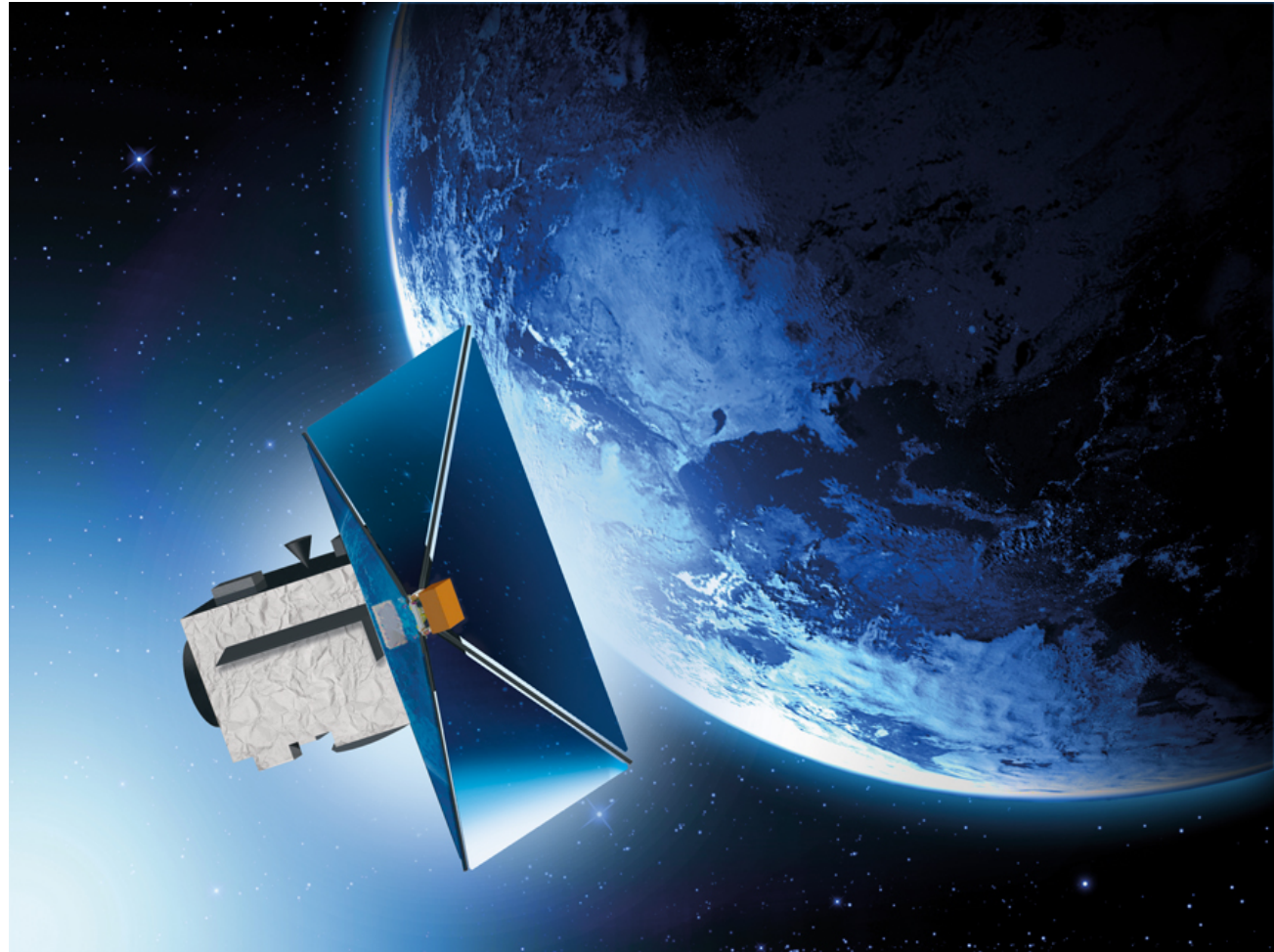
S/S Mass: ~ 19.5kg

25m<sup>2</sup> drag area (4 triangular  
sails)

Truncated pyramid with 10  
degrees angle (easily adaptable  
to other angles)

Reference Satellite Size:

3.0 x 2.0 x 1.8 m<sup>3</sup>

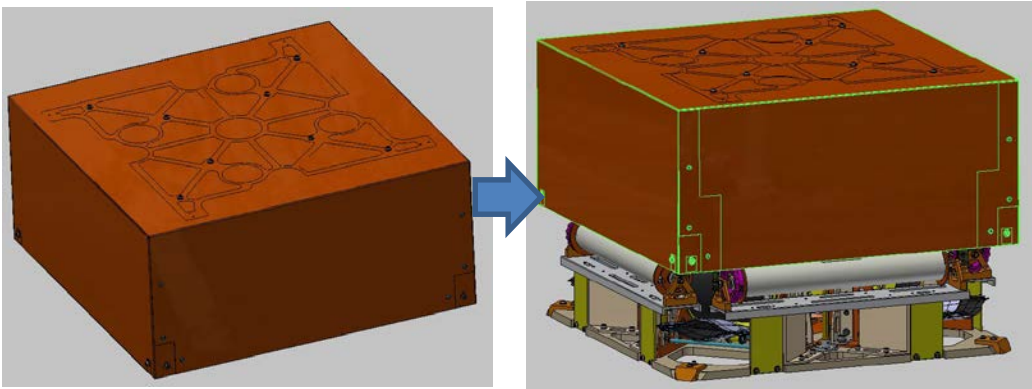


*Artist impression of deployed ADEO subsystem attached on to be de-orbited satellite*

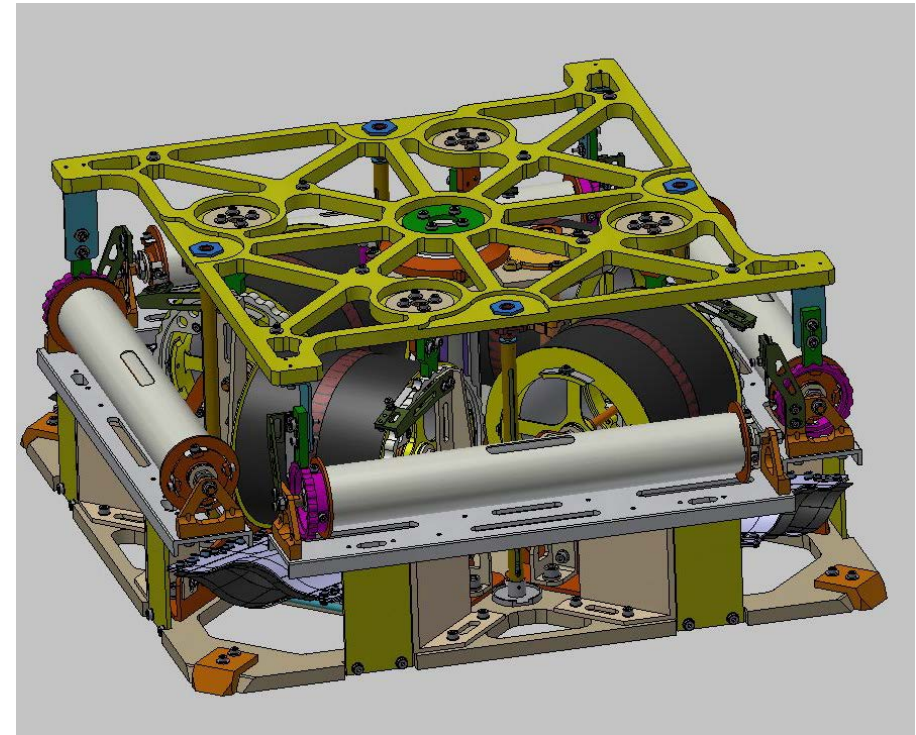


## ADEO Subsystem Design

- 4 boom spools, 4 membrane spools
- 1 stepper motor for boom deployment
- Protective cover for in orbit storage period
- Lifting cover solution limiting number of mechanisms, HDRM with pin puller
- Launch locks on all spools released with HDRM aktivation



*CAD of ADEO in stored configuration and with lifted cover*

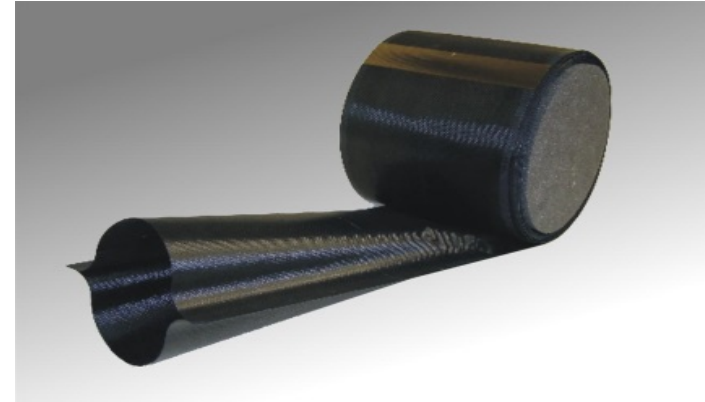


*CAD of ADEO with hidden cover*

## Boom and Membrane

### Boom:

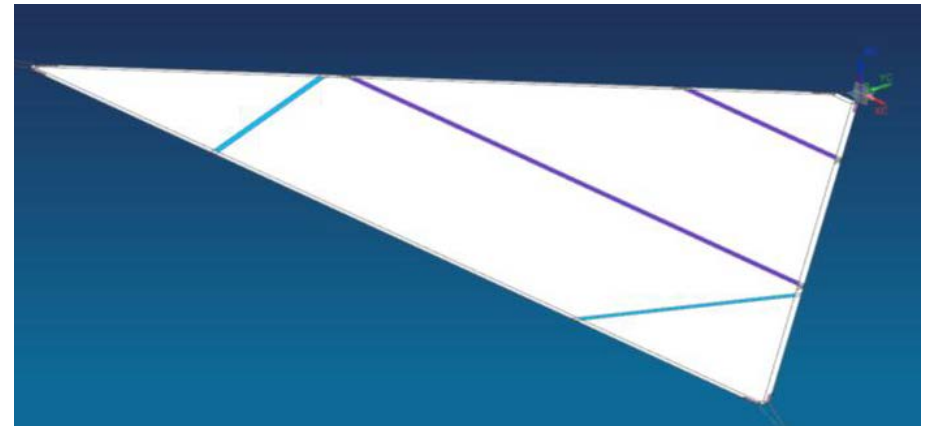
- CFRP boom (4m length)
- Double-omega shape
- Flattened profile stowed on coil



*Stowed CFRP boom deployed from coil, source: DLR*

### Membrane:

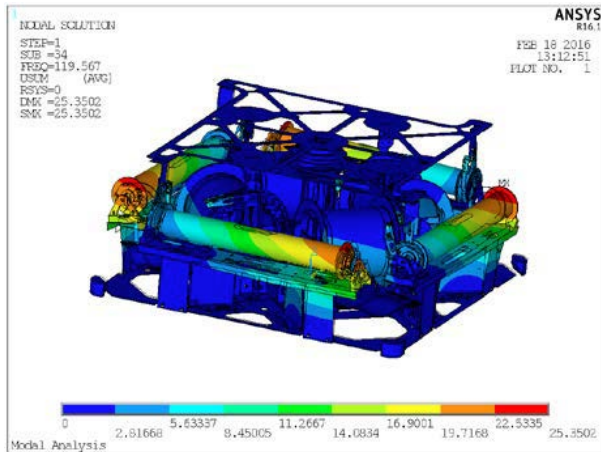
- Triangulars with 5m edge length
  - Stored on membrane spools
  - Protected ultralight polyamid foil
- > DEPLOYABLE MEMBRANE presentation



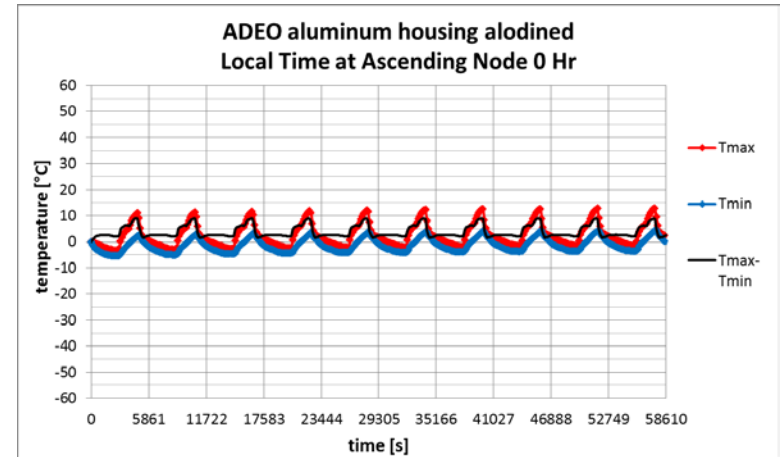
*CAD model of membrane traingular, source HTS*

# Analysis

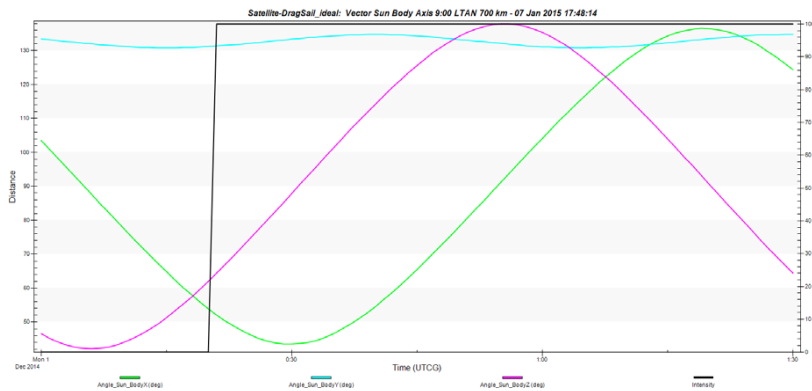
## FEM



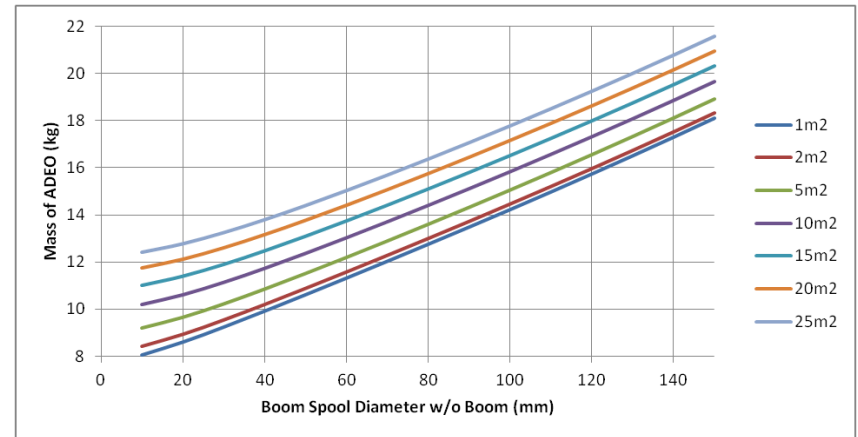
## Thermal Analysis



## Stability

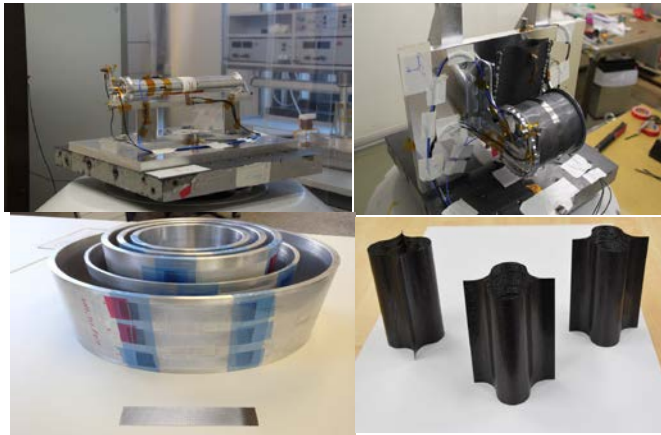


## Scalability



## Critical Breadboards

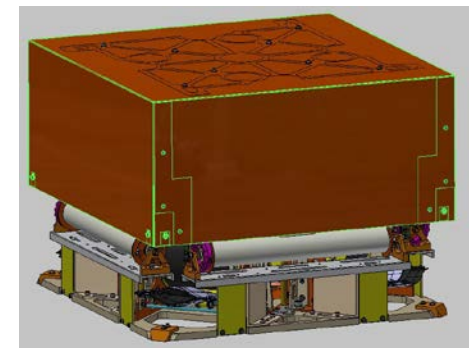
- Boomspring Assembly
- Membranespring Assembly
- Boom Creep Samples
- Sail-Boom I/F Specimens
- Boom and Membrane Impact Samples



*ADEO Breadboards*

## Demonstrator

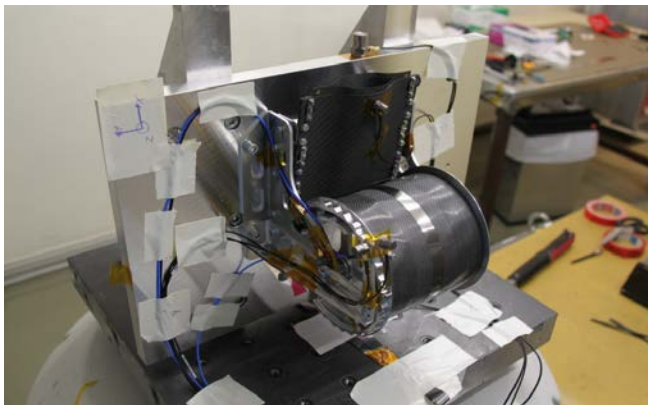
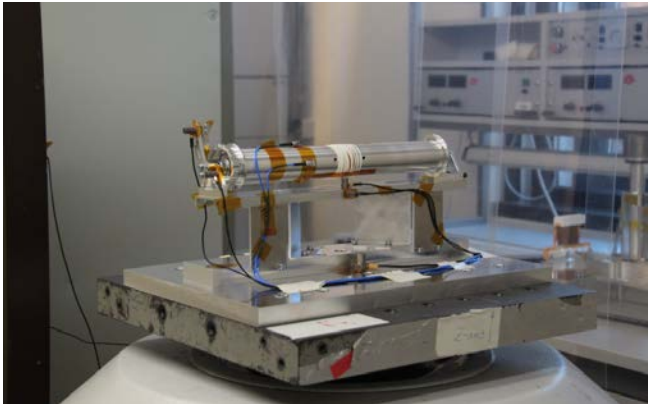
- Full ADEO subsystem with
  - Support Structure
  - Cover +HDRM + Motor
  - $\frac{1}{4}$  drag area with
    - 1 sail
    - 2 CFRP Booms



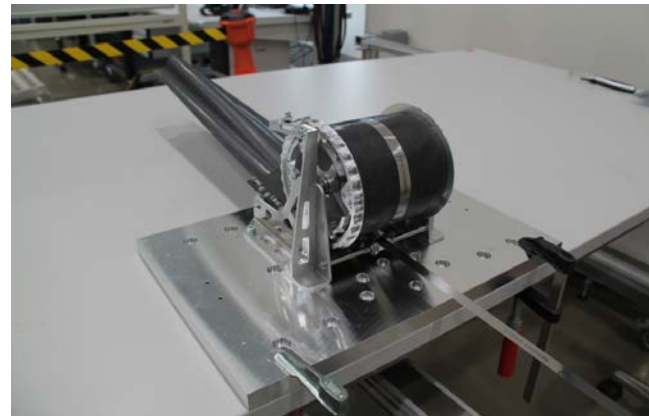
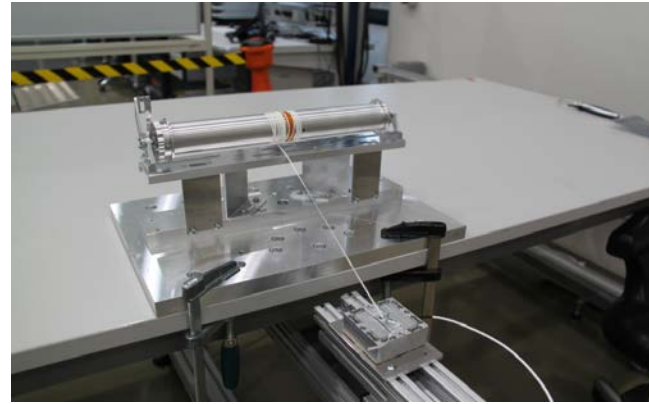
*ADEO Demonstrator*

## ADEO Breadboards

› Vibration and functionality tests



*Boom and sail assembly vibration tests, source DLR*



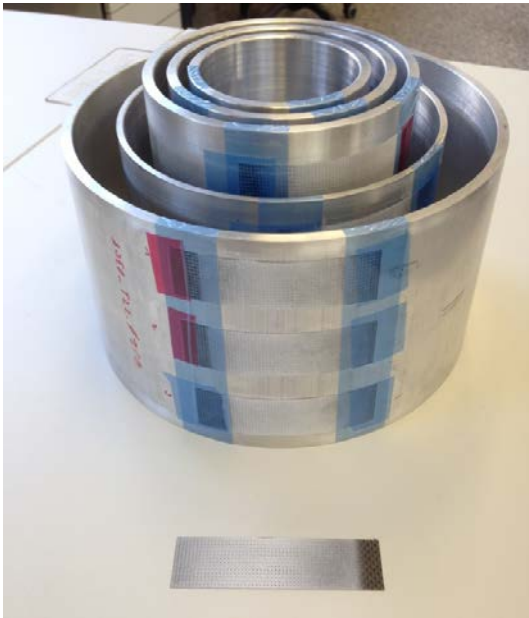
*Boom and sail assembly functionality breadboards, source DLR*



*Fully deployed ADEO boom, source DLR*

## ADEO Breadboards

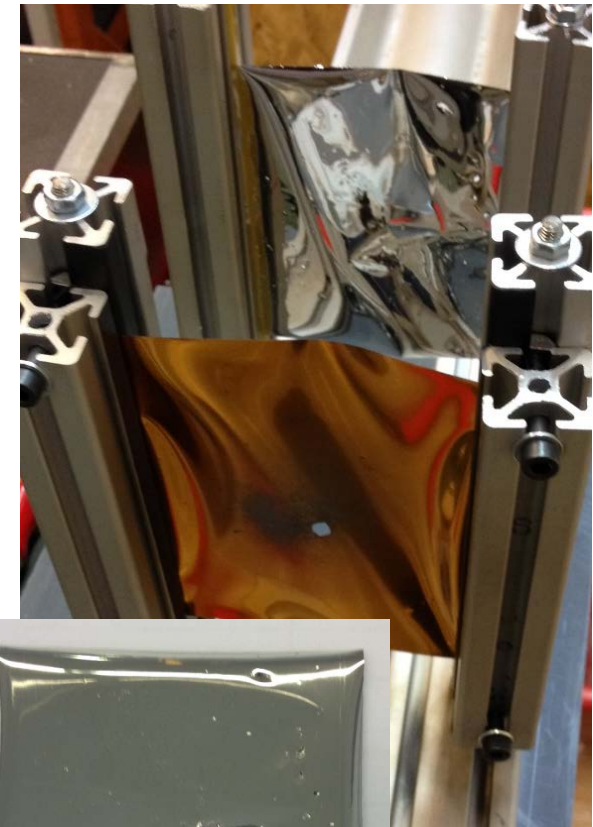
› Creep and Impact BB Tests



*Boom creep tests, source DLR*



*Boom impact tests, source TUM*



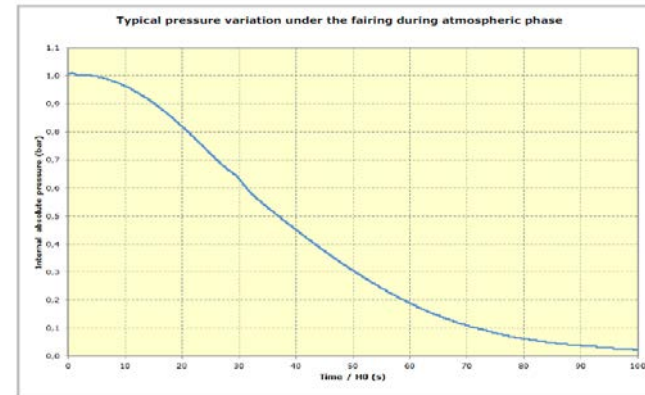
*Sail impact tests, source TUM*

# Demonstrator Test Programm (3rd quarter 2016)

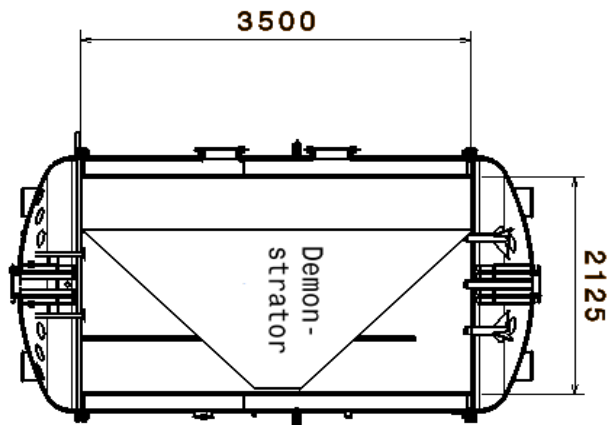
## Vibration and Shock Test



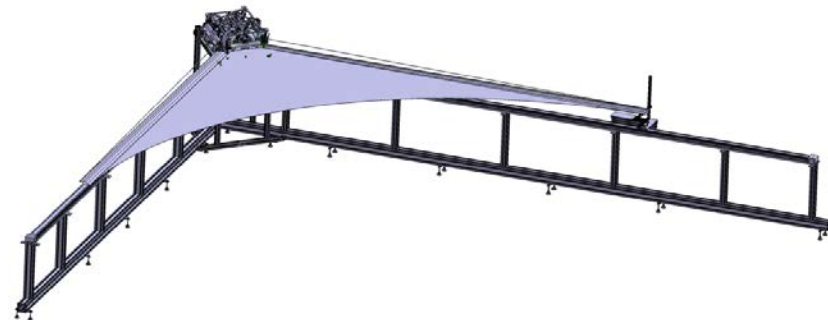
## Rapid Decompression Test



## Life Test



## Deployment Test



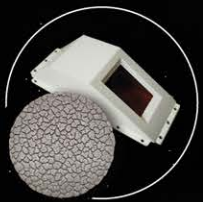
## Conclusions

- Scalable drag sail adaptable for multiple LEO missions (simple adaptable I/F)
- 25m<sup>2</sup> drag sail area to deorbit 1000kg satellite from LEO (650km)
- Deployment via CFRP booms and drag area via membrane (-> DEPLOYABLE MEMBRANE)
- Analysis including FEM, thermal, stability and environment (ATOX, UV, Space Debris)
- Breadboards for vibration & functionality tests, creep and high velocity impacts
- Demonstrator fabrication currently ongoing, demonstrator test campaign planned for 03<sup>rd</sup> Quarter 16
- Paper on ADEO accepted for the ECSSMET in Toulouse in September:





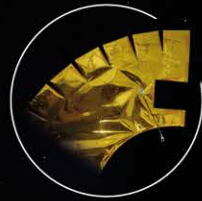
Thank you for your attention.



Launcher and  
Re-entry  
Components



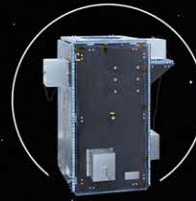
Equipment,  
Instruments



MLI



Radiators



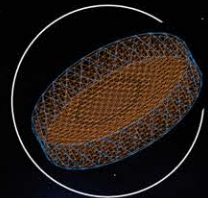
Satellite  
Structures



Antennas



Reflectors



Deployable  
Structures

