

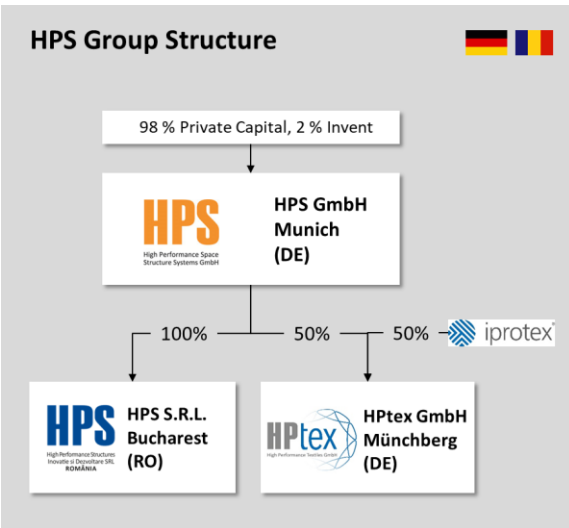
# The ADEO Space Sail Products

Daniel Stelzl, Patric Seefeldt (DLR), Matthias Killian et al.

ADEO Team (HPS)

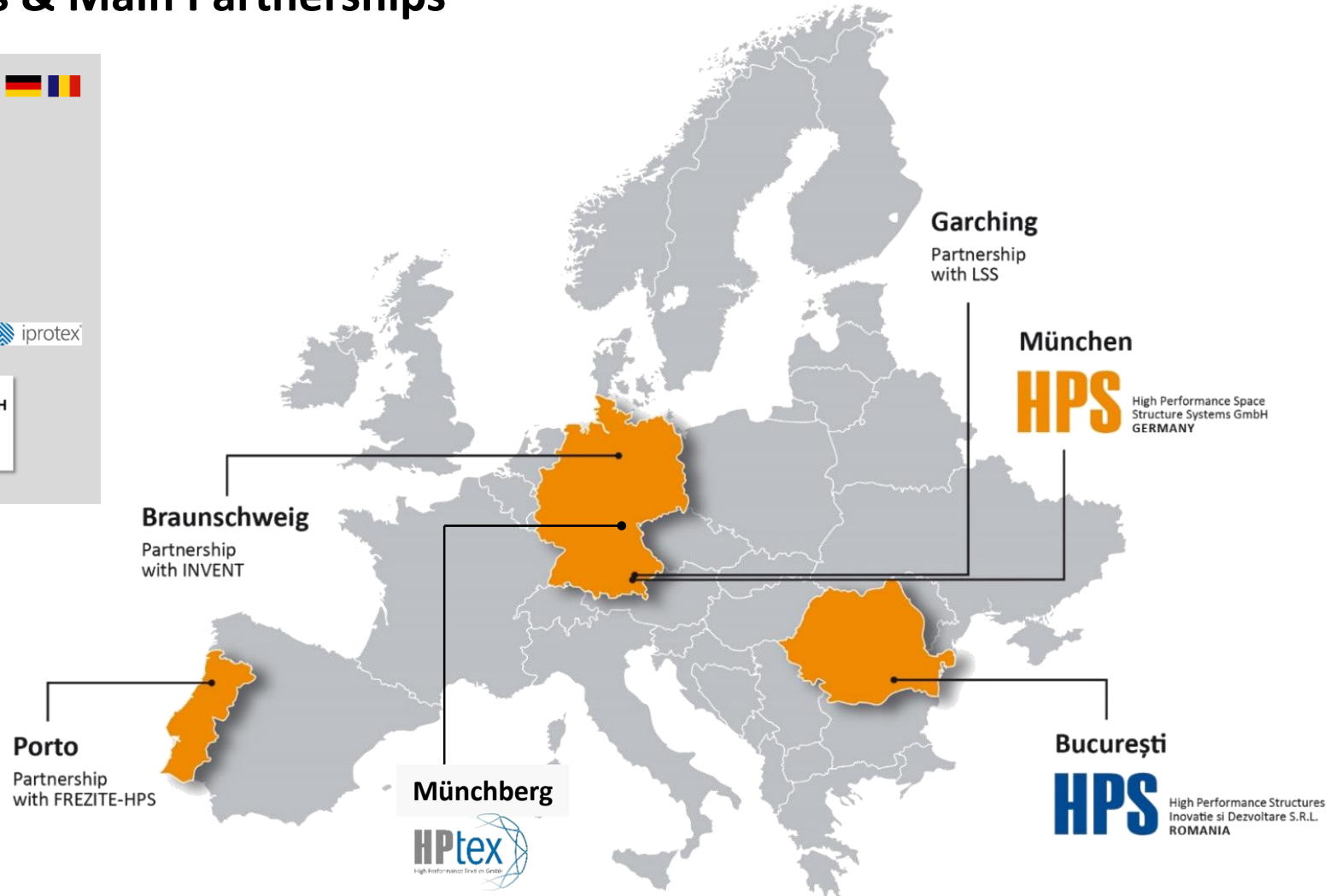
Munich | 2023

## HPS Group Sites & Main Partnerships



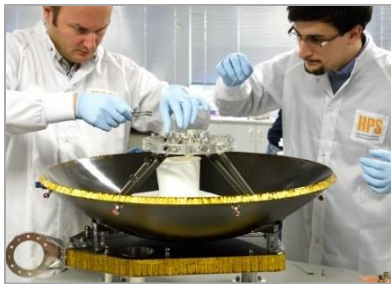
### Number of Employees 2023:

- HPS Munich: 55
- HPS Romania: 15
- HPtexas: 5

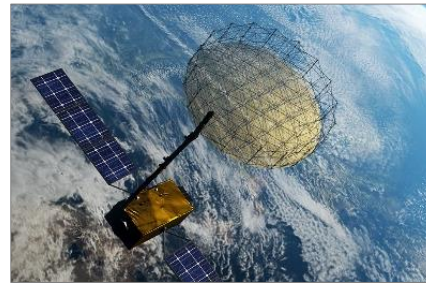


## Product Portfolio HPS Group

Solid Reflector  
Antennas



Large Deployable  
Reflector Subsystems



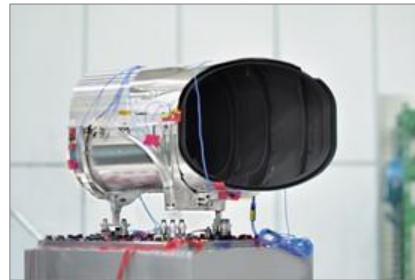
Deployable Deorbit  
Sail Subsystems



Thermal H/W (Radiators,  
Thermal Straps, MLI, etc)



Secondary  
Structures



Antenna  
Components



Mechanical Ground  
Support Equipment

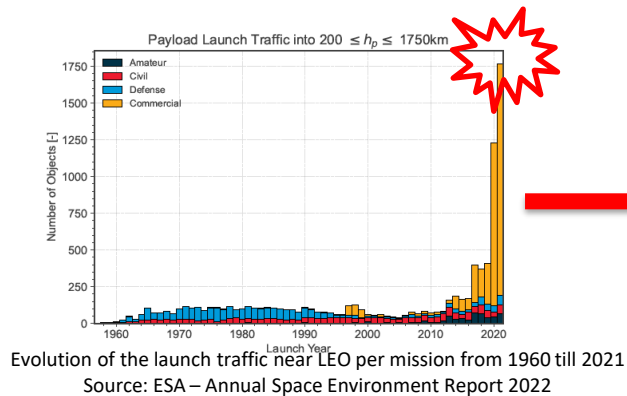


**Other Products and Services:** radiation protection caps, composite structures, engineering & integration service

# Space Debris – Deorbiting – Current & New Regulations



**Past:** 25 year rule/recommendation from IADC was derived before the „NewSpace“ age and does NOT reflect the current situation of launches and S/C in orbit



**Current:** New FCC-Regulation (USA), Zero Debris Policy (ESA) and Space Traffic Management (EC):  
Decommission all **LEO S/C** out of at the end of their operational live  
within **≤ 5 YEARS**  
with **DEORBIT RELIABILITY → ≥ 90%**

## Contributor to several ESA, European and National – Debris Avoidance and CleanSpace Commites and Associations:



CleanSpace Initiative & Zero Debris Policy



ESOC Space Safety Programs



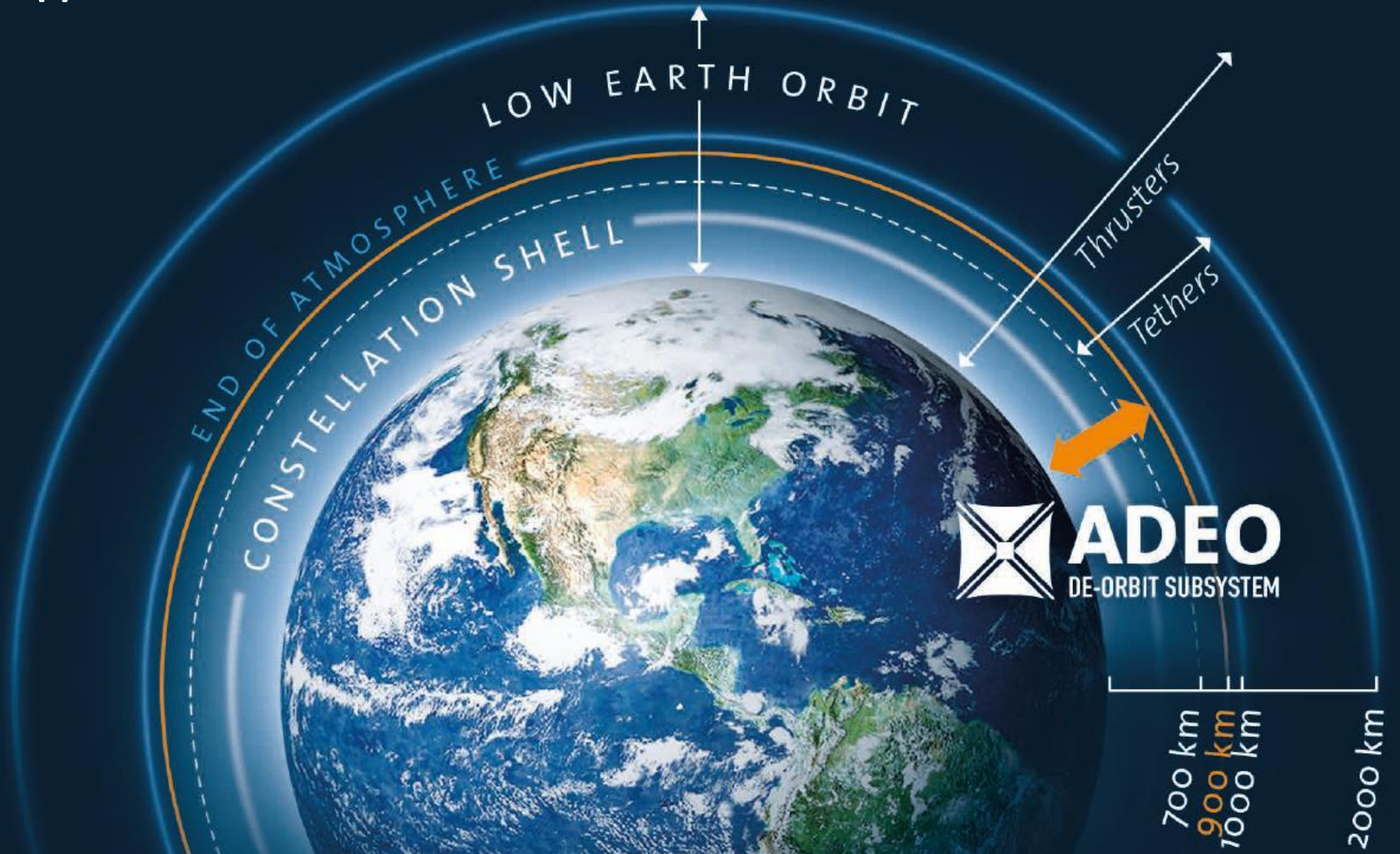
European Space Traffic Management



German BDI NewSpace Initiative – sustainable astronautics



## Application Area





## Generic Active vs. Passive Deorbiting Comparison

### Active Deorbiting (e.g. propulsion systems)

- ❖ Active deorbiting system need an active S/C and propulsion system but they are failure prone
- ❖ Active deorbiting require high operational expenses required (OPEX)
- ❖ ADR – Active Debris Removal very expensive

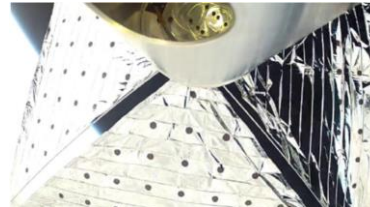
### Passive (automatic) Deorbiting (e.g. dragsails or tethers)

- ❖ Prolonging missions due to autonomous capability (ADEO)
- ❖ No active S/C necessary → Fail Safe with autonomous function (ADEO)
- ❖ Solution for S/C with no propulsion system e.g. CubeSats, Rocket Bodies
- ❖ Low/No operational expenses

## From Science to Product



- Over the last 10 years different space sail technologies have been industrialize originating from DLR research and development projects going back at least to 1990s.



M. Leipold, C.E. Garner, R. Freeland, et al. ODISSEE, A proposal for demonstration of a solar sail in earth orbit, *Acta Astronautica* 1999 45/4, 557-566

D. Agnolon, Study overview of a solar sail demonstrator: GEOSAIL, DLR/ESA, 2008

N. Wolff, P. Seefeldt, W. Bauer, et al., Alternative application of solar sail technology. In *Advances in Solar Sailing*, pages 351-365. Springer, 2014.

P. Seefeldt, P. Spiez, T. Spröwitz, et al., Gossamer-1: Mission Concept and Technology for a Controlled Deployment of Gossamer Spacecraft, *Advances in Space Research* 59.1 (2017): 434-456

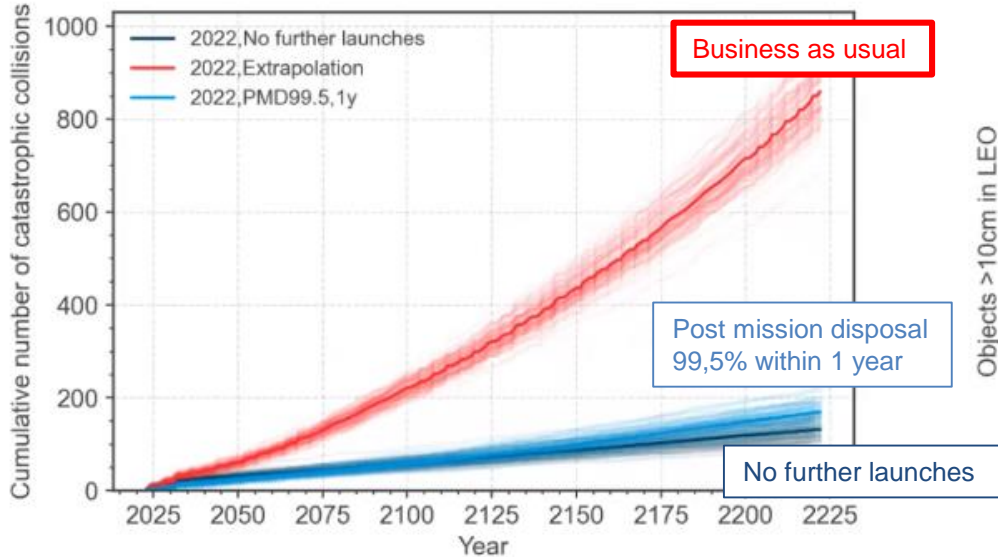
...

## ESA Projects for technology transfer:

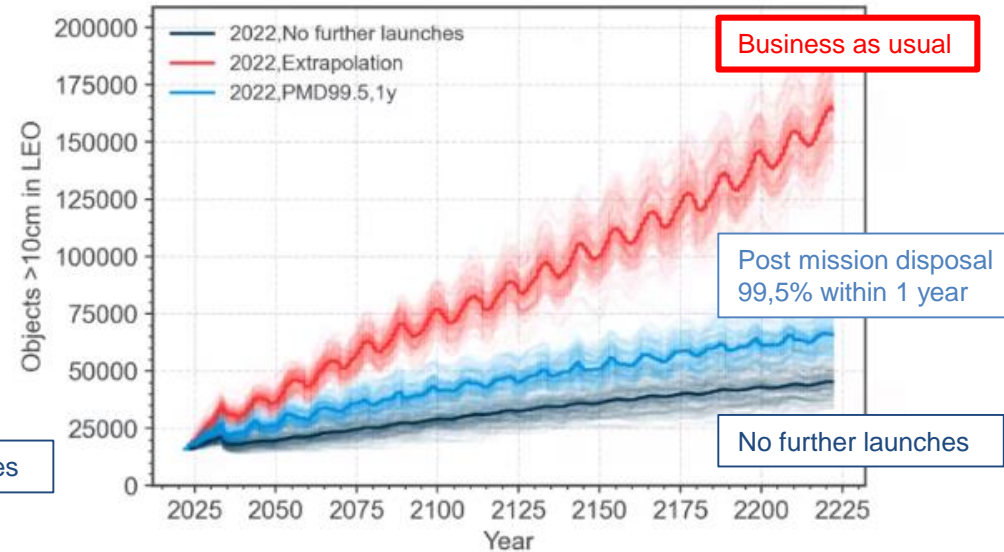
- Deployable Membranes (2014), ESA contract 4000112241/14/NL/SW
- ADEO (2015), ESA contract 4000112253/14/NL/SW
- ADEO-2 (2018), ESA contract 4000124984/18/NL/LvH-zk
- AFO (2023), ESA contract 4000138835/22/NL/GLC/va



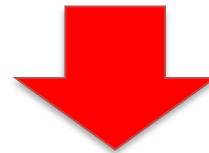
## Orbital Population Evolution Models



Number of catastrophic collisions in LEO  
(Source: ESA/Euroconsultant)



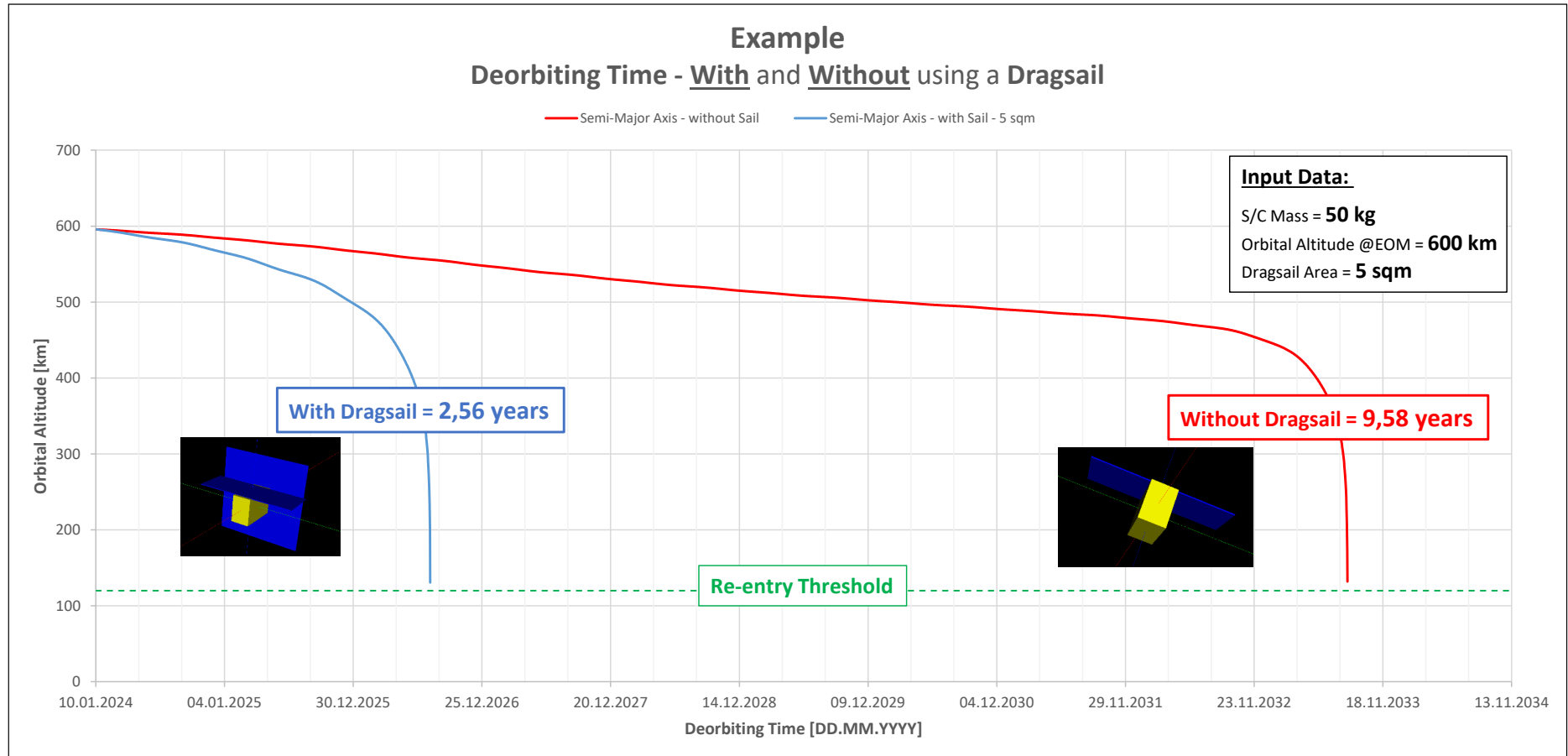
Number of objects >10 cm in LEO  
(Source: ESA/Euroconsultant)



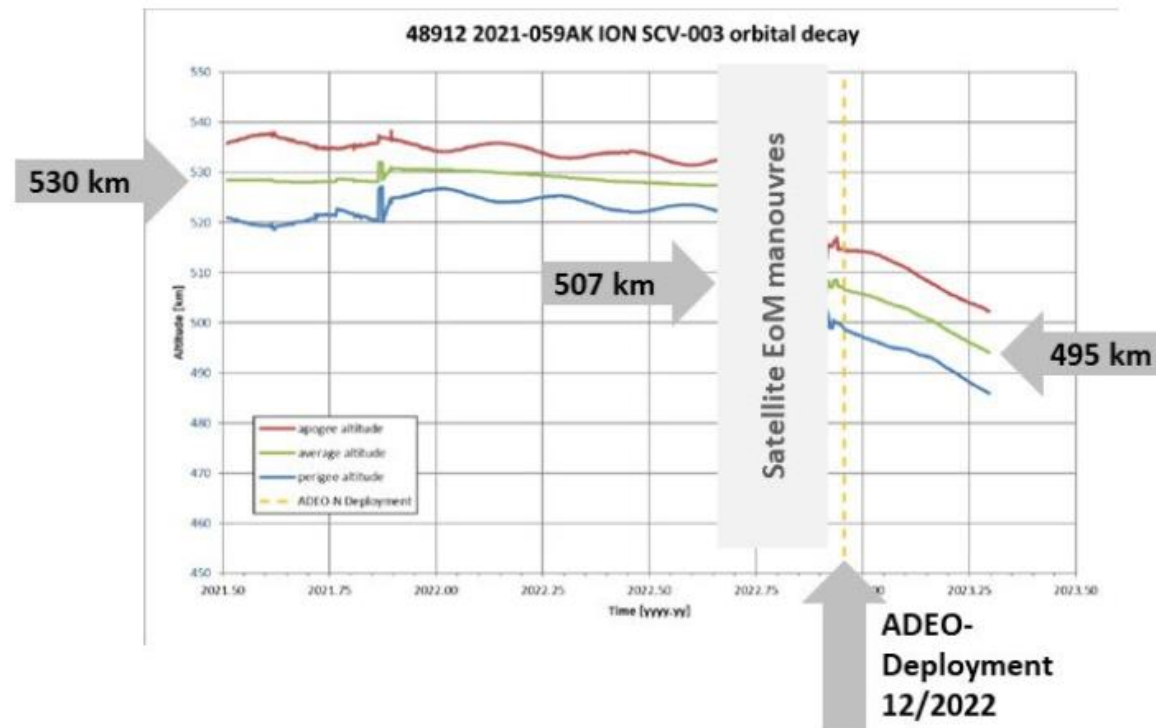
**New mission types** and **sustainable space activities** need to be implemented to realise **post mission disposals** and to **ensure future space missions** – e.g. with missions using **deorbit dragsails**



# Deorbit Example – S/C = 50 kg, Orbital Altitude = 600 km



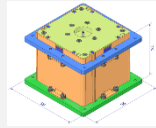
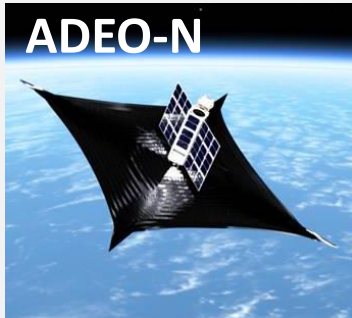
## ADEO-N2 Heritage



- Deorbit without sail: 3 km within 10 months.
- Deorbit with sail: 12 km within 7 months (escalated: 17 km within 10 months).
- In general, the deorbit time with a deployed sail can be assumed to be 6 to 10 times quicker than without sail, with a mass penalty (ADEO-mass) of 1.0 kg (ADEO-N) to 3.5 kg (ADEO-M).



## The ADEO Product Family



### Application Satellites:

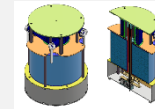
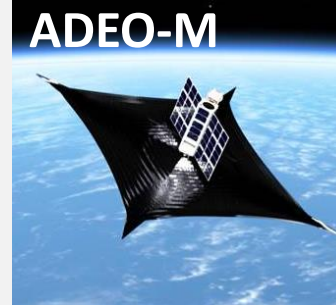
1 – 250 kg

### Sail Sizes:

nominal: 5 m<sup>2</sup>  
+/-2 m<sup>2</sup>

### Characteristics:

mass: 1 kg  
size: 10x10x10 cm



### Application Satellites:

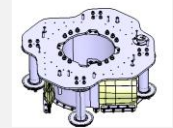
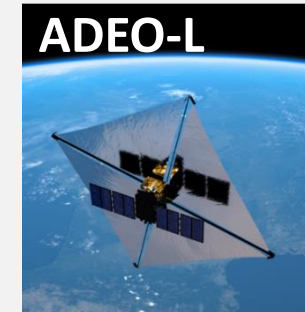
100 - 700 kg

### Sail Sizes (tbc):

nominal: 15 m<sup>2</sup>  
+/-5 m<sup>2</sup>

### Characteristics (tbc):

mass: 4 kg  
size: 20(dia.)x20 cm



### Application Satellites:

200 -1,500 kg

### Sail Sizes:

nominal: 25 m<sup>2</sup>  
-5 / + 75 m<sup>2</sup>

### Characteristics:

mass: 9,5 kg  
size: 40x40x10 cm

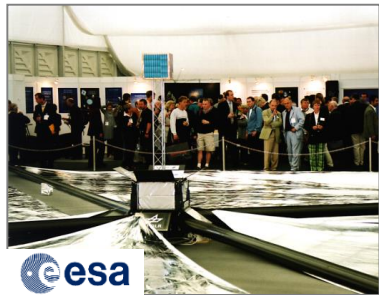
# ADEO Family



|   | ADEO-Cube  | ADEO-N        | ADEO-M   | ADEO-L                                      |
|---|--|---------------|--|---|
| <b>Status</b>                                       | In Development<br><i>In Production beg. 2024</i> | In Production | In Development<br><i>In Production beg. 2024</i> | In Production                               |
| <b>Technology Readiness Level (TRL)</b>             | 4 (04/2023)<br>7 (12/2023)                       | 9             | 4 (02/2022)<br>9 (06/2024)                       | 7   |
| <b>Satellite Masses [kg]</b>                        | 1-50   | 1-250         | 100-700  | 200-1.500                                   |
| <b>ADEO Module Mass [kg]</b>                        | 0.5  | 0.8           | 4  | 9.5   |
| <b>ADEO Module Size – stowed<br/>[cm x cm x cm]</b> | 9 x 9 x 5 ( <i>tbc</i> )                         | 10 x 10 x 10  | 20 x 20 x 20                                     | 40 x 40 x 10                                |
| <b>Sail Area [m<sup>2</sup>]</b>                    | 2  | 5 ± 2         | 15 ± 5   | 25 +75/-5                                   |
| <b>Deployment Mechanism</b>                         | Mechanical                                       | Mechanical    | Mechanical                                       | Motor                                       |
| <b>Activation System</b>                            | PyroCutter                                       | PyroCutter    | PyroCutter                                       | Motor                                       |
| <b>Mechanical Interface (*)</b>                     | CubeSat Standard                                 | 4 x M5        | 4 x M5   | 8 x M6                                      |
| <b>Electrical Interface (*)</b>                     | 2 Cables only                                    | 2 Cables only | 2 Cables only                                    | 6 x RS-422                                  |
| <b>Electrical Power (*)</b>                         | 12V @1A 1msec                                    | 12V @1A 1msec | 12V @1A 1msec                                    | 24-38 V<br>( <i>&lt;280 mW in Standby</i> ) |
| <b>Autonomous Functionality</b>                     | Coming Soon                                      | Coming Soon   | Coming Soon                                      | Available                                   |

\* Costumisable

# ADEO Launch- and Activity Log (1/3)



ADEO-L Proto -  
Development of  
the ADEO-L Ver.1  
dragsail  
subsystem



ADEO-L1 -  
Development of the  
ADEO-L Ver.2  
dragsail FM  
subsystem

2000

2011

2014

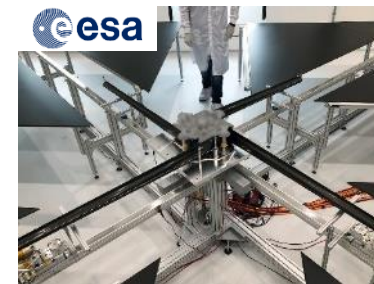
2018

..continuation, next page

Solar sailing  
Activity and Product  
Development in the  
frame of an ESA  
Contract - HPS was  
founded ☺



Deployable Membrane  
Project in the frame  
of an ESA Contract -  
Extensive  
investigations on the  
dragsail membrane  
material



# ADEO Launch- and Activity Log (2/3)



ADEO-N on  
Parabolic Flight

2018



ADEO-N on ION  
SCV009 from  
Dorbit, Launch  
with Falcon 9 from  
SpaceX

- ✦ ADEO-N on EnduroSat
- ✦ ADEO-N on GenaSat

2019

2021

2023

*upcoming*

ADEO-N on Electron  
Kickstage from  
RocketLab  
„It’s Business  
Time“ Mission

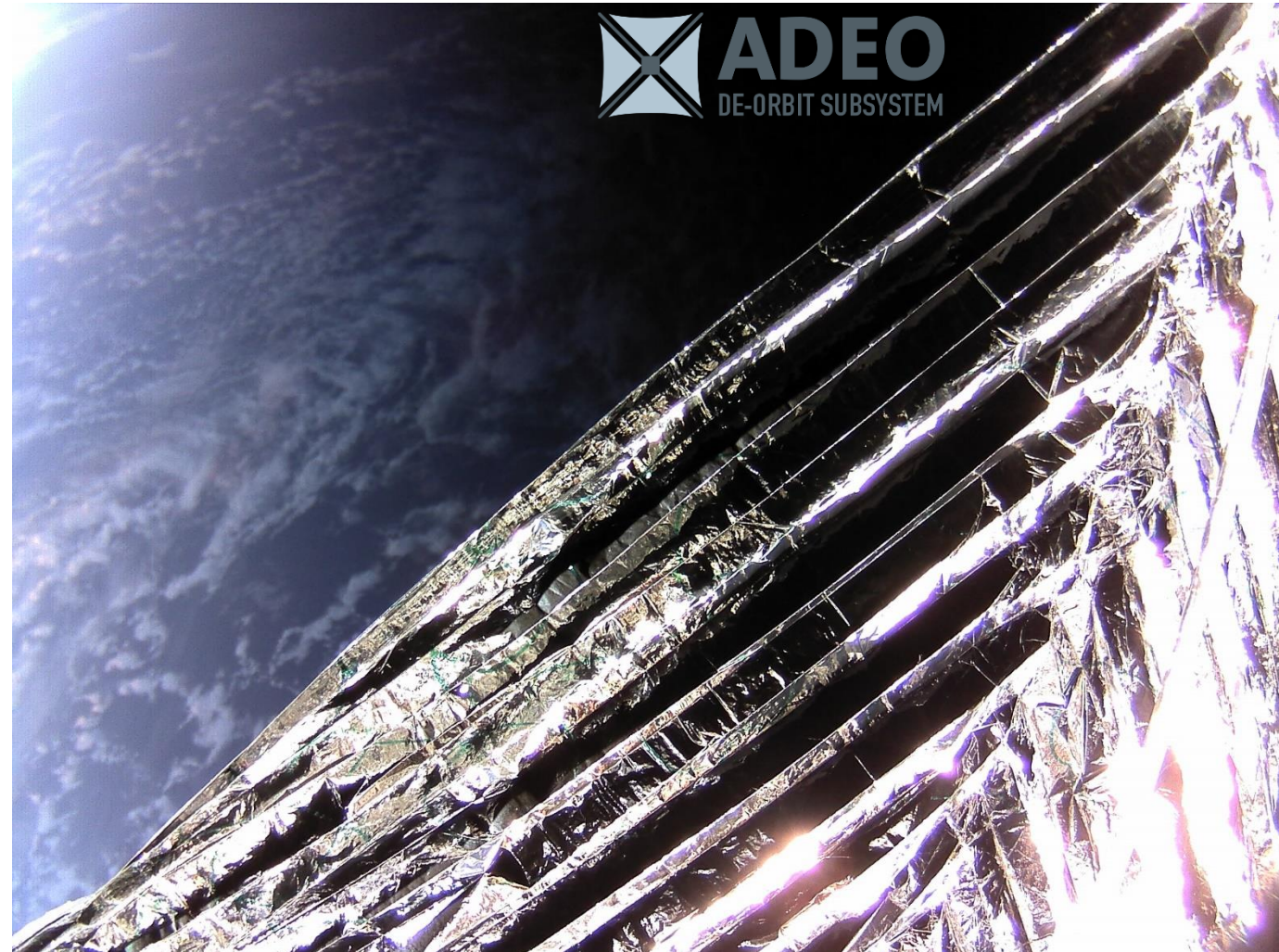


ADEO-N on ION SCV003  
from Dorbit, Launch  
with Falcon 9 from  
SpaceX



- ✦ ADEO-L on Redwire Space Mission

## ADEO-N Deployment Verification in Orbit



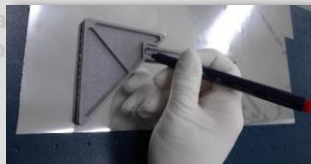
Picture was captured on the  
**15<sup>th</sup> of December 2022**  
from ION the D-Orbit's  
Satellite Carrier





# The Route to Space: Manufacturing and Supply Chain

## Manufacturing

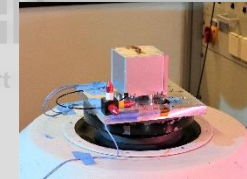


Qualified Supplier xy

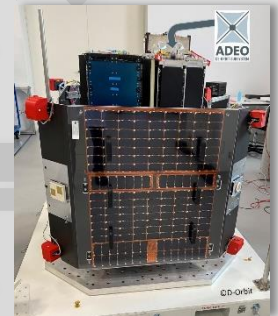
## Assembly



## Tested @ DLR



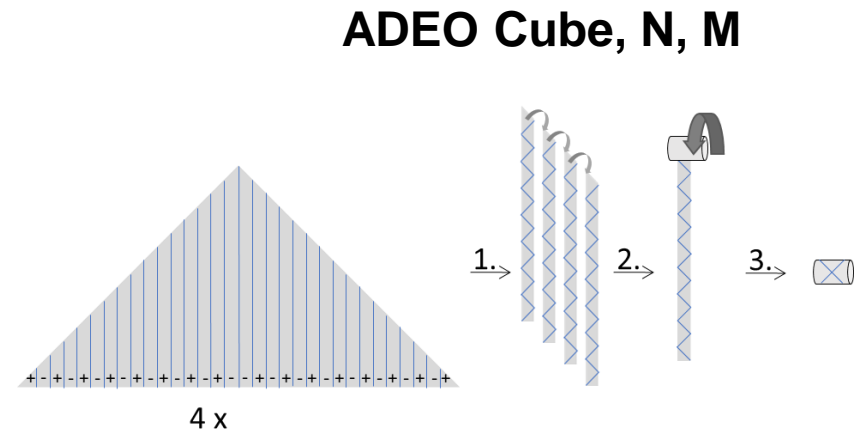
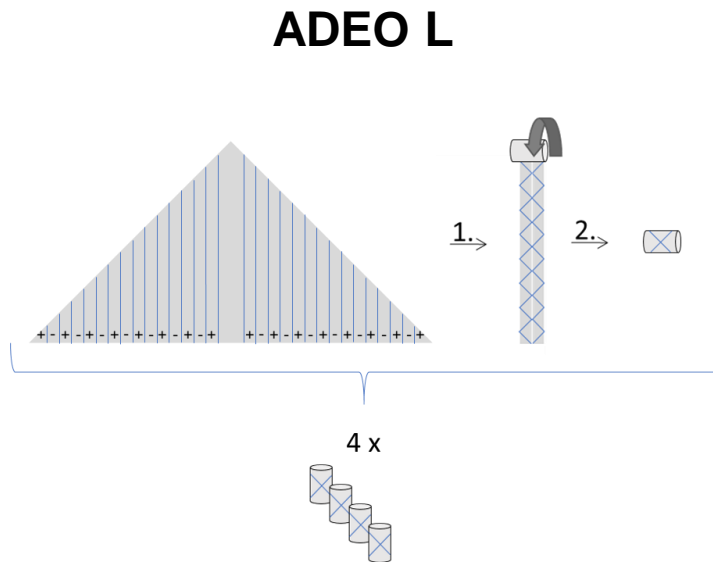
## Integration



## ADEO Deployment Strategy



- ✦ Different techniques were explored and implemented in recent years.
- ✦ Within the current AFO activity the ADEO products are streamlined, resulting in similar deploying strategies for all products.

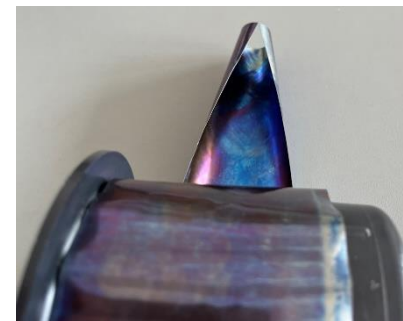


## ADEO Boom Technology

✦ ADEO-Cube and ADEO-N bi-stable tape springs

✦ ADEO-M STEM

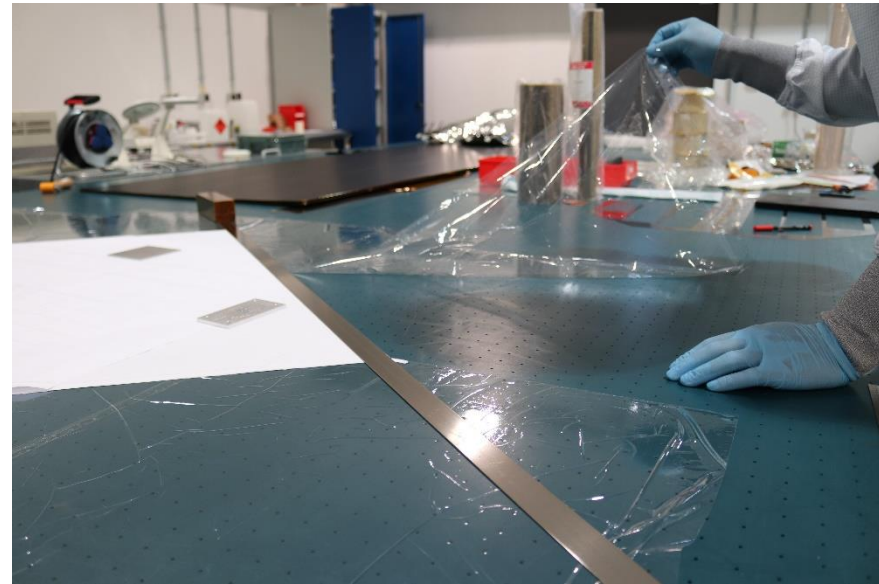
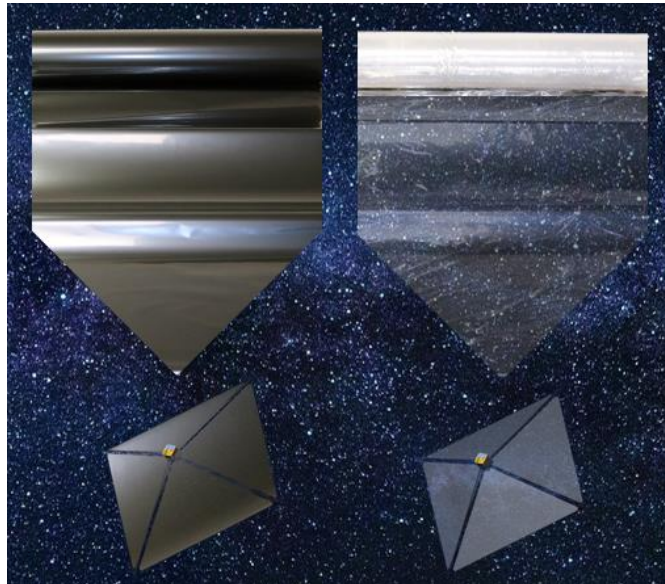
✦ ADEO-L Composite Shell Booms (Gossamer-1)



## Non-Reflective Drag Sails



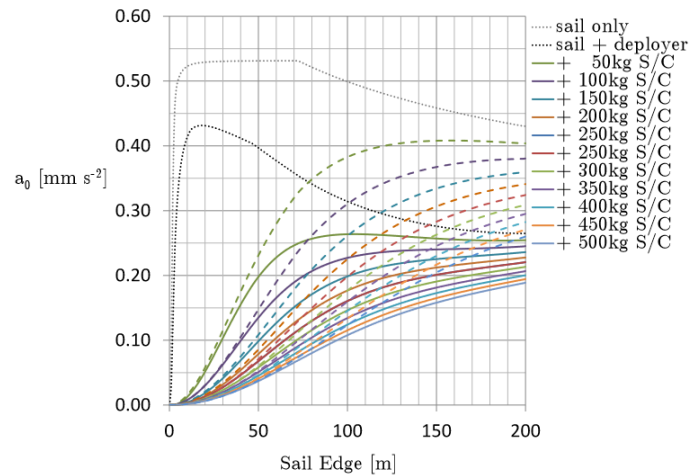
- ❖ NO to light pollution in the night sky!
- ❖ In cooperation with the DLR Institute of Space Systems, new non-reflective ATOX resistant materials are now implemented in the latest ADEO activity AFO.



## ADEO-L as a Solar Sail



- ✦ The ADEO-L technology is based on DLR's Gossamer-1 as described in Seefeldt et al. (2016) <https://elib.dlr.de/111077/>.
- ✦ An estimate of the characteristic acceleration for a system with a central non-ejectable deployment mechanism has been derived in Seefeldt et al. (2021) <https://elib.dlr.de/146823/>:



- ✦  $a_0$  between  $0.125 \text{ mm/s}^2$  and  $0.2 \frac{\text{mm}}{\text{s}^2}$ .
- ✦ Enabling first solar sail missions, e.g.
  - ✦ Multiple Near-Earth Asteroid Rendezvous or
  - ✦ Displaced Lagrange missions

# TIME TO ACT

More than **30,000**  
new on-orbit spacecraft  
endanger mission  
sustainability

ADEO products are suitable for  
satellites & launchers (1-700 kg)  
de-orbiting from LEO (< 800 km)



## CleanGreenSpace Missions

Deorbit dead satellites and expended  
launchers fast and reliably with our  
deployable dragsail:



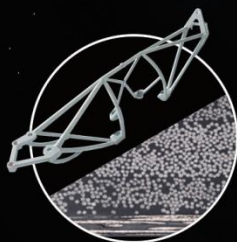
**ADEO**  
DE-ORBIT SUBSYSTEM



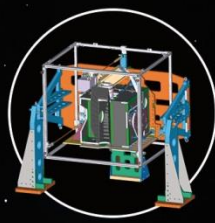
## Let's Deorbit your Spacecraft Together!



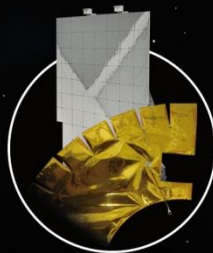
Engineering &  
Integration  
Services



New Materials &  
Processes



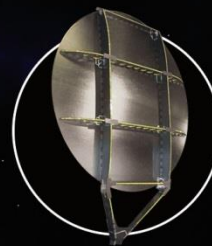
MGSE



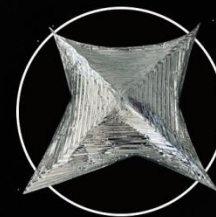
Thermal  
Hardware



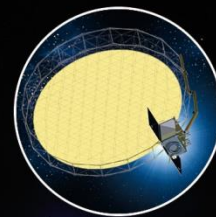
Lightweight  
Structures



Reflector  
Antennas



Deployable  
De-orbit Sails



Large Deploy.  
Reflector/  
Boom Subsystems

## HPS Group Customers

### Agencies



### System Primes



### Other Companies



### R&D Entities

