HPS High Performance Space Structure Systems GmbH GERMANY

THE ADEO PASSIVE DE-ORBIT SUBSYSTEM: REFERENCE MISSION SELECTION AND PRELIMINARY DESIGN OF PROTO FLIGHT MODEL

Clean Space Industrial Days 2018

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ESA ESTEC | 25th of October 2018

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ADEO
DE-ORBIT SUBSYSTEM

1. Avoiding Space Debris for a Clean Space

Current Space Environment:

› Space debris in orbit increases since beginning of space flight

› LEO, MEO, GEO full of space debris

Europe for a Clean Space:

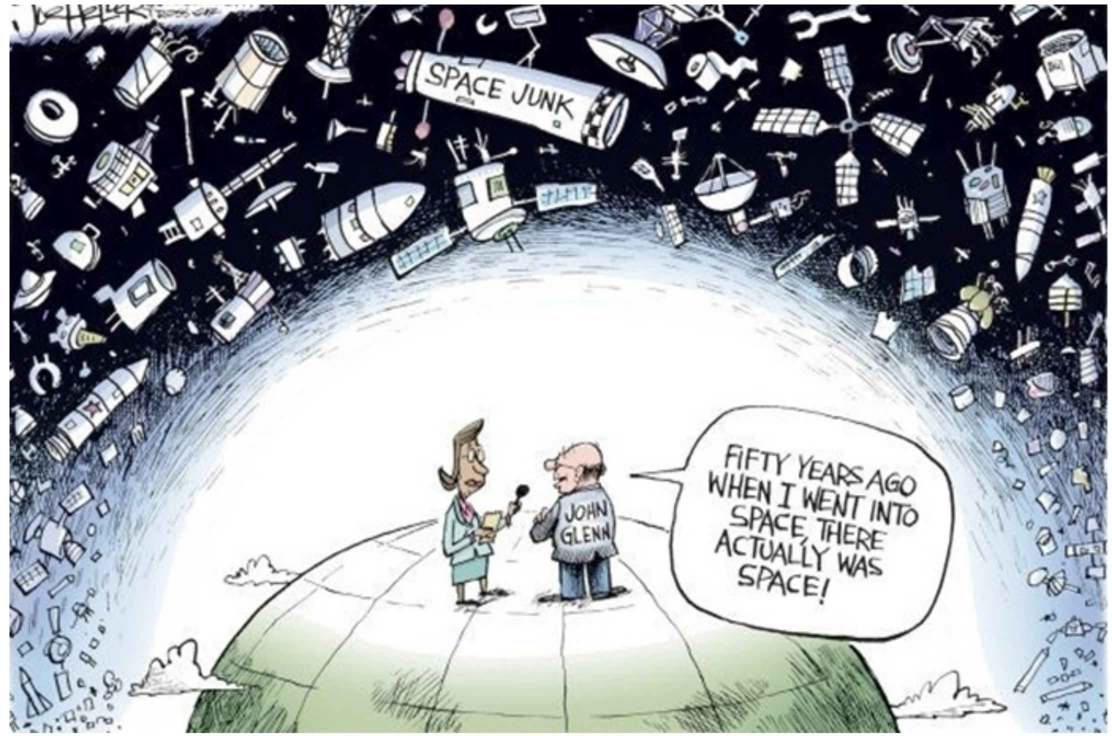
› International guidelines enforce disappearance 25 years after end of mission

› ESA is pushing, as global leader, for a „Clean Space". (Ref: Space Debris Legislation: ESA/ADMIN/IPOL(2014)2)

Technical Solutions:

› Many variants under discussion and development:

- Rocket engine for de-orbiting
- Dragsails
- Tethers



Source: http://www.themarketforideas.com/space-debris-visua the-risk-and-informing-stakeholders-a190/

The „ADEO“ Solution

ADEO-Application Area:

› passive solution:
  - using rest-atmosphere to decelerate
  - augmentation of drag-area by a deployed sail.

› Applicable to LEO-orbit: up to 750 km (perigee)

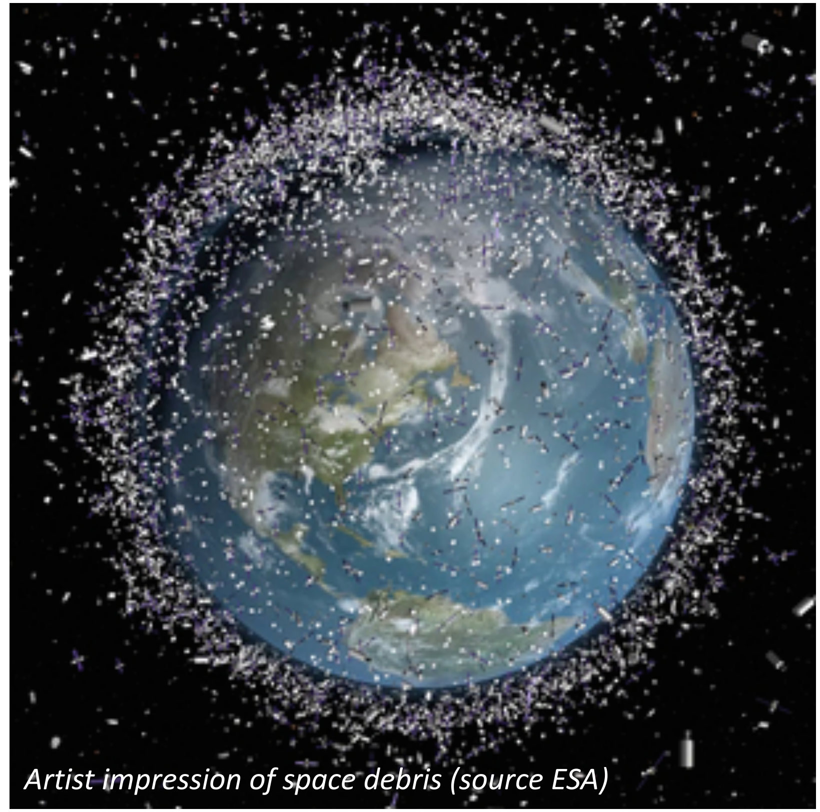
› For all satellites cleared for uncontrolled de-orbit

ADEO „Family“:

› ADEO-L (Large for satellites between 100 and <1.500 kg)

› ADEO-N (Nano for cubesats and larger: 1 – 100 kg)

› ADEO-M (Medium class: overlapping L- and N-class).



Artist impression of space debris (source ESA)

ADEO
DE-ORBIT SUBSYSTEM

2. Previous Activities

2.1 ADEO(1) (2014-2017): Technology Demonstrator Design, Manufacturing and Testing

The ADEO-1 Project (2014-2017)

Project Team

› ESA: Customer

› HPS Germany: Prime, system engin., design & analysis, S/S AIT

› DLR Bremen/Braunschweig: boom and sail technology

› HTS: sail development and mechanisms

› ETAMAX: debris modelling & stabilisation techniques

Programmatics:

› GSTP-Program

› SME driven

› Parallel activity („DEPLOYABLE MEMBRANE“): sail development, primed by HTS

› Duration: 11/2014 – 03/2017.

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DLR

HTS

etamax
member of the ckc group

Preliminary De-orbiting Analysis

Key Specifications:

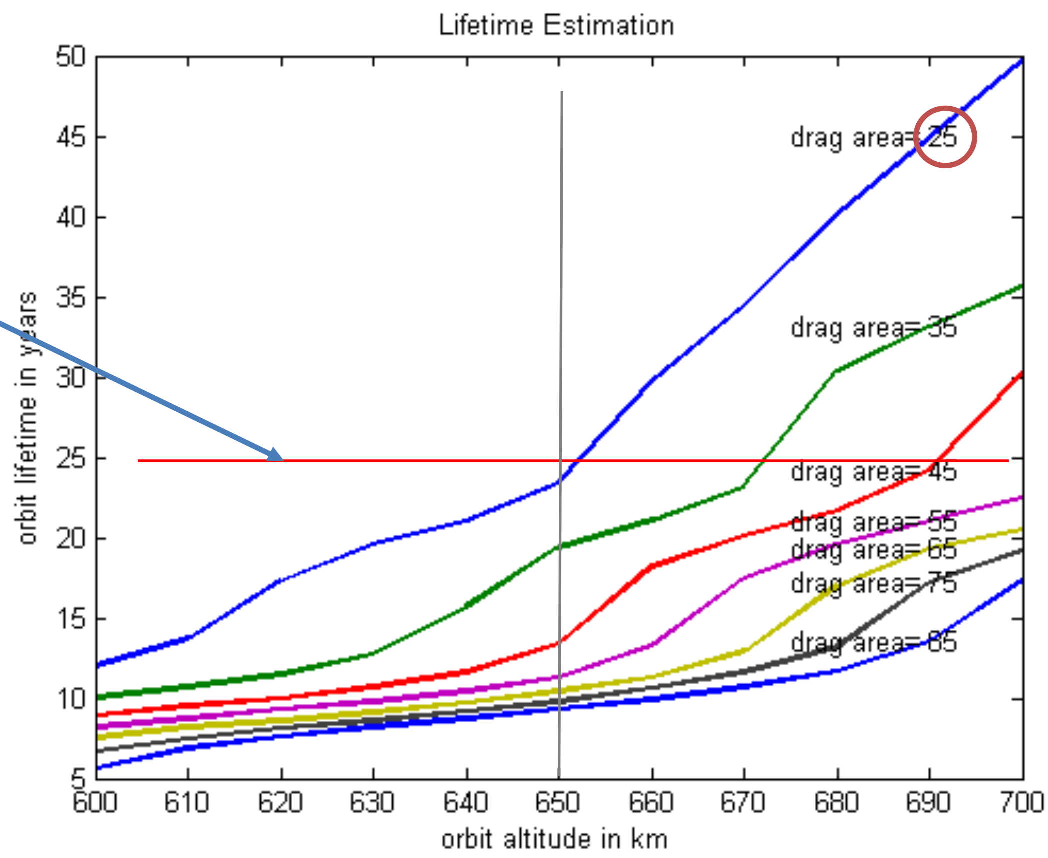
- 1.000 kg satellite
- 650 km orbit altitude
- De-orbiting within max. 25 years

⇒ 25 m² drag area.

Simulation:

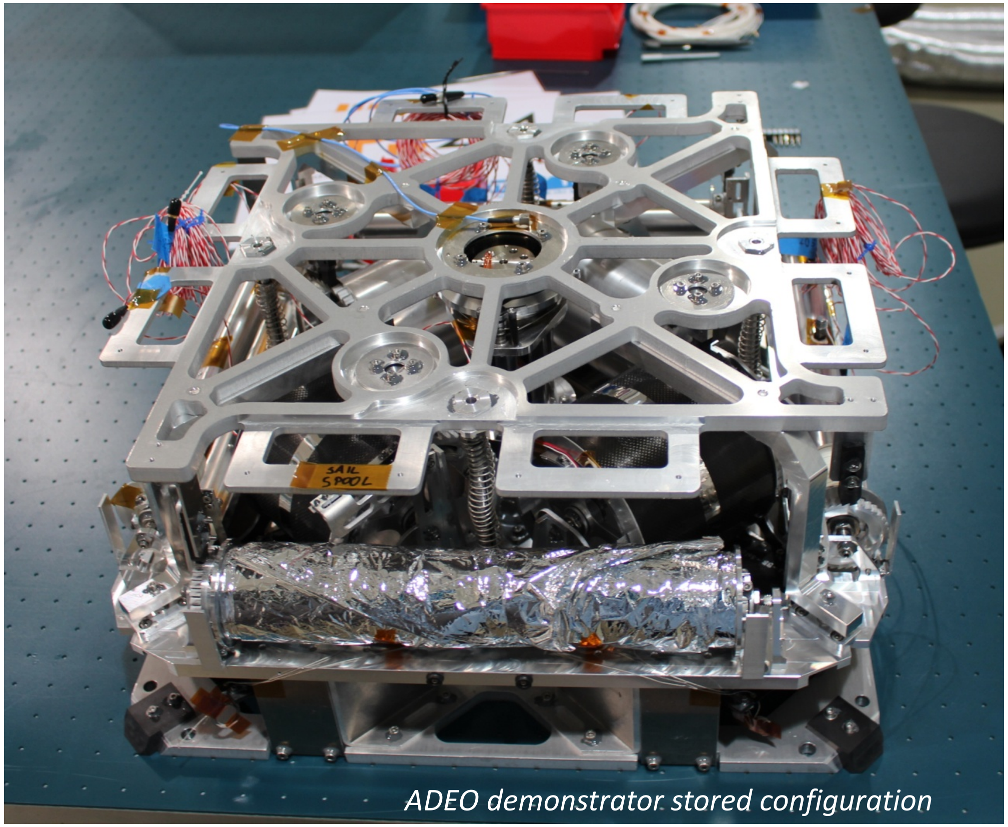
- 2014 start solar activity

⇒ above 700 km solar pressure is dominant.



ADEO Demonstrator

- Complete subsytem with flight representative mechanisms and components
- Designed for 25 m^2 drag sail area with 4 sails, but demonstrator testing with 1 sail segment only
- Deployment via 4 CFRP booms, but demonstrator testing with 2 booms only



ADEO demonstrator stored configuration

ADEO Demonstrator Test Campaign

Test as you fly approach:

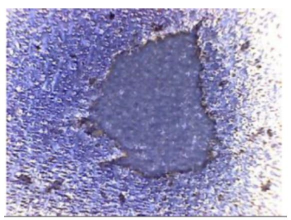
Launch:	First a **vibration test** (representative sine and random loads on all three axes) was carried out simulating the launch loads followed by a **rapid decompression** test mimicking the pressure decrease during launch (Vega launcher depressurization profile).
In-Orbit Storage:	The temperature change of an orbiting space craft was mimicked via **thermal cycling** test.
Deployment:	The deployment was initiated with **mechanism activation in hot and cold TVAC conditions** leading to a **full deployment** (partial in **TVAC** and rest in ambient)
De-Orbit:	The **survivability** of the materials during the **25 year de-orbiting** time was verified by extensive **Atomic Oxygen (tested @ ESA/ESTEC labs), UV and thermal cycling** tests. Furthermore, the effect of **space debris impacts** was verified by crack propagation analysis and impact tests.

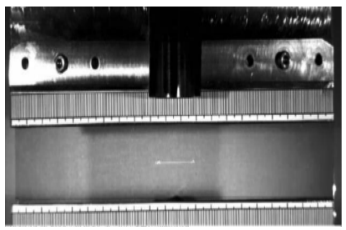
Sail Critical Testing

(as part of DEPLOYABLE MEMBRANE Study (HTS prime, HPS & DLR sub))

Environmental survivability

- Vibration, thermal cycling, rapid decompression, full sail deployment
- Impact and Crack Propagation





- ATOX & UV radiation

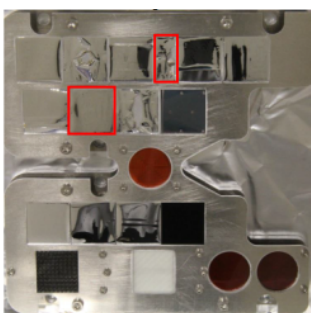
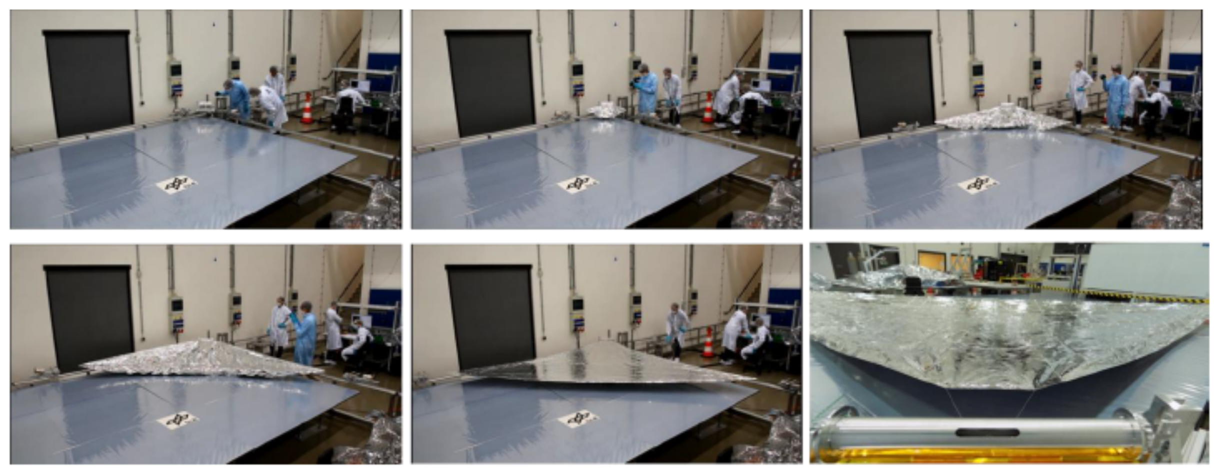


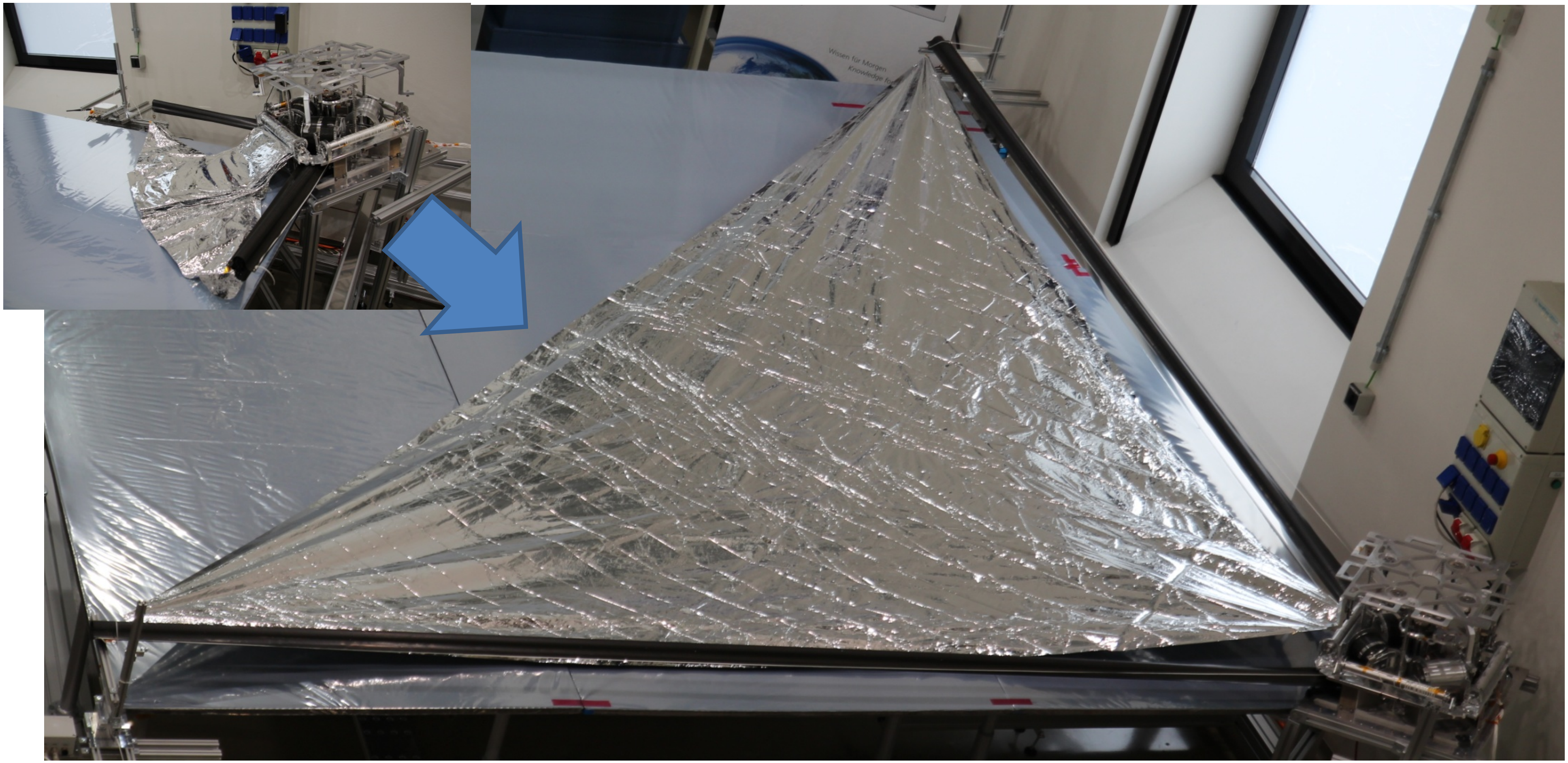
Figure 16 A set of samples after 150h of the irradiation time.

Folding of sail segment



Deployment of sail segment

Deployment Test: Full Ambient Deployment (after vibration, TC & TVAC)



Full deployment successful: Demonstrator Test Campaign sucessful, raising TRL of ADEO to 5/6.

2.2. ADDA ADEO De-Risk Dynamical (De-Orbit) Analysis

The ADEO De-Risk Activity

Project Team

› ESA: Customer

› HPS Germany: Prime, Reference Mission Review

› ASTOS Solutions:

  · Dynamic analysis

  · De-orbit & stability assessments and analysis

Programmatics:

› GSTP-Program

› SME driven

› Duration: 05/2017 – 08/2017.

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Astos Solutions

Conclusions of ADEO De-Risk Activity ADDA

1. The drag sail shortens the post mission life time significantly : e.g. 97% faster de-orbit time with a 25m² sail on a 300 kg satellite from a 600 km orbit compared to the same satellite without a sail: 5 years instead of 140 years).
2. Depending on the satellite (mass, inertia, …) and the start altitude the best de-orbit behavior can be optimized using different sail angles (change of pyramidal angle between 0° to 60°.
3. Sail angles of 0° are fully acceptable for meeting de-orbit requirements without GNC.
4. No active GNC is required, passive de-orbit is possible. In high altitudes (>500 km), the dragsail will slightly tumble. But a tumbling rate of non critical 1.4°/sec and a maximum torque moment of only 4.0 x 10^{-4} Nm will not be exceeded over the de-orbit time (assuming worst case conditions).
5. Analysis and tests during ADEO and previous activities (e.g. DLR's Gossamer) showed that the ADEO subsystem has a safety factor of well over 100 to the worst case tumbling loads (tumbling rate and maximum torque).

IN CONCLUSION IT HAS BEEN VERIFIED THAT THE DE-ORBIT WITH DRAGSAILS IS FEASABLE AND THAT IT IS A VERY EFFICIENT PASSIVE DE-ORBIT SOLUTION FOR SMALL SPACECRAFTS.

3. Current Activities

3.1 ADEO(2) (2018-2020): Towards a flight ready dragsail PFM

ADEO2 (ESA GSTP activity) - Objective

The objective of this activity is to:

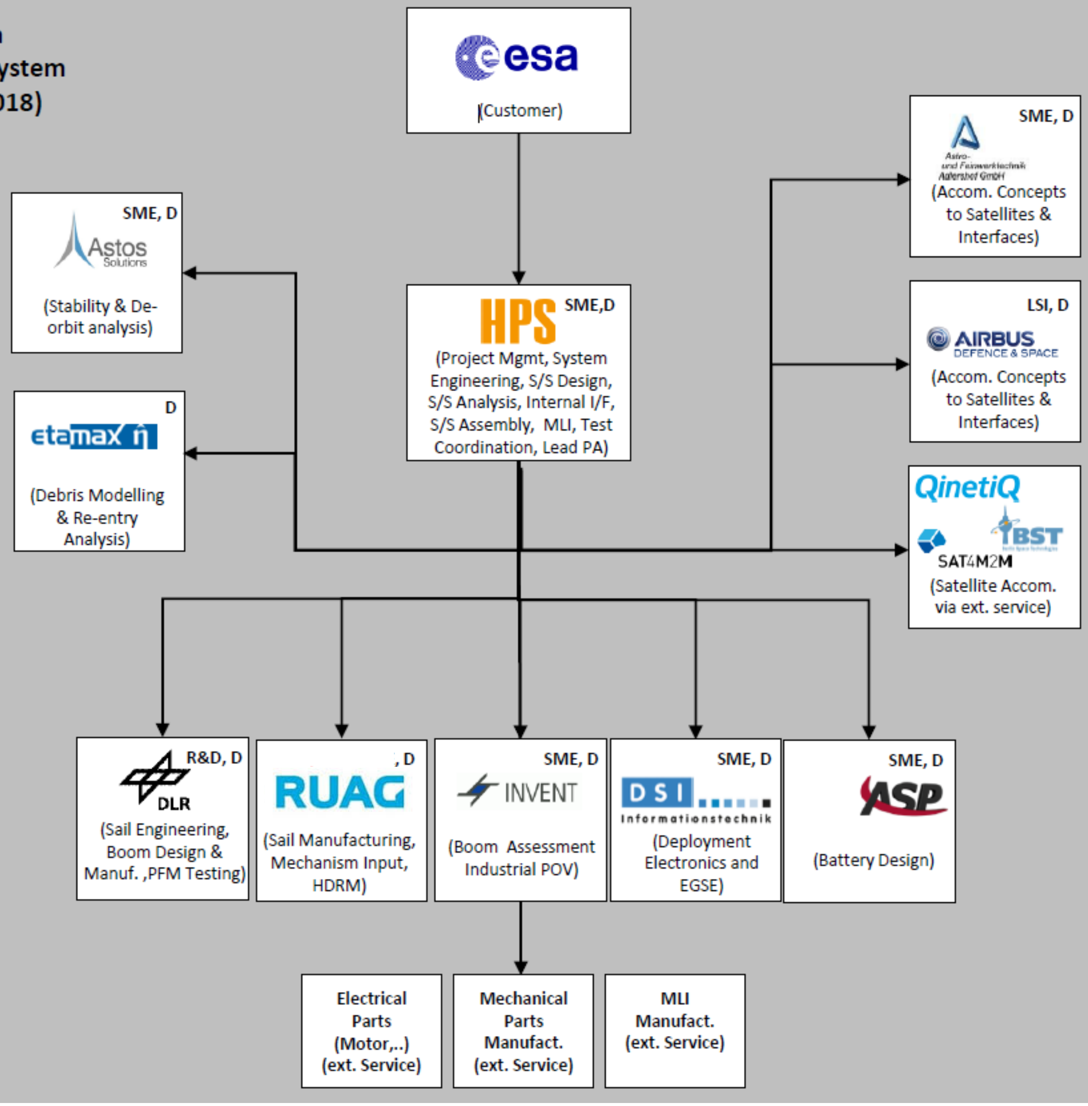
- **define a reference mission for a passive de-orbiting sub-system (ADEO) for a LEO S/C**
- **define requirements for the ADEO subsystem to be flown with this reference mission**
- **Based on this mission and requirements, to flow down the requirements to an IOD.**
- **Based on the IOD requirements, a PFM shall be designed, developed, manufactured and fully qualified.**

The refurbished (after all environmental tests) PFM is the final deliverable which can then be directly used for an IOD in a follow-up activity.

The de-orbit subsystem shall be built using the technologies developed in the previous ESA GSTP developments. Electronics for an autonomous deployment shall be flight standard. An on-board camera for a possible future IOD mission shall be included in the subsystem design (it shall not be a new development) and it must be possible to download the pictures. Mechanical and ground support equipment (GSE) for the verification of the de-orbit subsystem shall be designed and manufactured.

Teaming

ADEO2:
Prototype and Qualification of a De-orbiting Subsystem (Issue 1, 04.04.2018)



Project Flow

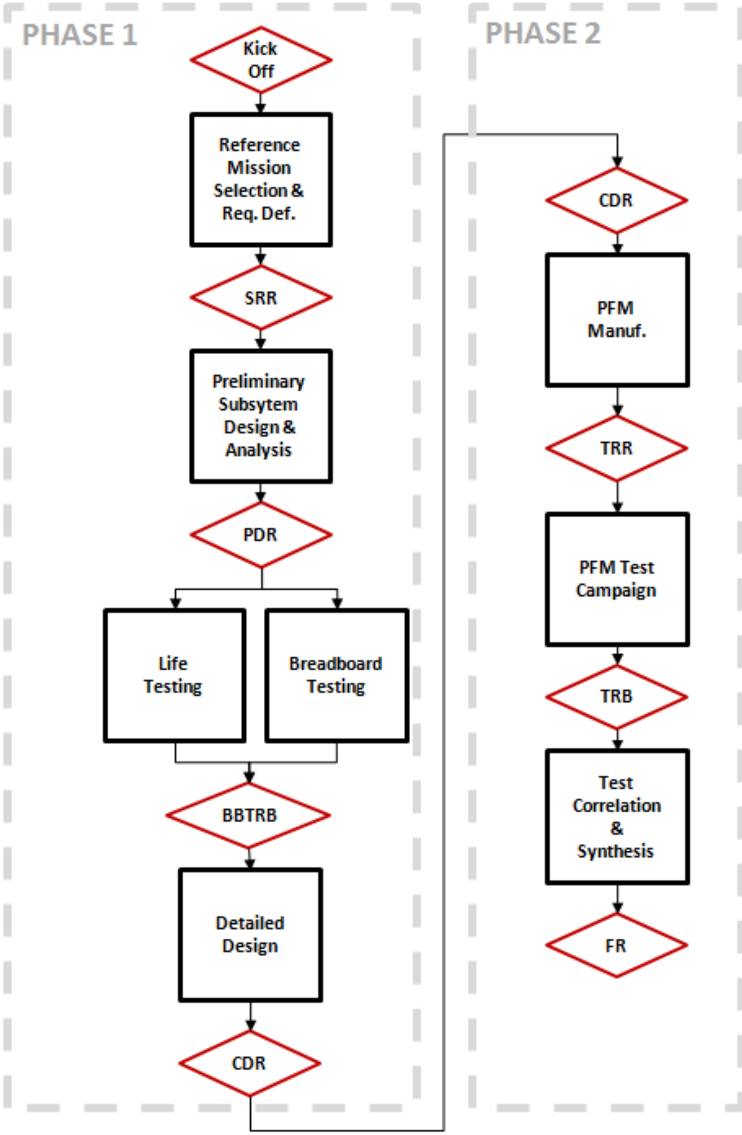
Phase 1:

- **Requirment Definition for Reference Mission and IOD (-> 10/18)**
- **Preliminary Design (->12/18)**
- **Breadboards and Confidence Life Tests (-> 04/19)**
- **Detailed Design (-> 10/19)**

1 Month Gap (Kick-off Phase 2: 11/19)

Phase 2:

- **Manufacturing/Assembly of PFM (-> 03/20)**
- **Testing of PFM (->06/20)**
- **Refurbishment of PFM (->08/20)**



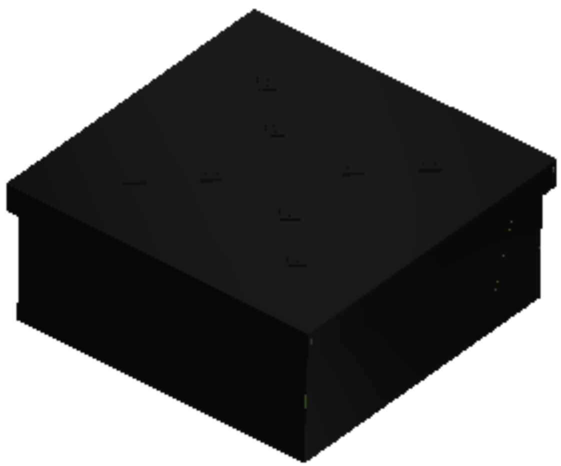
ADEO2: Main dimensions Preliminary Design

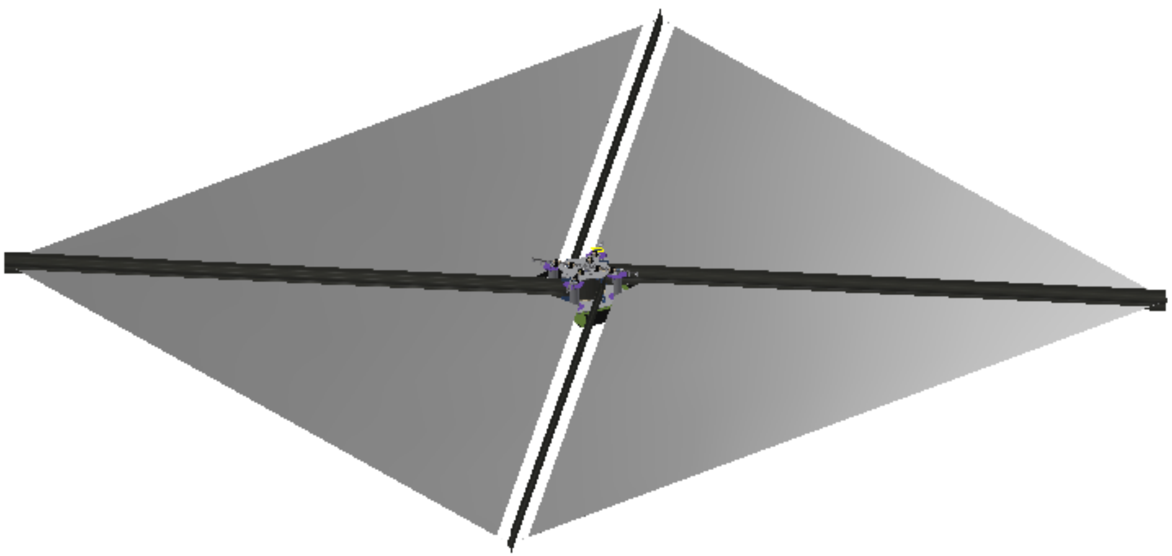
- **Stowed Configuration:**

  Stored in a box of 42 cm x 42cm x 18 cm

- **Deployed Configuration:**

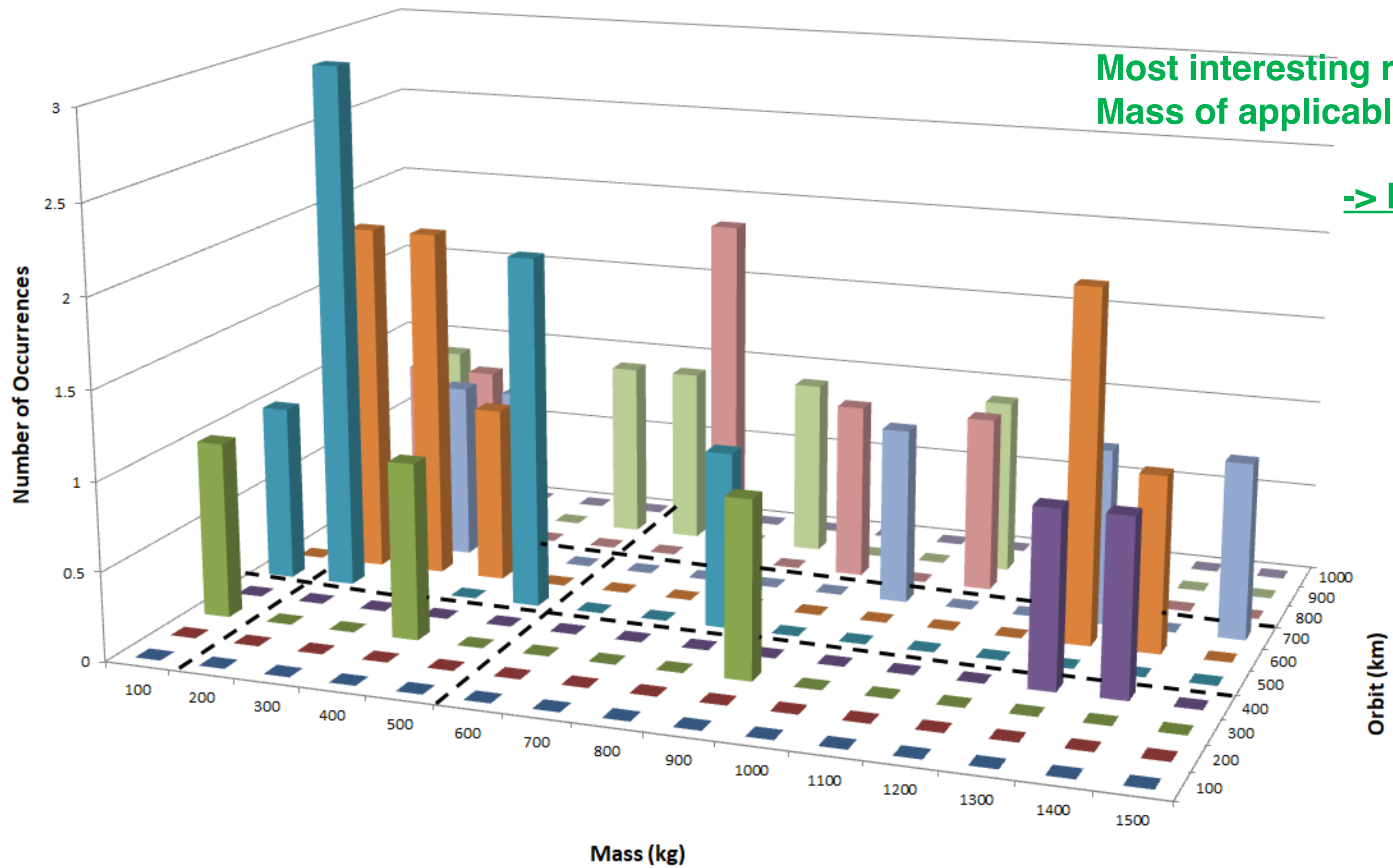
  25 m^2 drag sail area 5m x 5m





- **Total mass of 8 kg**
- **First natural frequency = 140 Hz**

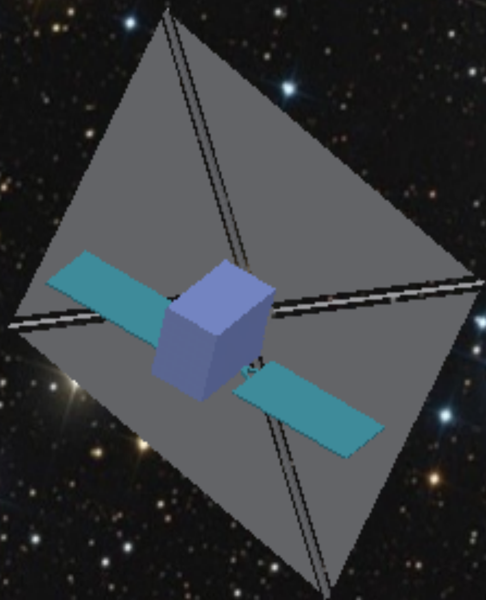
ADEO2: Reference Mission Trade Off

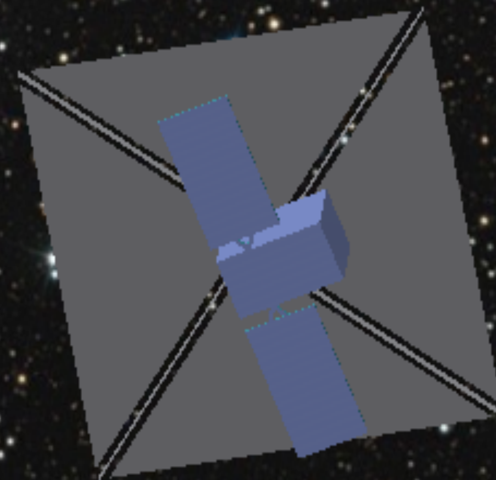


Most promising as future missions: ALTIUS & PICE

Most promising as IOD/IOV: EC IOD/IOV call, RocketLab/Ecliptic Enterprises Hosted Payload Programme

Accomodation:
Satellite size 0.8m x 0.65m x 1.2 m



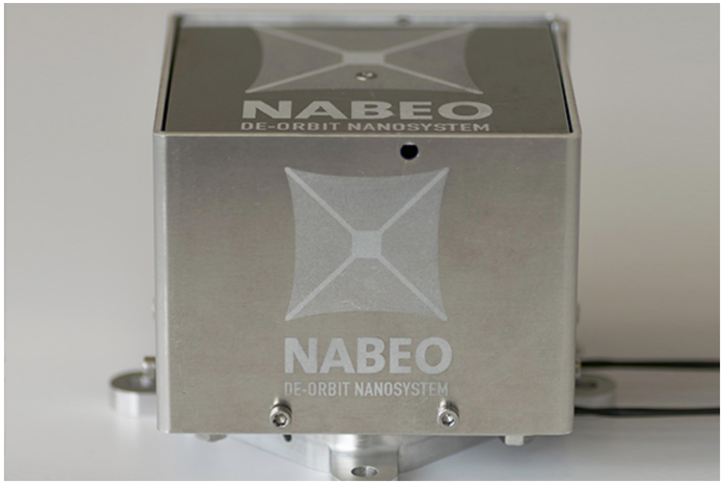


ADEO2: Main Requirements

- The ADEO subsystem shall be designed, build and tested **for a S/C** with a wet mass of **100-500 kg** in an sun synchronous orbit with a starting altitude of **400-700 km.**
- The ADEO subsystem shall de-orbit the S/C with **re-entry taking place within 25 years**.
- The ADEO subsystem shall be **passively stabilized**.
- The S/C plus ADEO subsystem shall **not exceed the maximum allowable casualty risk** upon re-entry.
- The ADEO subsystem shall be **scalable and easily adaptable for multiple missions** (generic interfaces).
- The **mass** of the ADEO subsystem shall be not greater than **5 % of reference mission S/C**.
- The ADEO subsystem's deployment shall be initiated by going through the subsystem internal deployment arming and deployment procedure (**WATCHDOG and DEAD MAN SWITCH**)
- ADEO shall be completely powered by the ADEO subsystem by a **subsystem internal battery**.

3.2 NABEO (ADEO-N): Launching onboard Rocket Lab’s #ItsBusinessTime

NABEO (ADEO-N): Overview



Summary:

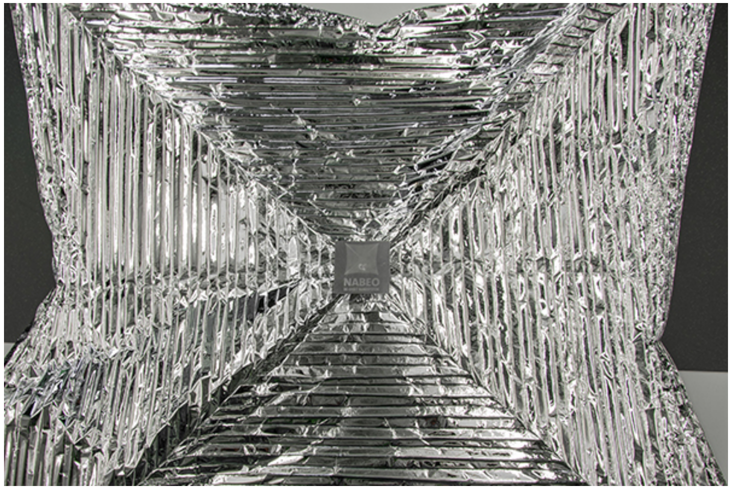
› 2.5m^2 dragsail subsytsem deployed out of 1U cube

› Subsytsem applicable to nanosatellites (cube sats) up to perigee of 750km and a mass of 1-100kg

› Technology demonstrator to be launched and deployed onboard Rocket Lab‘s #It‘s Business Time in 2018

› Designed, built and tested in March - May 2018

› Delivered to Rocket Lab (Auckland, New Zealand) on 28.05.2018



The NABEO (ADEO-N) Project

Stakeholders:

› Launch Provider: RocketLab (USA/NZ)

› Hosted P/L program (by Ecliptic Enterprises)

› NABEO cube sat dragsail by HPS GmbH (DE)

- Co-funding: Bavarian Ministry of Economics (DE)
- Development partners:

  Fraunhofer EMI (DE)

  DLR Bremen (DE)

Onboard Camera: Ecliptic Enterprises (USA)

Programmatics:

› Offer for an IOV by RocketLab: April 2018

› 1st launch attemt: 23rd of June 2018 (weather delay)

› 2nd launch attempt: 27th of June 2018 (technical issue with rocket motor controller)

› Updated launch date: Beginning of November 2018

ROCKET LAB

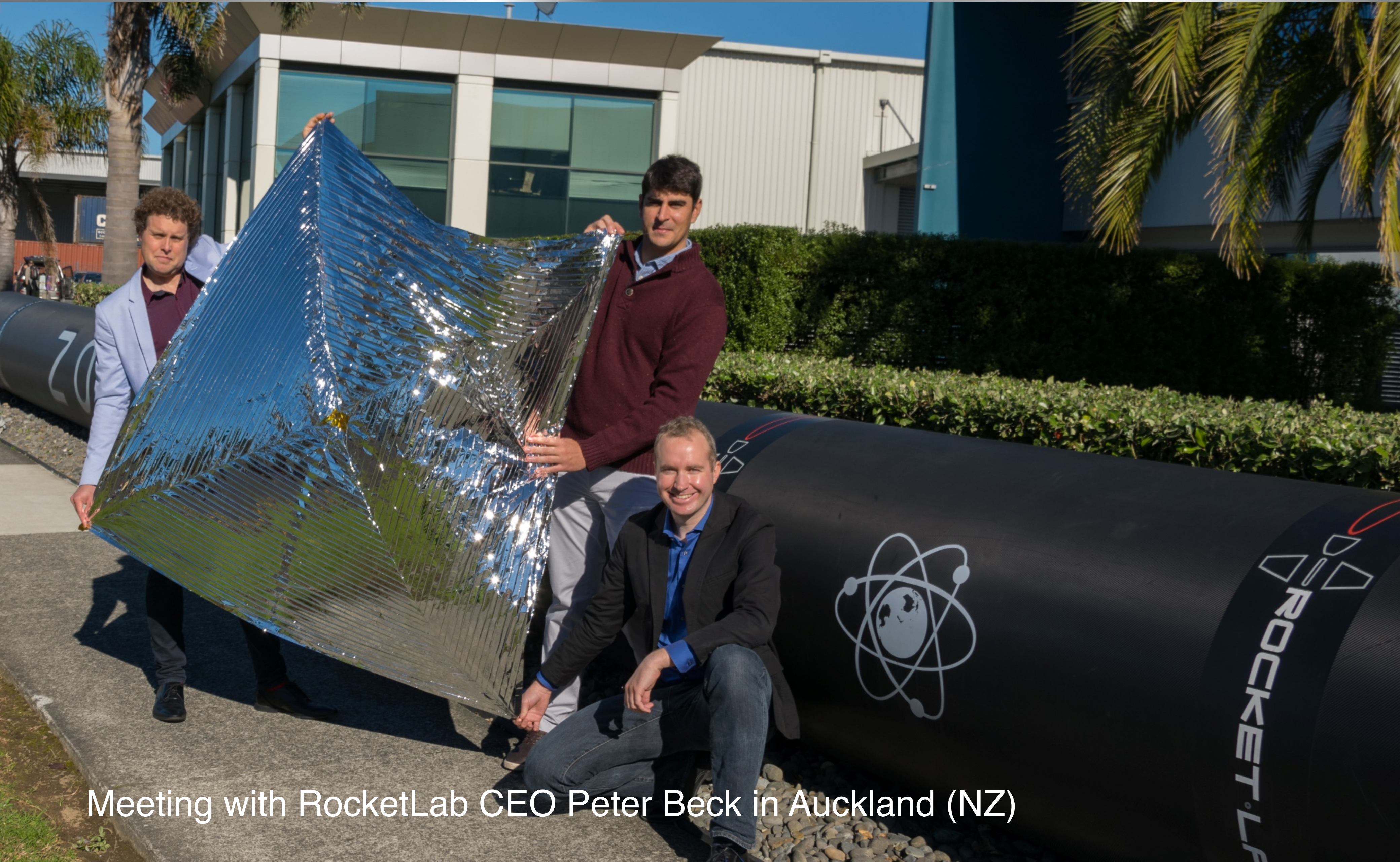
HPS High Performance Space Structure Systems GmbH

ECLIPTIC

Bayerisches Staatsministerium für Wirtschaft und Medien, Energie und Technologie

Fraunhofer EMI

DLR



Meeting with RocketLab CEO Peter Beck in Auckland (NZ)


Electron 3 #ItsBusinessTime on Launch Pad with NABEO in payload fairing
at launch pad in Mahia Peninsula (NZ)
Launch Beginning of November 2018, for launch and mission updates
follow us on Twitter (@HPS_GmbH) and Facebook (@HighPerformanceSpace)
ELECTRON
ROCKET LAB
Picture Source:
https://www.rocketlabusa.com/

NABEO(-2): Next Steps

Progress since June launch scrub:

› Revisiting of design and improvement of key components based on lessons learned during flight model test campaign and dedicated key components breadboard campaign in July/August 2018

› Simplification of parts to significantly decrease manufacturing costs, incorperation of ALM (3D printed) parts

› Manufacturing and assembly of **NABEO2** (SN003, SN004 and SN005) finished, full qualification testing currently ongoing

Updated NABEO-2 properties

› Dragsail area: 2.5m^2

› First Eigenfrequency: 400 Hz

› Mass: 834 g (incl. I/F plate)

› Stored volume: 10 cm x 10 cm x 8,7 cm (incl. I/F plate)

4. Conclusions

Conclusions

- Means to **de-orbit passively within 25 years**, no GNC required
- **Modular and scalable** subsystem:
  - ADEO-L (Large for satellites between 100 and <1.500 kg)
  - ADEO-N (Nano for cubesats and larger: 1 – 100 kg)
  - ADEO-M (Medium class: overlapping L- and N-class).
- Designed based on **requirements envelope** of applicable satellites (>30 mission analysed), **generic standard interfaces**

- **ADEO-M/L PFM cu**rrently being designed for **IOD in 2020/2021, commercial phase to start 2021/2020**
- **ADEO-N IOD** to be carried out in **November 2018, commercial phase to start in 2019.**

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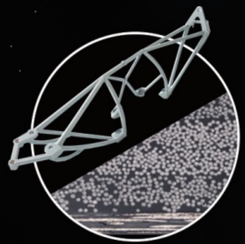
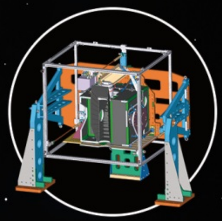
Thank you for your attention!

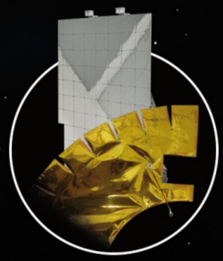
Engineering & Integration Services



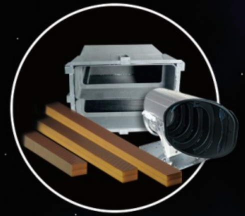
New Materials & Processes



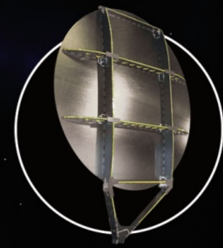
MGSE



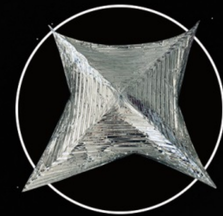
Thermal Hardware



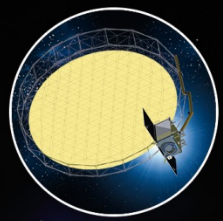
Lightweight Structures



Reflector Antennas



Deployable De-orbit Sails



Large Deploy. Reflector/ Boom Subsystems

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