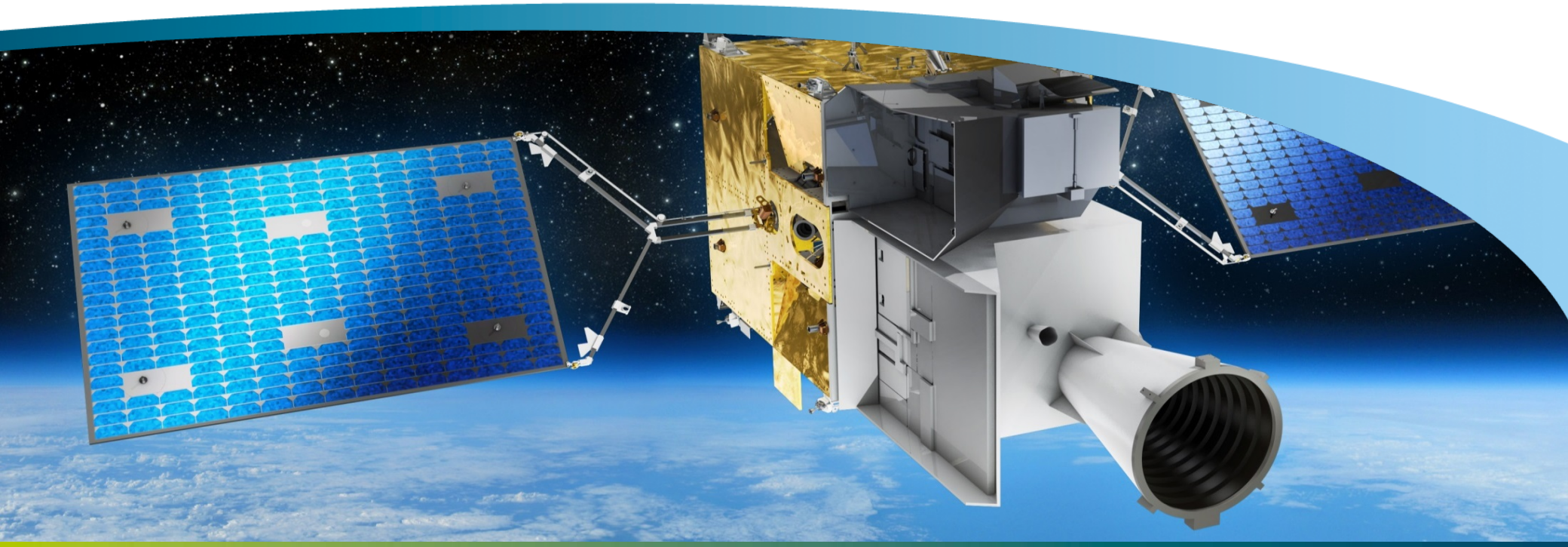
Jan-C. Meyer
11.05.2015, Noordwijk



SPACE SYSTEMS

Tentacles based clamping mechanism for ADR ASTRA 2015

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Active Debris Removal – Mechanism

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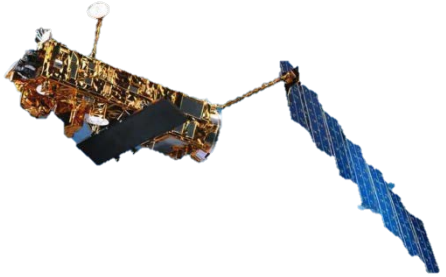
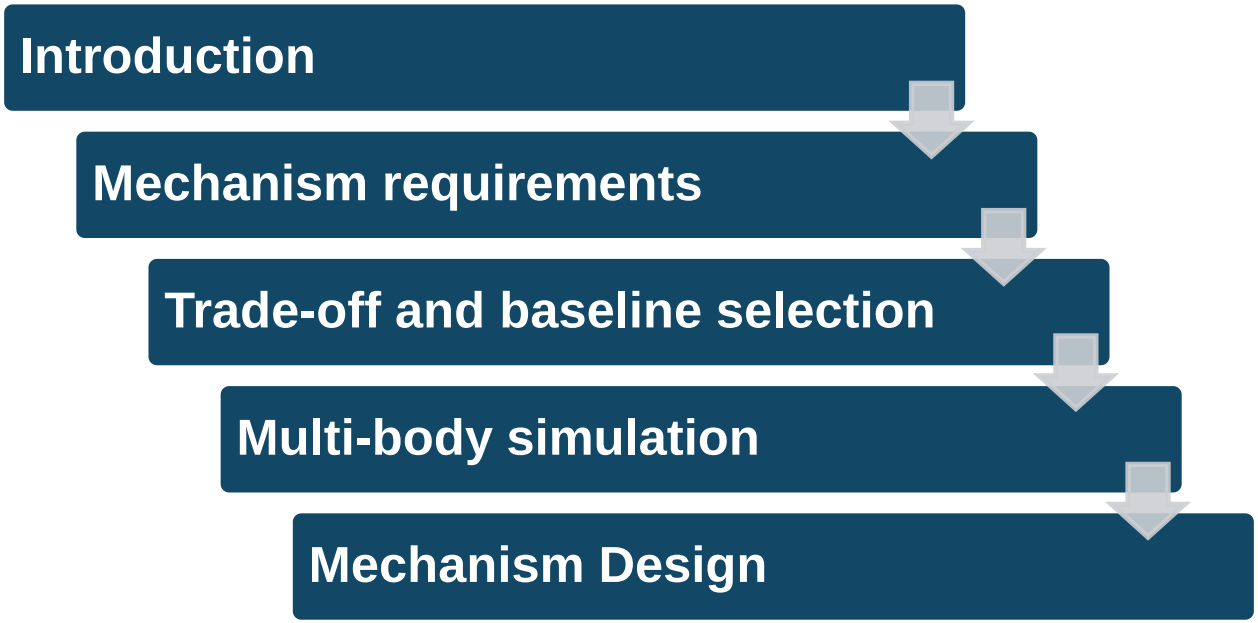
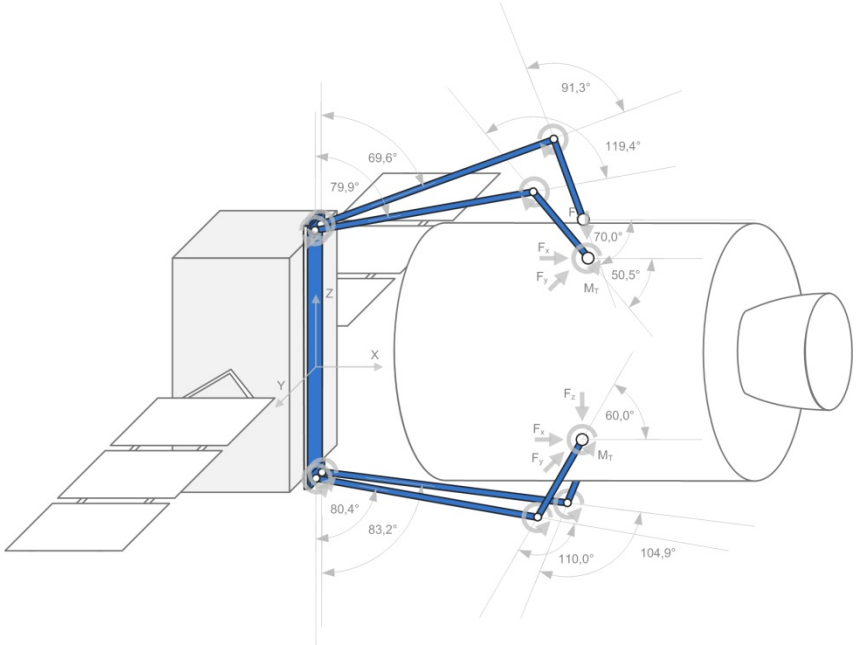


Agenda


Introduction
Mechanism requirements
Trade-off and baseline selection
Multi-body simulation
Mechanism Design



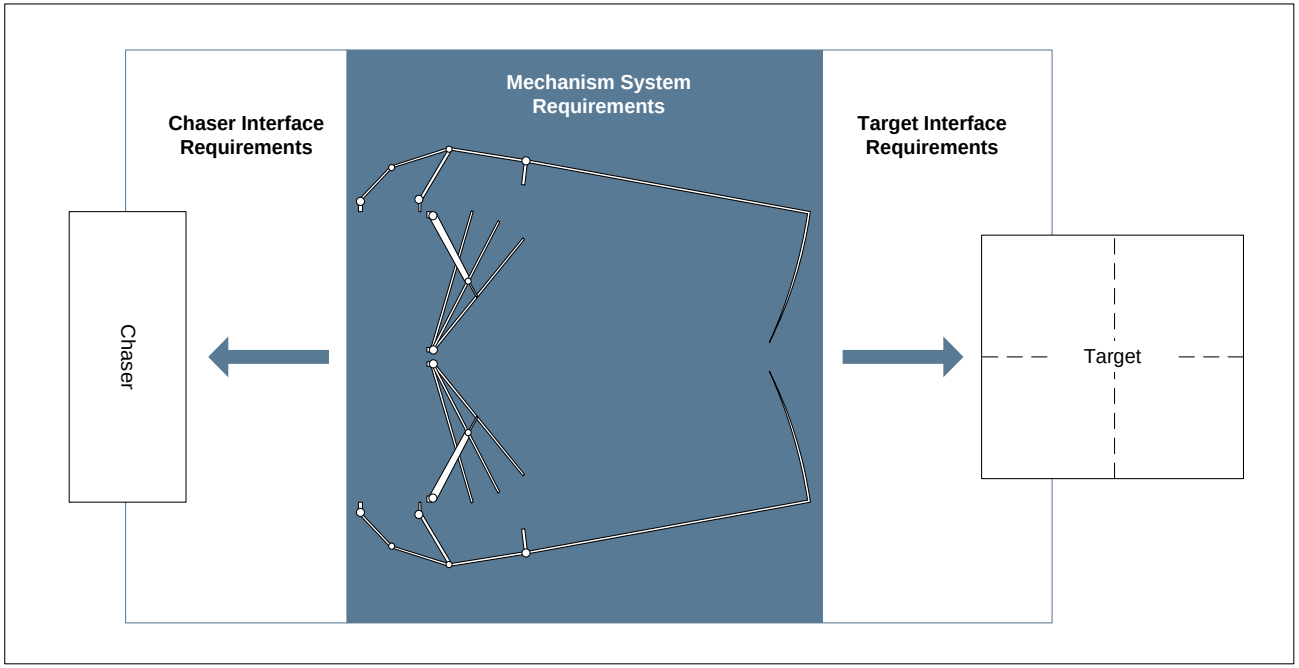
- Introduction
- Mechanism requirements
- Trade-off and baseline selection
- Multi-body simulation
- Mechanism Design

Mechanism Requirements

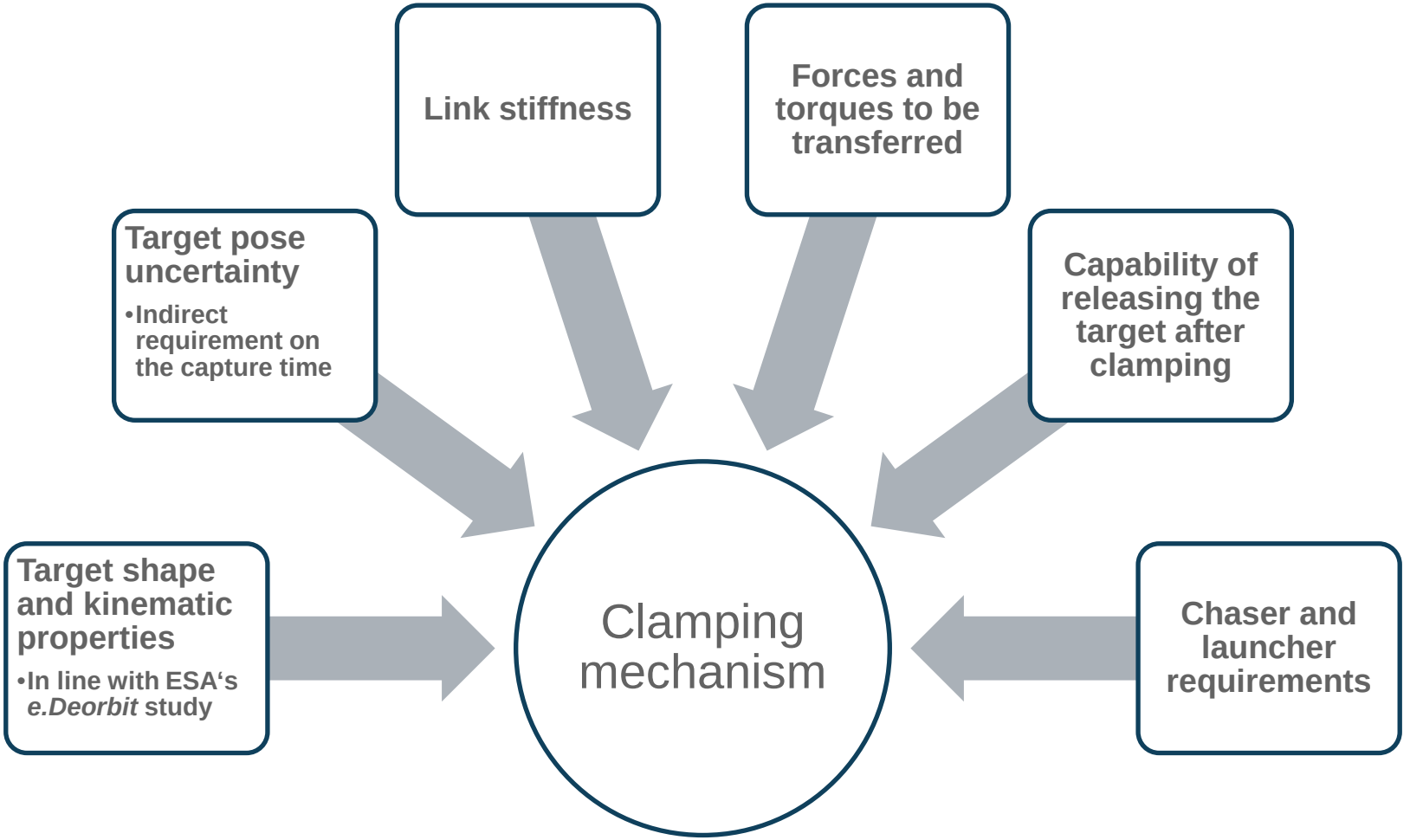
Requirements Categorisation

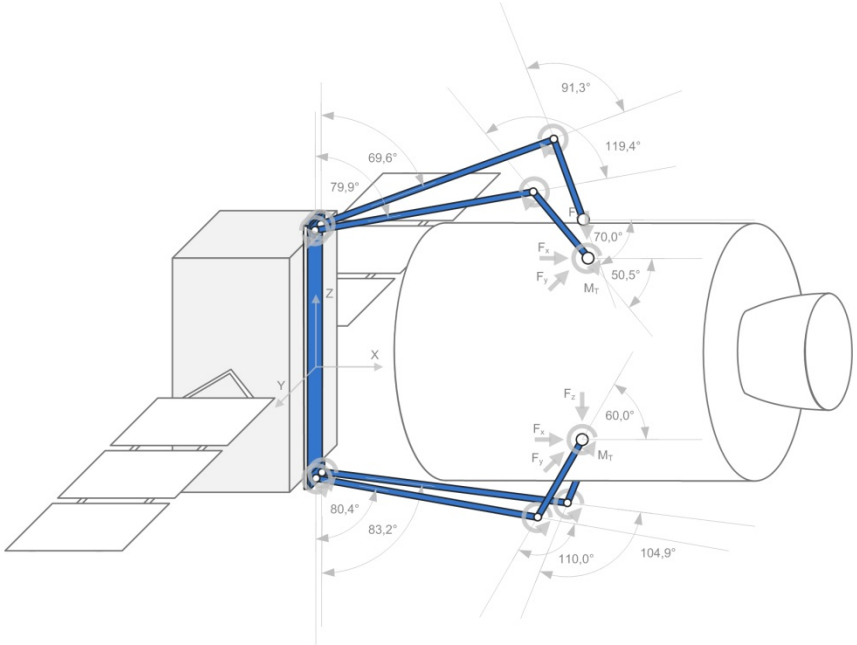
- The functionalities reveal three main categories of requirements necessary to provide a full picture of the system. These are as follows:

  - Mechanism system requirements
  - Target interface requirements
  - Chaser interface requirements



Driving Requirements





- Introduction
- Mechanism requirements
- **Trade-off and baseline selection**
- Multi-body simulation
- Mechanism Design

SPACE SYSTEMS

Trade-off and baseline selection

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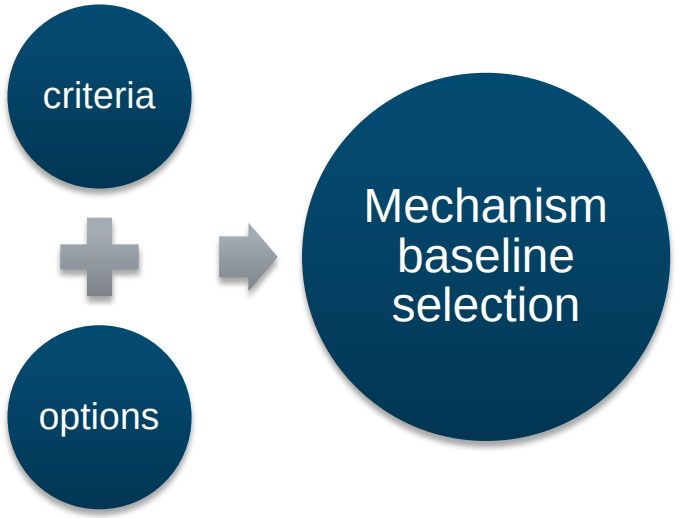
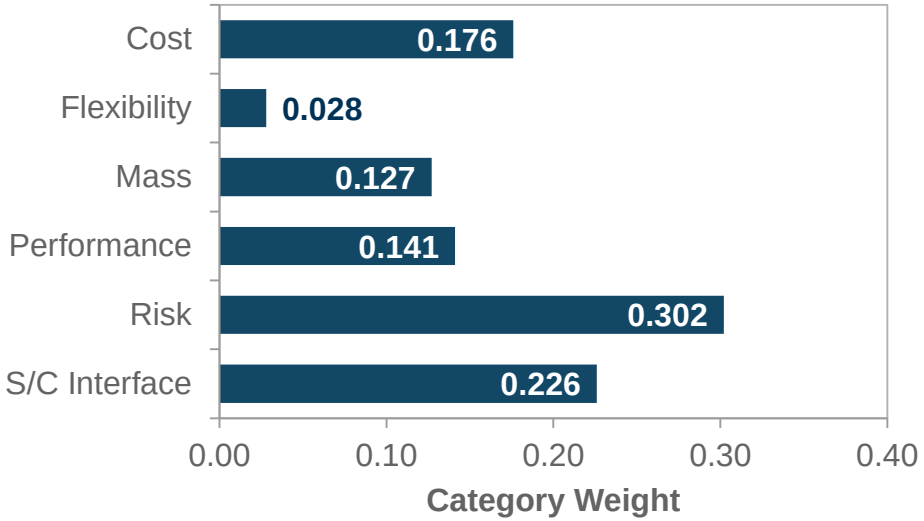
Trade-off methodology and criteria

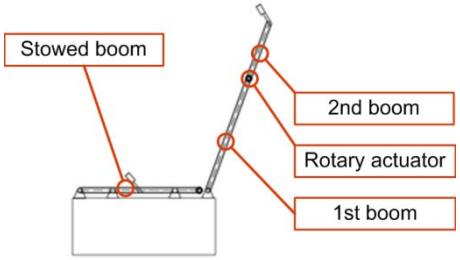
- Six categories of criteria
  - *S/C interface* rates the constraints put on the chaser platform
  - *Fexibility* indicates the mechanism‘s ability to adjust its position on the target
- Weights are determined by pairwise comparison between the criteria





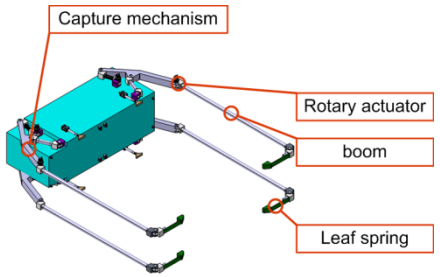
Trade-off options (1/3)

Option A



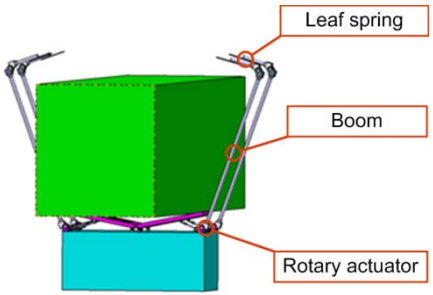
Two booms tentacle

Option B



Boom on a capture mechanism

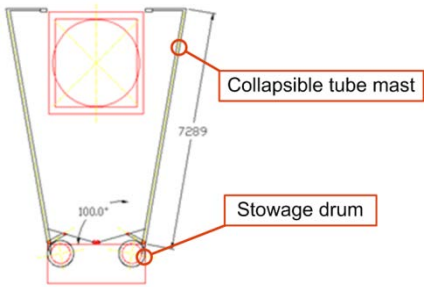
Option C



Boom tentacle

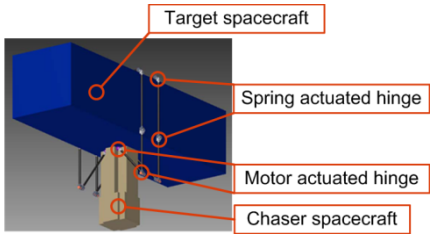
Trade-off options (2/3)

Option D



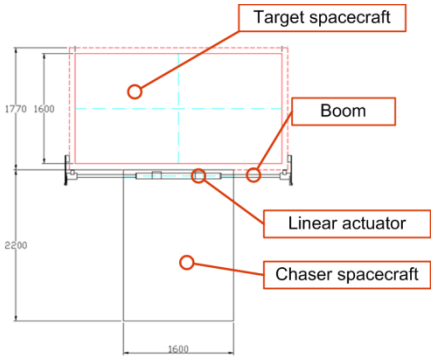
Collapsible tube mast tentacle

Option E



Three booms tentacle

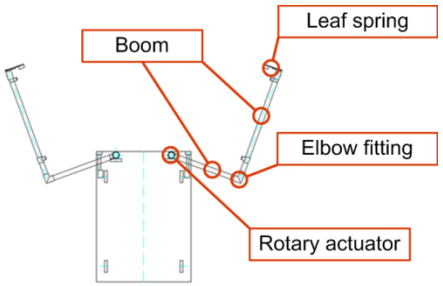
Option F



Linear tongs

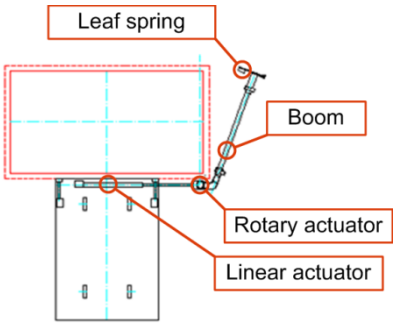
Trade-off options (3/3)

Option G



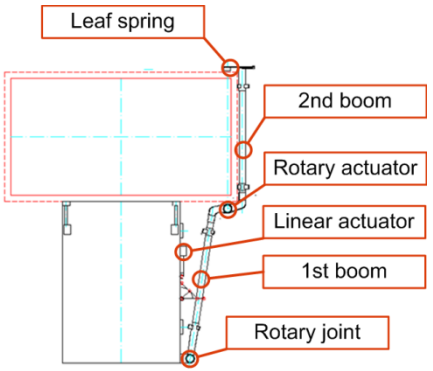
Hook tentacle

Option H



Tong and hook tentacle

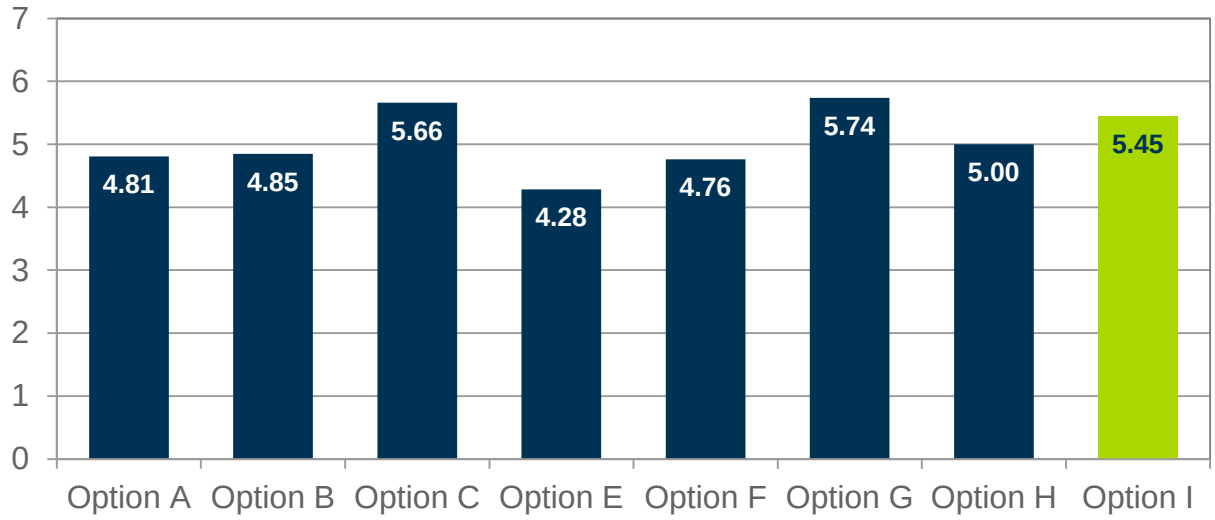
Option I

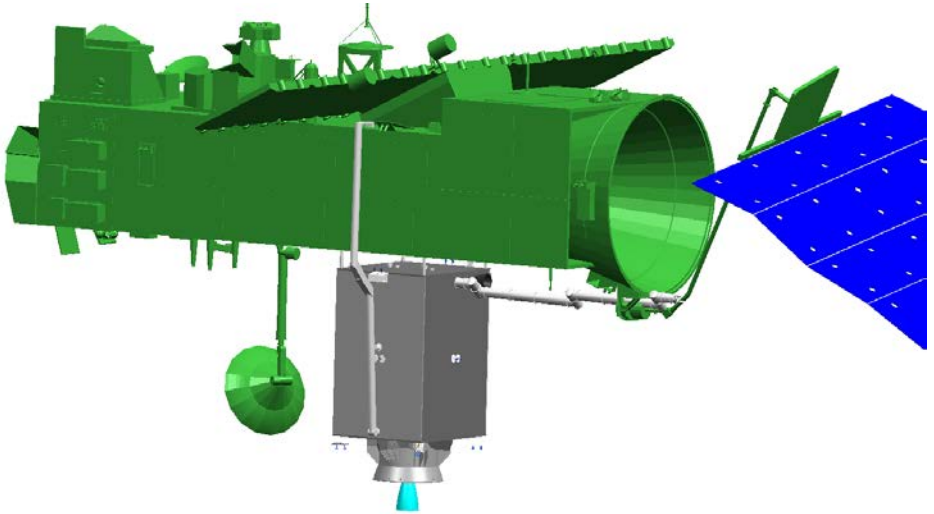


Tong and hook tentacle II

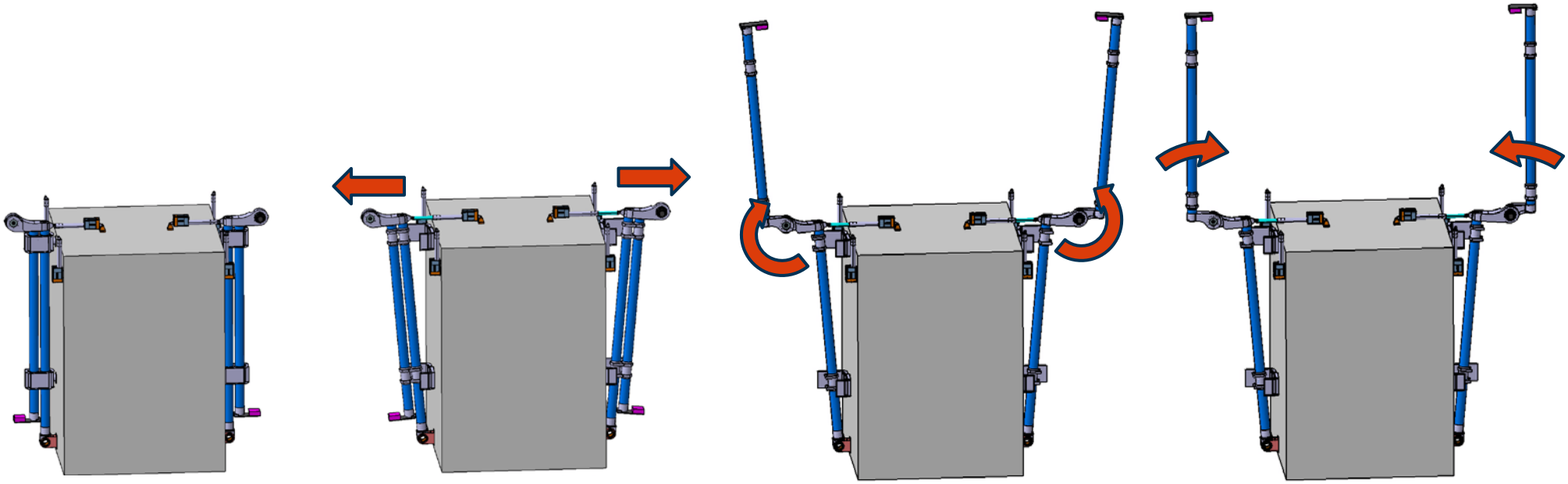
Trade-off results

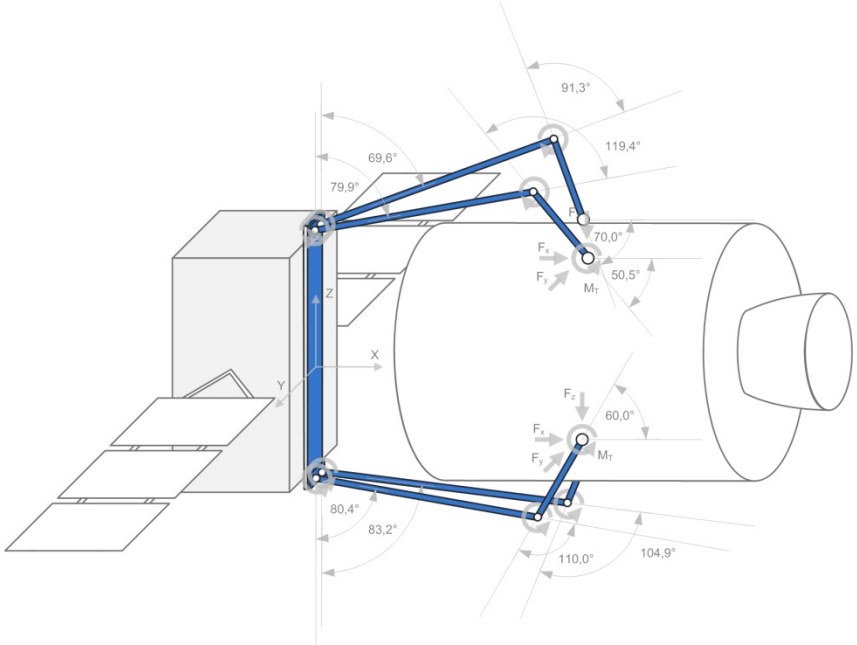
- Score range is 1 to 10
- Three options with high scores – C, G, I
  - Option G is an evolution of option C
  - Option I is specifically designed for e.Deorbit platform
  - Option I can be realised with two tentacles only
- Option I is chosen as baseline





Baseline design overview





- Introduction
- Mechanism requirements
- Trade-off and baseline selection
- **Multi-body simulation**
- Mechanism Design

SPACE SYSTEMS

Multi-body Simulation (MBS)

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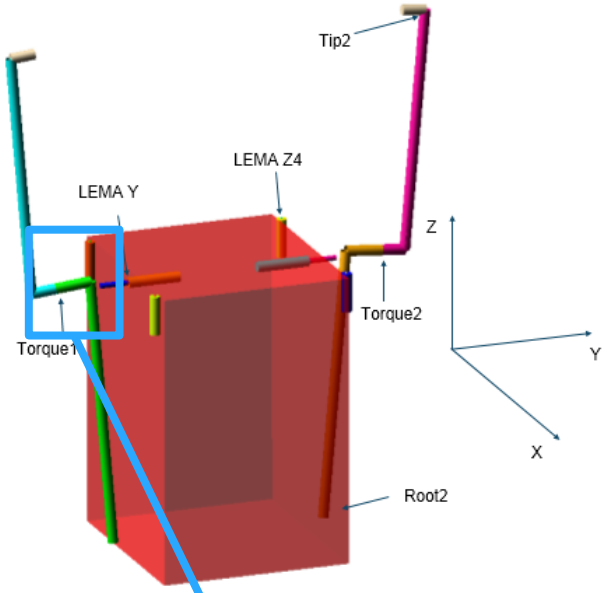
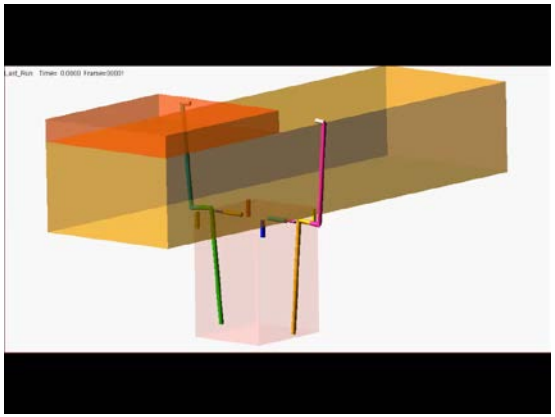
MBS Model Description



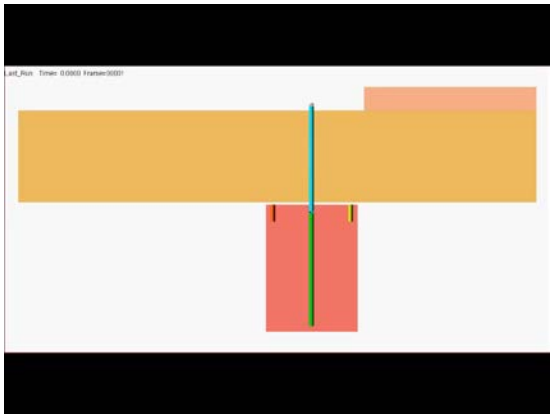
Harmonic Drive Rotary Actuator (HDRA)

- Two step methodology:
  - Worst-case identification
  - Detailed analysis for mechanism component sizing
- Worst-case is determined by finding the combination of parameters that maximises the x-component of *Torque1* and *Torque2*
- Feasibility of solution is constrained by HDRA maximum holding torque
- Design parameters and requirements are adapted to create feasible solution

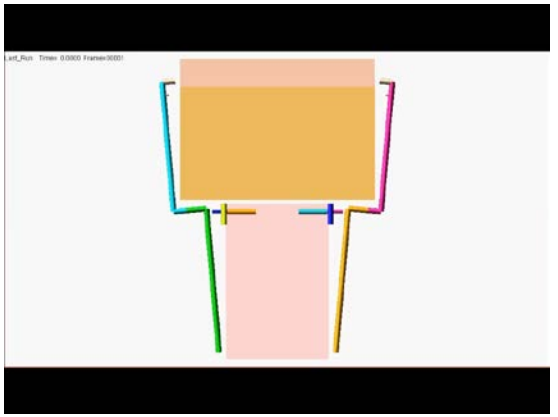
MBS worst-case visualisation



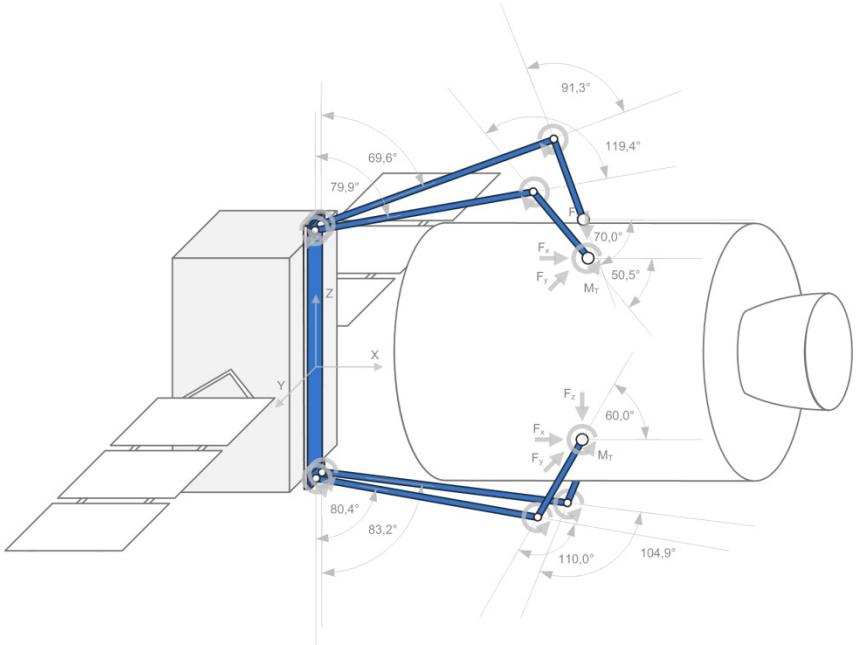
Isometric view



Side view fitting the camera to global reference



Front view fitting the camera to the Chaser

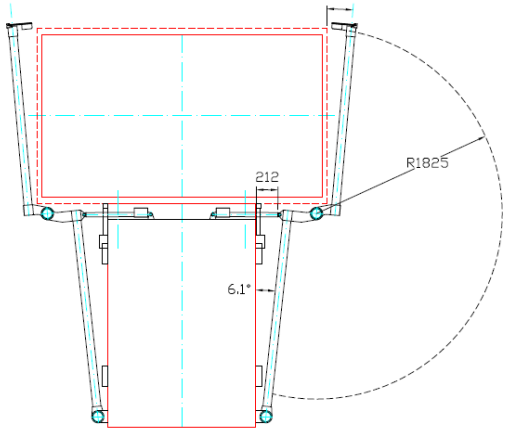


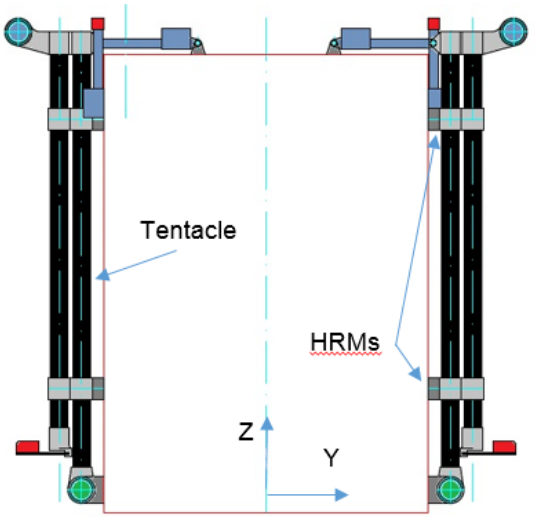
- Introduction
- Mechanism requirements
- Trade-off and baseline selection
- Multi-body simulation
- **Mechanism Design**

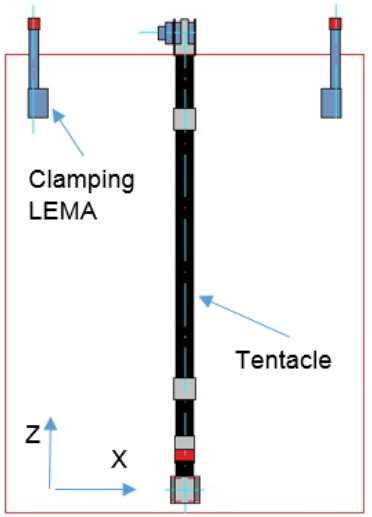
Mechanism Design

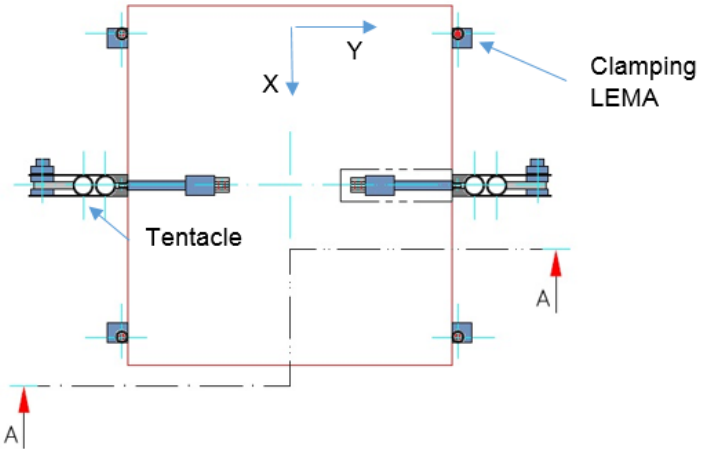
Design overview

- Two tentacles
  - Two booms each
  - Connected by a rotary actuator
  - One linear actuator for lateral extension each
  - Two HDRMs each
- Four linear actuators for target clamping

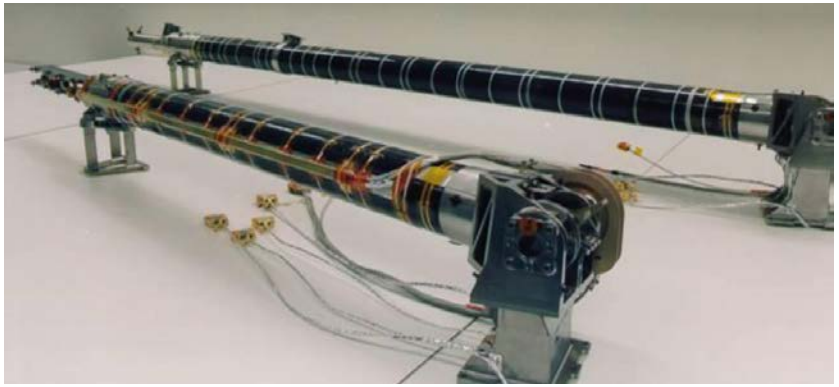


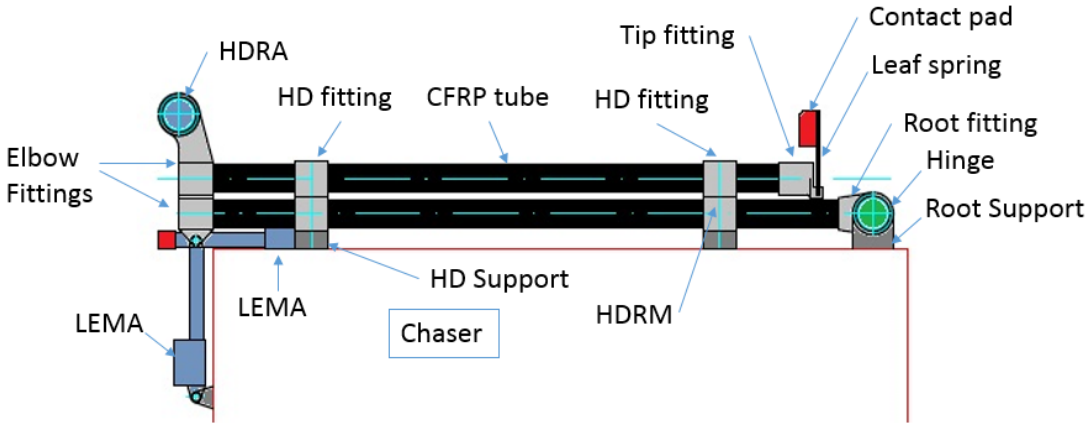


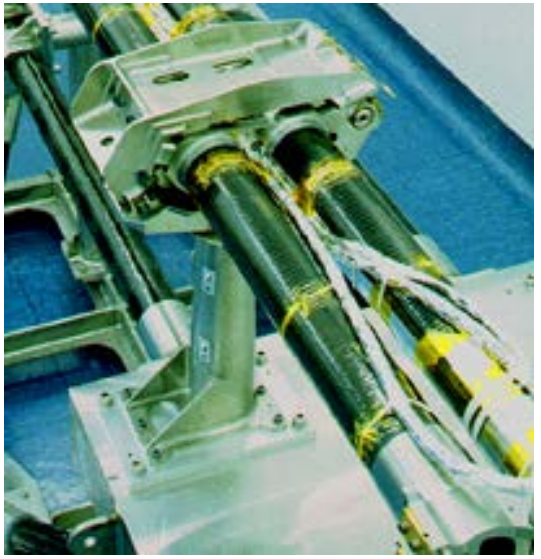




Mechanism components

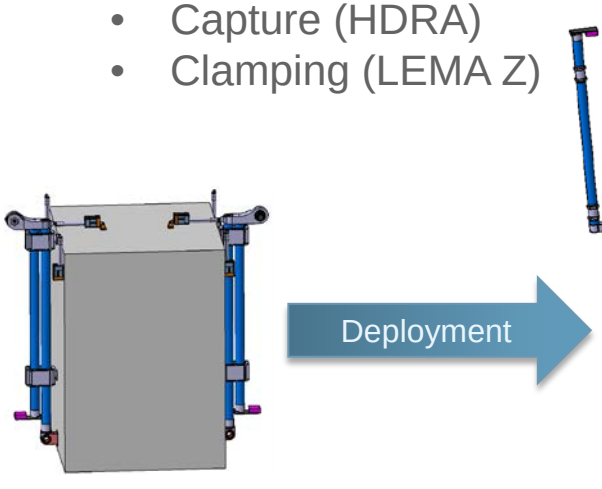


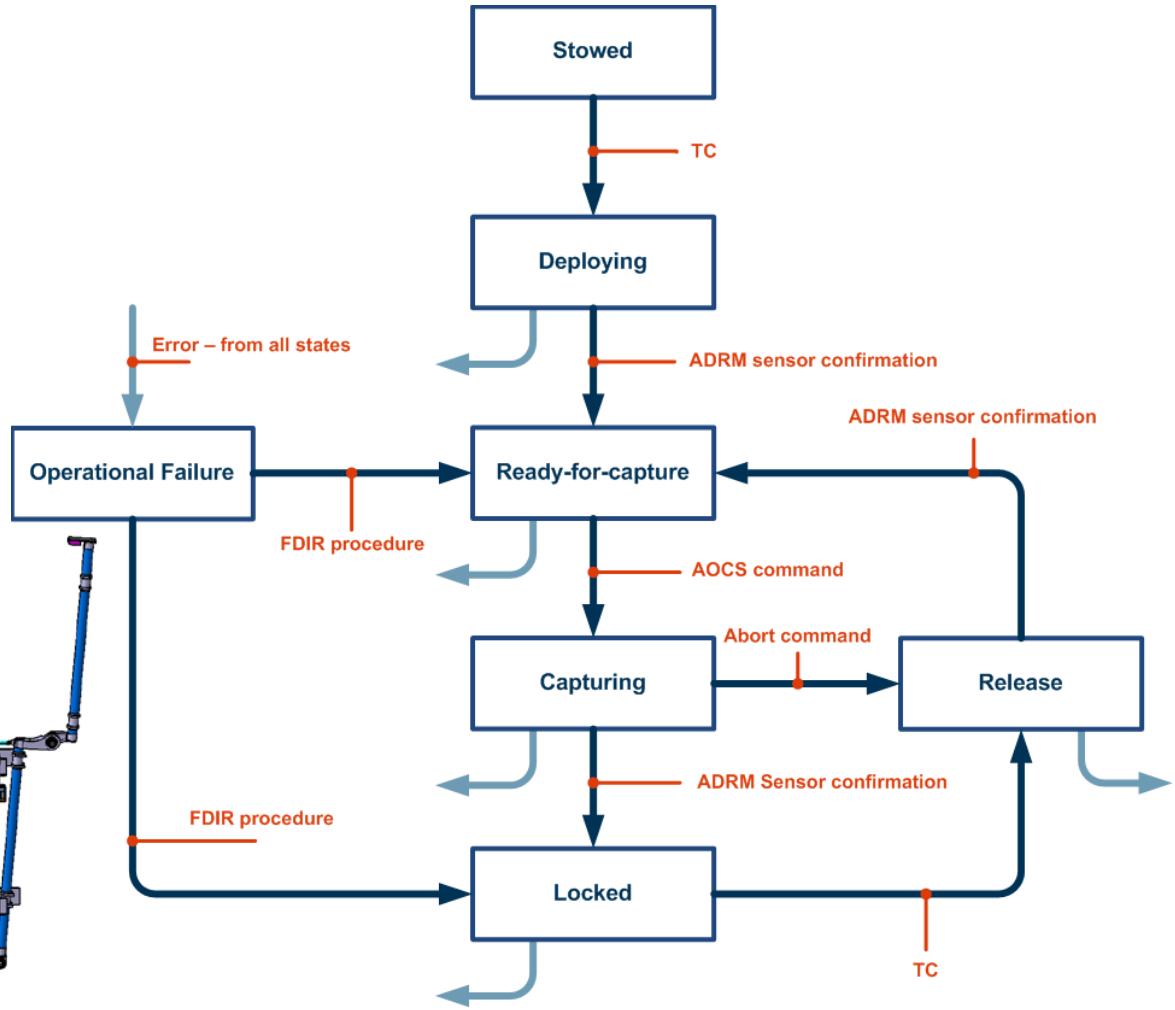




Mechanism operations

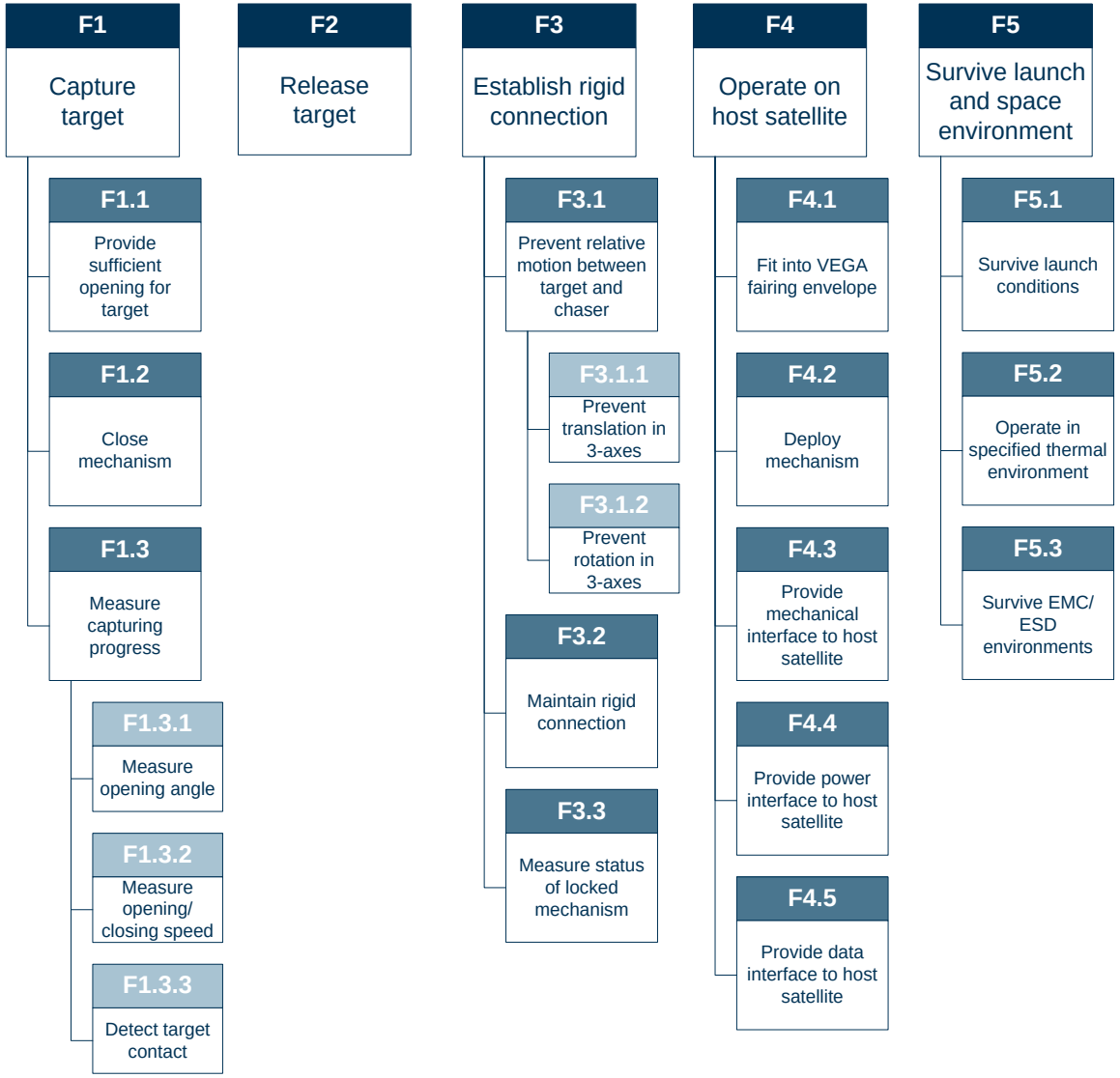
- Sequential boom tentacle deployment
  - Reduction of deployment shocks
  - Simpler handling of perturbations by AOCS
  - Time for deployment is (practically) not limited
  - Easier failure handling
- Capturing consists of two parts:
  - Capture (HDRA)
  - Clamping (LEMA Z)

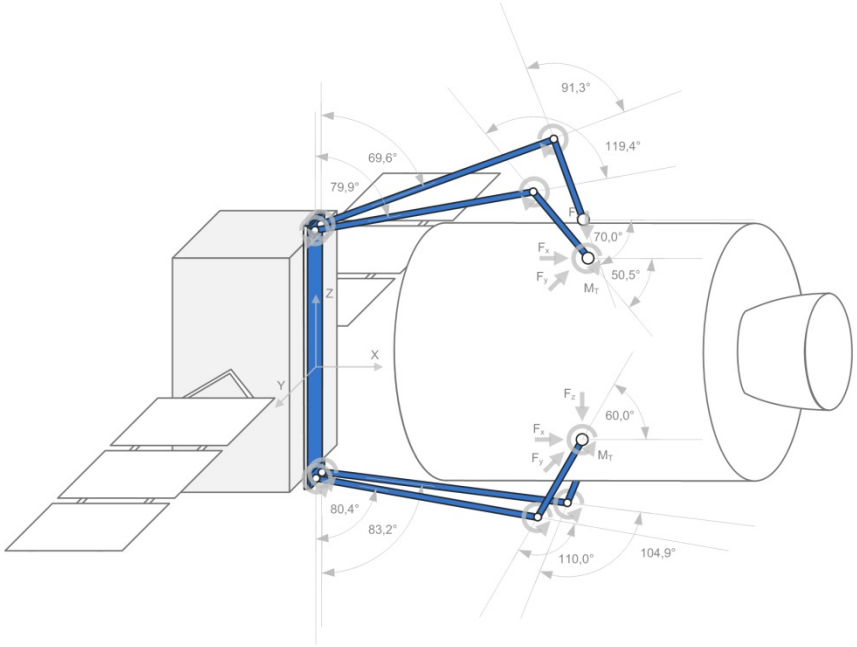




Function tree

- **F1: Capture target**
  Tentacles
- **F2: Release target**
  Open tentacles
- **F3: Establish rigid connection**
  Brakes + preload mechanism
- **F4: Operate on host satellite**
  Power, data, and mechanical interfaces
- **F5: Survive launch and space environment**
  HDRM + environmental specifications





SPACE SYSTEMS

Conclusions and outlook

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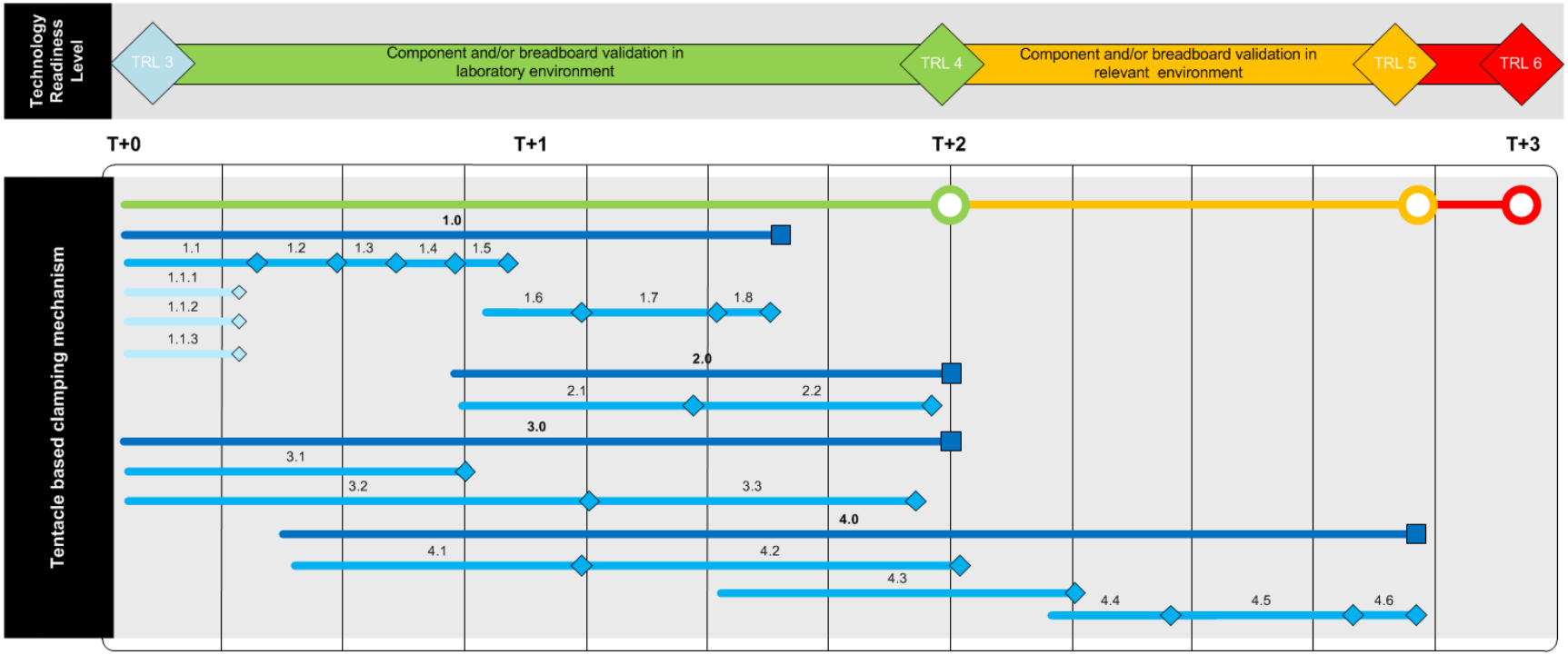
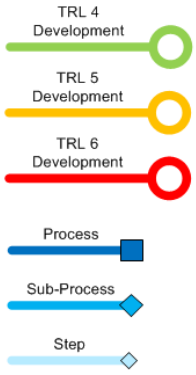
Tentacles based clamping mechanism





Step	Description	Step	Description	Step	Description
1.0	**LEMA Development**	1.6	QM Manufacturing	**4.0**	**Mechanism Development**
1.1	Detailed design	1.7	QM Testing	4.1	Preliminary Design
1.1.1	Non-Backdrivability	1.8	QM Test Documentation	4.2	Detailed Design
1.1.2	Lateral stiffness	**2.0**	**Structural Components Development**	4.3	Analysis
1.1.3	Load capability	2.1	Detailed design	4.4	QM Manufacturing
1.2	Analysis	2.2	Analysis	4.5	QM Testing
1.3	BB Manufacturing	**3.0**	**Mechanism Electronics Development**	4.6	QM Test Documentation
1.4	BB Testing	3.1	Electronics design		
1.5	BB Test Documentation	3.2	Software design		
		3.3	Simulation		

Conclusions and outlook

- Definition of a clamping mechanism has been performed
- Component sizing supported by multi-body simulation
- Operational and functional design
  - Including FMEA
- Mechanism and technology development roadmap
- Validation test plan including
  - Test facility identification
- Further evaluated for evolving e.Deorbit mission

The presented activity was part of an ESA contract under the Basic Technology Research Programme. It is part of the Clean Space Branch 4 Roadmap.

Image: www.faz.net

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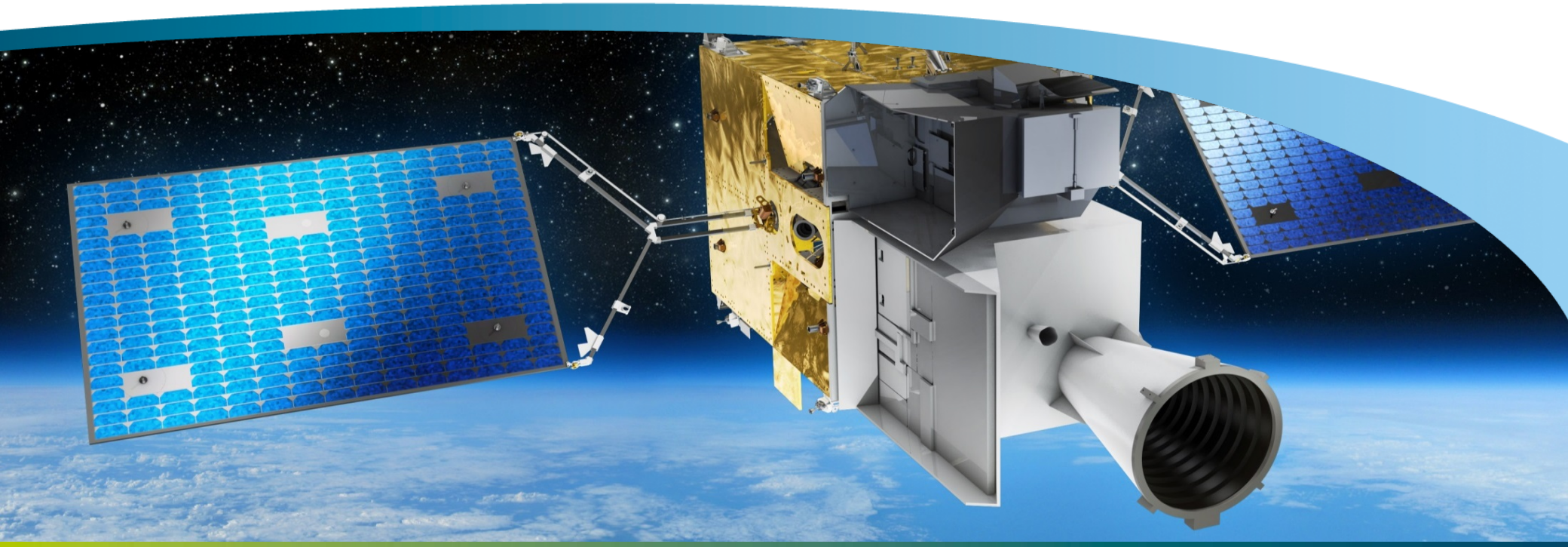
12.03.2015, Noordwijk



SPACE SYSTEMS

Tentacles based clamping mechanism
Mechanism Final Presentation Days

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