Harpoon Design, Development and Testing

Cleanspace Industrial Days

Alastair Wayman
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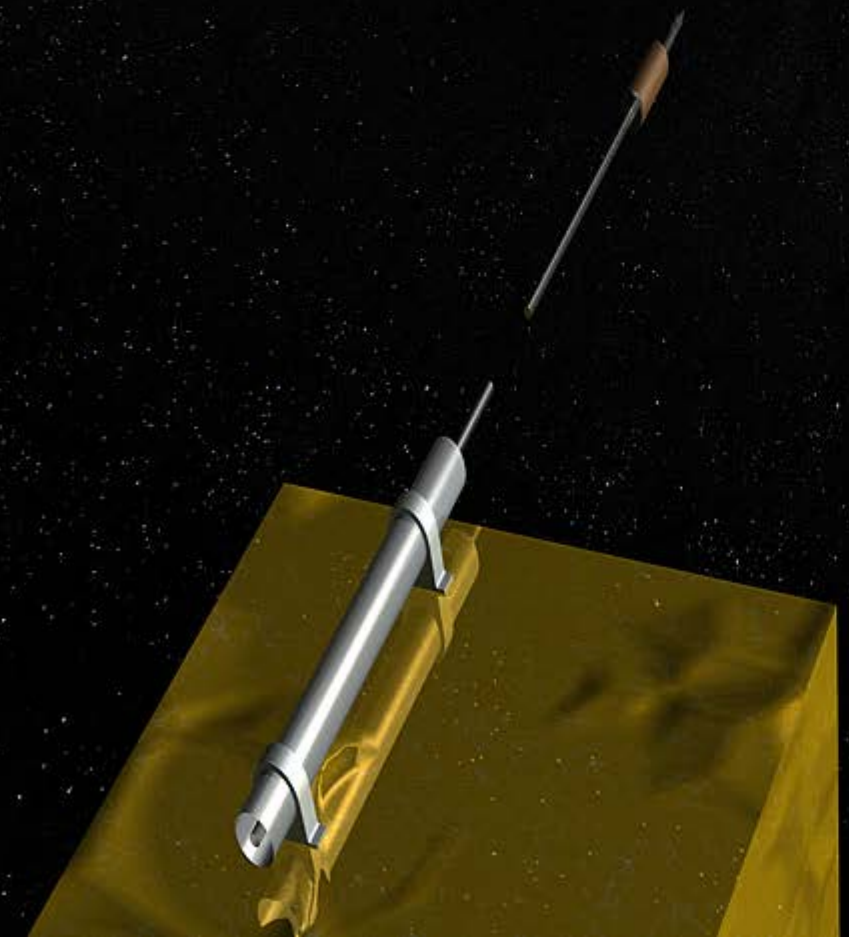

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  - Requirements
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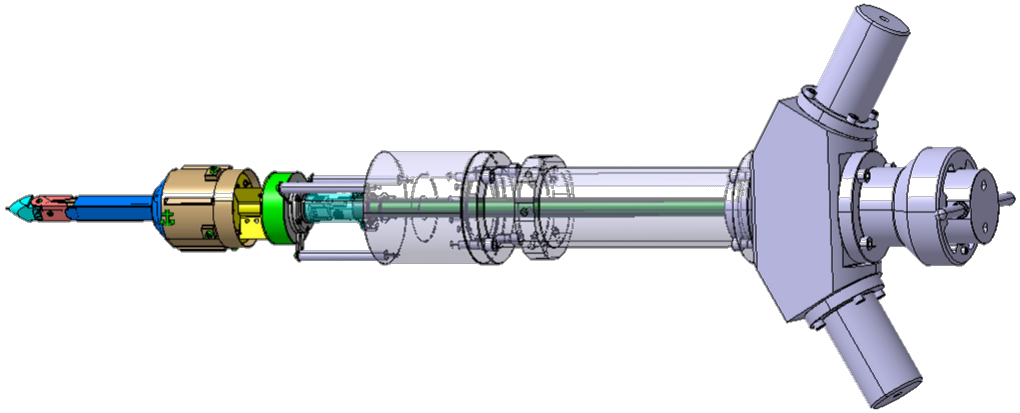

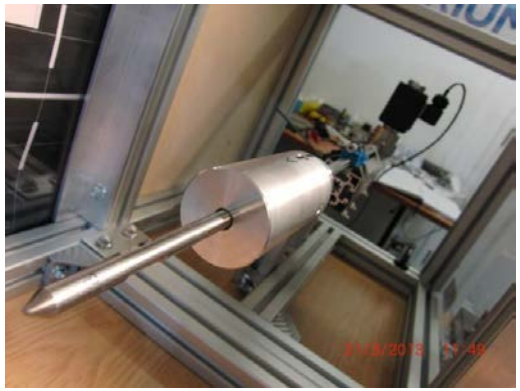

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Why Harpoons?

Several attractive features that led to development of harpoon system:

- Low mass and volume allows many harpoons on one spacecraft
- Simple, highly reliable and low risk
- High firing speed is compatible with high target spin rates
- Compatible with wide range of targets from small to large
- Easy to test and validate on ground reducing system cost

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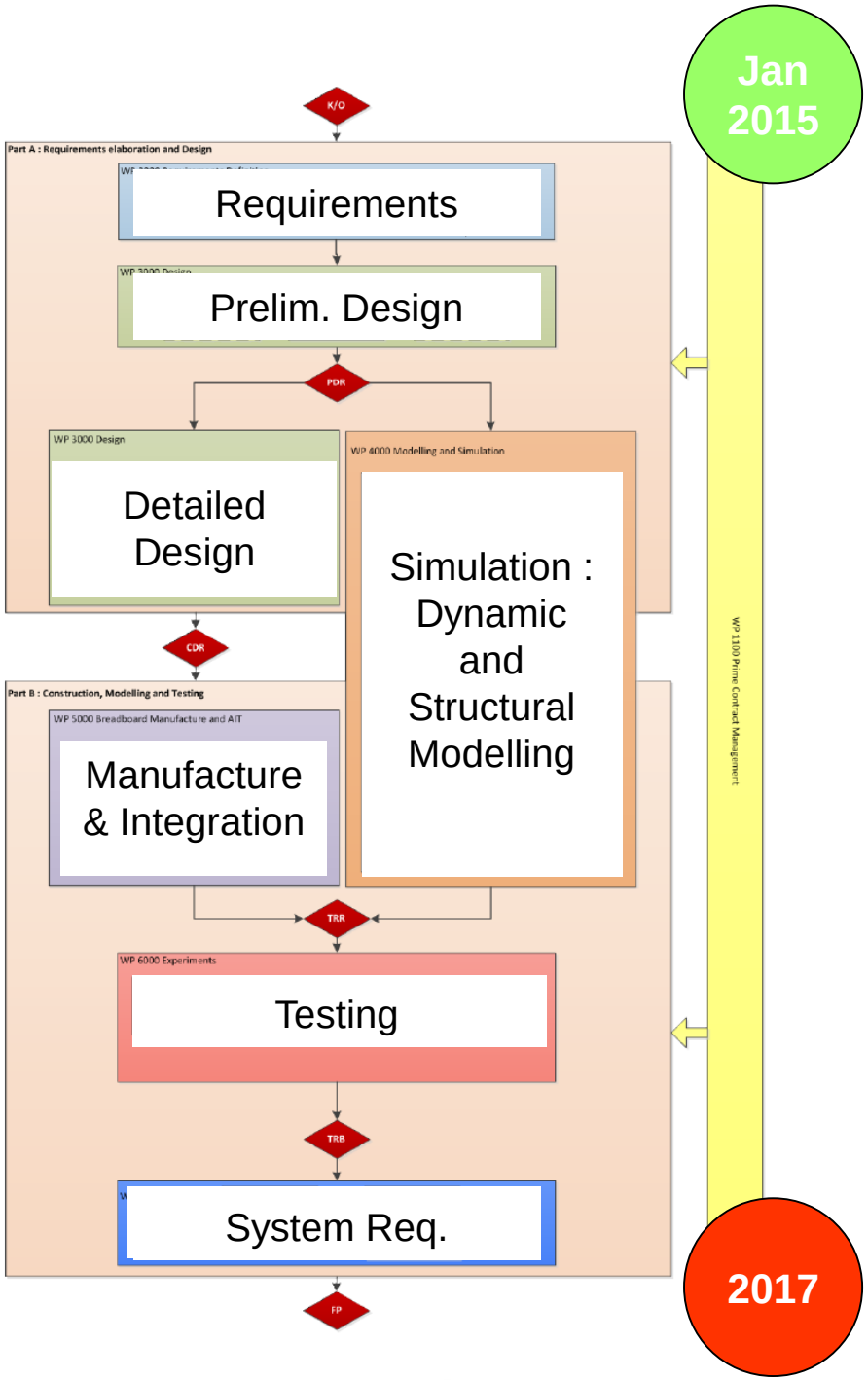
Scope of the Activity

Raise harpoon system TRL and maturity

1. Derive requirements
2. Design harpoon system
3. Model harpoon-target interaction
4. Develop breadboards and test rigs
5. Perform comprehensive test campaign
6. Derive system requirements



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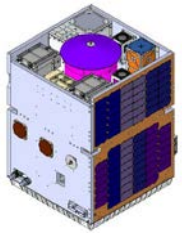
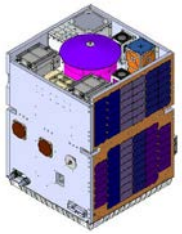
History & On-going Activities

System Activities

RemoveDebris K/O



RemoveDebris Launch

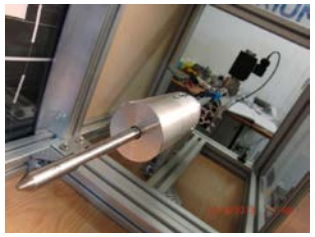


Future Possibilities ?

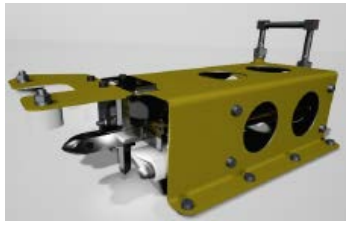
ESA in-orbit demonstrator
ESA debris removal flagship
ADR Service

2010 2012 2014 2016 2018 2020+

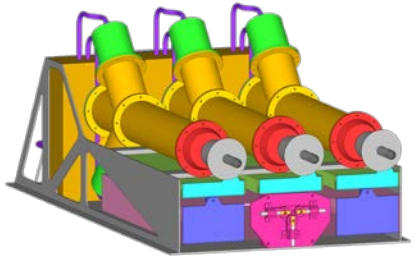
Airbus DS UK Activities



R&D Harpoon



RemoveDebris Harpoon



Clean Space Harpoon

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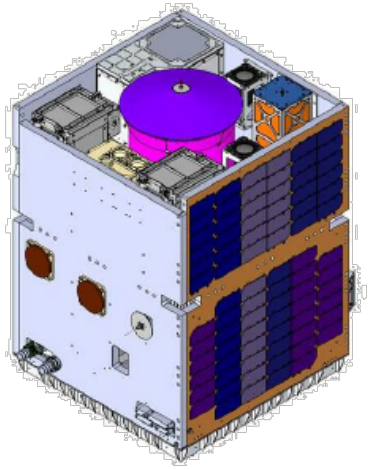
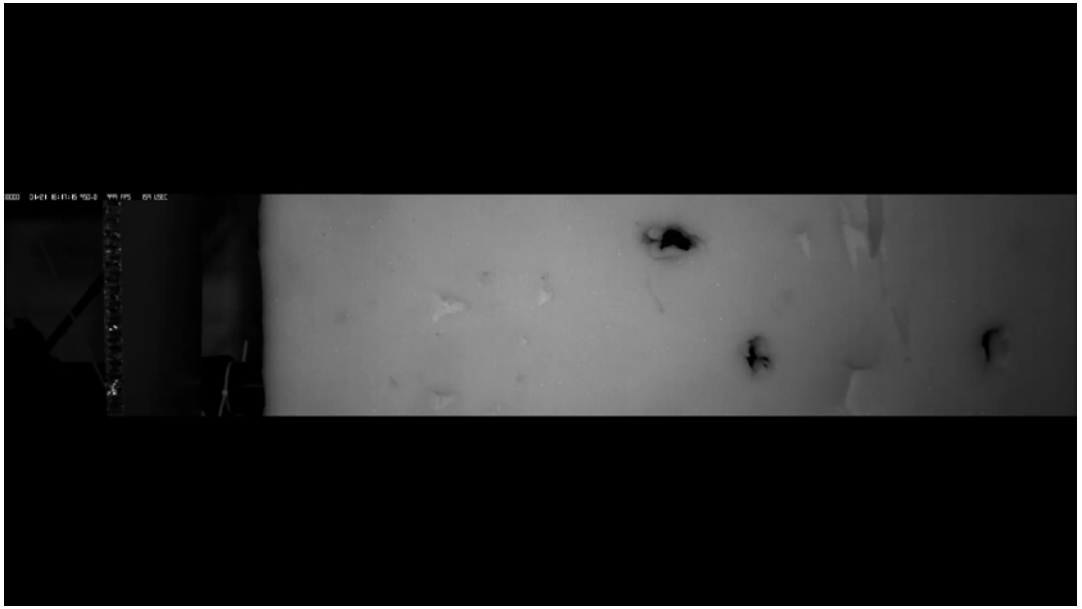
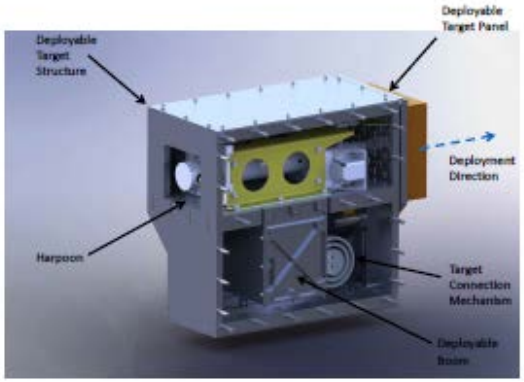
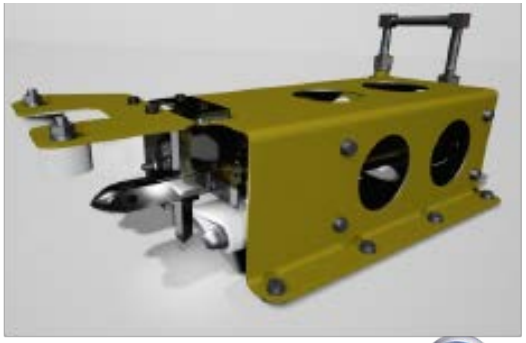
RemoveDebris Harpoon Payload

- EC FP7 RemoveDebris Mission
  - Demonstrate on-orbit key ADR technologies
- Large Consortium
- Launch : Mid 2017
- Harpoon development status :
  - EM testing finalised
  - PFM build to be kicked off









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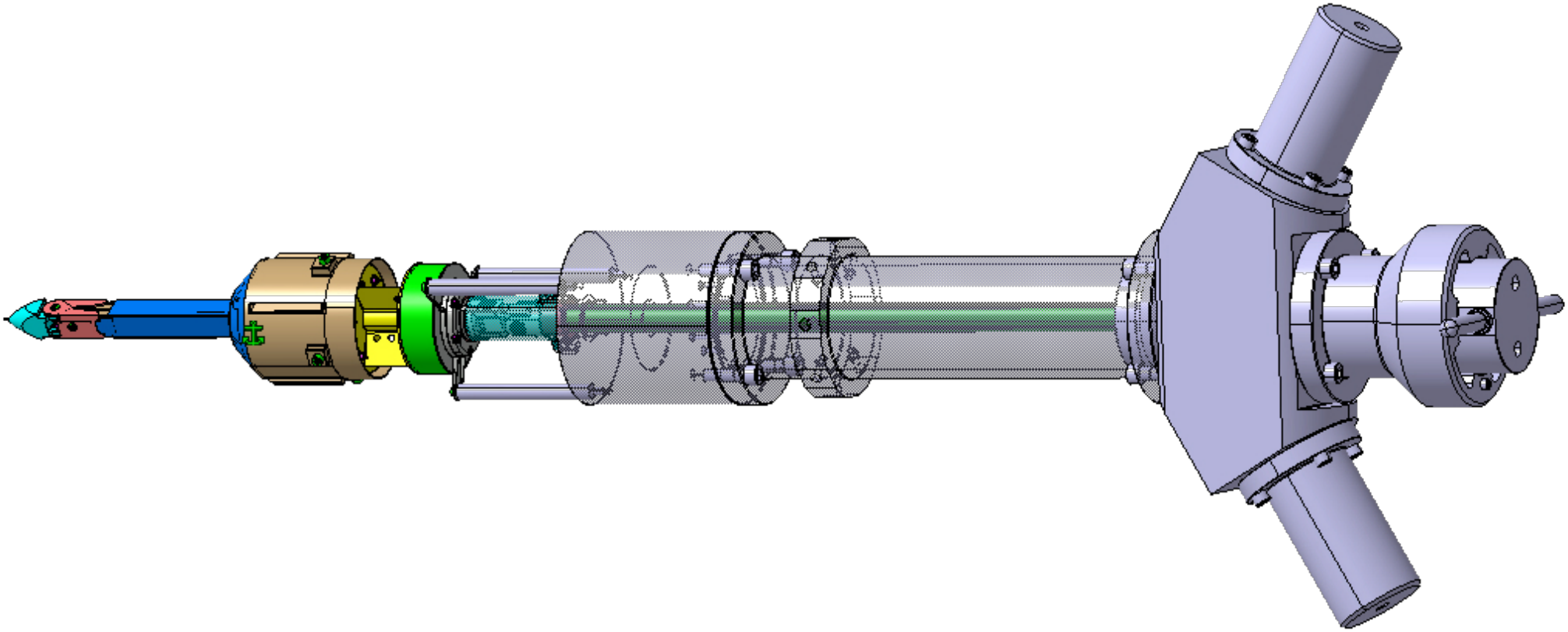
Cleanspace Harpoon



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Functional Requirements

- Sized to capture a range of realistic targets
  - In particular Envisat
- Shall verify the capture is secure
- Shall limit the generation of any additional debris >1mm
- Shall withstand the corresponding range of forces and torques

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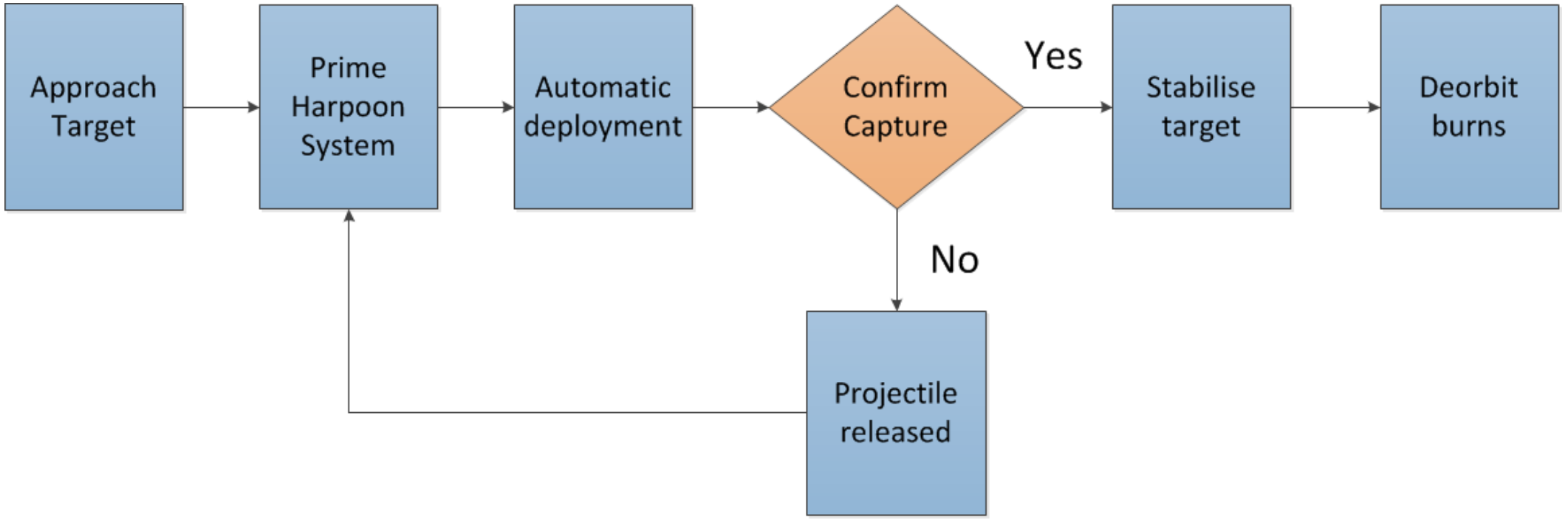
Concept of Operations



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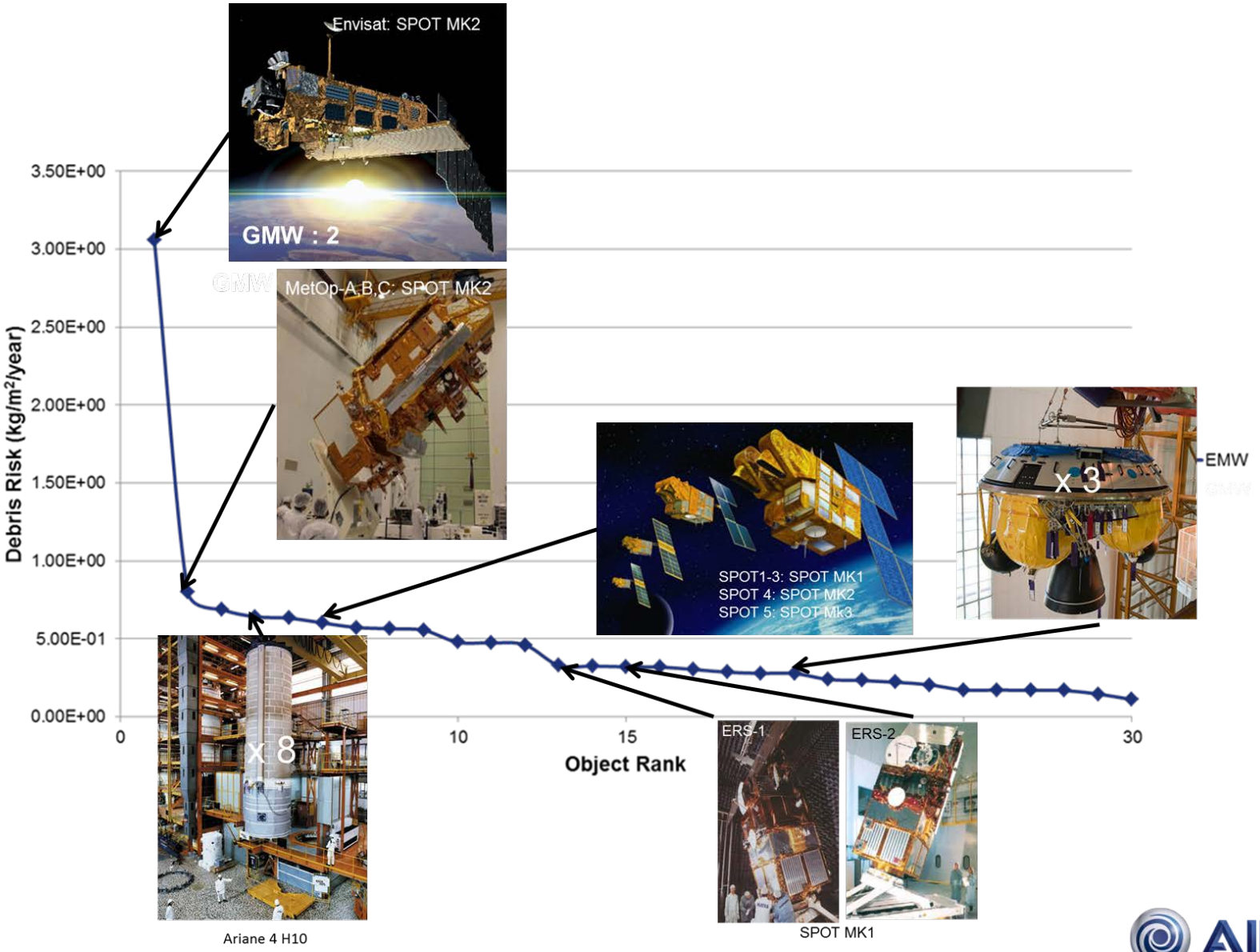
Target Selection



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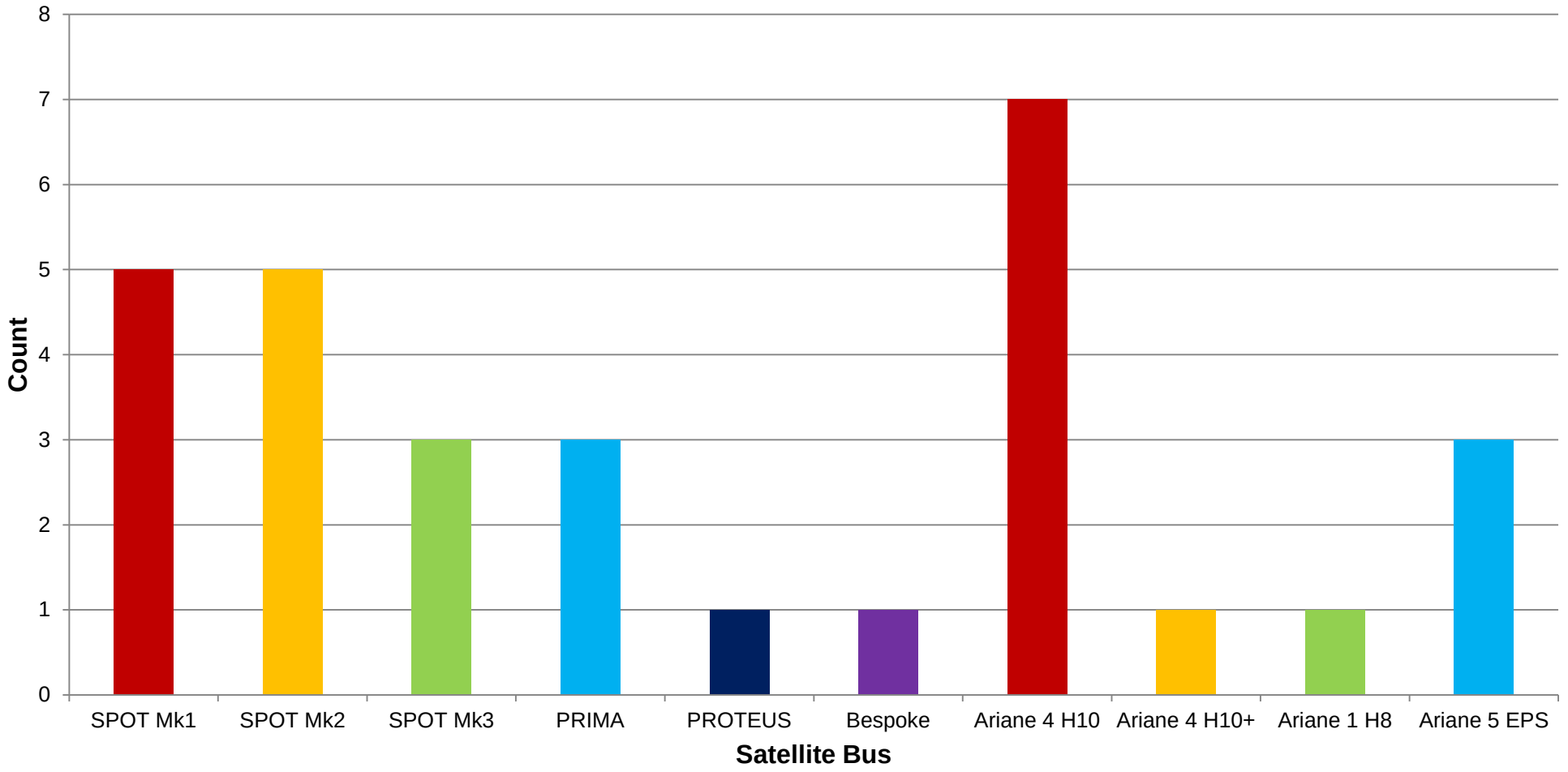

Top European Targets by Bus

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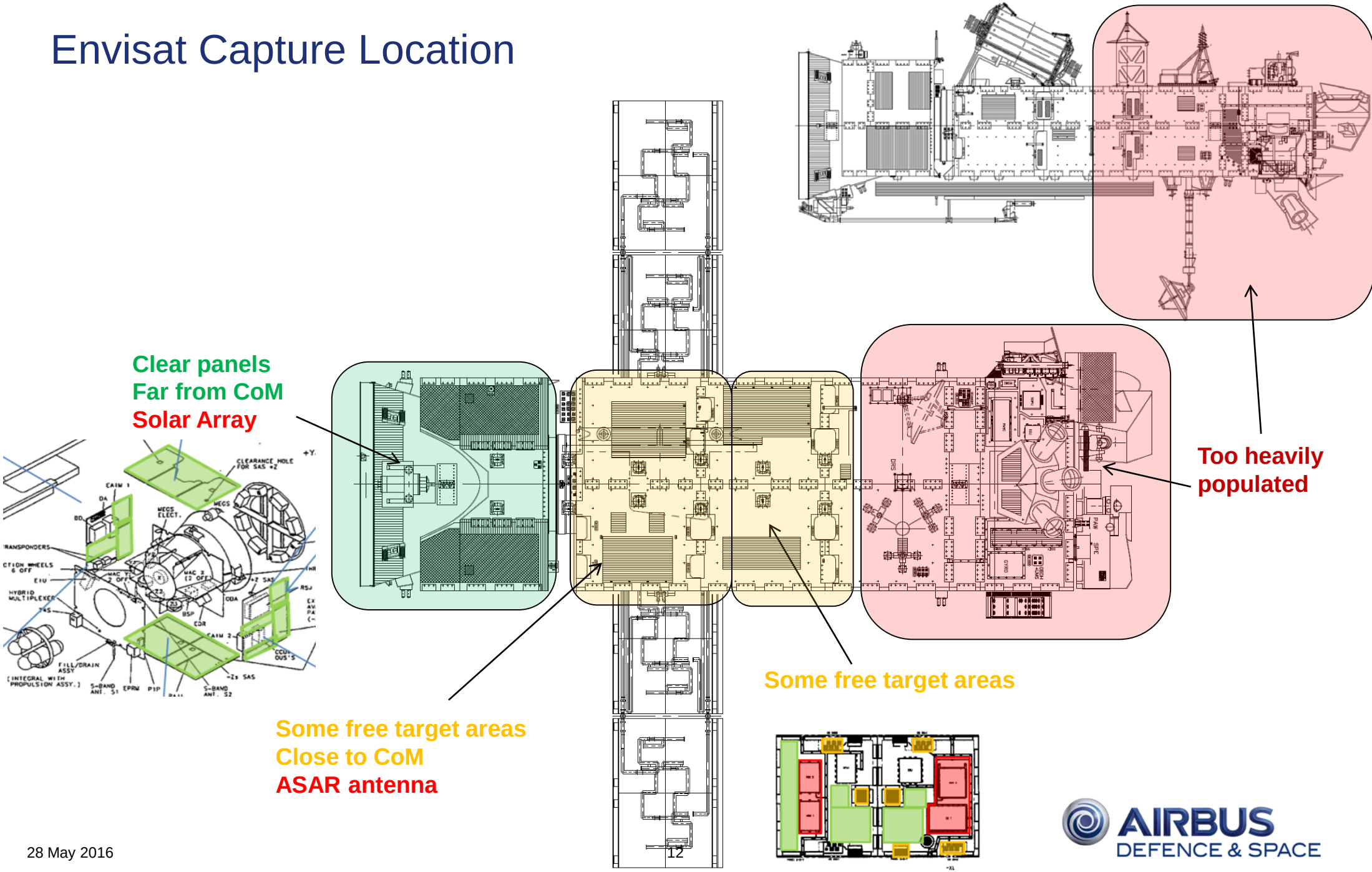
Envisat Capture Location



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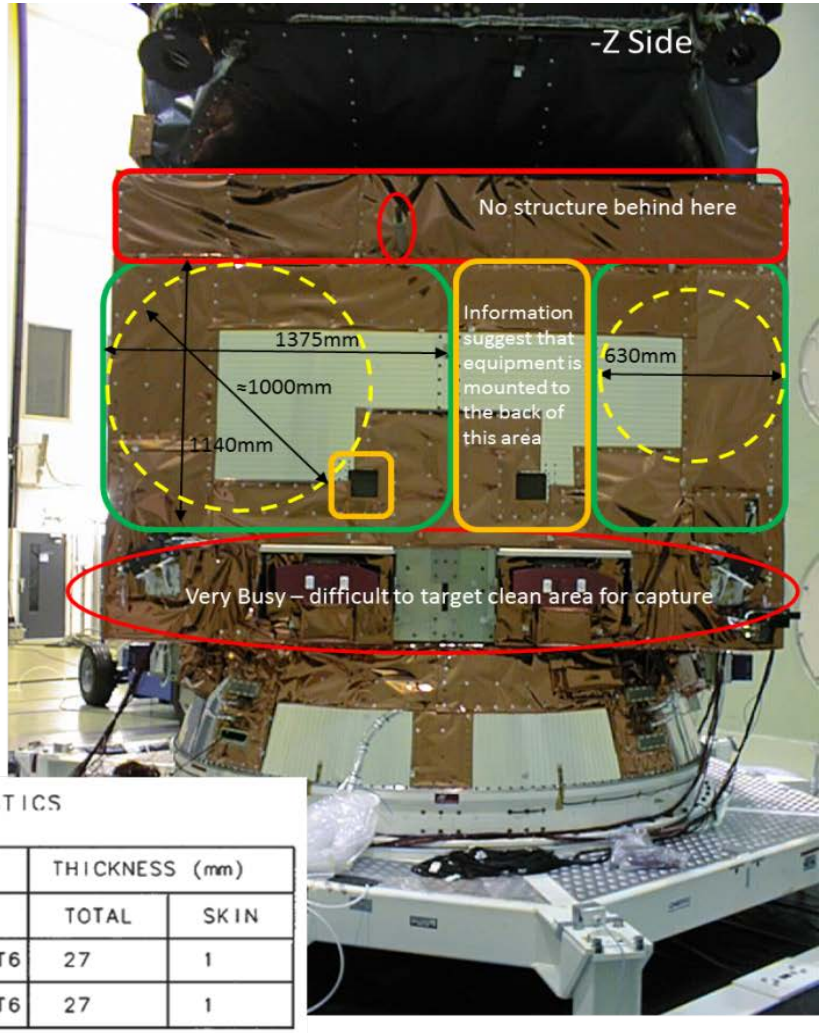

SANDWICH PANEL CHARACTERISTICS

ELEMENT	MATERIAL		THICKNESS (mm)	
	CORE	SKIN	TOTAL	SKIN
SIDE WALL -Z +Y	3/16-.001-5056P	AA 7075 T6	27	1
SIDE WALL -Z -Y	3/16-.001-5056P	AA 7075 T6	27	1

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Test Target Panel

Target	Core Thickness (mm)	Skin Thickness (mm)
Envisat	25	1
MetOp	35	1
Test Panel	35	1.22

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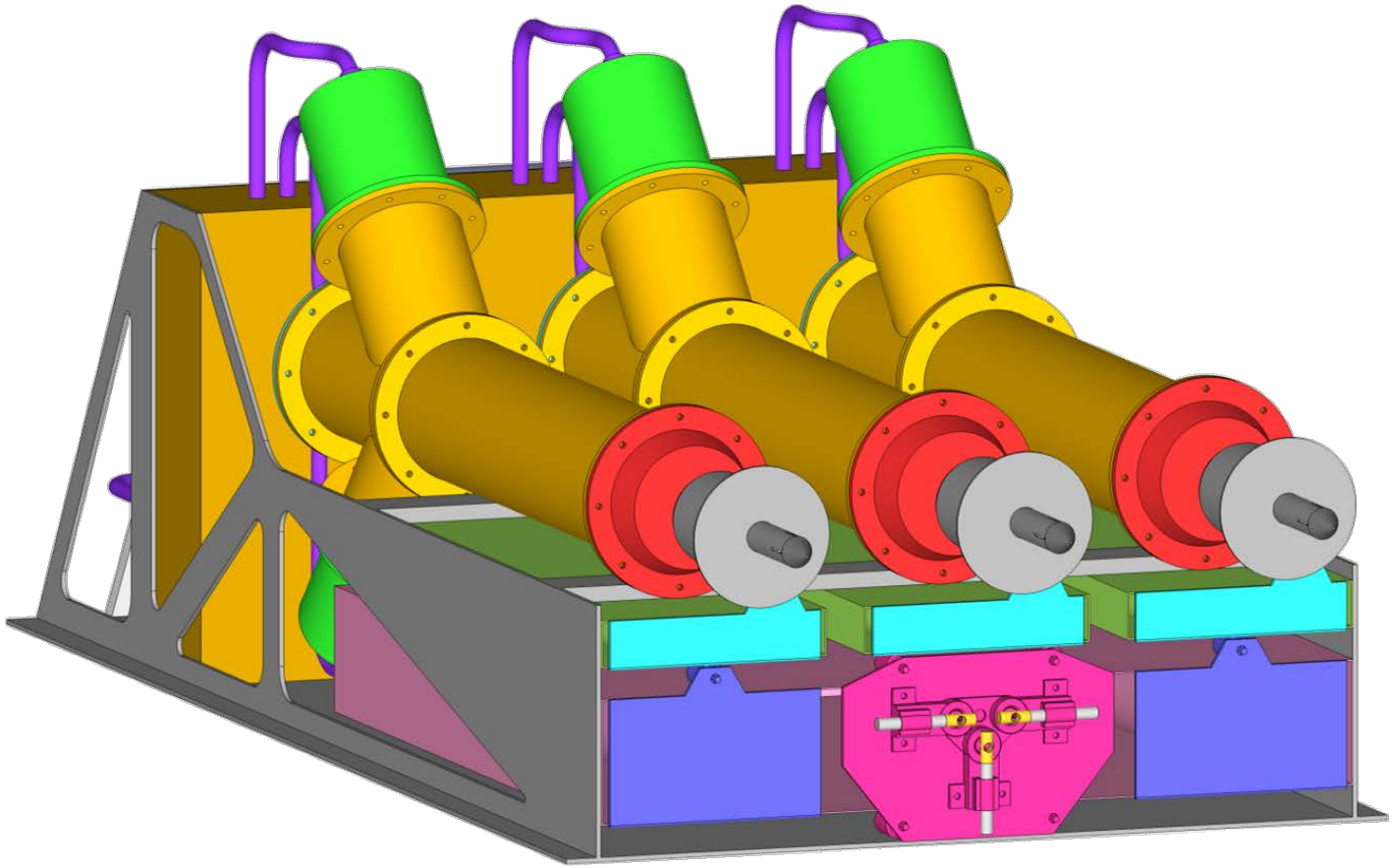
Preliminary Design



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Target Panel Characterisation

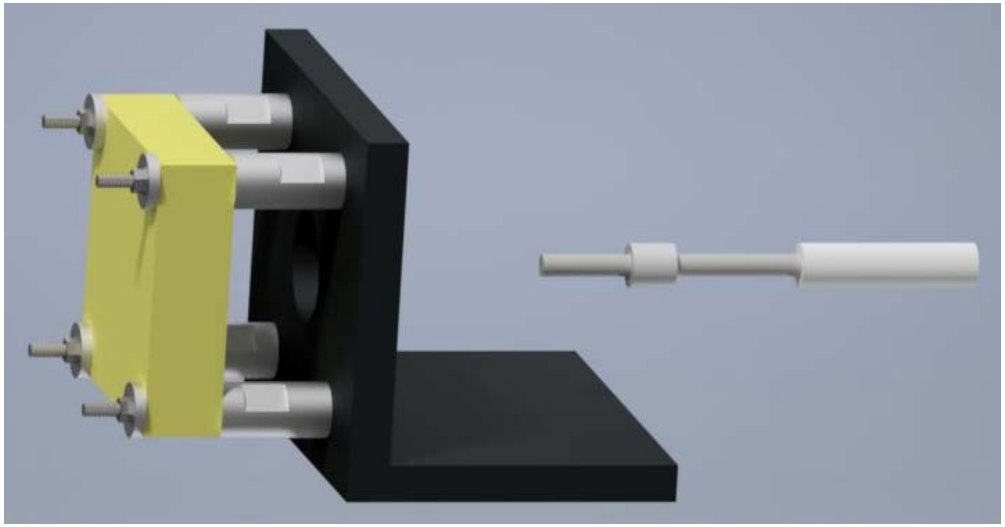
Ballistic limit testing performed on panel coupons at Cavendish Laboratory

10cm square target panel

150g projectile

Investigated various parameters

- Tip diameter
- Tip geometry
- Impact angle



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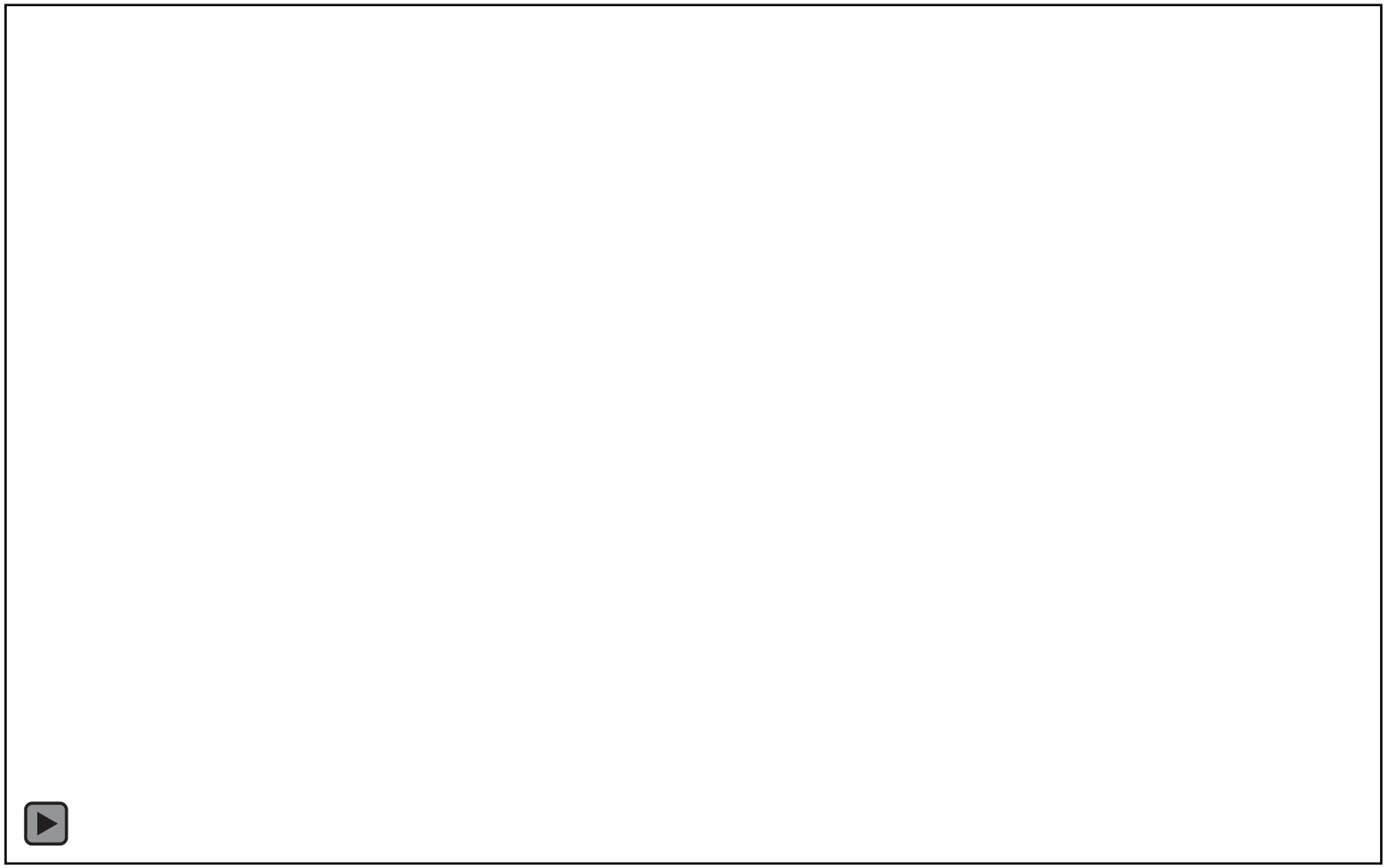
Target Panel Characterisation



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Target Panel Characterisation

Testing further expanded by Brunel University modelling

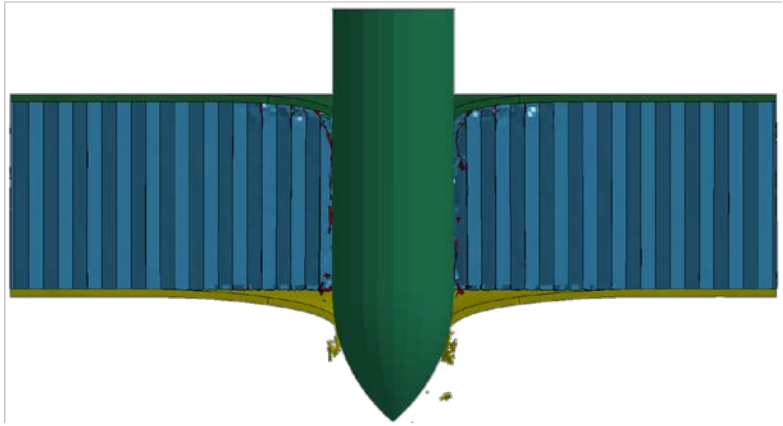
Began with Cavendish test set-up

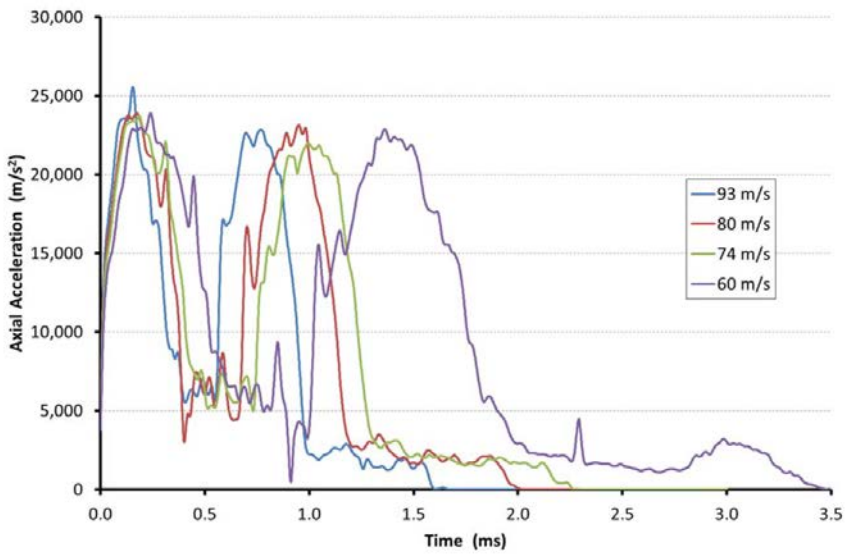
Moved to full scale target panel and 1.6kg projectile

Tests at 0°, 22.5° and 45°

Limit velocity varies with impact angle

- 15.5m/s at 0°
- 20.8m/s at 45°





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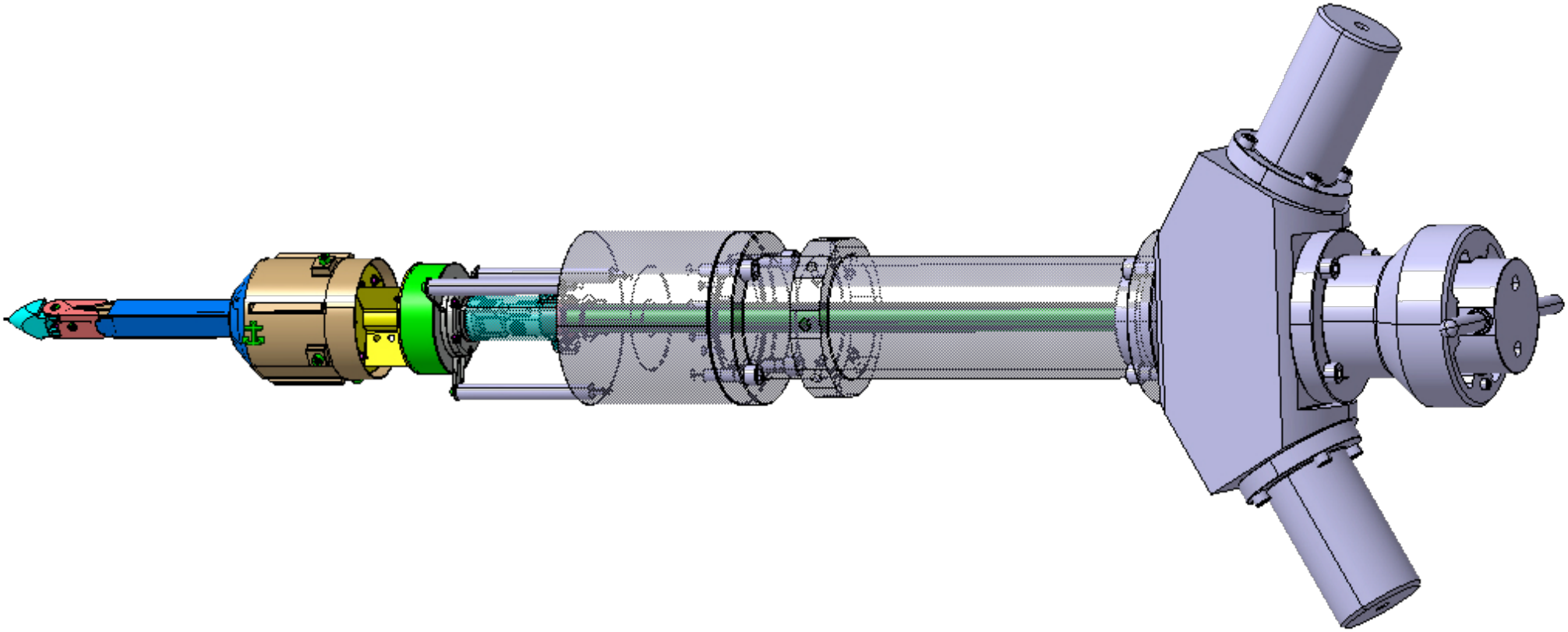
Design & Development



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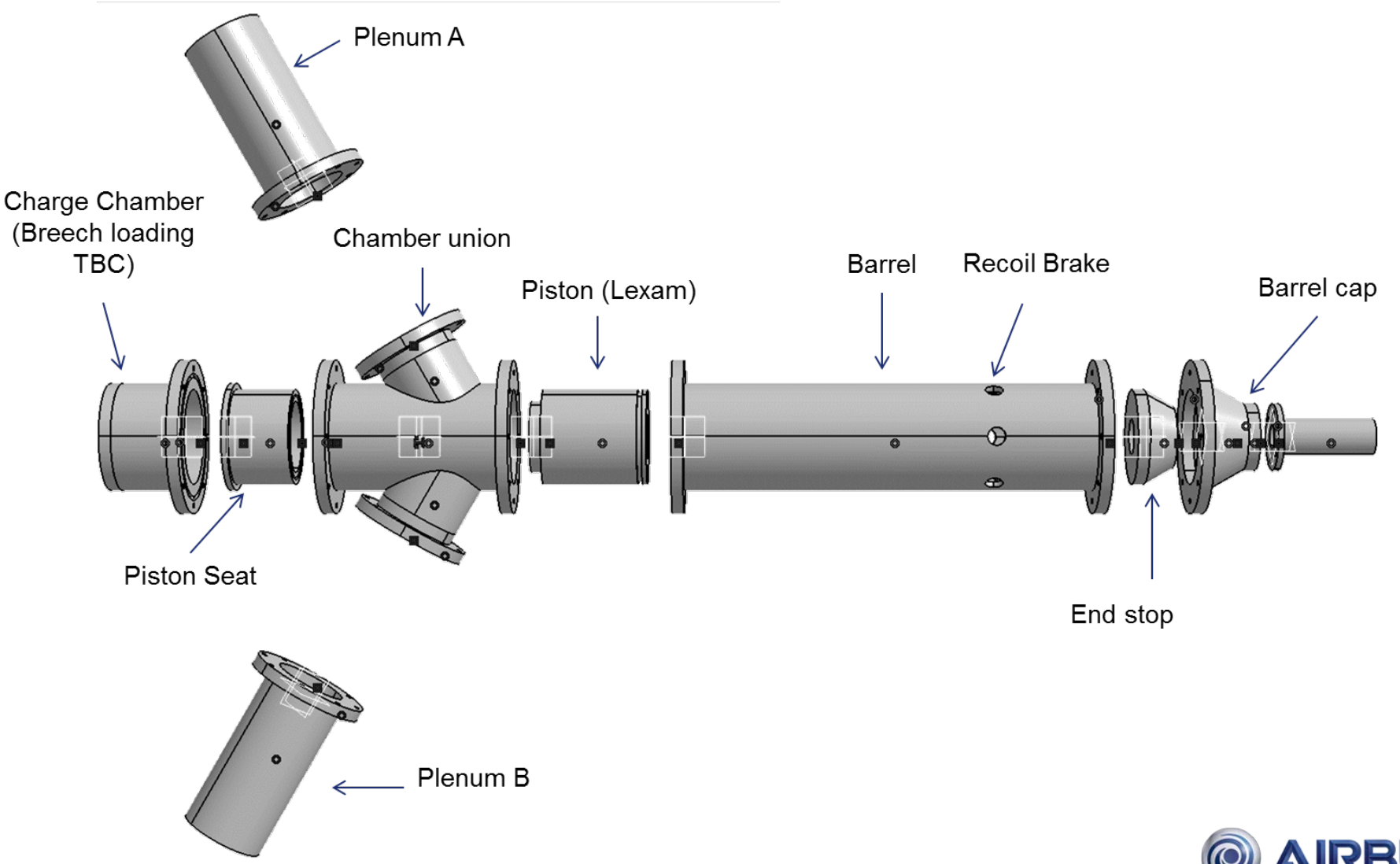
Deployer



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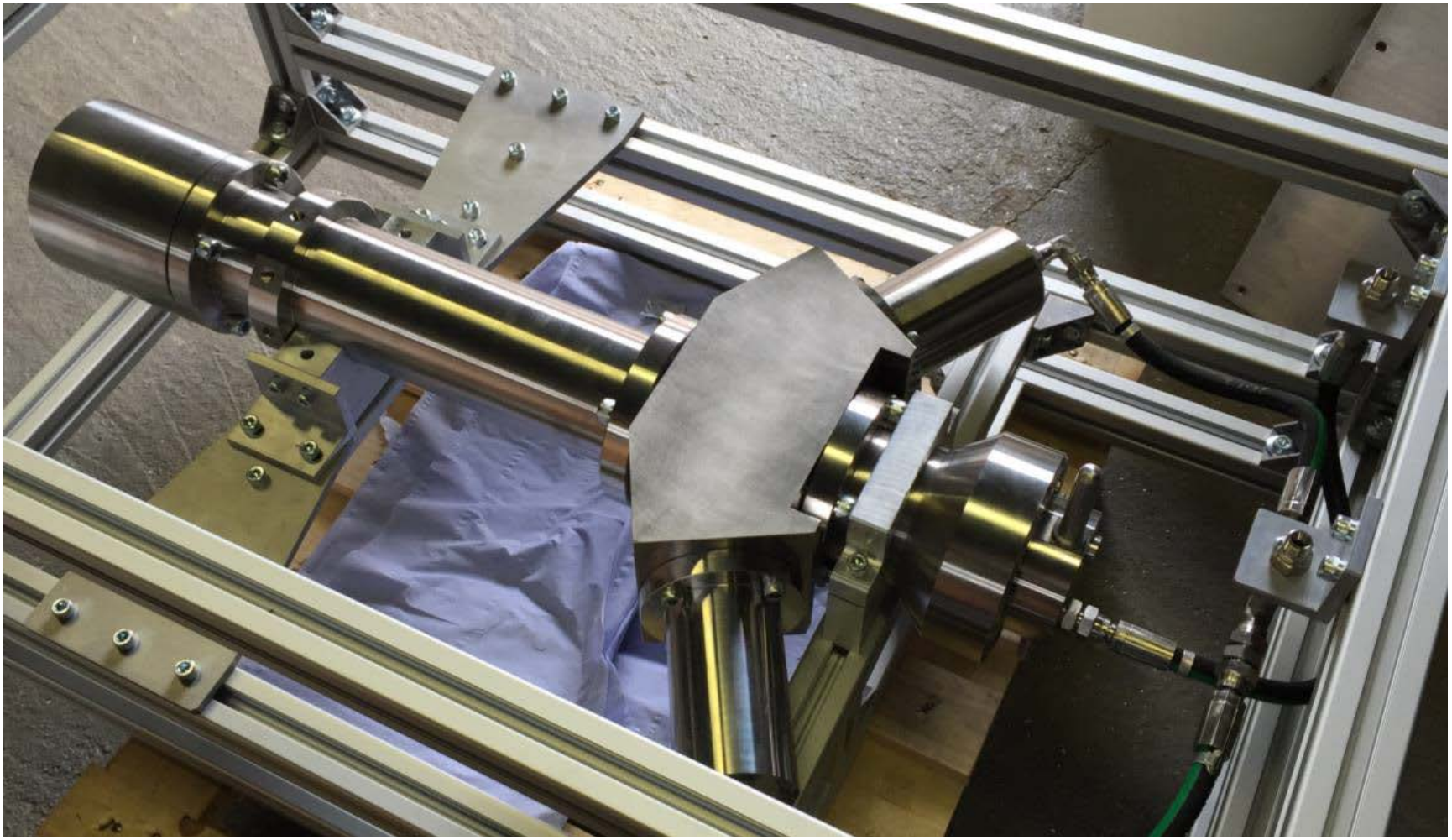

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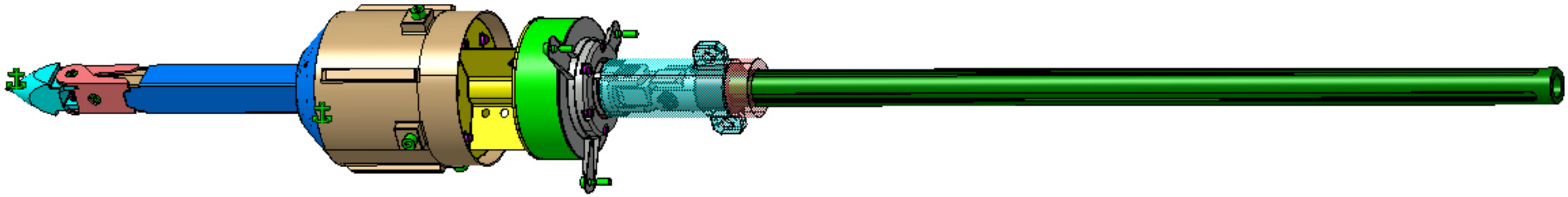
Projectile



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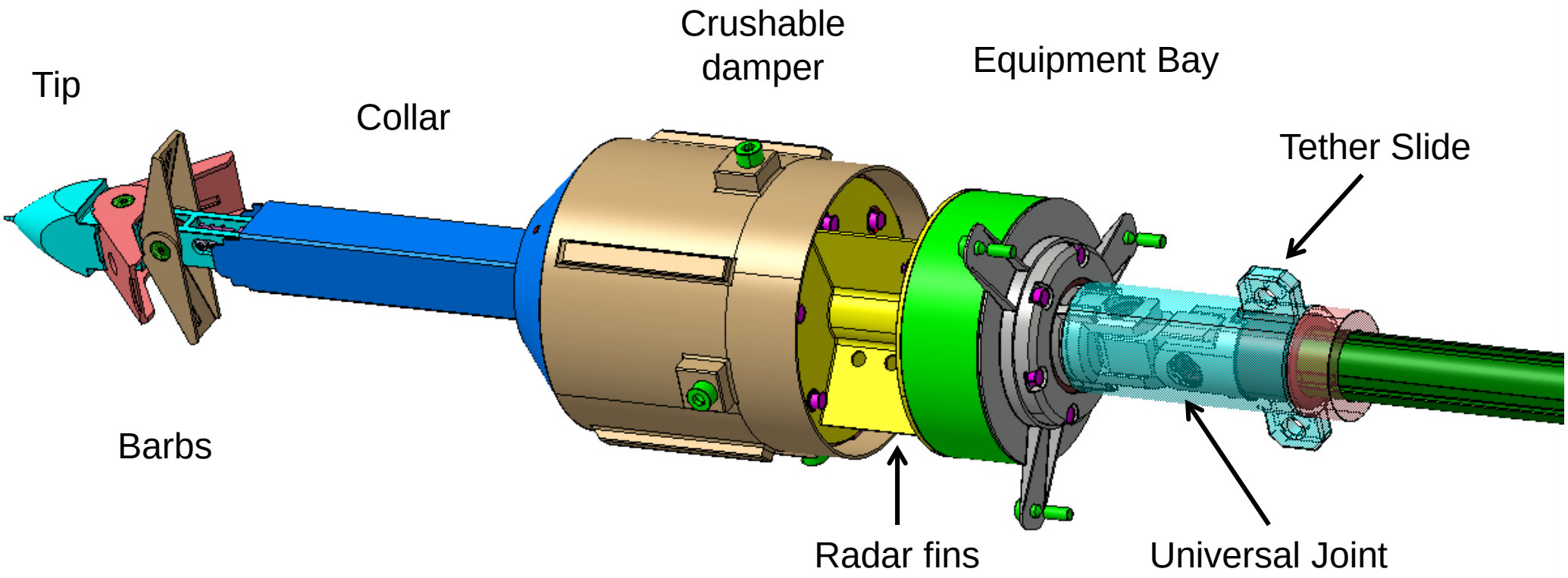

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Tether

3mm diameter Technora

Sized to comfortably survive highest loads expected

25m long to reduce risk of impact with target

Wound in figure of eight around two cores for rapid deployment

Passive separation mechanism sized to break following projectile miss

Passive method required due to very tight time requirements before rebound

Places limit on maximum loads seen during whole mission

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Dynamics Modelling

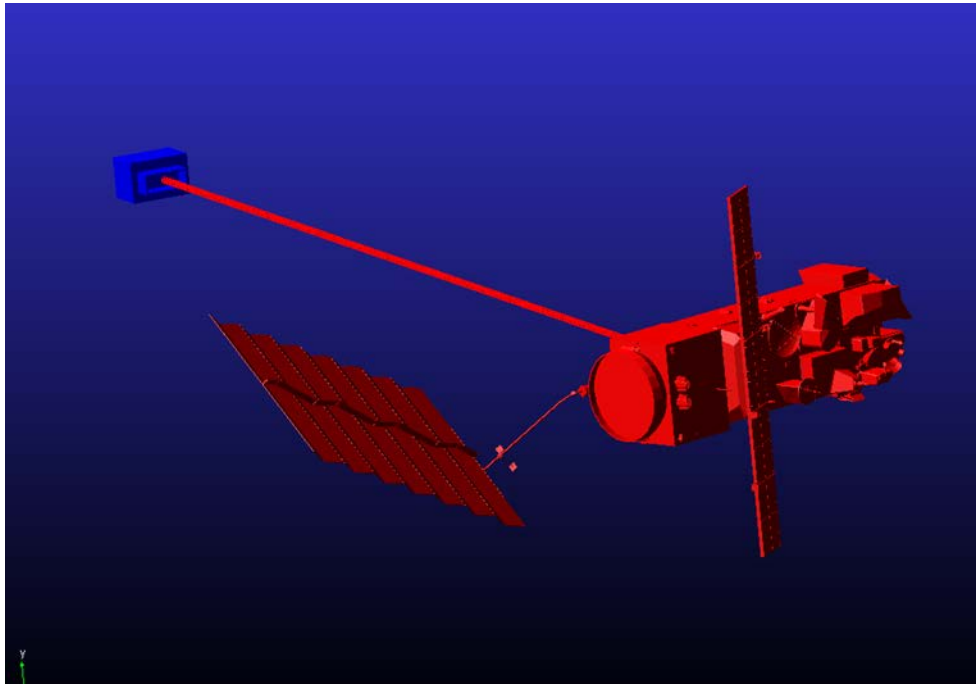
MSC ADAMS model used to determine loads seen during detumbling and towing phases

Initially large snatch loads seen at start of detumbling

Largely driven by uncertainties in target-chaser separation

Further modelling has shown this can be reduced and mitigated

On-going modelling of additional targets
- MetOp
- Ariane 4 Upper Stage



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Testing

Comprehensive test plan in place to characterise system and verify compliance to requirements

All testing with full scale deployer and projctile

Majority of testing over reduced distance

Vertical tests to remove effect of gravity

Tests investigate all key parameters including:

- Projectile velocity
- Impact angle
- Debris generation

End-to-end tests performed over full distance at end of test campaign

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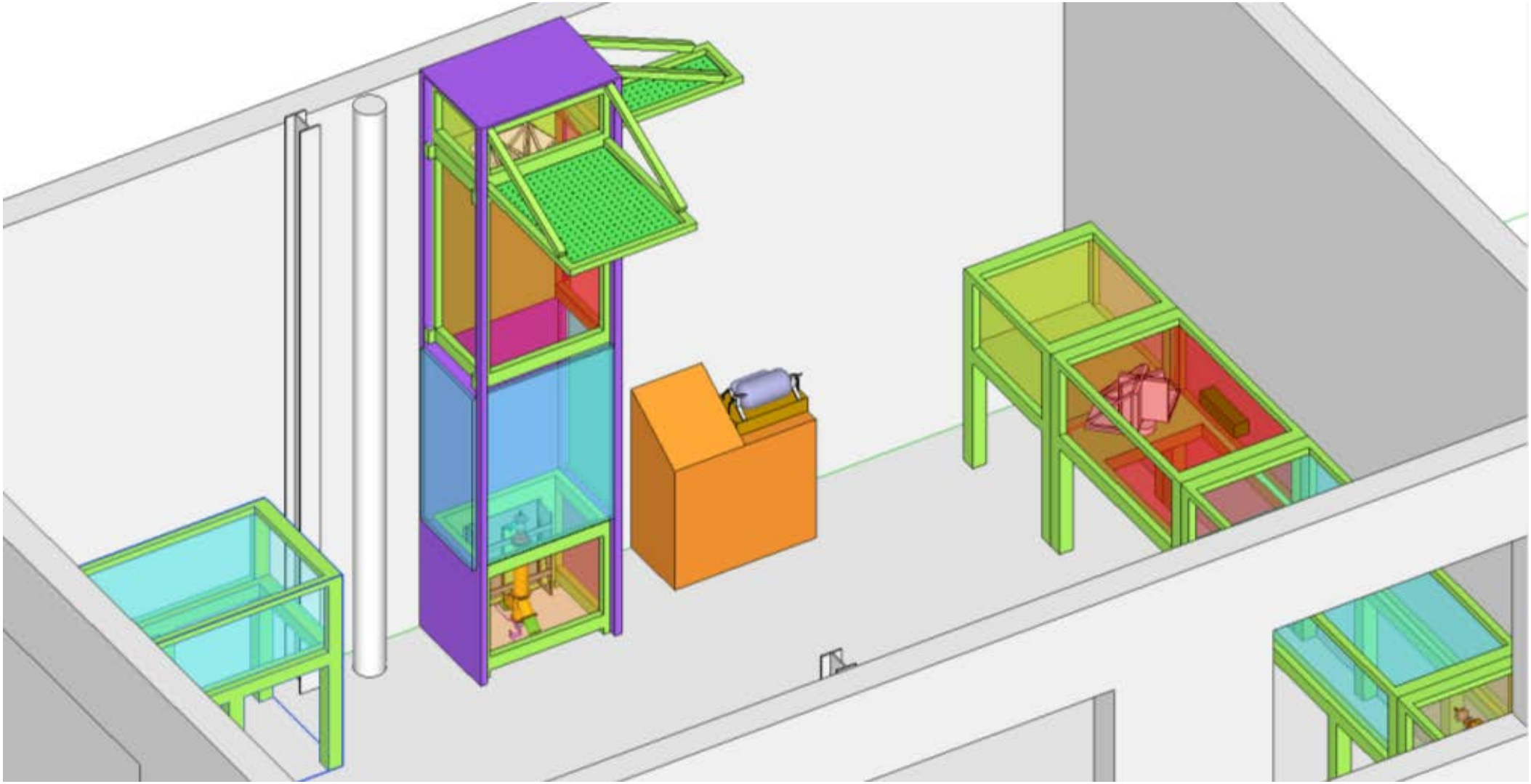
Test Rigs



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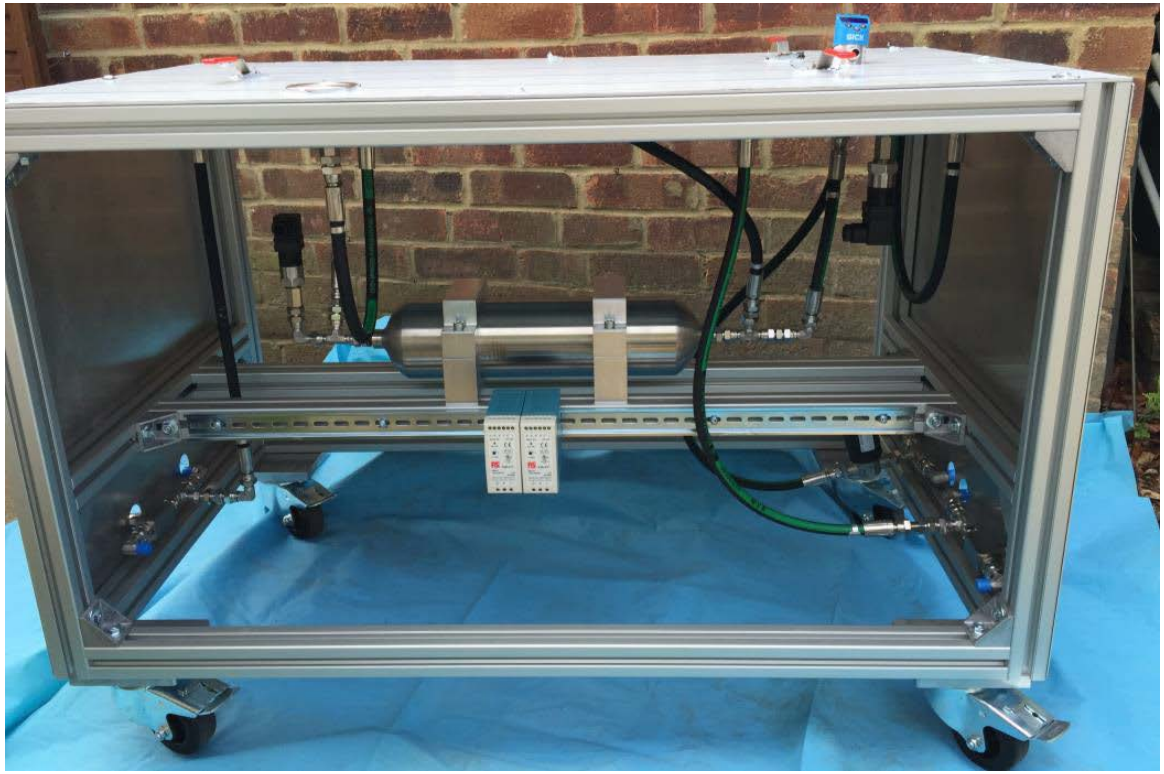

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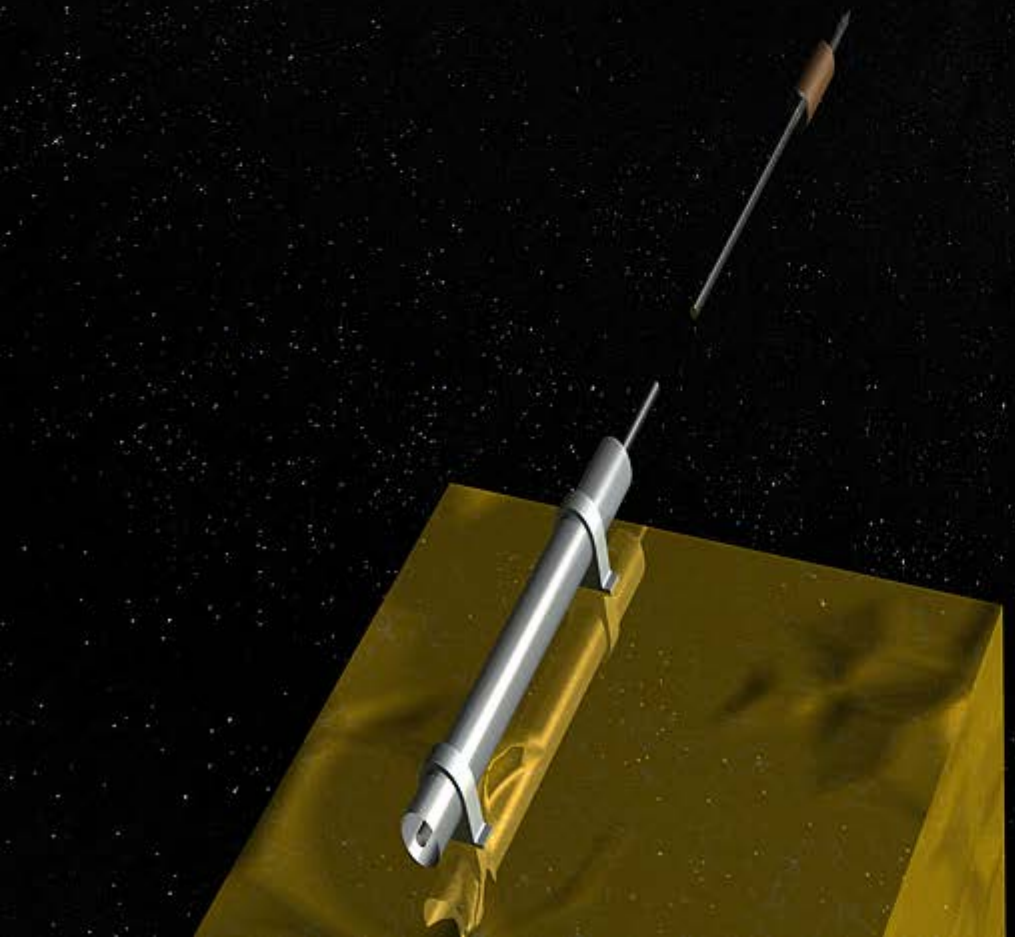
Next Steps

Breadboard components currently being manufactured

Begin full test campaign in August

Full scale testing late 2017

Develop requirements specification for system prime



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