An In-Orbit Active Debris Removal Mission – RemoveDebris

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Introduction

- Low cost ADR mission to demonstrate, de-risk and mature key ADR in-orbit technologies

- An R&D science / engineering project with an in orbit research component

- A European Commission FP7 project, €13 million[1]
- 9 Partners, over 60 staff
- Project duration: 3 years Project start: late 2013 Launch: early 2017

- Technologies and payloads demonstrated
  - capture technologies with a net and harpoon
  - de-orbiting technologies with a drag augmentation sail
  - proximity rendezvous operation technologies with vision-based navigation and LiDAR

- One chaser (main platform) which holds the payloads. Two targets (CubeSats) which are ejected to test the technologies

[1]Source: European Commission Participant Portal

Partners

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Mr. Robert Axthelm

Stevenage
Mr. Mark Roe
Mr. Andrew Ratcliffe

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Mr. Andy Stock
Mr. Andy Phipps

ISIS

Mr. Cesar Bernal

informatics mathematics

Dr. François Chaumette

csem

Mr. Alexandre Pollini

UNIVERSITEIT STELLENBOSCH UNIVERSITY

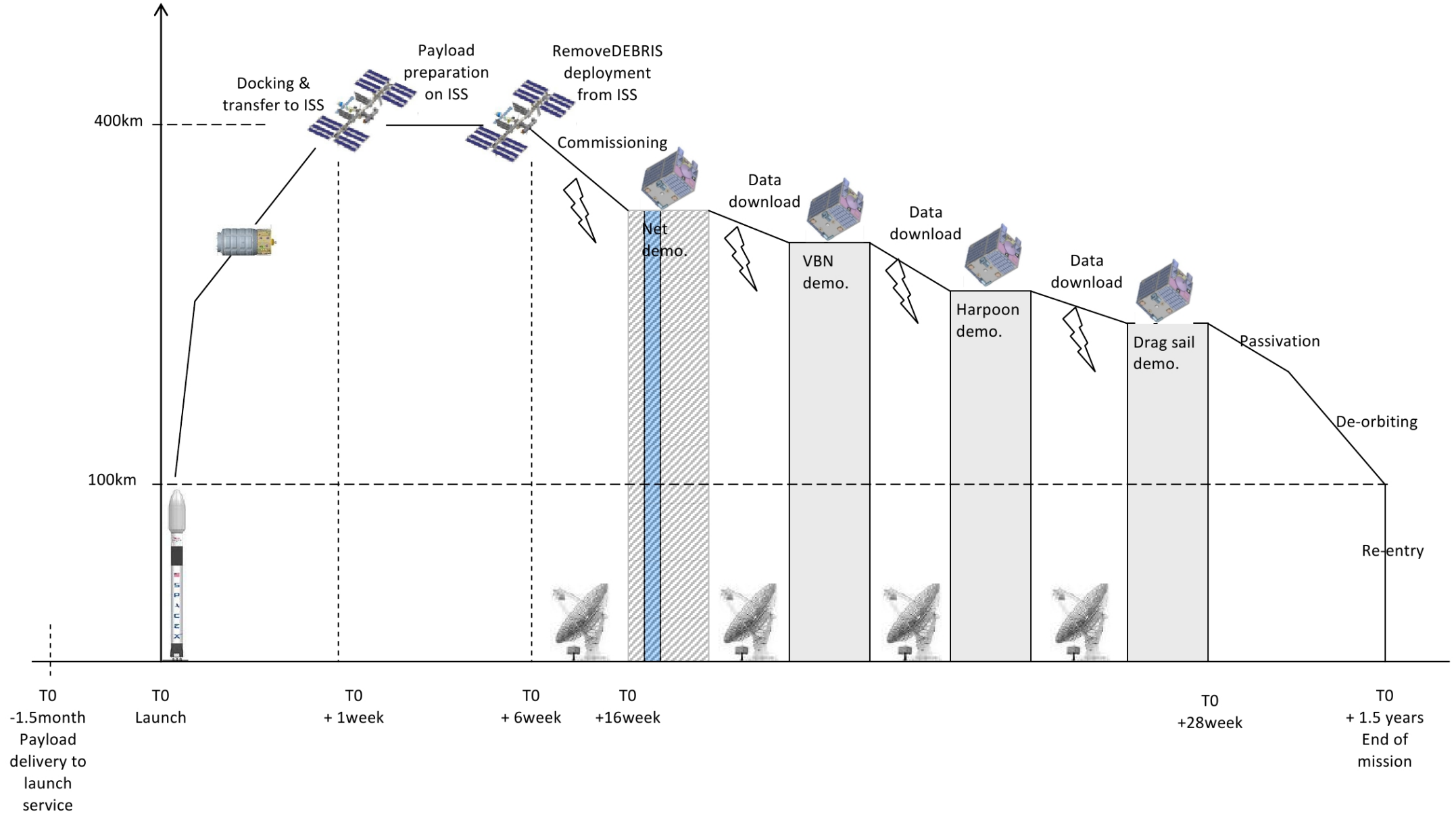
Prof. Willem Steyn

Partner Responsibilities

	Short name	Country	Business activity	Roles in the project
1	SSC	United Kingdom	University (Research)	Project management, Payloads: CubeSats, Dragsail, Harpoon structure
2	SSTL	United Kingdom	Space Prime for small satellites	Platform provider, Satellite operations
3	Airbus D&S	Germany	Space Prime for space transportation and satellites	Payloads: Net
4	Airbus D&S	France		Mission & System Engineering, Payloads: Vision-based navigation
5	Airbus D&S	United Kingdom		Payloads: Harpoon
6	ISIS	Netherlands	SME, specializing in nanosatellites	Payloads: CubeSat deployers
7	CSEM	Switzerland	Research Institution	Payloads: LiDAR camera
8	INRIA	France	Research Institution	Payloads: VBN algorithms
9	STE	South Africa	University (Research)	Payloads: CubeSat avionics

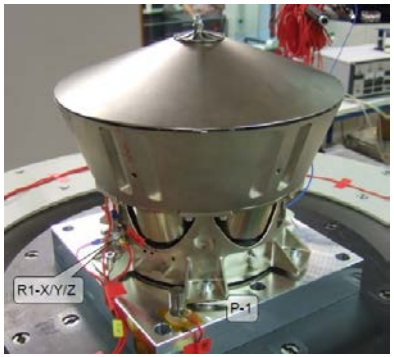
Mission Video

Experimentation Sequence

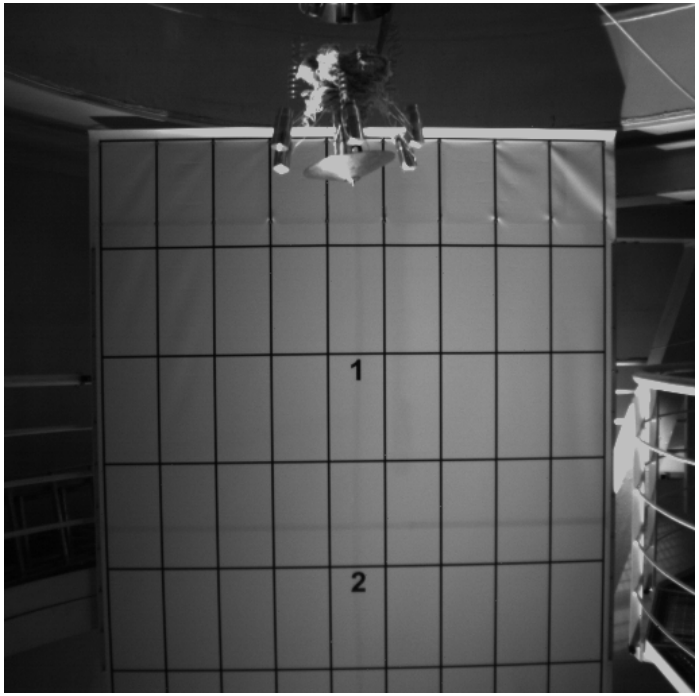


Payloads Demonstrations (1/4)

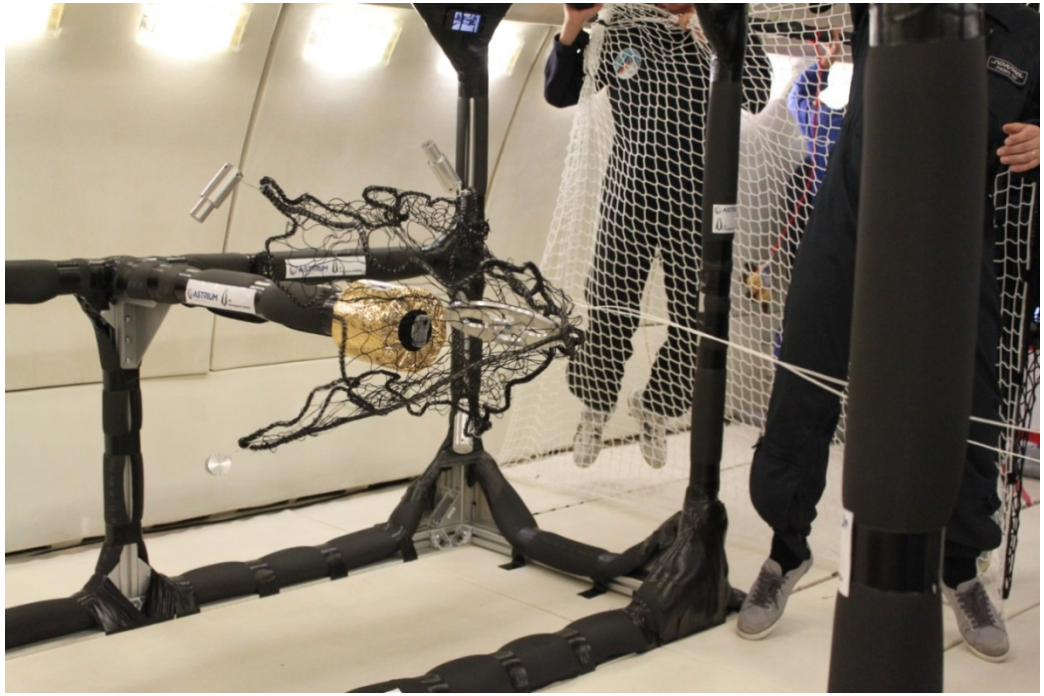
- Net demonstration



Net System

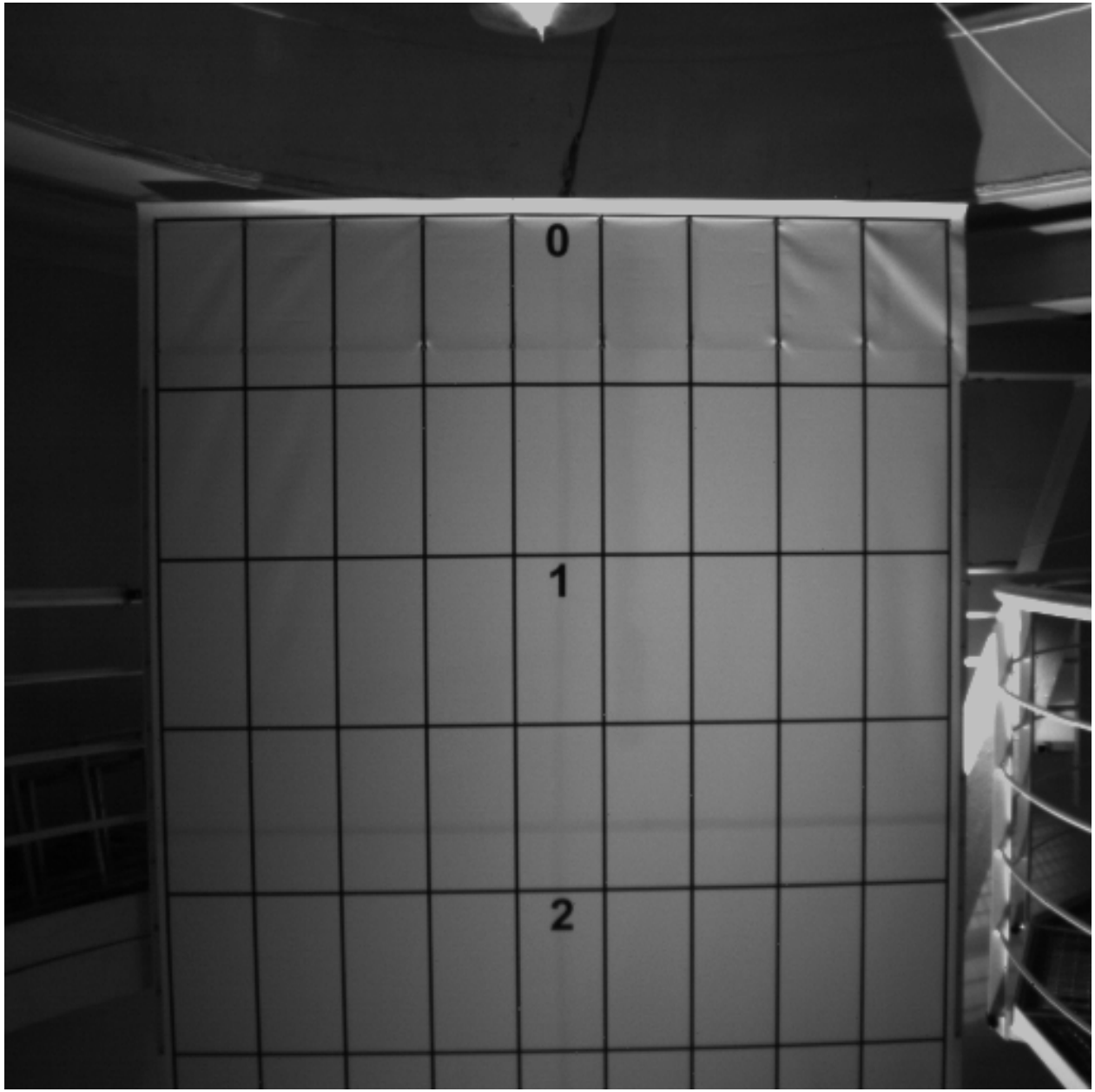


Deployment in Bremen Drop Tower



Deployment in Novespace A300 Parabolic Flight

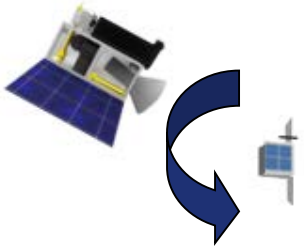
Payloads Demonstrations (1/4)

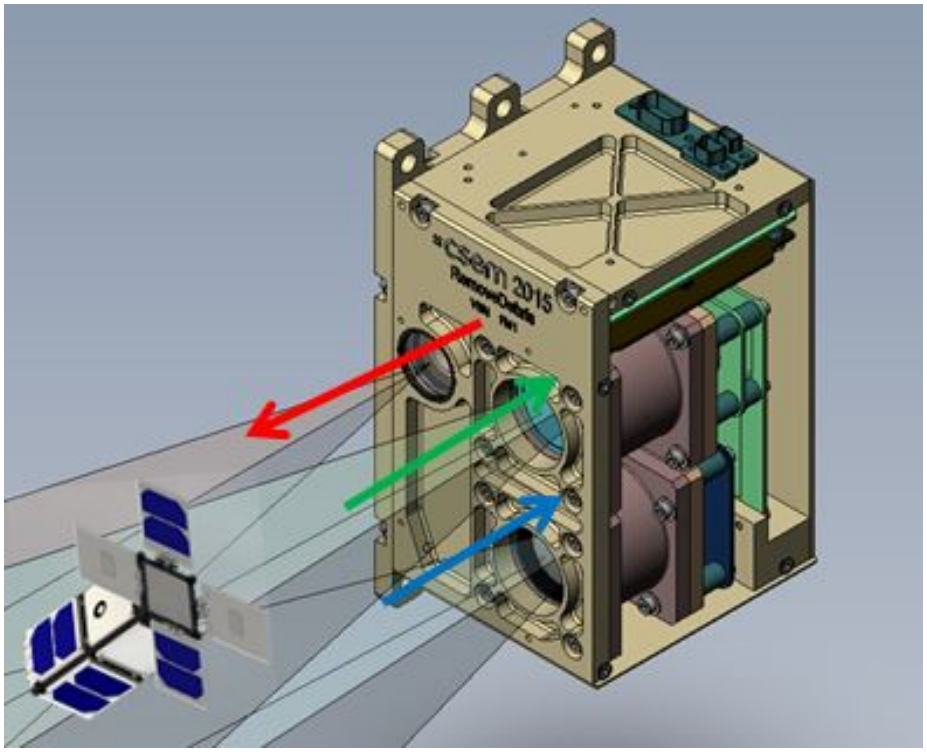


Payloads Demonstrations (2/4)

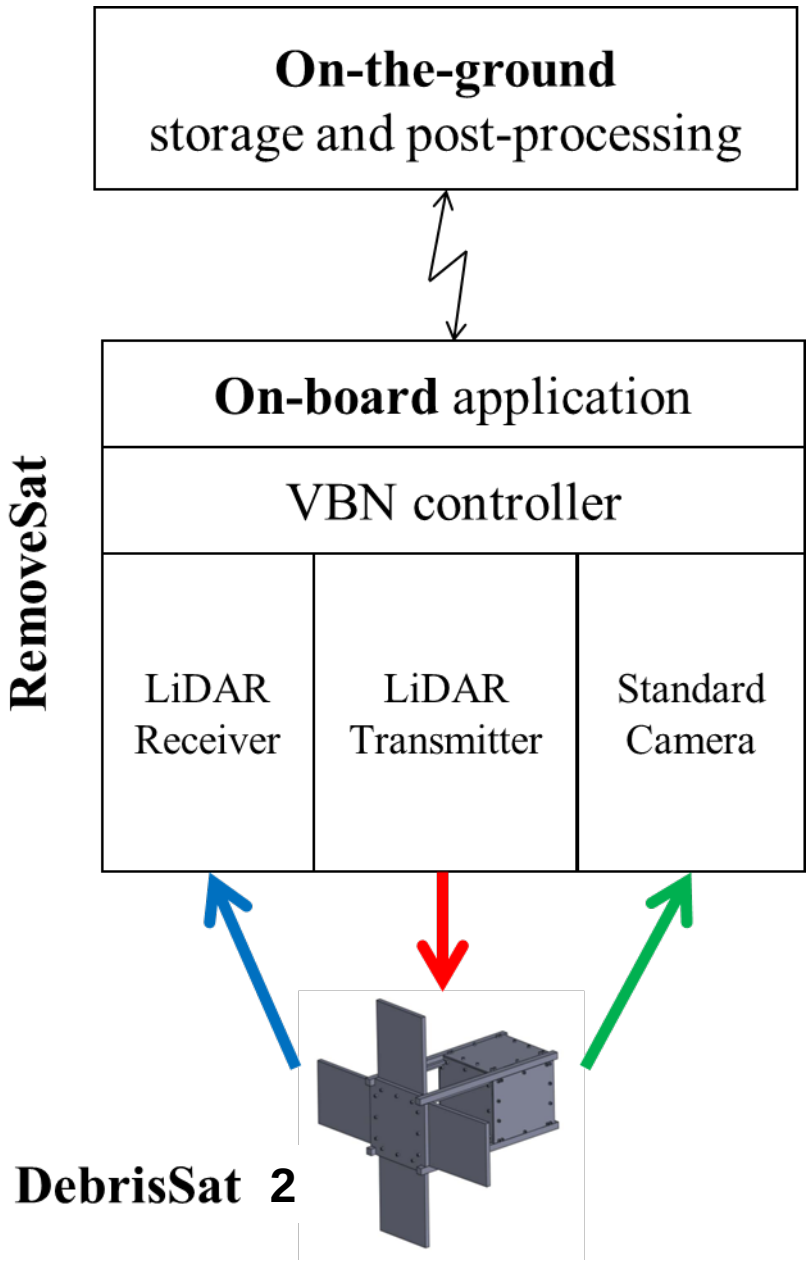
- VBN demonstration

2





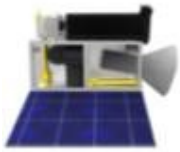
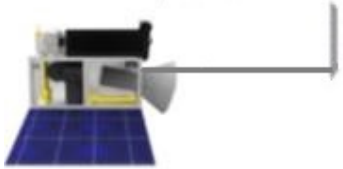
Vision-Based Navigation System

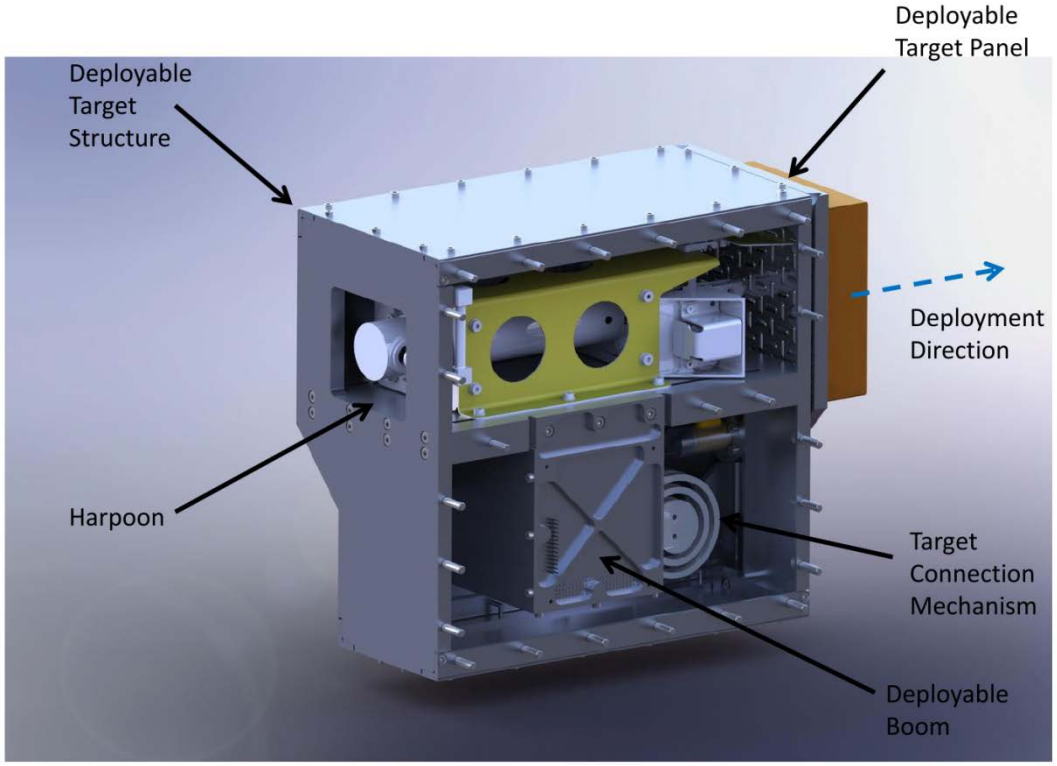


Payloads Demonstrations (3/4)

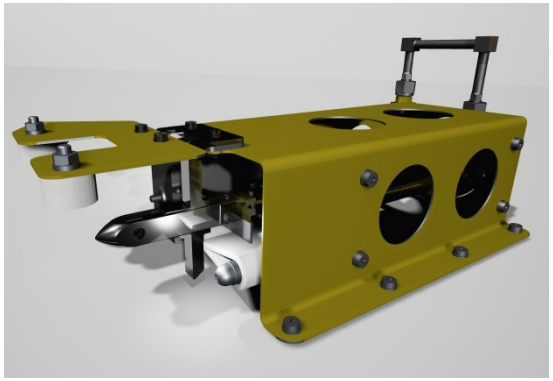
- Harpoon demonstration

3

Harpoon Target Assembly Payload



Harpoon System

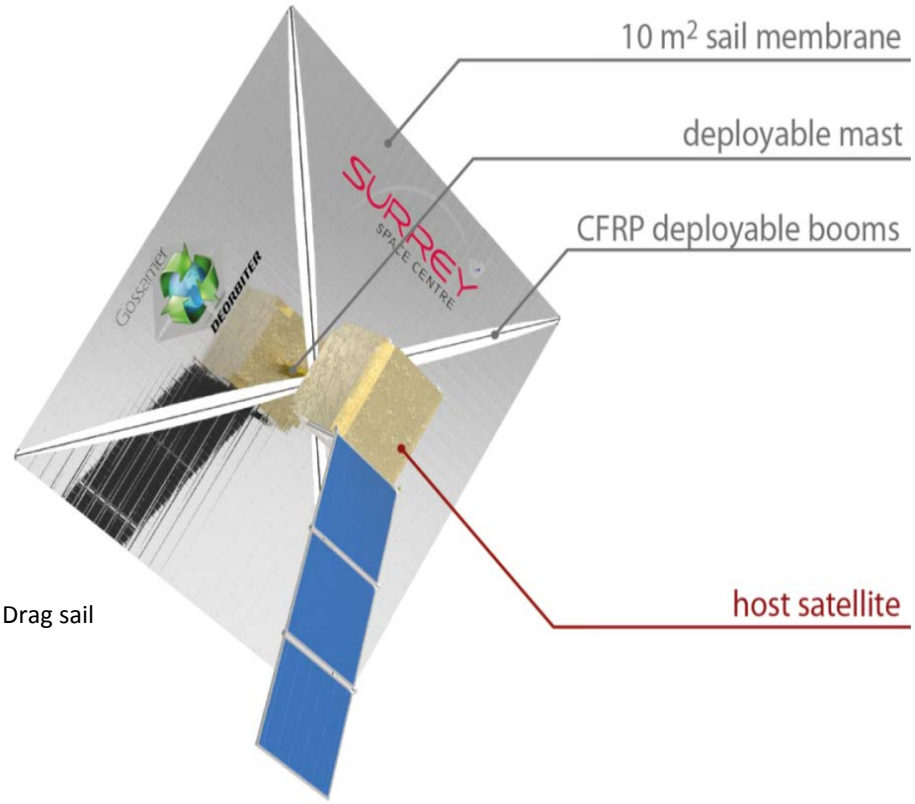
Projectile Prototypes and Evolution

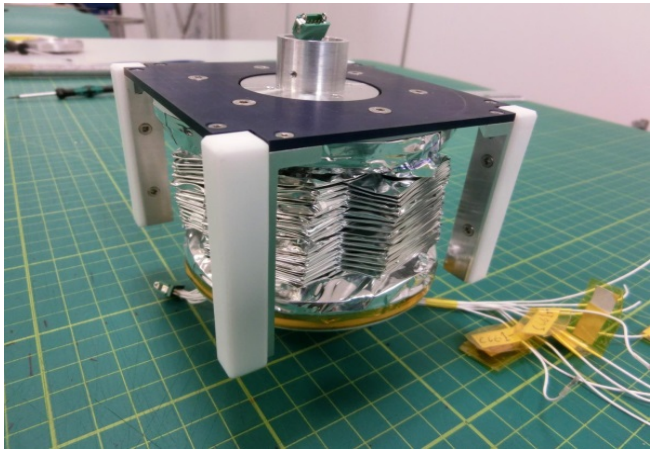
Payloads Demonstrations (4/4)

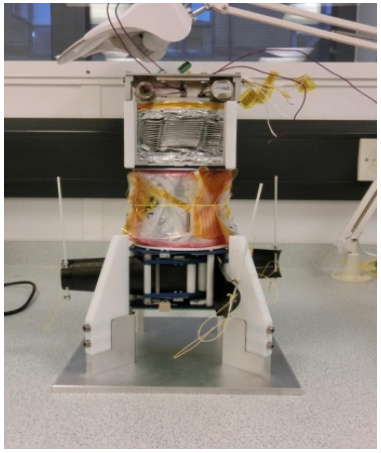
- Drag sail demonstration

4 Dragsail deorbiting experiment

- Inflatable mast
- Deployment of a mast with a drag sail of ~9m2
- No need to control platform during demonstration
  (CoG front to aero pressure centre)
- Based on InflateSail mission (but payload version)



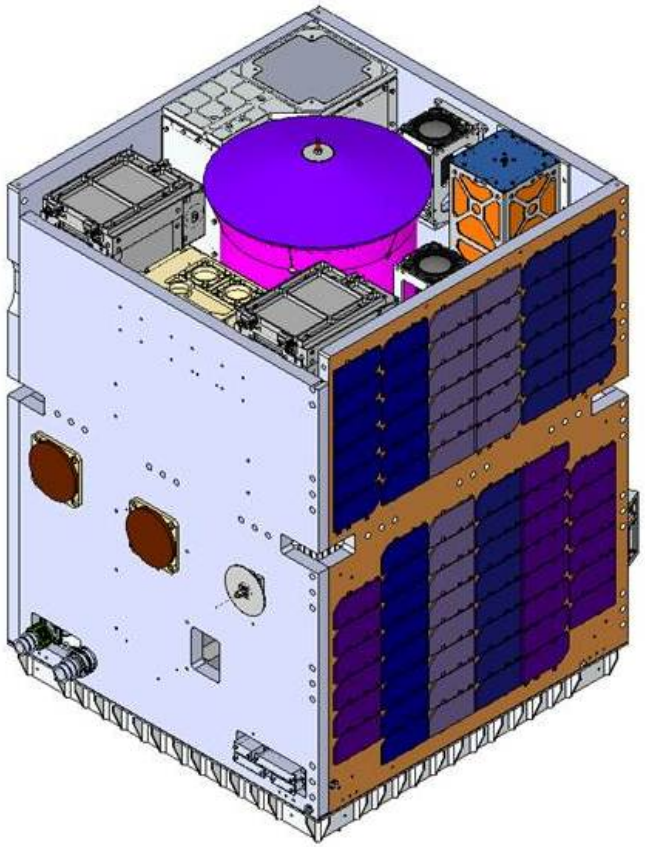


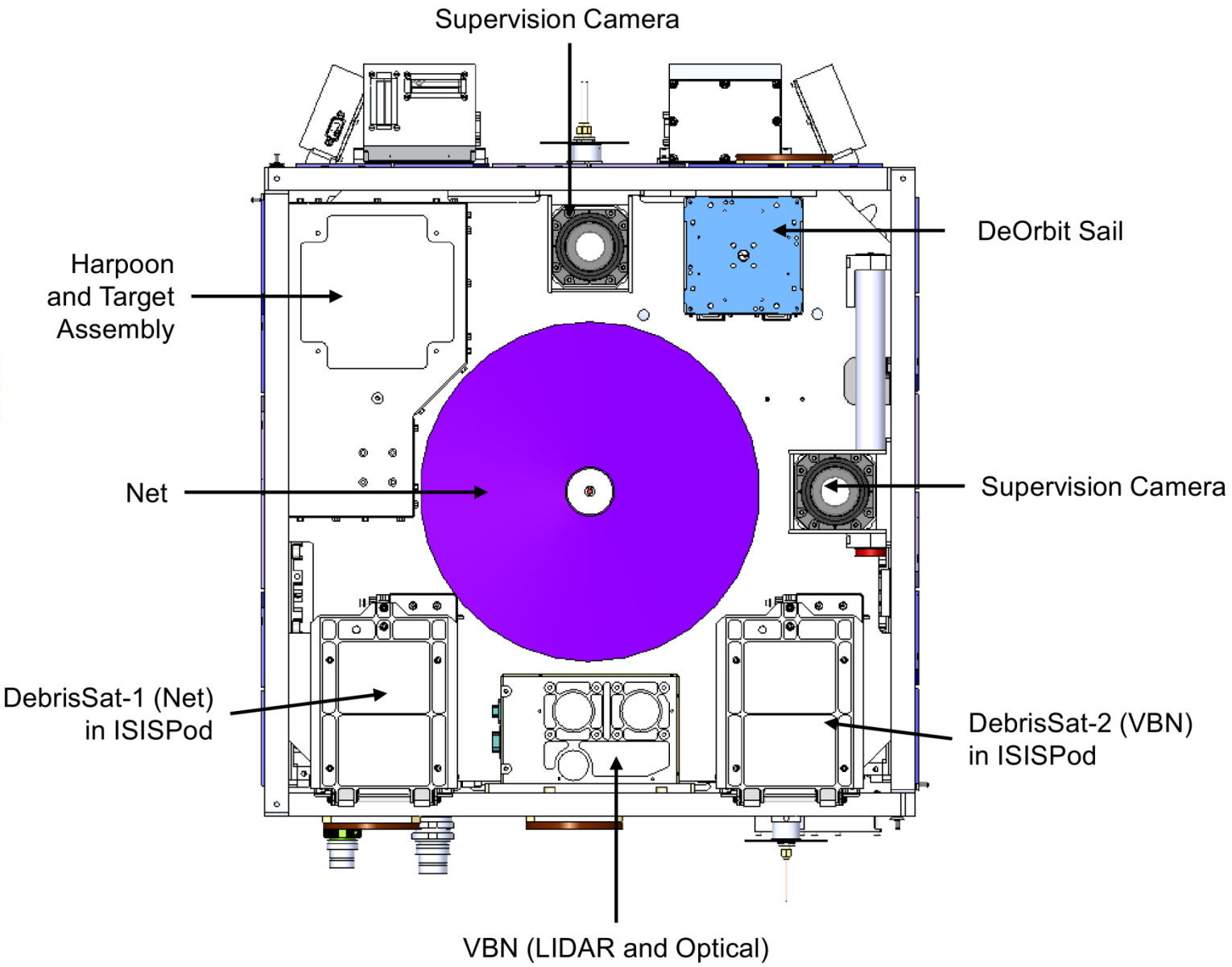


Packaged Inflatable; Combined Inflatable and Deployable Boom Mechanism

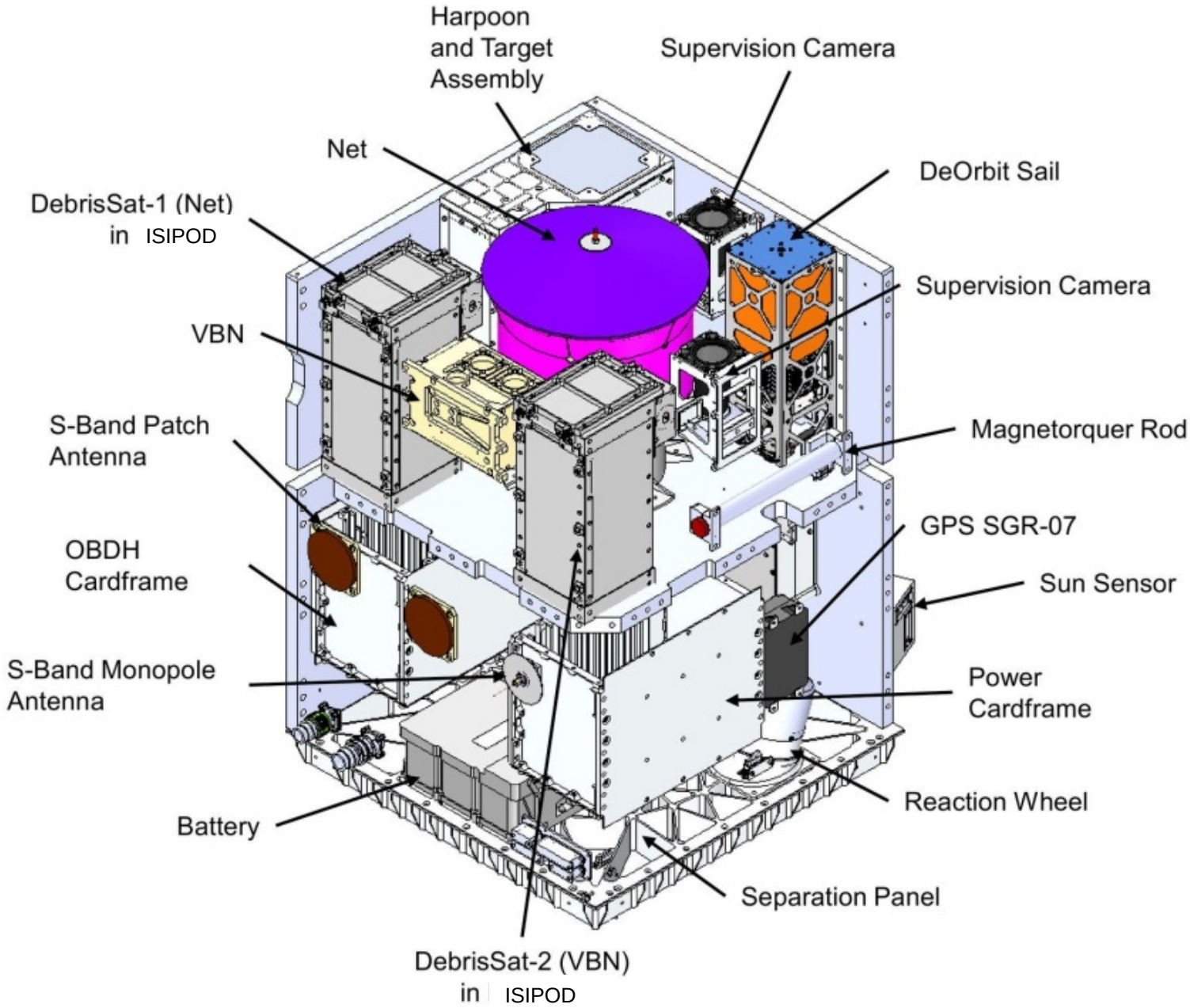
Payloads Demonstrations (4/4)

Platform – I




Supervision Camera
DeOrbit Sail
Harpoon and Target Assembly
Net
Supervision Camera
DebrisSat-1 (Net) in ISISPod
DebrisSat-2 (VBN) in ISISPod
VBN (LIDAR and Optical)

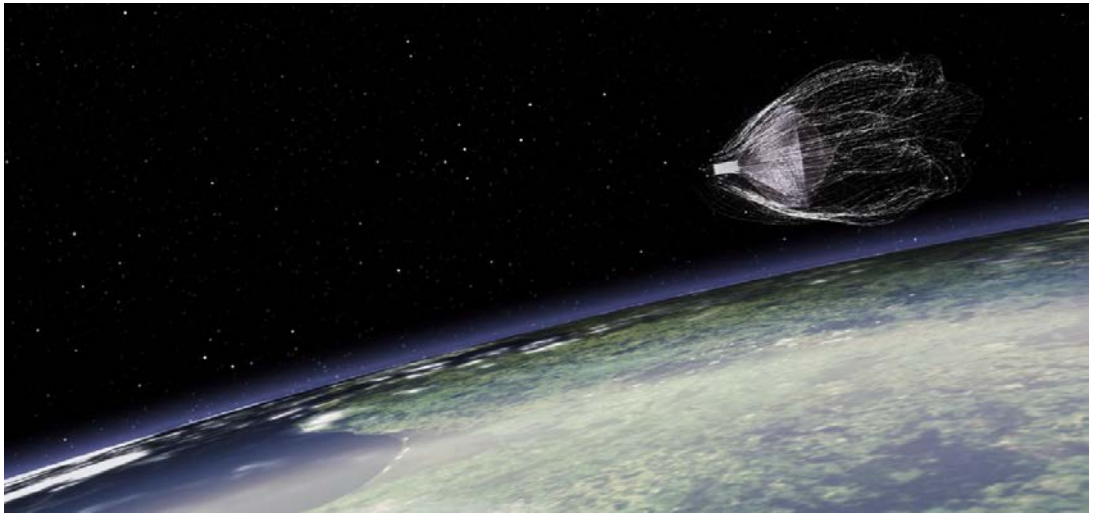
Platform – II

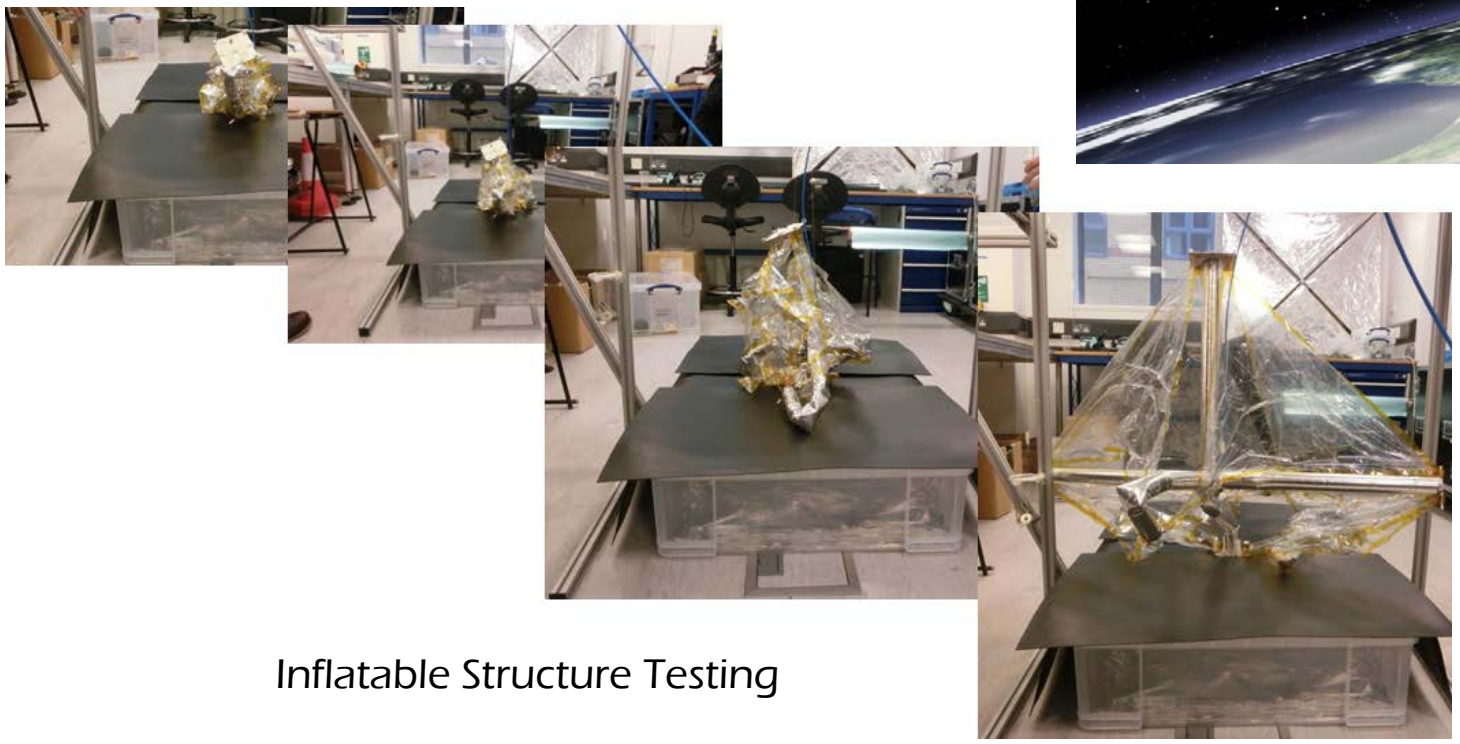

Harpoon and Target Assembly
Supervision Camera
Net
DeOrbit Sail
DebrisSat-1 (Net) in ISIPOD
Supervision Camera
VBN
S-Band Patch Antenna
Magnetorquer Rod
GPS SGR-07
OBDH Cardframe
Sun Sensor
S-Band Monopole Antenna
Power Cardframe
Reaction Wheel
Battery
Separation Panel
DebrisSat-2 (VBN) in ISIPOD

CubeSats – I

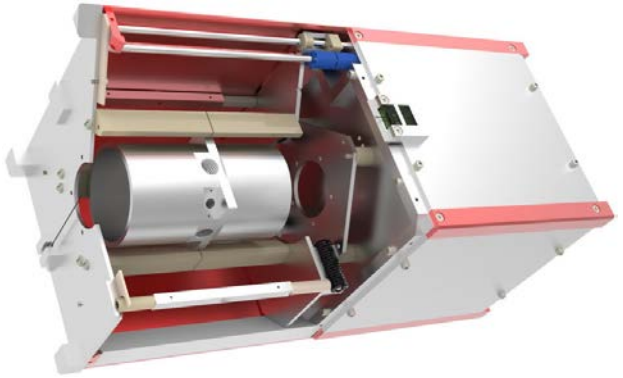
Targets – 2 x 2U Cubesats, mainly based on COTS, Mass ~ 2kg each

- DSAT-1: Semi active – Net Experiment (OBC + Power + Inflatable Structure)





Inflatable Structure Testing

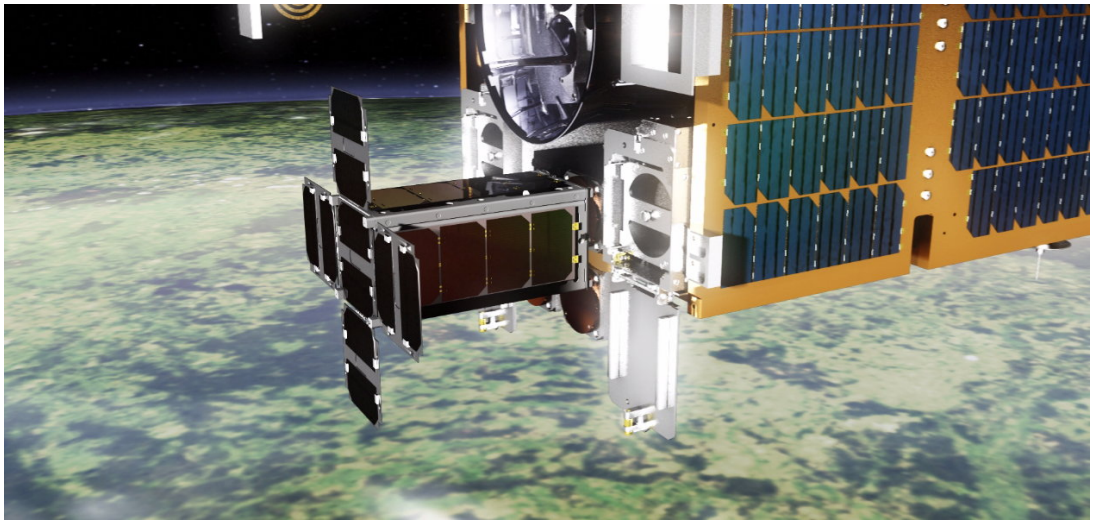


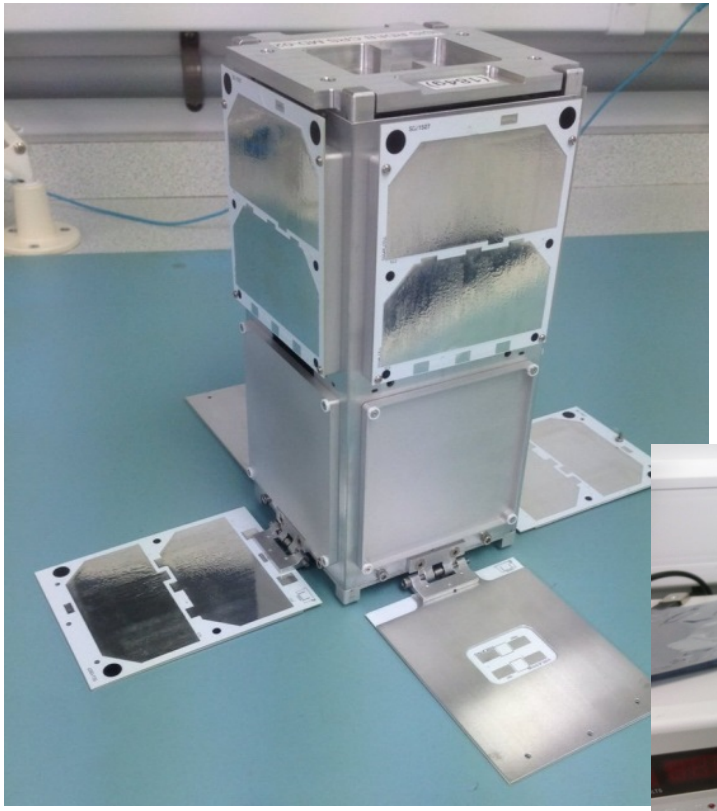
Internal CGG and Valve

CubeSats – II

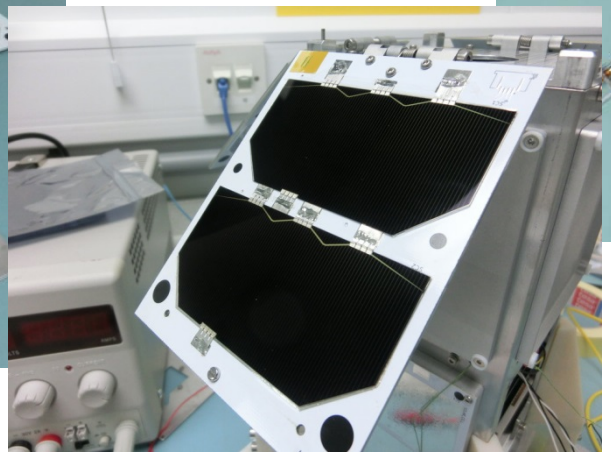
Targets – 2 x 2U Cubesats, mainly based on COTS, Mass ~ 2kg each

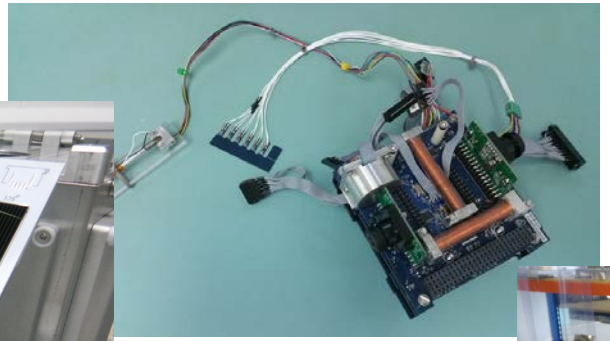
- DSAT-2: Fully active – VBN Experiment (OBC + Power + AOCS + ISL)





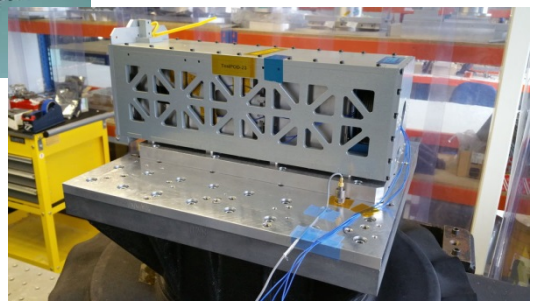
Structure and Solar Panels





Avionics Core

Vibe Testing

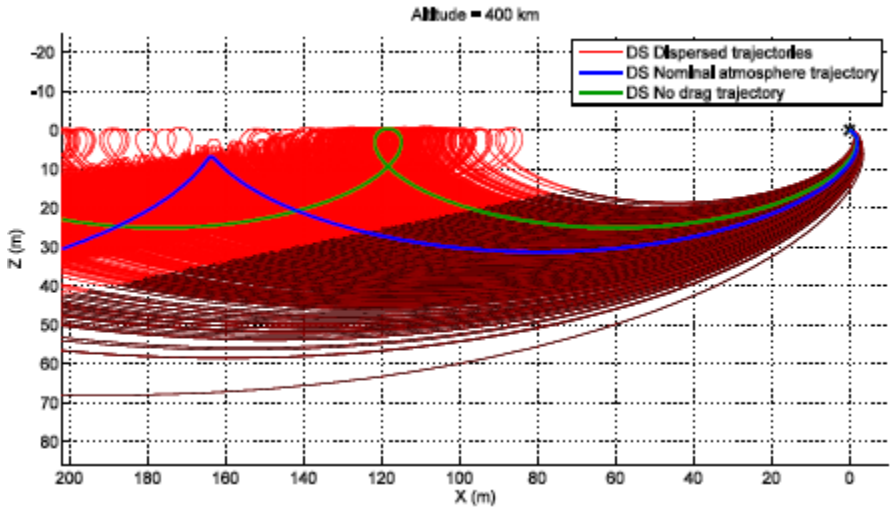


Mission Analysis – I

- Decay Duration
  - Both ESA's DRAMA (debris risk assessment and mitigation analysis) and CNES's STELA (semi-analytic tool for end of life analysis) used.
  - Specification: Orbit decay < 25 year
    - Sensitive to solar activity, altitude, BN (ballistic number)
    - Decay driven by Platform BN ~140kg/m2 (worst case compared to CubeSat, Net, Harpoon)
  - No issue with regard to decay duration
    - Decay < 5 years (without drag sail)
  - Deployment above 370km recommended

Orbit lifetime duration (years)		Initial date			
		2016/01	2016/06	2017/01	2017/06
Initial altitude (km)	330	0.33	0.40	0.42	0.49
	370	0.87	0.99	1.2	1.4
	400	1.9	2.2	2.7	3.0
	435	4.8	4.7	4.3	4.1

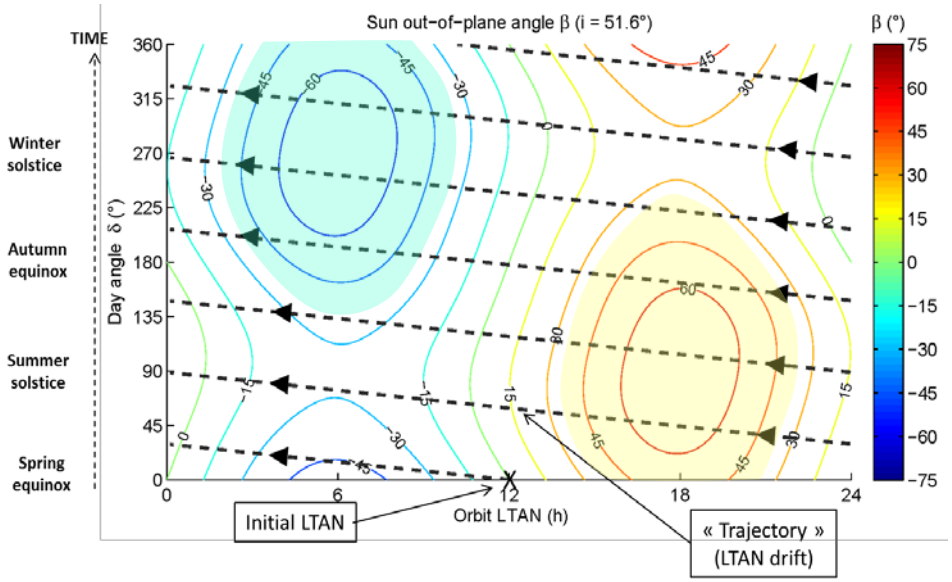
- Drag Effects
  - VBN demo sensitive to target trajectory dispersions
    - Platform pointing to target in open loop
  - Drag major contributor to trajectories dispersions at ISS altitude
    - Other key drivers: Platform absolute pointing and Deployer accuracy (velocity & direction)
  - Net & Harpoon demo not sensitive to drag effects

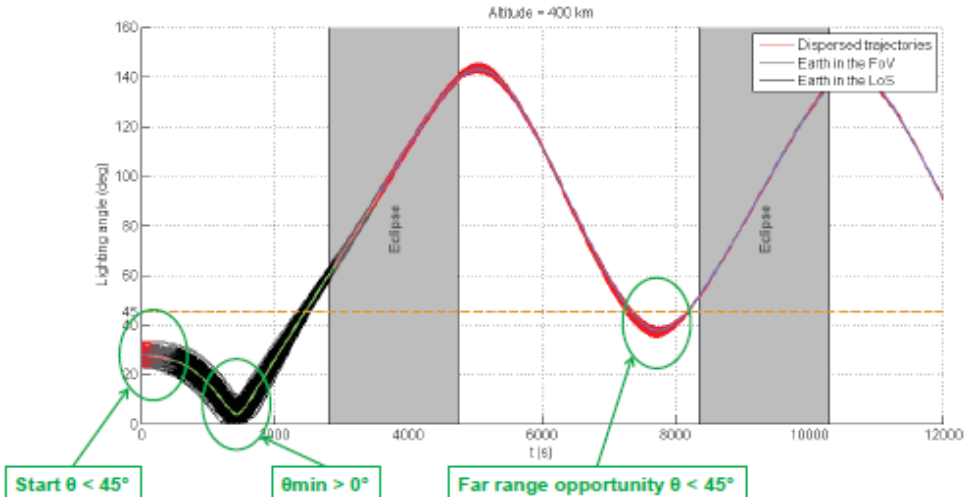


Mission Analysis – II

- **Lighting Conditions**
  - Key parameter for supervision cameras for successful assessment in demonstrations
  - **Lighting parameters**
    - Consideration given to local direction of the sun and local direction of the target as seen by the cameras.
  - Opportunities with correct lighting conditions not all time !

- **Further Information**
  - Joffre, E., Forshaw, J. L., Secretin, T., Reynaud, S., Salmon, T., Aurelien, P., Aglietti, G. (2015), "RemoveDebris – Mission Analysis for a Low Cost Active Debris Removal Demonstration in 2016", **25th International Symposium on Space Flight Dynamics** (ISSFD), Munich, Germany.

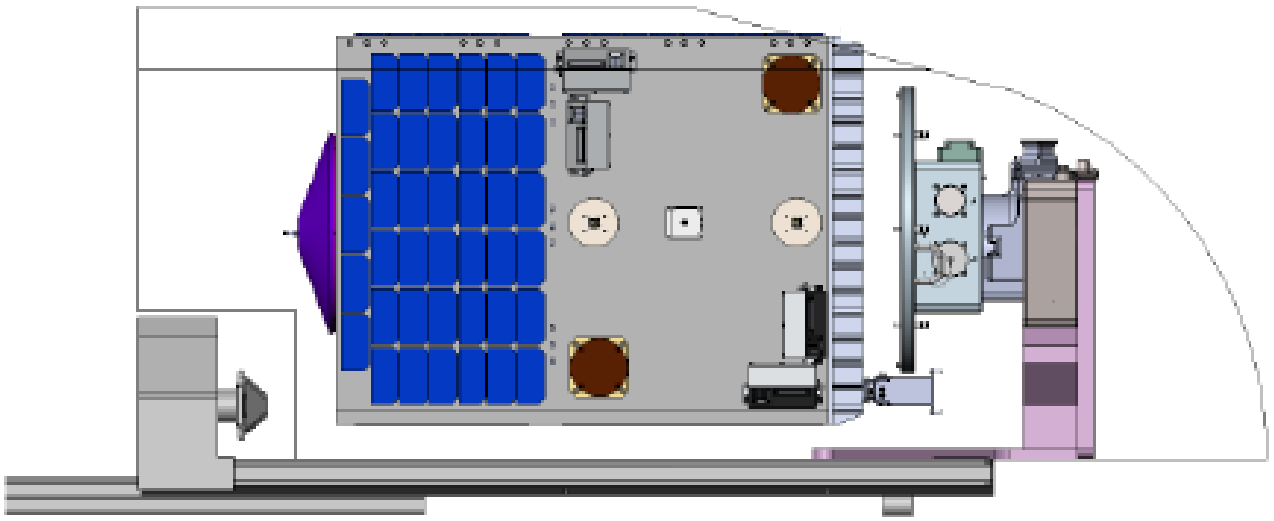




Launch

Nanoracks Launch

- Launch under procurement, likely candidate is early 2017 launch from ISS
- ~400 km orbit, 51.6 degrees inclination



Launch Process

1. Launch by ISS visiting vehicle
2. Platform transported in bag or box
3. Platform unpacked by ISS crew and installed into Japanese module
4. Air lock and slide table allow grapling of payload with robotic arm
5. Robotic arm positions and releases platform

Conclusions – I

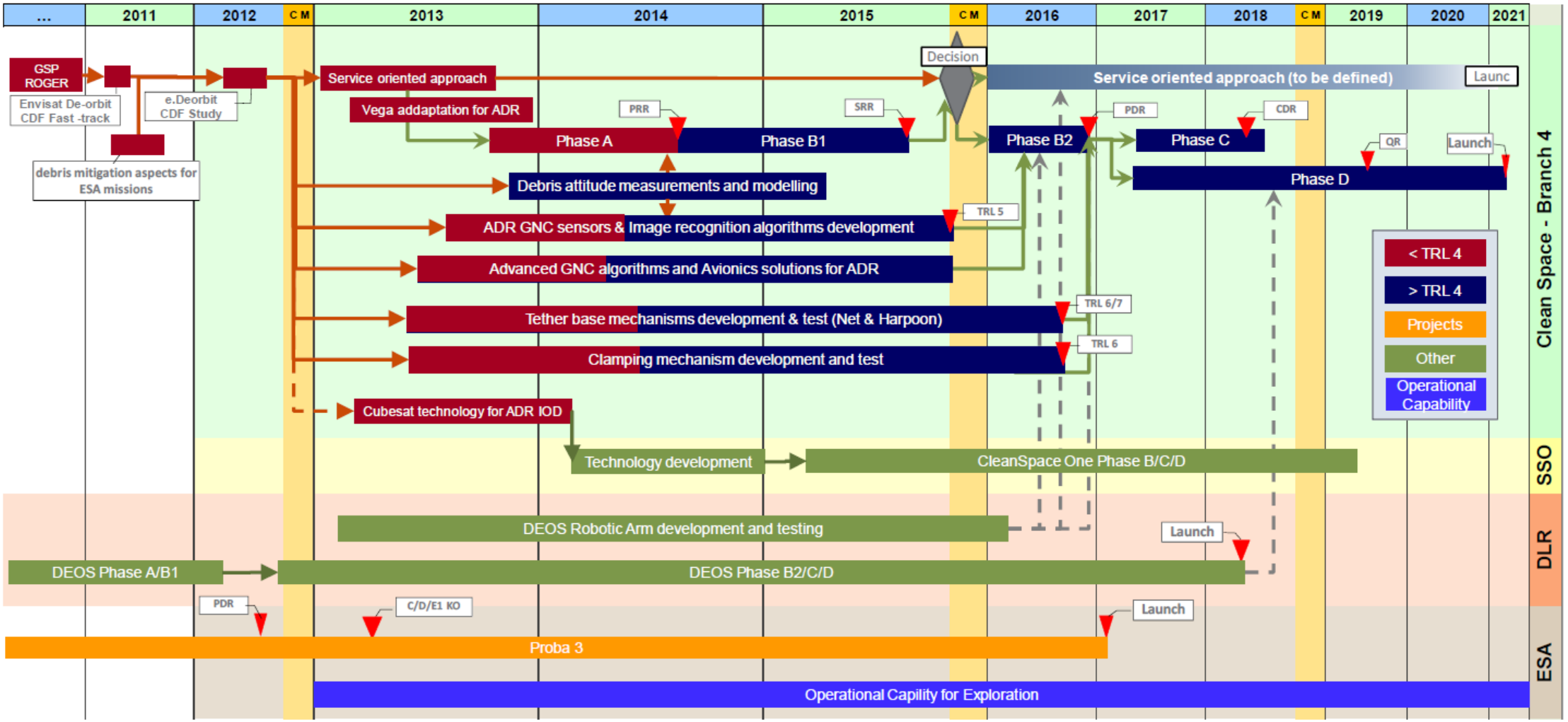
Progress

- Final mission design and preparation for flight models for late 2016. Launch planned for early 2017 (depending on flight roster).

Mission Novelty

- Low cost ADR mission to demonstrate, de-risk and mature key ADR in-orbit technologies.
- Valuable to the community:
  - Opportunities and funding to perform IOD debris removal missions are scarce.
  - An opportunity to mature net, harpoon, VBN technologies, which can be scaled up to use on future missions which target heavy debris.
- Likely to be the world's first active debris demonstration mission using "artificial targets".

Conclusions – II



RemoveDebris

Conclusions – III

Publications

- Massimiani, C., Forshaw, J. L., Richter, M., Viquerat, A., Simons, E., Duke, R. and Aglietti, G. (2015), "Review of Surrey Space Centre Debris Removal Research Missions", **3rd IAA Conference on University Satellite Missions & CubeSat Workshop**, Rome, Italy.
- Forshaw, J. L., Aglietti, G., Navarathinam, N., Kadhem, H., Salmon, T., Joffre, E., Chabot, T., Retat, I., Axthelm, R., Barraclough, S., Ratcliffe, A., Bernal, C., Chaumette, F., Pollini, A. and Steyn, W. H. (2015), "An In-Orbit Active Debris Removal Mission – RemoveDEBRIS: Pre-launch Update", **66th International Astronautical Congress**, Jerusalem, Israel.
- Forshaw, J. L., Massimiani, C., Richter, M., Viquerat, A., Simons, E., Duke, R. and Aglietti, G. (2015), "Surrey Space Centre: A Survey of Debris Removal Research Activities", **66th International Astronautical Congress**, Jerusalem, Israel.
- Chabot, T., Kervendal, E., Despré, N., Kanani, K., Vidal, P., Monchieri E., Rebuffat D., Santandrea, S., Forshaw, J. (2015), "Relative Navigation Challenges and Solutions for Autonomous Orbital Rendezvous", **EuroGNC 2015**, Toulouse, France.
- Forshaw, J. L., Lappas, V. J., Pisseloup, A., Salmon, T., Chabot, T., Retat, I., Barraclough, S., Bradford, A., Rotteveel, J., Chaumette, F., Pollini, A. and Steyn, W. H. (2014), "RemoveDEBRIS: A Low Cost R&D ADR Demonstration Mission", **CNES 3rd European Workshop on Space Debris Modeling** and Remediation, Paris, France
- Forshaw, J. L., Aglietti, G. (2014), "The EU Project RemoveDEBRIS", 5th **AIRBUS DS Space Systems Research and Technology Days**, Berlin, Germany.


Thank You!