High Performance Space
Structure Systems GmbH
GERMANY

ADEO - Architectural Design and Testing of De-orbiting Subsystem

CleanSat Workshop 17.-18.03.2015
ESA ESTEC

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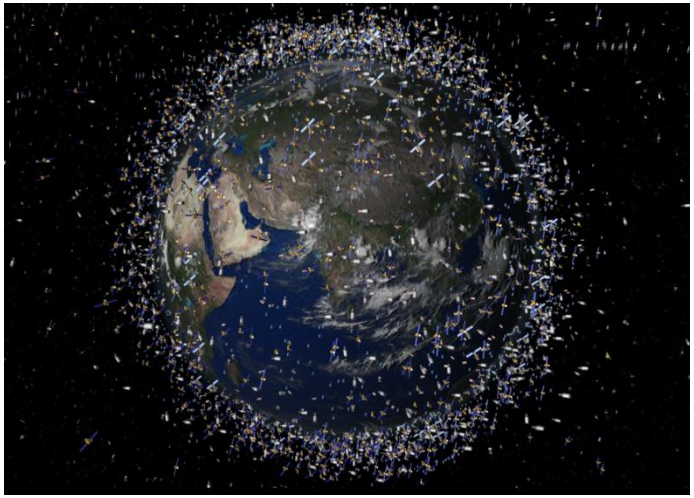
Noordwijk | March 17th 2015

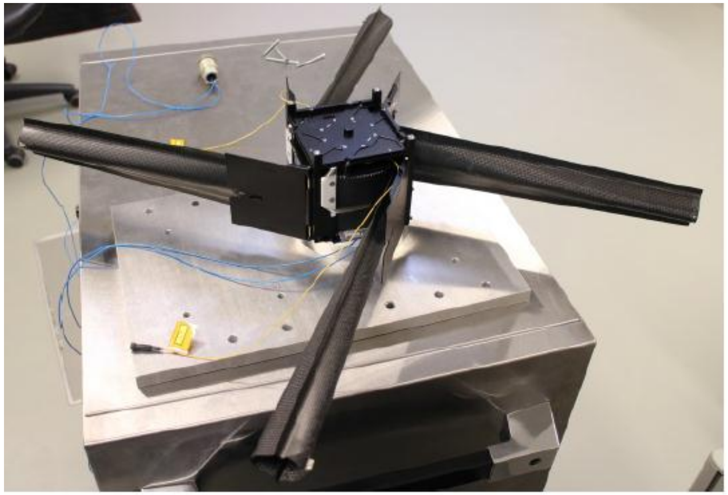
Motivation and rationale

Deliberate de-orbiting is one measure to reduce the debris in Earth's orbits, so that future missions are not subject to higher debris impact risks.

One way to do so is the use of thrusters to decelerate the satellites. The other way is a large sail or parachute that makes use of the residual atmospheric gas and its affecting drag at LEO.

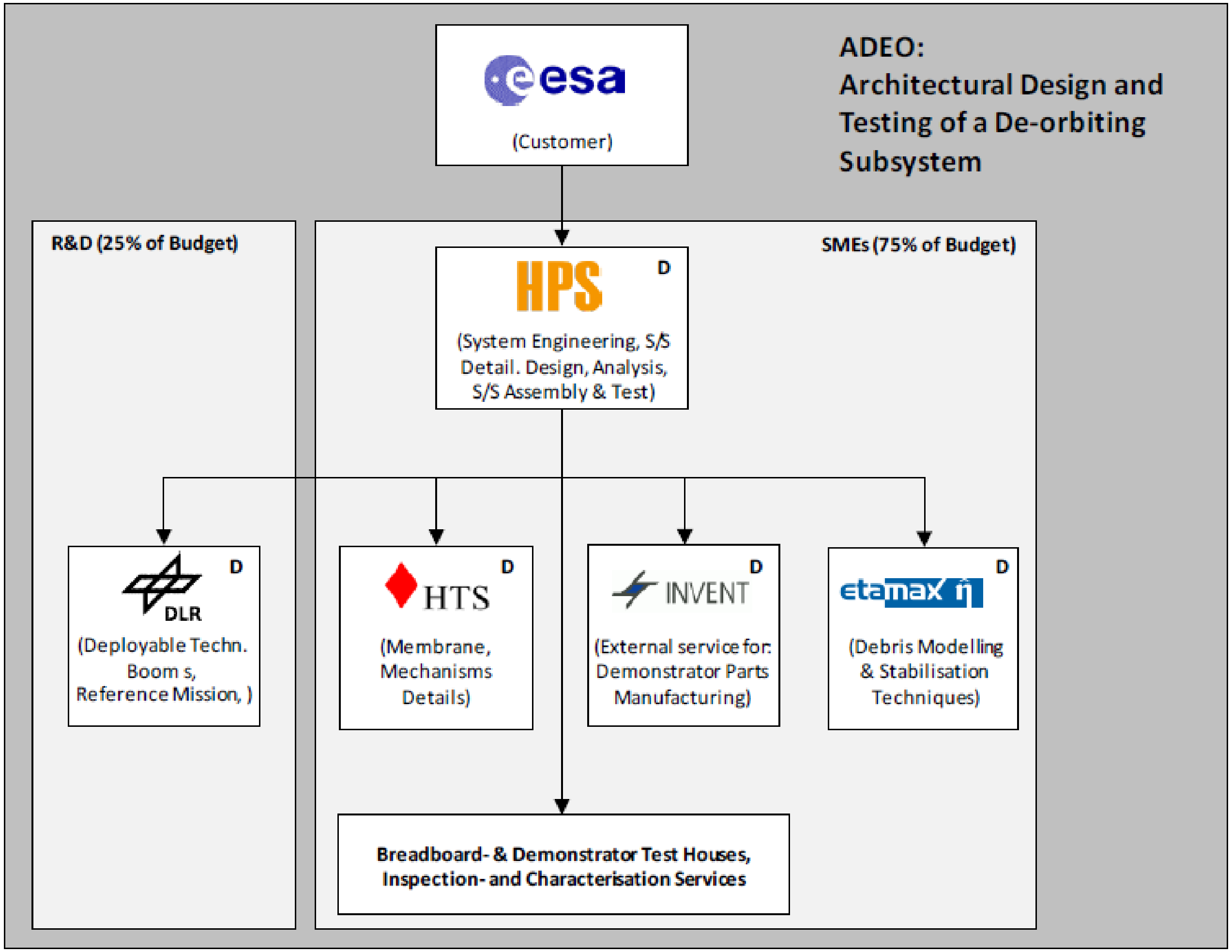


Artist impression of space debris in LEO, source ESA



DeOrbit Sail boom deployment module, source DLR

The ADEO team



Key requirements

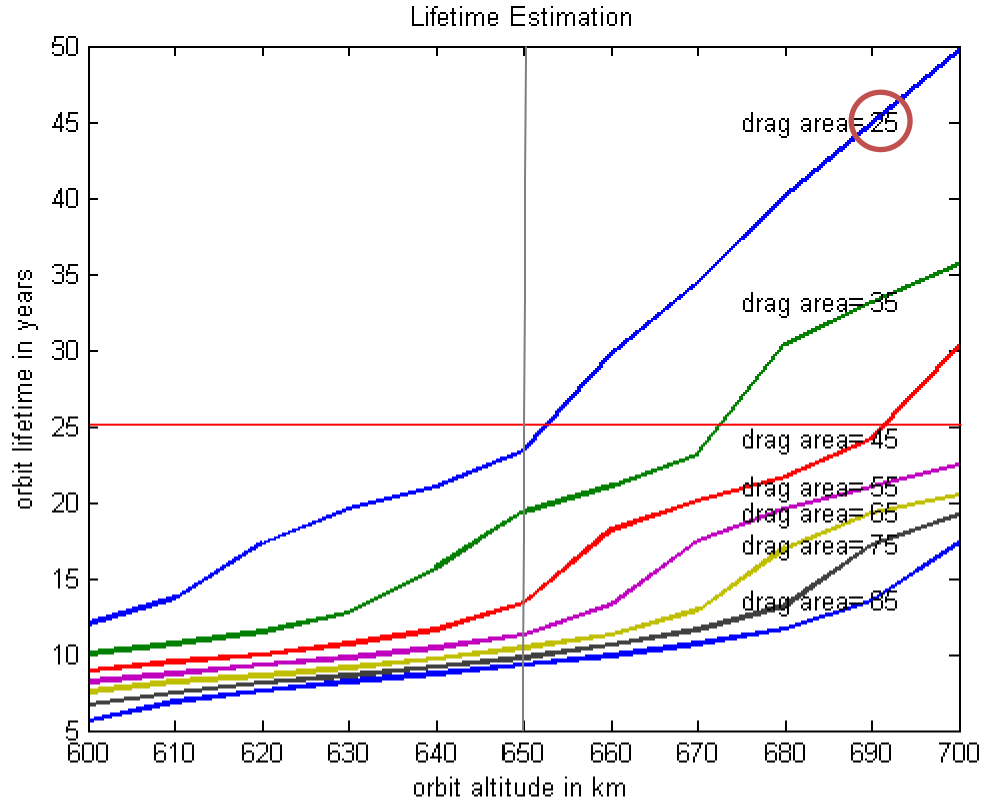
- **Boom+membrane drag sail**
- **VEGA launcher**
- **Orbit lifetime <25yrs**
- **Subsystem shall be**
  - ultra-light weight
  - scalable
  - generic
  - passively stabilized

Preliminary De-orbiting Analysis

- **1000kg satellite**
- **2014 start solar activity**
- **>700km solar pressure is dominant**
- **Top Requirement:**
  De-orbiting within max. 25yrs

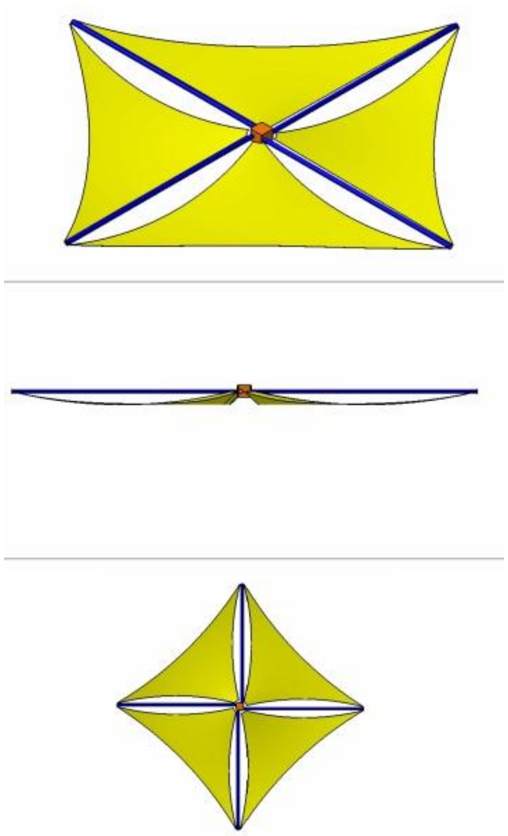
→ **650km orbit altitude**

→ **25m² drag area**

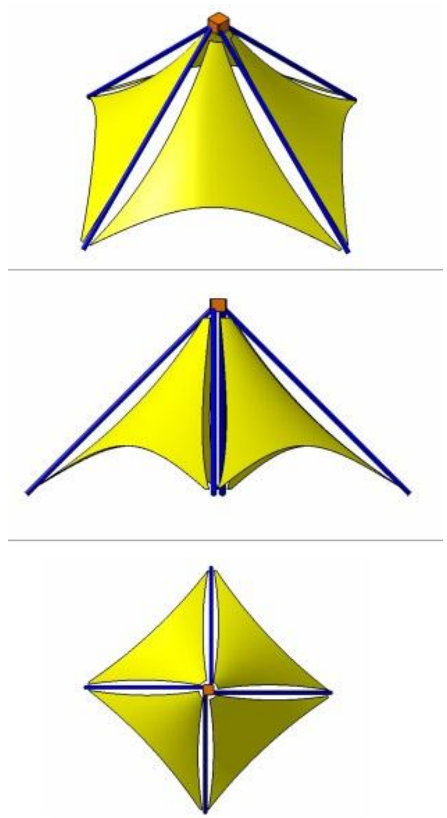


Initial Concepts

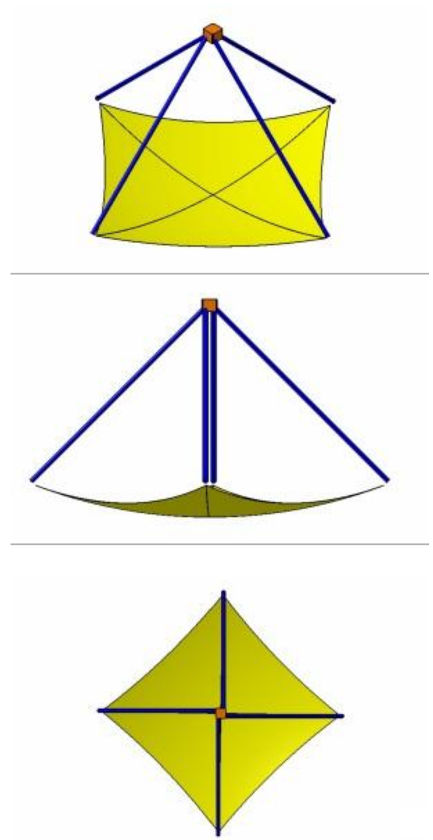
planar with slack



pyramidal



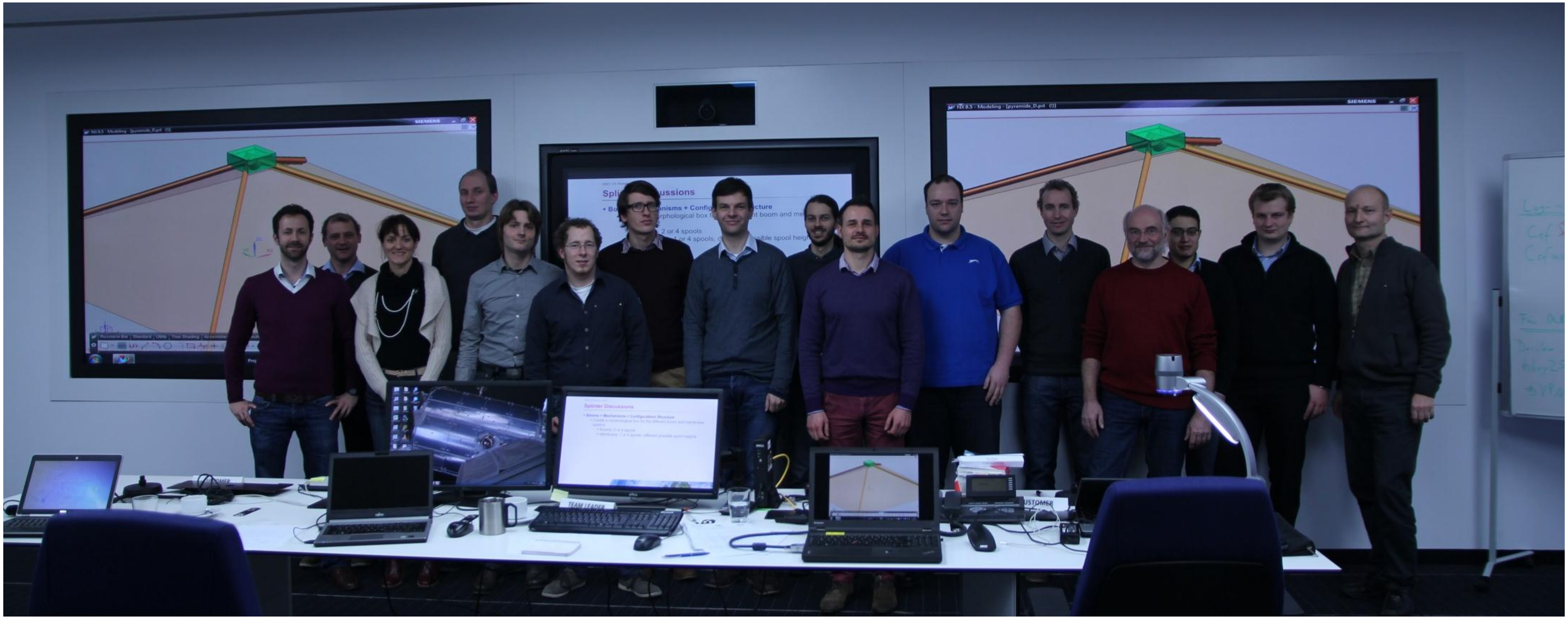
parachute



Concept Evaluation

Parameter	Weighing Factor	Details	Configuration 1		Configuration 2		Configuration 3	
			Description	Mark	Description	Mark	Description	Mark
Mass	10	mechanism	one motor needed	5	several motors or gearing needed	3	several motors or gearing needed	3
	5	boom	shortest booms	5	longer booms	4	longer booms	4
	5	membrane	lowest membrane area	5	highest membrane area	4	small membrane area	5
Required stowed volume	7	see mass	see mass	5	see mass	3	see mass	3
Stability	10		lowest torque	3	highest torque	5	medium torque	4
Boom loading (load type)	8	deployment is design driver	mainly axial compression	5	combination of bending and axial compression	3	combination of bending and axial compression	2
Reliability	8	impact risk	small area, short booms	5	large area, long booms	4	small membrane area, long booms	4,5
	6	boom/membrane I/F failure	several interfaces per segment	5	several interfaces per segment	5	four interfaces for sail	2,5
Complexity	10	packaging/ deployment	short booms and small sail area but 4 chambers for sail parts needed	5	large booms and big sail area and 4 chambers needed	5	large booms but small sail area with less interfaces and just one sail	4
Spacecraft interface	10	free/undisturbed volume	needs free volume close to S/C external surface	2	needs free surface close to Subsystem	5	needs free surface close to Subsystem	5
Heritage in consortium	5		high	5	medium	4	low	2
Total				**370**		**347**		**303**

CEF Workshop in Bremen 7.-8.1.2015

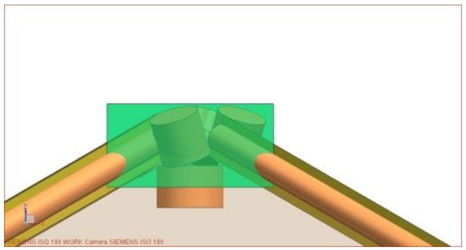
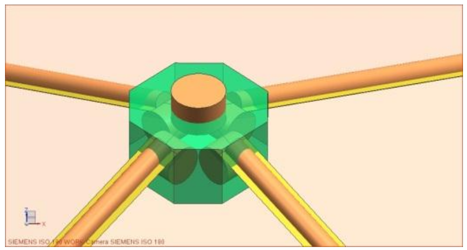
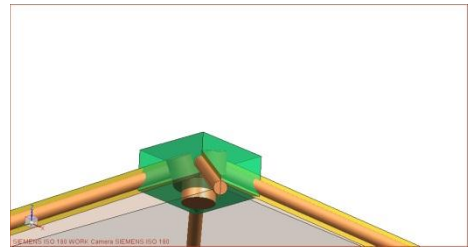
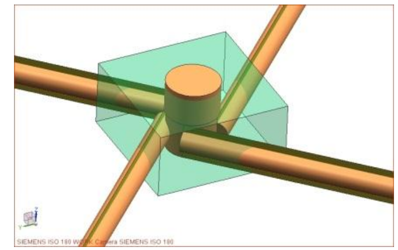
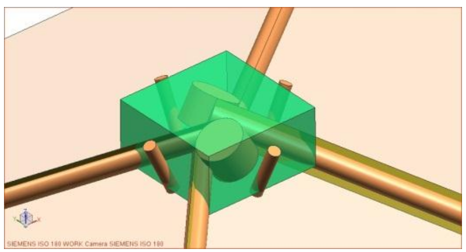
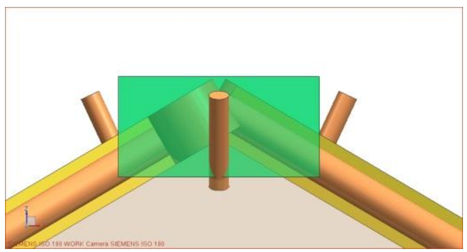
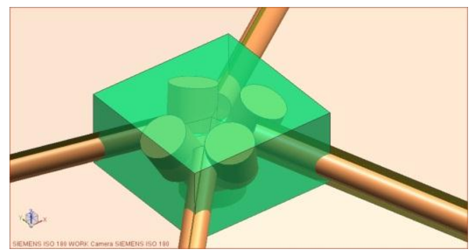
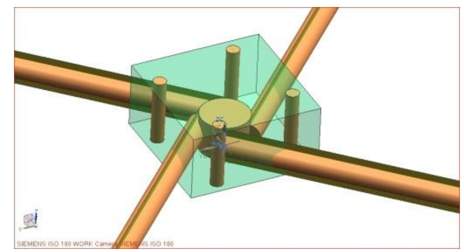
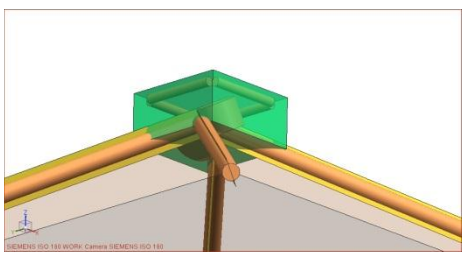
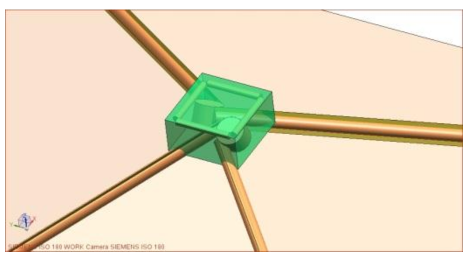
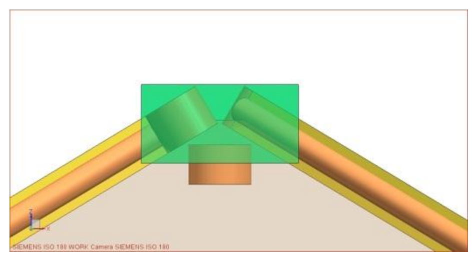
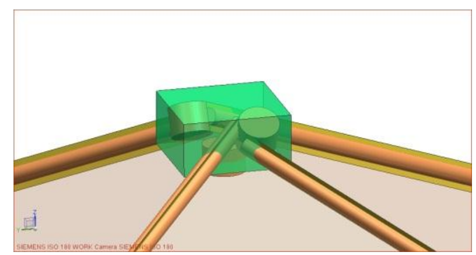


Subsystem Configuration Selection Morphological Box

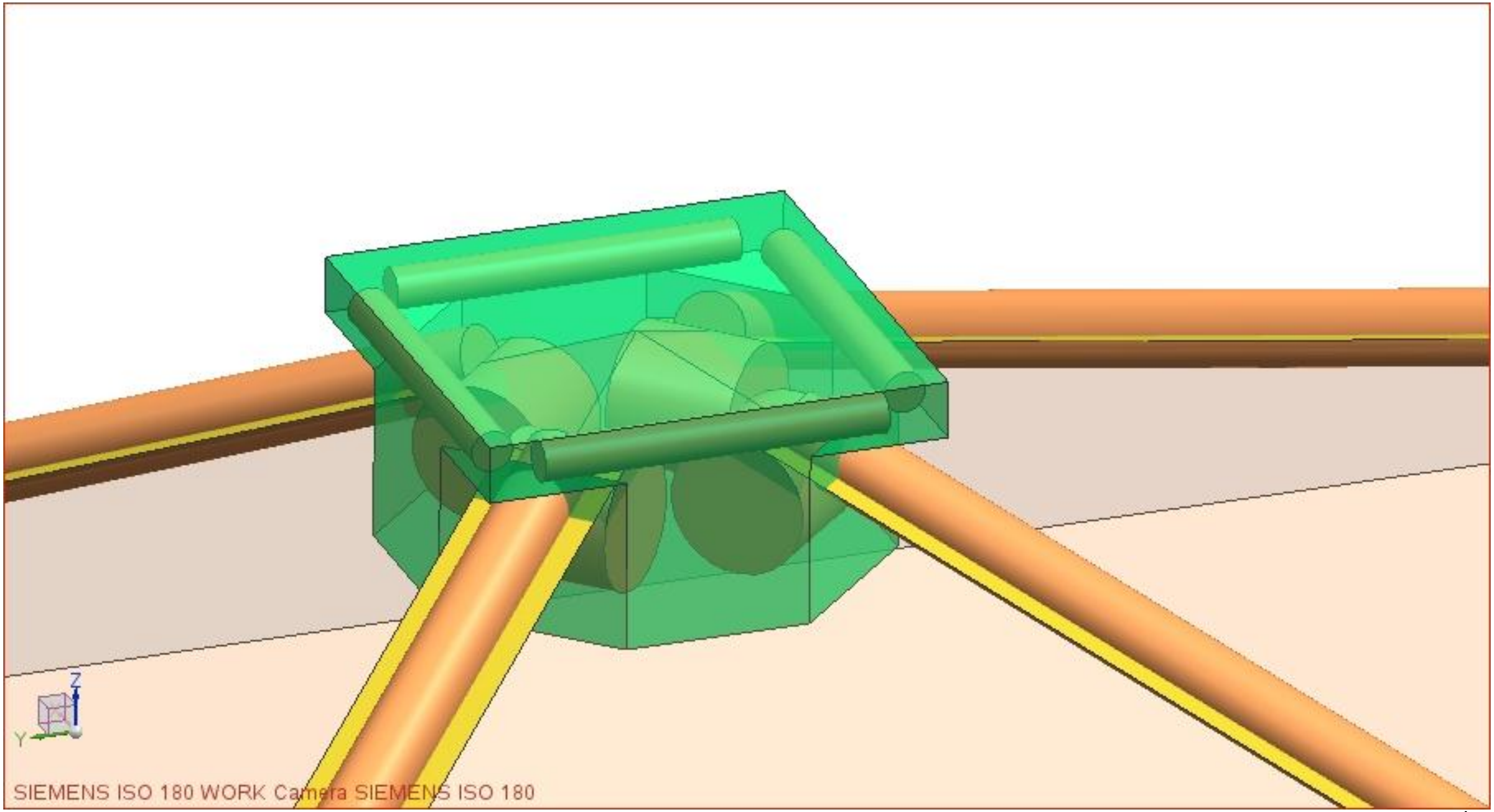
No of Booms	1	2	3	4
No of Belt-Spools	1	2	3	4
Boom Orientation	Vertical	Horizontal		
No of Sail Spools	1	2	3	4
Sail Orientation	Vertical	Angled	Horizontal	
No of levels	1	2	3	

	A	B	C	D	E	F	G	H	I	J	K	L	M
	1	1	2	2	2	4	4	4	4	4	4	4	4
	1	1	1	2	2	4	4	4	4	4	4	4	4
	V	V	V	V	V	V	V	V	V	H	H	H	V
	1	4	1	4	4	1	1	4	4	1	1	4	4
	V	V	V	H	A	V	V	H	A	V	V	H	A
	2	1	2	2	1	1	2	2	1	1	2	2	2
No spools	2	2	3	6	6	5	5	8	8	5	5	8	8
Adapt.	-	-	0	0	0	0	0	0	0	+	+	+	0
Safe Depl.	+	+	0	-	+	0	0	-	+	0	0	-	+
Volume	+	+	+	+	0	-	0	0	-	-	0	0	-

Subsystem Configurations

Selected Concept



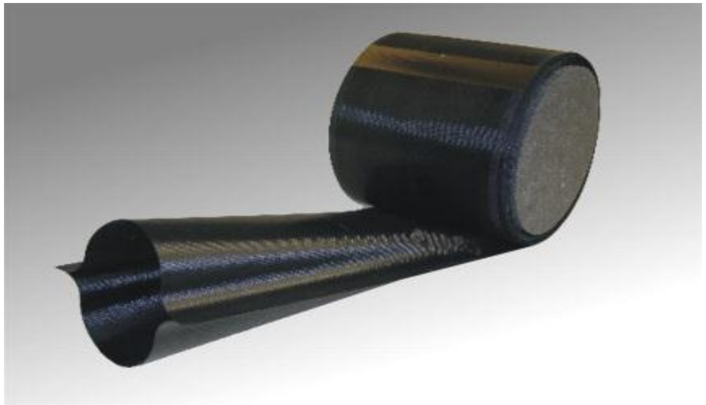
Boom concept

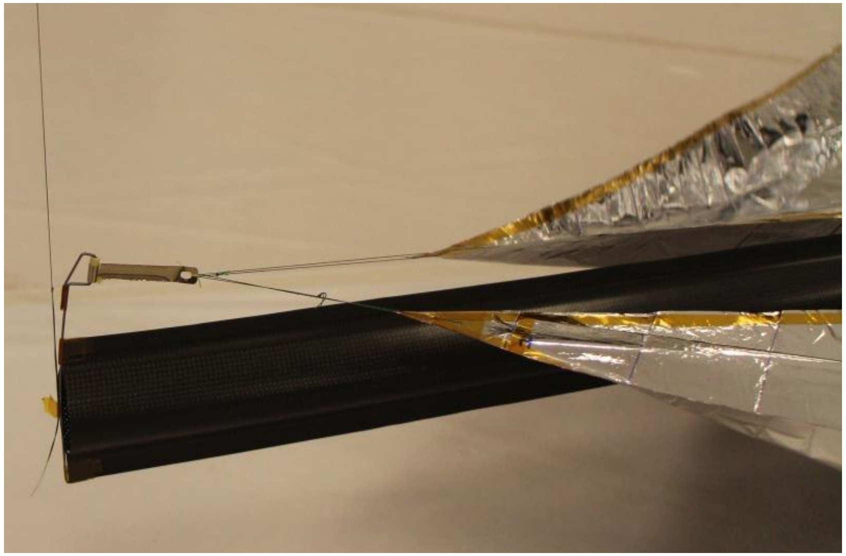
CFRP boom

Double-omega shape

Flattened profile stowed on coil

Stowed CFRP boom deployed from coil, source: DLR

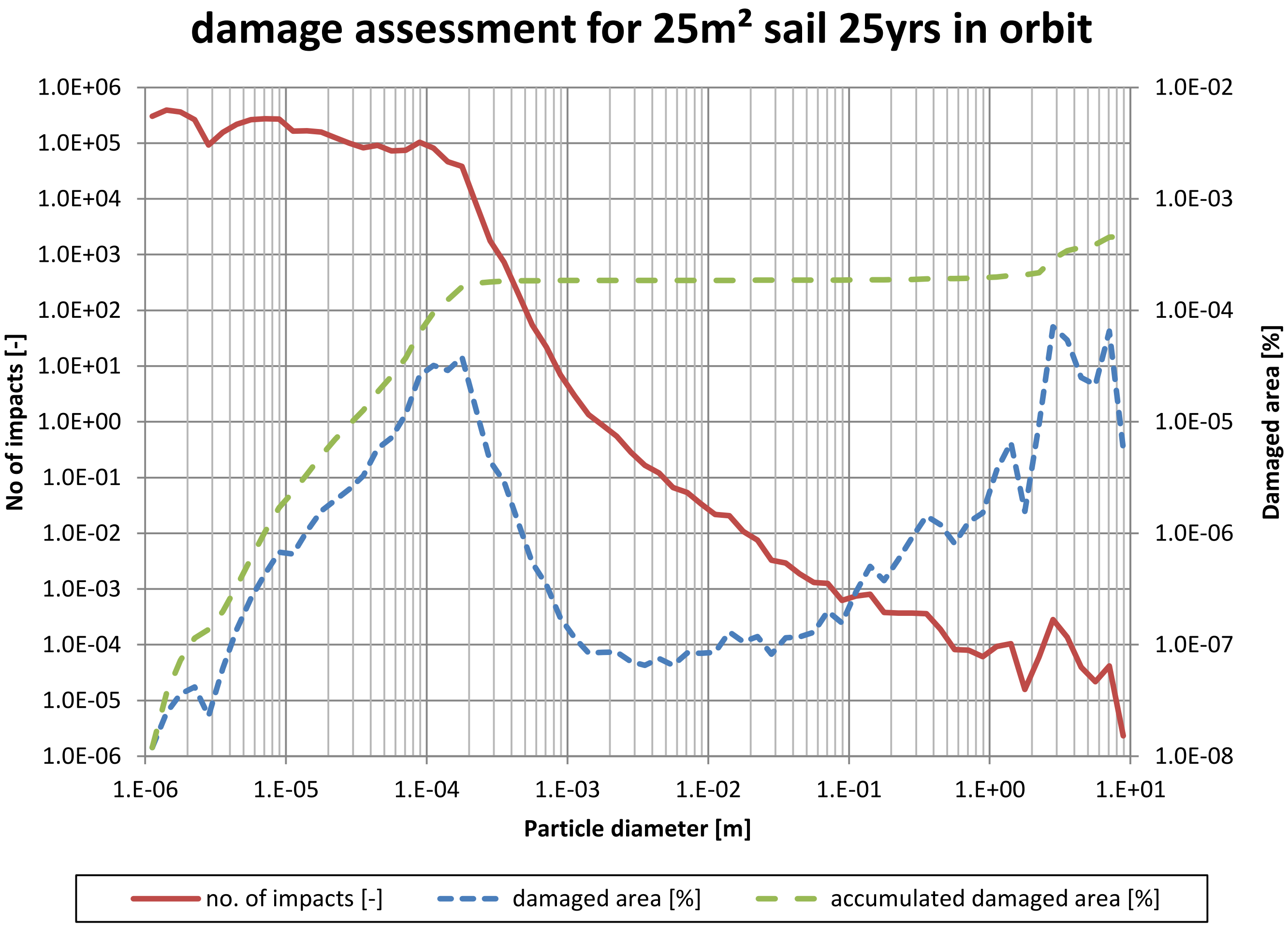




CFRP boom cross section, source: DLR

Example of boom – membrane interface, source: DLR

Preliminary damage assessment with MASTER 2009



Likelihood	No. of impacts	Particle diameter [m]
≤0.01% (minimum)	≤1e-4	≥6e-1
≤0.1% (low)	≤1e-3	≥8e-2
≤1% (medium)	≤1e-2	≥2e-2
≤10% (high)	≤1e-1	≥5e-3
>10% (maximum)	>1e-1	<5e-3

- → Impacts in the order of cm size cannot be neglected
- → The area loss is created by small debris <Ø0.2mm
- → Total area loss is negligible

Next Steps

- **Requirements for the selected concept**
- **Preliminary subsystem design**
  - Boom anlaysis and design
  - Membrane analysis and design
  - Mechanism analysis and design
- **Breadboard test plan**

Test programme

- **Breadboard tests**
- **Verification of demonstrator model**
  - Deployment test
  - Vibration test
  - Thermal balance
  - Thermal cycling
  - Vacuum deployment test

Thank you for your attention.

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