RemoveDEBRIS Mission: 2nd Briefing to UN COPUOS

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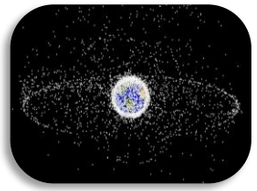
Content



RemoveDEBRIS mission overview

Intro & Aims
Video - Mission
Mission outline
Critical hardware testing

Launch & release from ISS

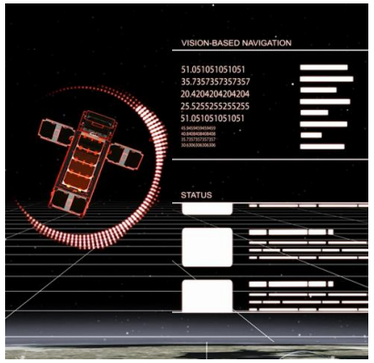
Packing & unpacking
Video: Launch & unpacking
Video: Deployment & flight

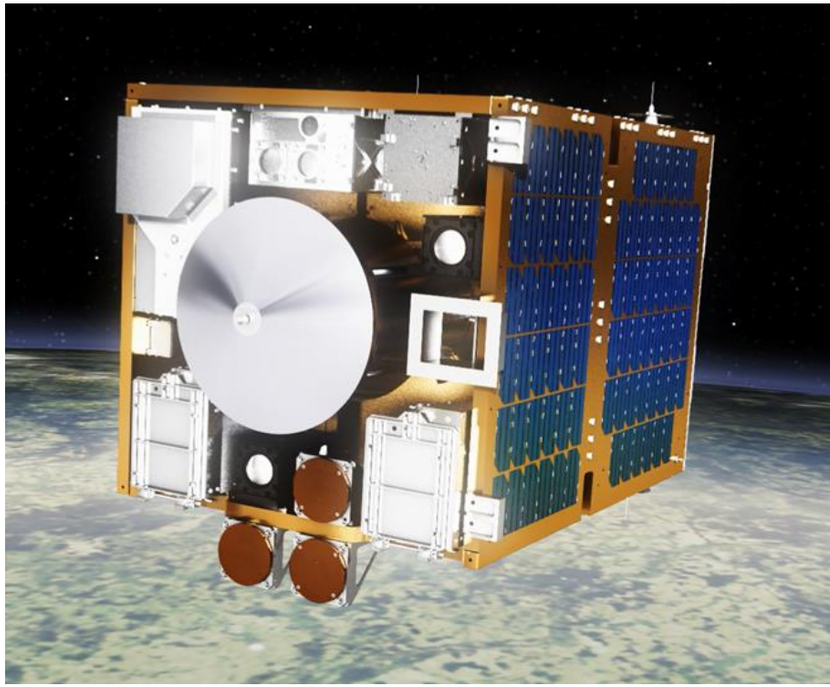
In orbit operation

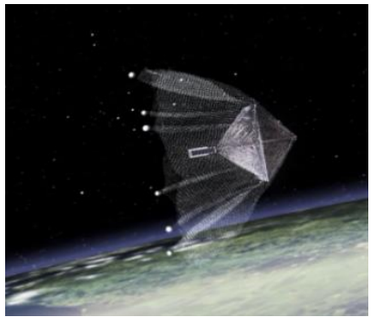
Commissioning
Video: Net experiment
VBN experiment
Conclusions

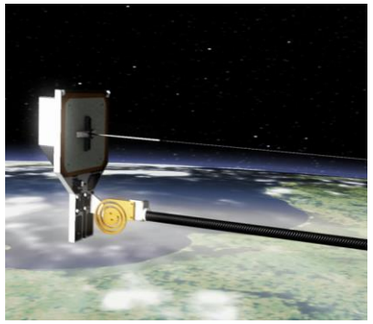
The RemoveDEBRIS mission

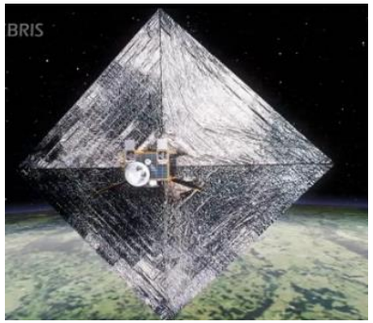
- **Ambitious**
  - **First successful in-orbit demonstration mission of series of technologies for Active Debris Removal**
    - ✓ observe (LiDAR camera),
    - ✓ capture (net & harpoon) and
    - ✓ de-orbit (dragsail) space debris
  - Complete development from concept to in orbit operations
- **High profile project**
  - Space mission significant for the whole space community & society
  - **Long term sustainability of LEO space environment**
  - Significant media interest (form local BBC to CNN international)
  - Strategically important for the partners
- **Challenging**
  - Cost effective, to pave the way to industrial exploitation
  - Manage risk ("lean" qualification) & launch via ISS
  - Started in Q4 2013 as €13 million value FP7 project receiving €7M from EC
  - Merge science & engineering developing the hardware and operating it in space

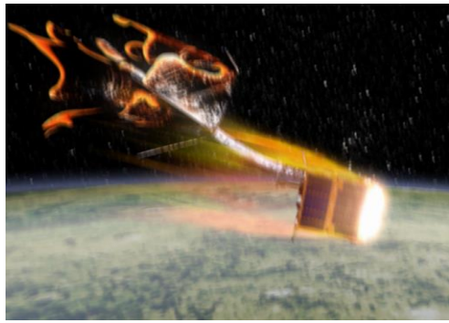












The RemoveDEBRIS Project Partners

Partners,
No subcon

	Partner	Country	Business activity	Roles in the project
1	SSC (project coordinator)	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, P/oads: Vision-based nav.
5	Airbus D&S	United Kingdom		Payloads: Harpoon
6	Ariane Group	France	Space Prime for space transportation and satellites	Mission & System Engineering
7	ISIS	Netherlands	SME, specializing in nanosatellites	Payloads: CubeSat deployers
8	CSEM	Switzerland	Research Institution	Payloads: LiDAR camera
9	INRIA	France	Research Institution	Payloads: VBN algorithms
10	STE	South Africa	University (Research)	Payloads: CubeSat avionics

The RemoveDEBRIS mission

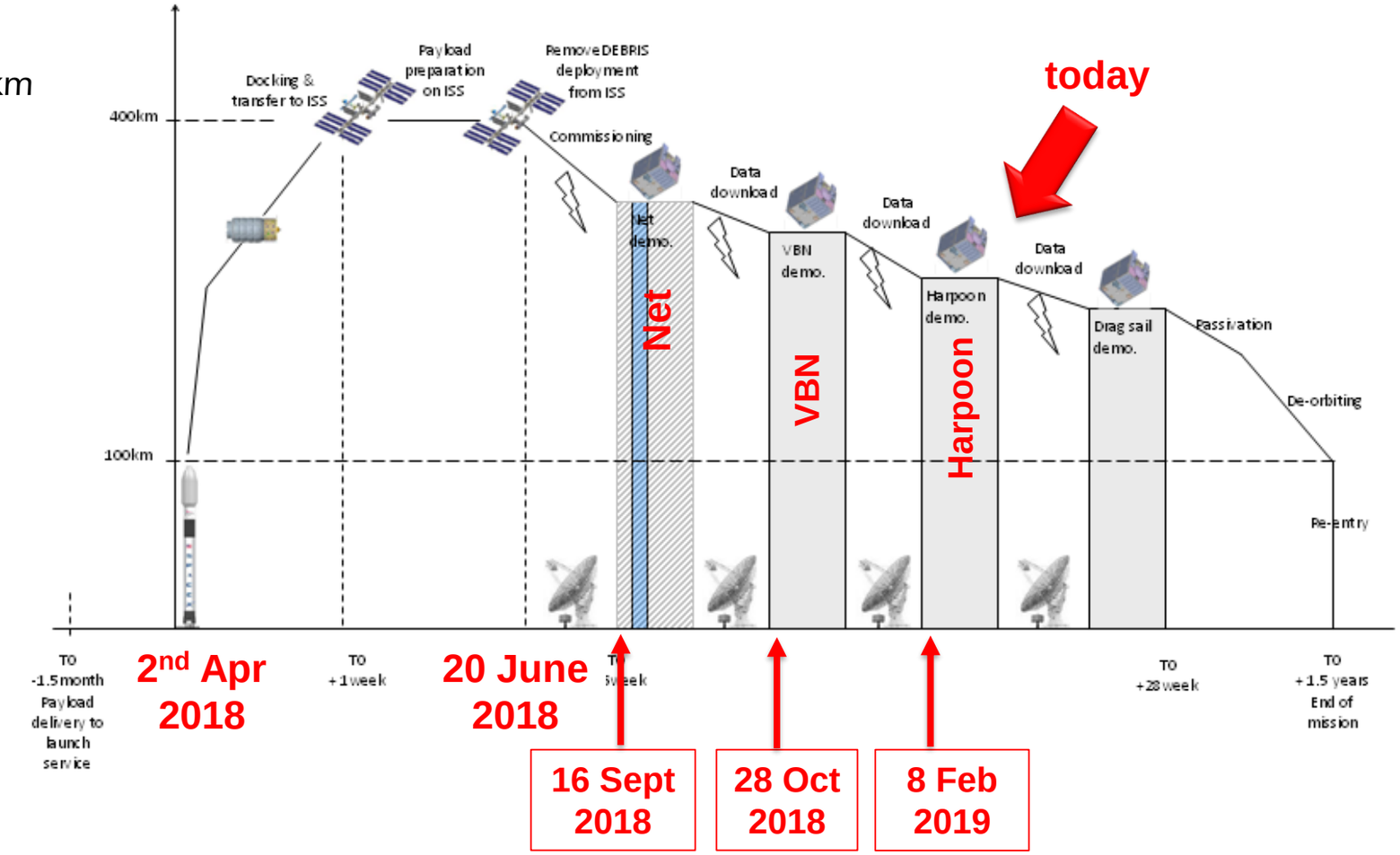
Mission video animation, short - 1 min 30 sec

RemoveDEBRIS mission overview

- **Orbital parameter**
  - Release from ISS orbit: altitude ~405km I=56.1°, LTAN (Local Time of the Ascending Node) not constant
  - Demonstrations sensitive to:
    - Altitude (drag effects)
    - LTAN & date (lightning conditions)

- **In-orbit mission**
  - 4 main demonstrations:
  - Each demonstration starts once previous one completed (data received on ground)
    - 1 week for each demonstration (preparation + demo)
    - ~2 weeks for data transfer

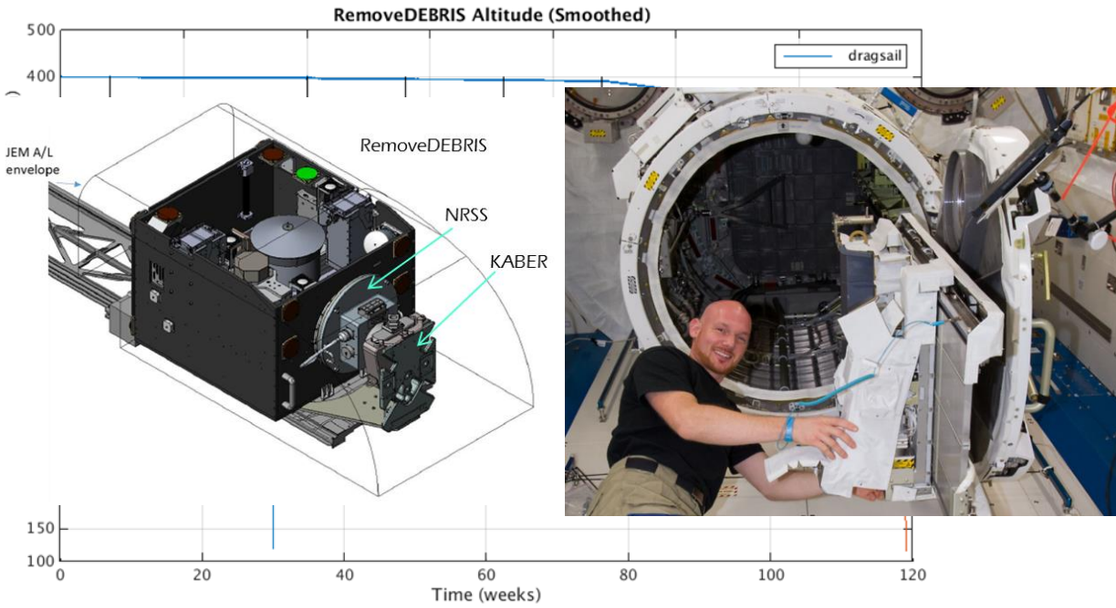
- **In-orbit duration > 9 months**
  - Launch + ISS ~2.5 months
  - LEOP + commissioning ~3 months
  - On orbit demonstrations ~6 months
  - Long waiting phases (weeks) for having correct lightning conditions



Mission key design drivers

Mission key design drivers

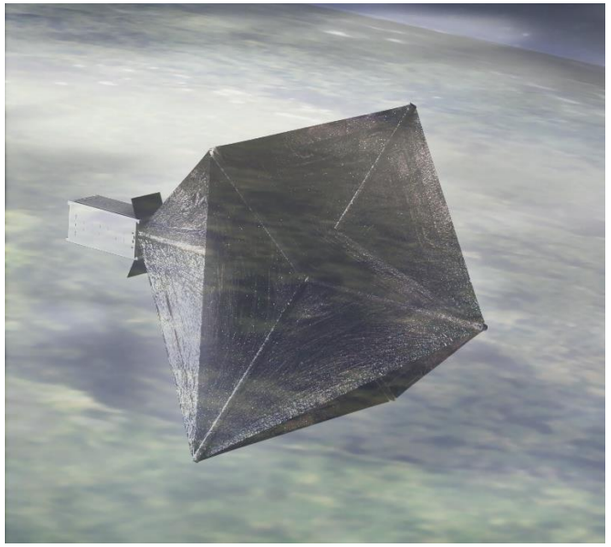
- **Relative to RemoveDEBRIS demonstrations**
  - ✓ Support payloads requirements
  - ✓ Demonstrations done autonomously (no need of Guildford ground segment visibility)
  - ✓ Lightning conditions with sun backward for supervision camera
  - ✓ Fail Safe (dual redundant architecture)
- **Relative to space law (license from UKSA):**
  - Avoid collision risks between platform & targets (fail safe trajectory)
  - Insurance – with SSTL/Airbus
  - All parts must be detectable from ground (no debris < 10cm) and re-enter in less than 25 years
- **Relative to ISS environment (compliance with Nasa req.)**
  - Key requirements relative to <u>interface with ISS</u>:
    - Mass < 100kg regarding KABER and SPDM systems
    - Volume compatible of the JEM airlock chamber
  - Key requirements relative to <u>ISS safety</u>:
    - No battery charging done onboard ISS
    - 3 electrical inhibits + 1 mechanical barrier for deployable items (Net, Harpoon, Drag sail and Deployers)
    - Platform "OFF" for 30min from deployment -> deviation wrt SSTL standards
    - Lower risk of recontact with ISS in case of unexpected payload deployment -> No software upload until risk of collision is quasi nil due to orbit decay



RemoveDEBRIS HTA

- Tether restraint test
  - Check tether restraint is sufficient
- Harpoon firing tests
  - 27 tests conducted
    - 22 EQM
    - 5 FM

RemoveDEBRIS Net

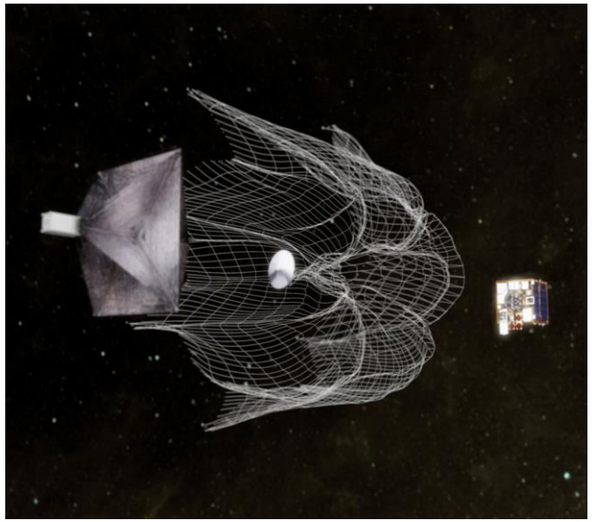


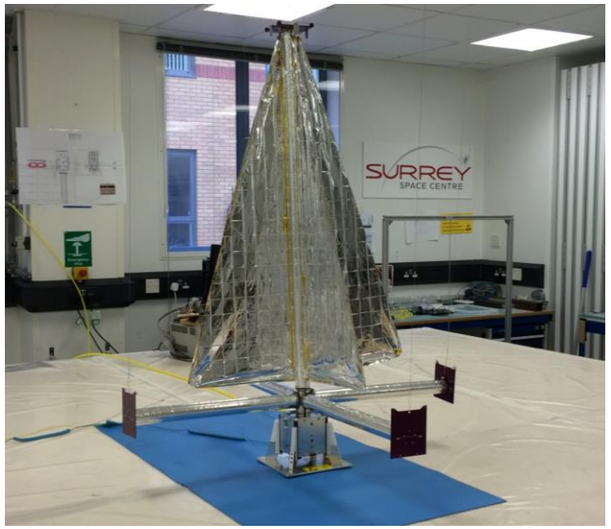
Target, 2U cubesat DS1 (Surrey Space Centre)

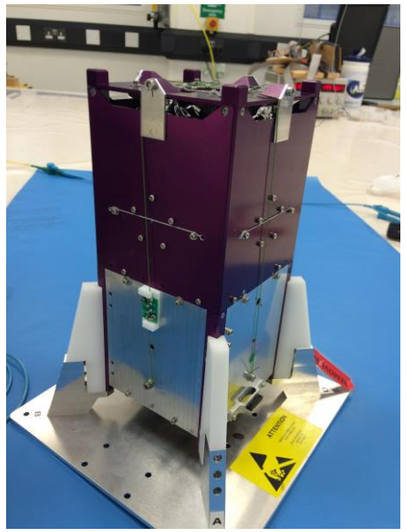
- Mass ~ 2kg
- Minimum avionics
- Inflatable Structure

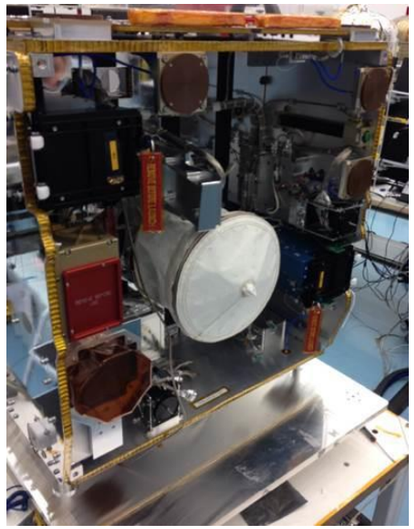
Net Capture Mechanism (Airbus Germany)

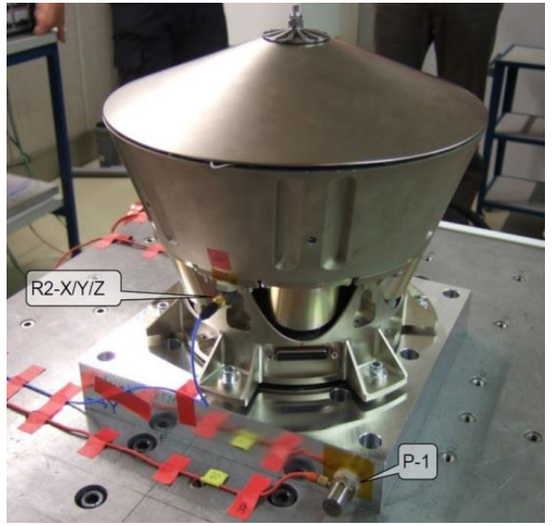
- Total mass: 6 kg
- Container Diameter 275 mm, height: 235 mm
- Net: Ø 5 m, hemispherical shape, ≈ 0.3 kg, Dynema
- 6 throw active weights

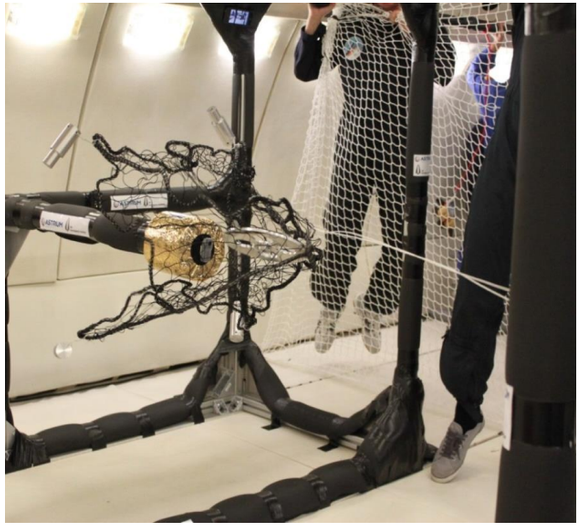








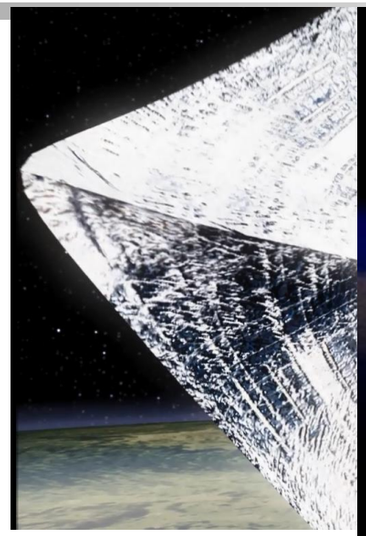


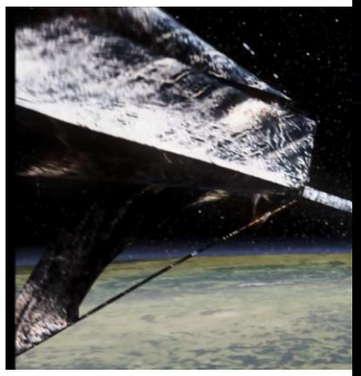


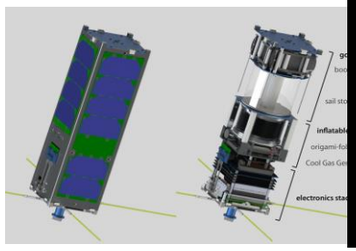
RemoveDEBRIS DragSail

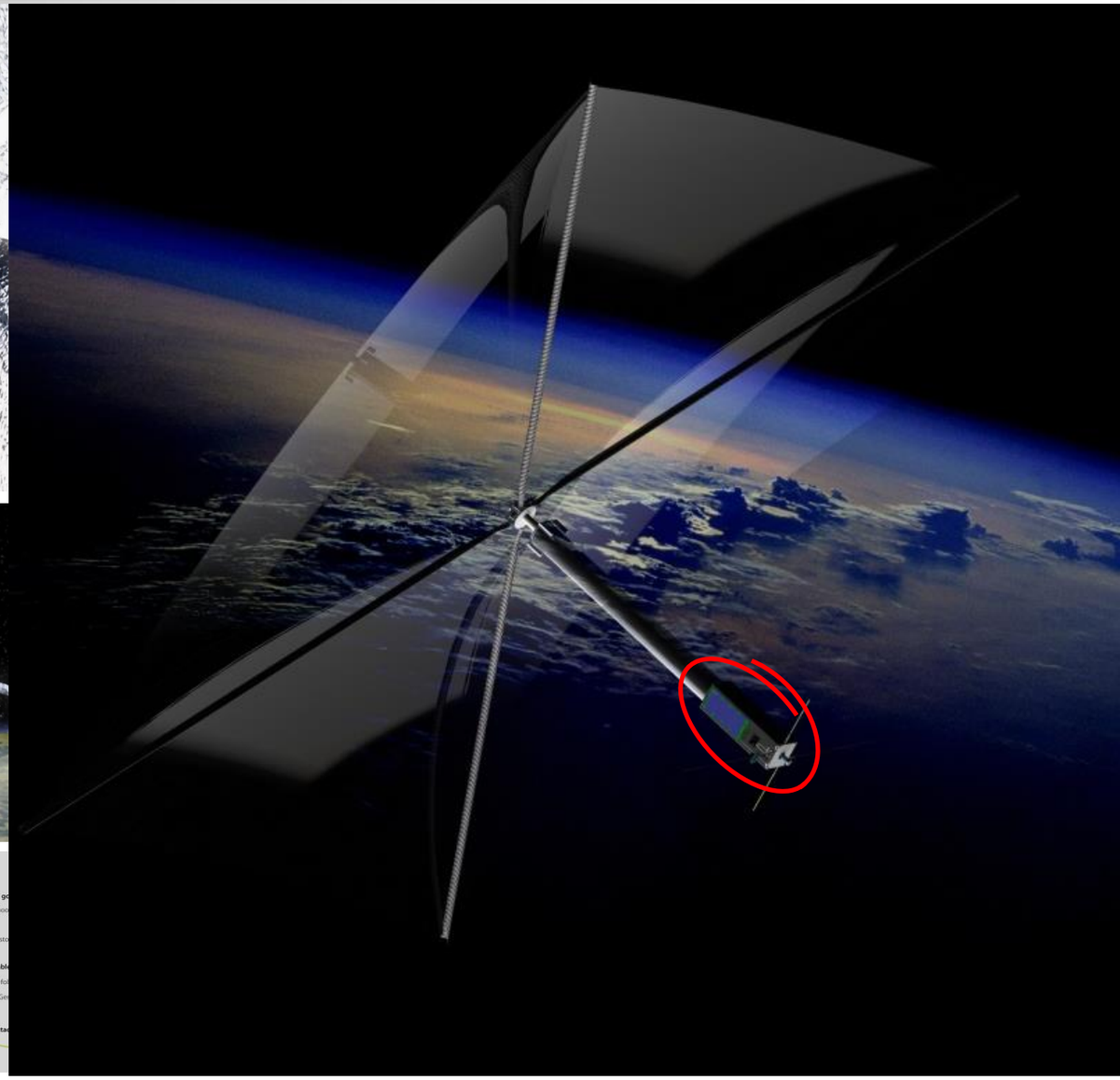
Drag sail demonstration

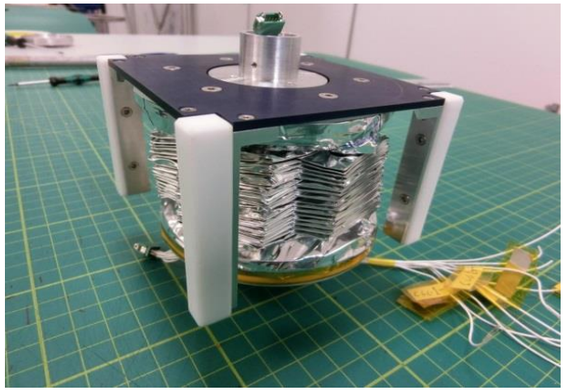
- Inflatable mast
- Deployment of a drag sail of ~9m2 at the tip of the mast
- No need to control platform during demonstration (CoM front to aero pressure center)
- Based on successful **InflateSAIL mission,** launched on QB50 mission 23 June 2017, re-entry 3 Sept 2017 (but payload version)

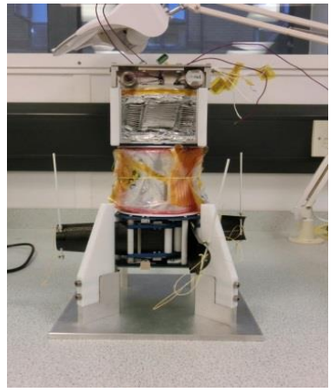












Packaged Inflatable; Combined Inflatable and Deployable Boom Mechanism

RemoveDEBRIS Launch & ISS unpacking

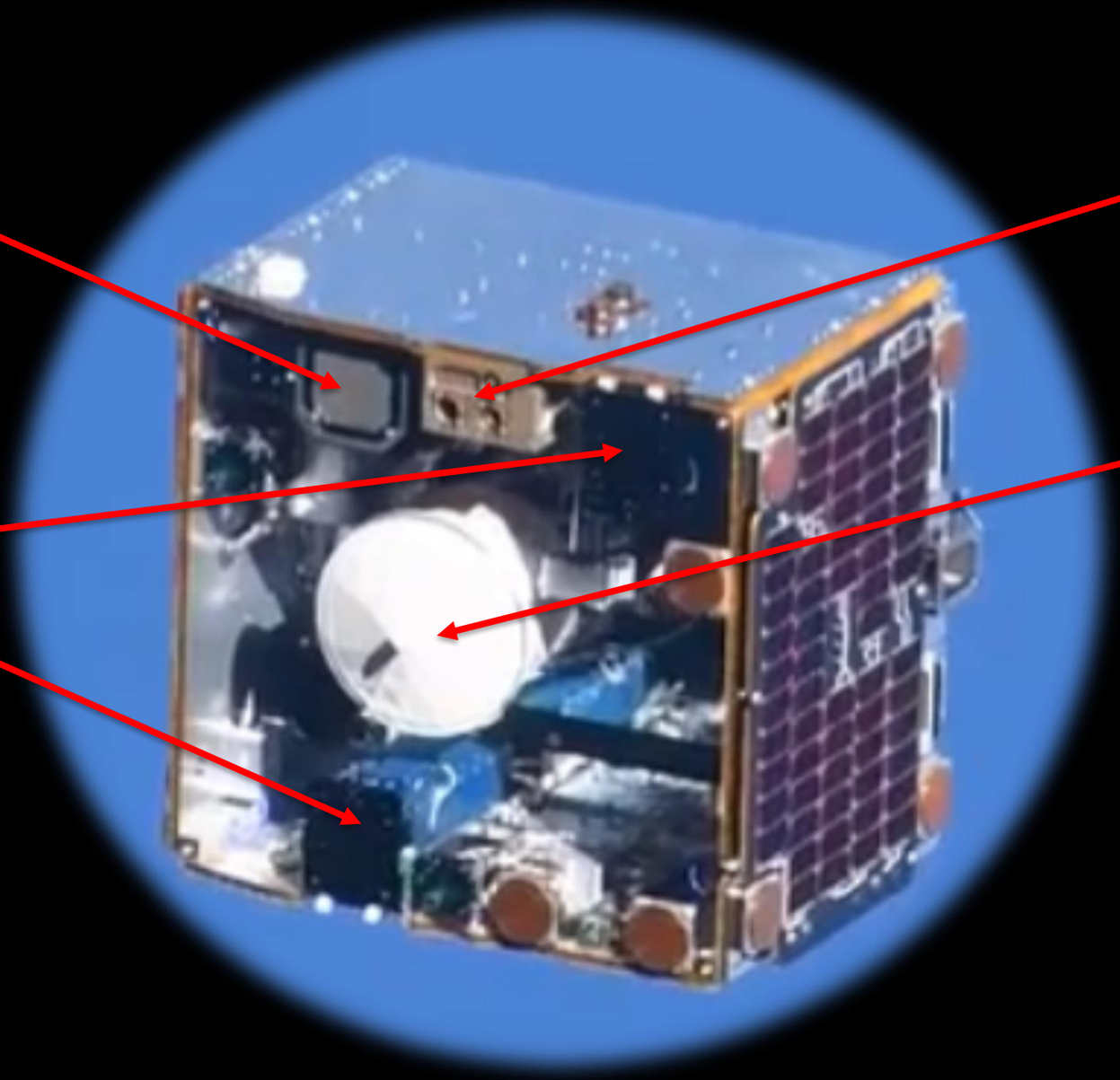
Video Launch & unpack 30 sec

RemoveDEBRIS release from Robotic Arm

Video release & flight 42 sec

RemoveDEBRIS on Twitter

RemoveDEBRIS in flight



Spacecraft commissioning

Launch and Early Operations Phase (LEOP)

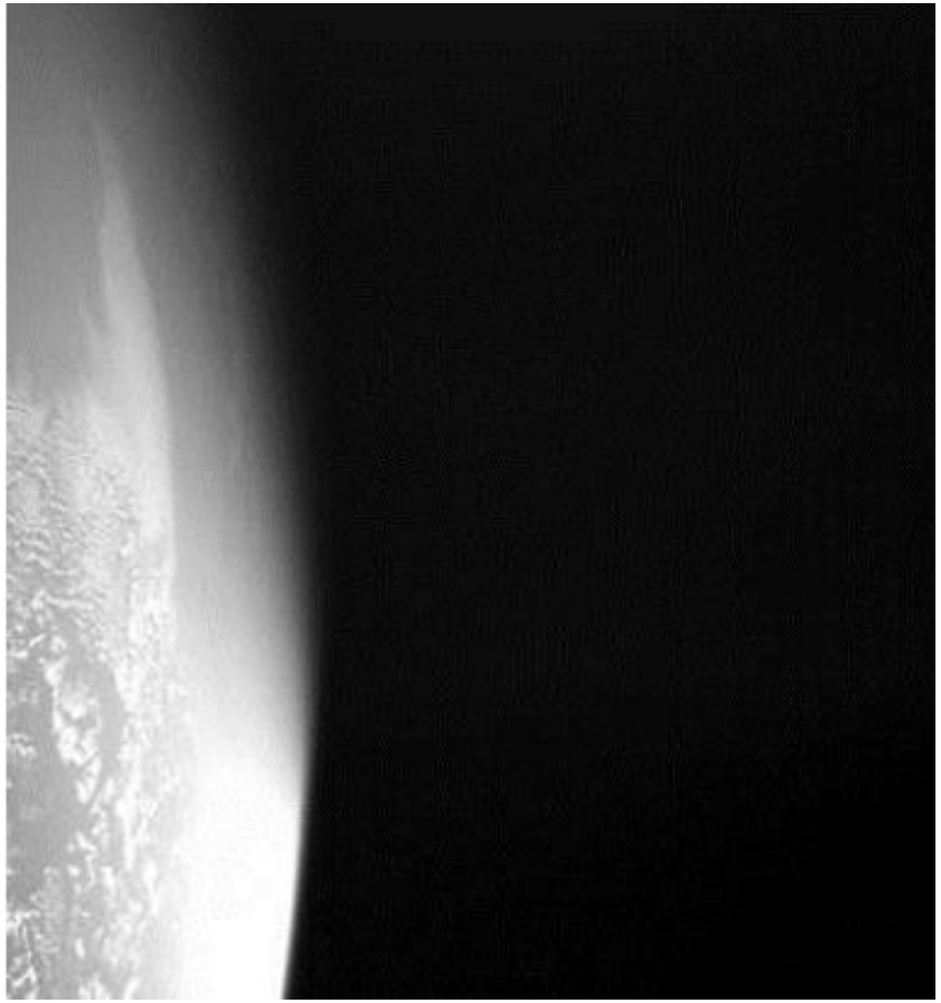
- ✓ Contact made during the first pass (20 June 2018) after power up over the SSTL groundstation in Guildford, UK.
- ✓ Spacecraft was performing nominally - Battery was fully charged.
- ✓ Commissioning progressed with switch on of the spacecraft OBC,
- ✓ De-tumbling from the slow initial angular rate to a controlled attitude state.
- ✓ AOCS commissioning then progressed until the platform was in a coarse Nadir pointing mode.

Platform Checkout

- ✓ Healthchecks on key platform modules not already checked
- ✓ Prime and redundant RF receivers, low rate transmitters and low level command links.
- ✓ The spacecraft then performed a series of AOCS manoeuvres to verify performance against that required for executing payload experiments.

Payload Calibration and Characterisation

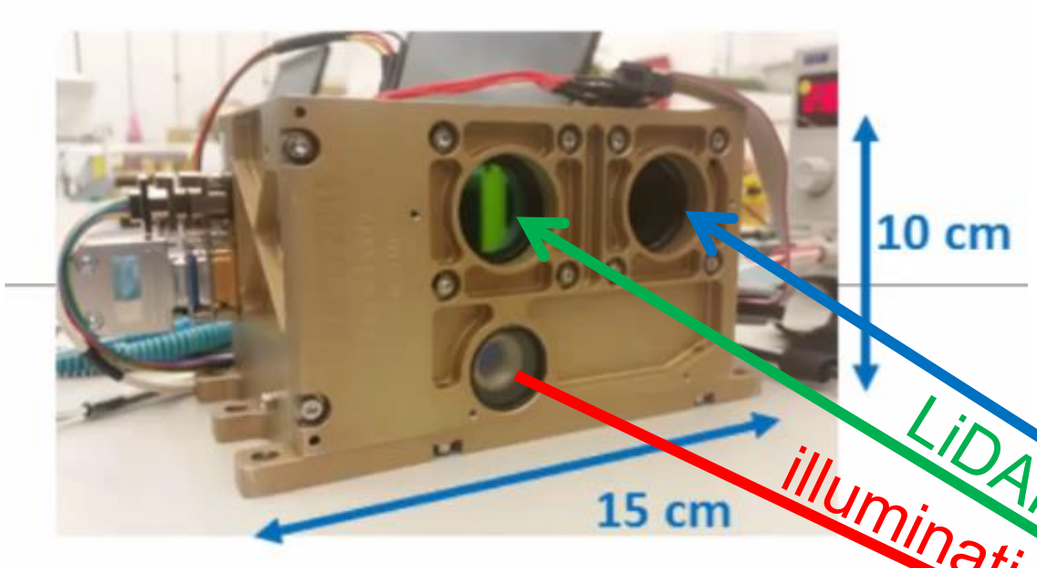
- ✓ The Supervision cameras and VBN camera were tested over a range of exposures and frame rates which are planned for use on the experimental demonstrations.
- ✓ Ready for Net experiment deployment 16-17 Sept 2018



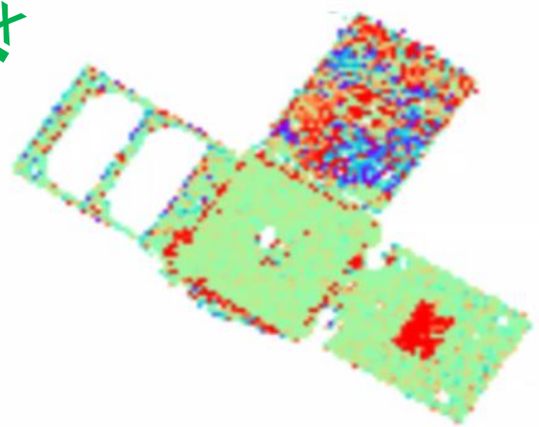
Net experiment

Video Net experiment 1 min

VBN experiment

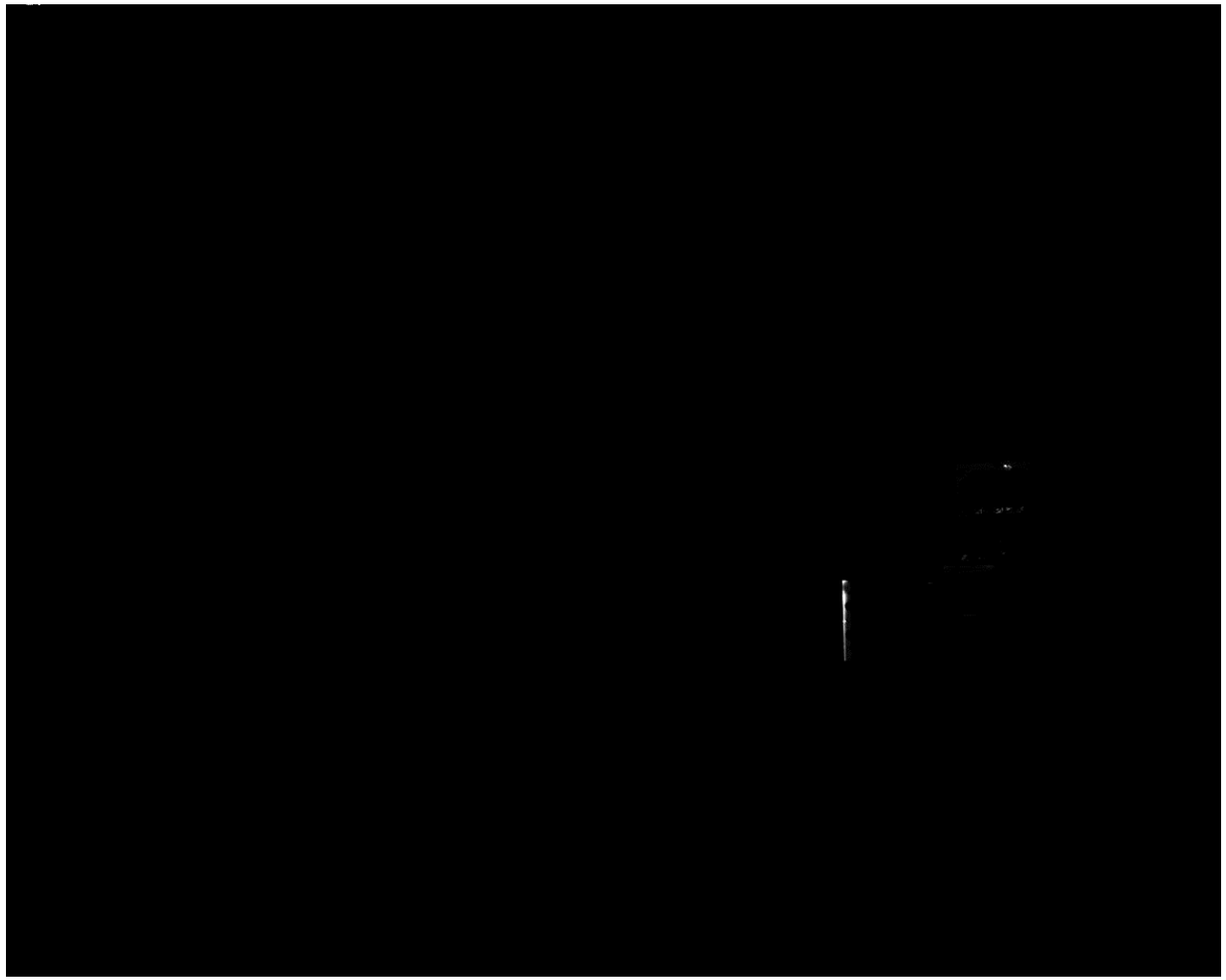


modified off-the-shelf color camera
and
flash imaging LiDAR (CSEM)

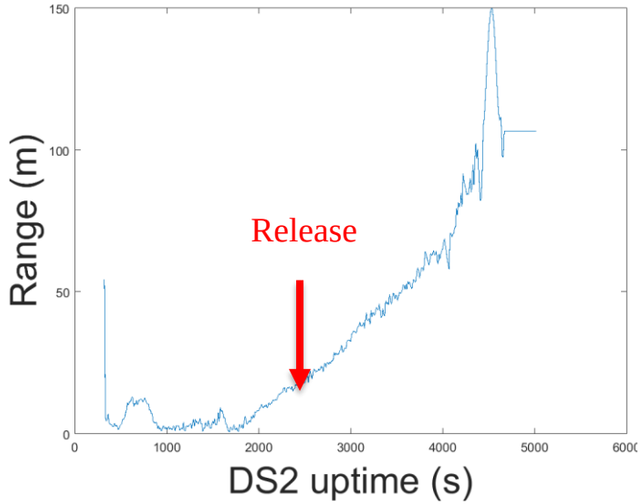


VBN experiment

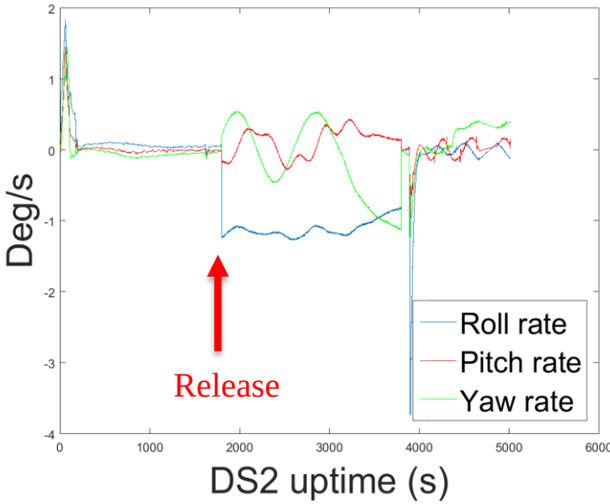
Platform Supervision Camera

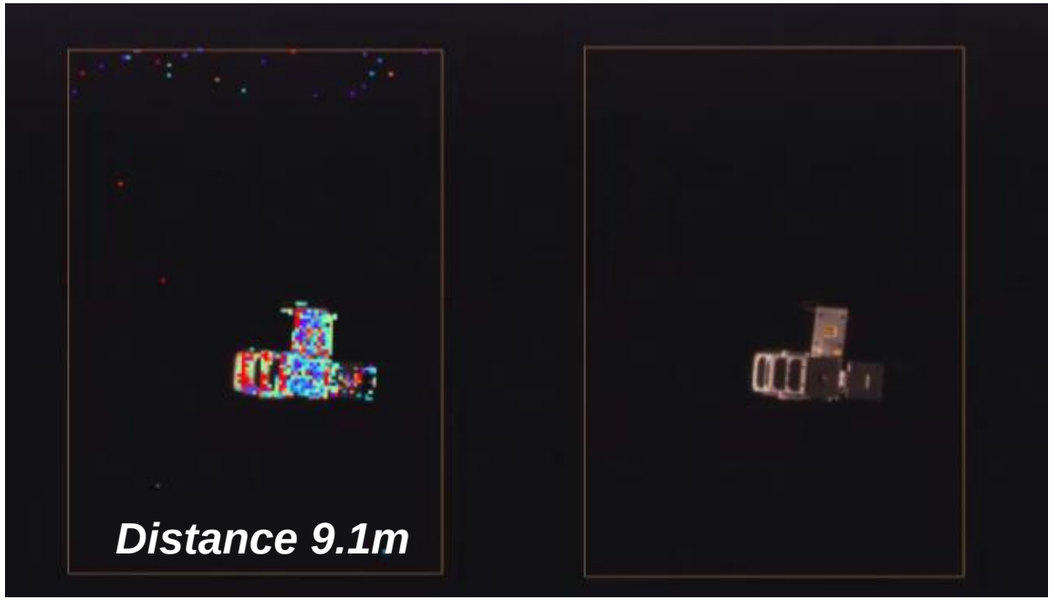


DS-2/Mothership relative GPS



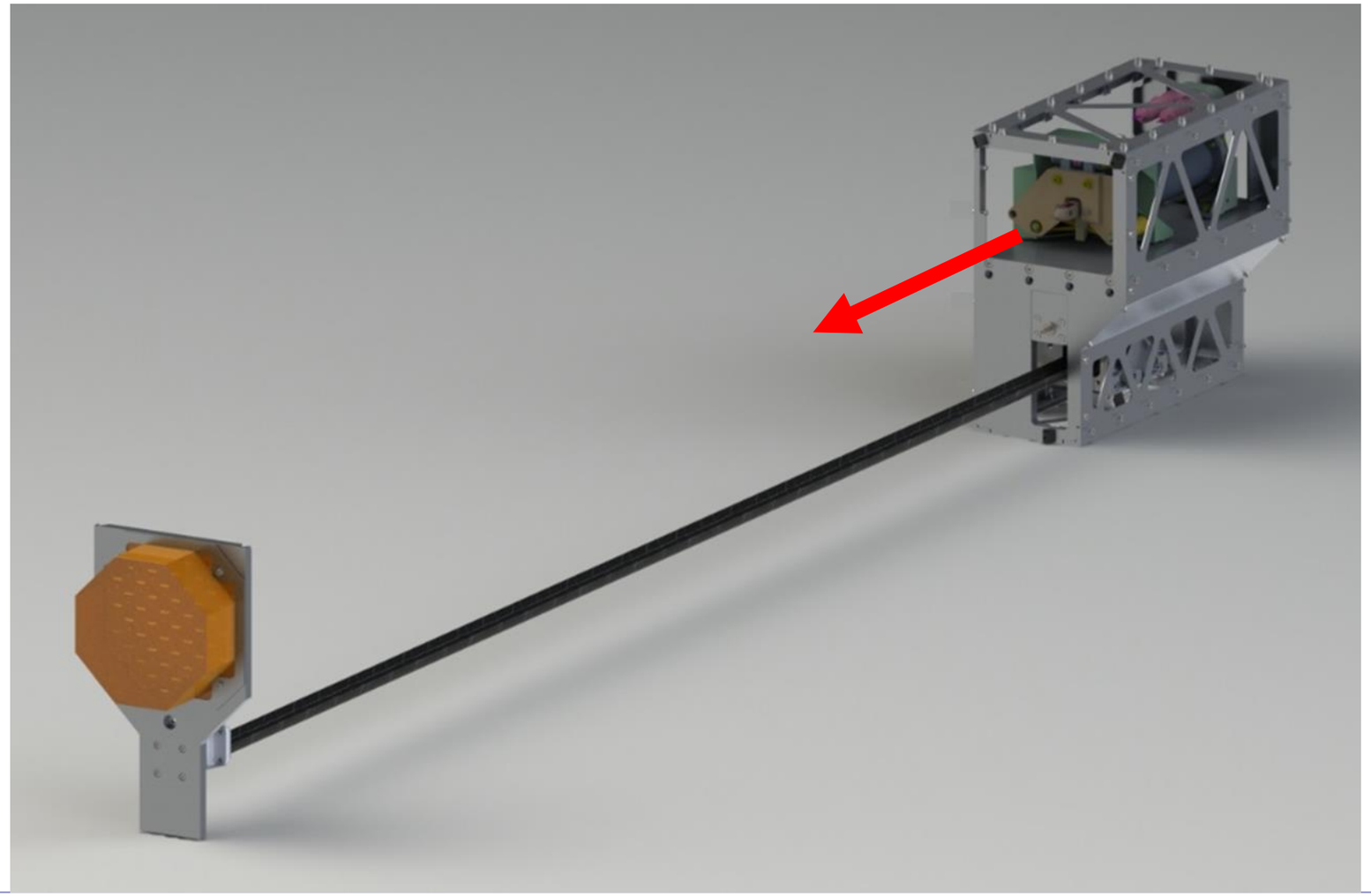
DS-2 Tumbling Rates



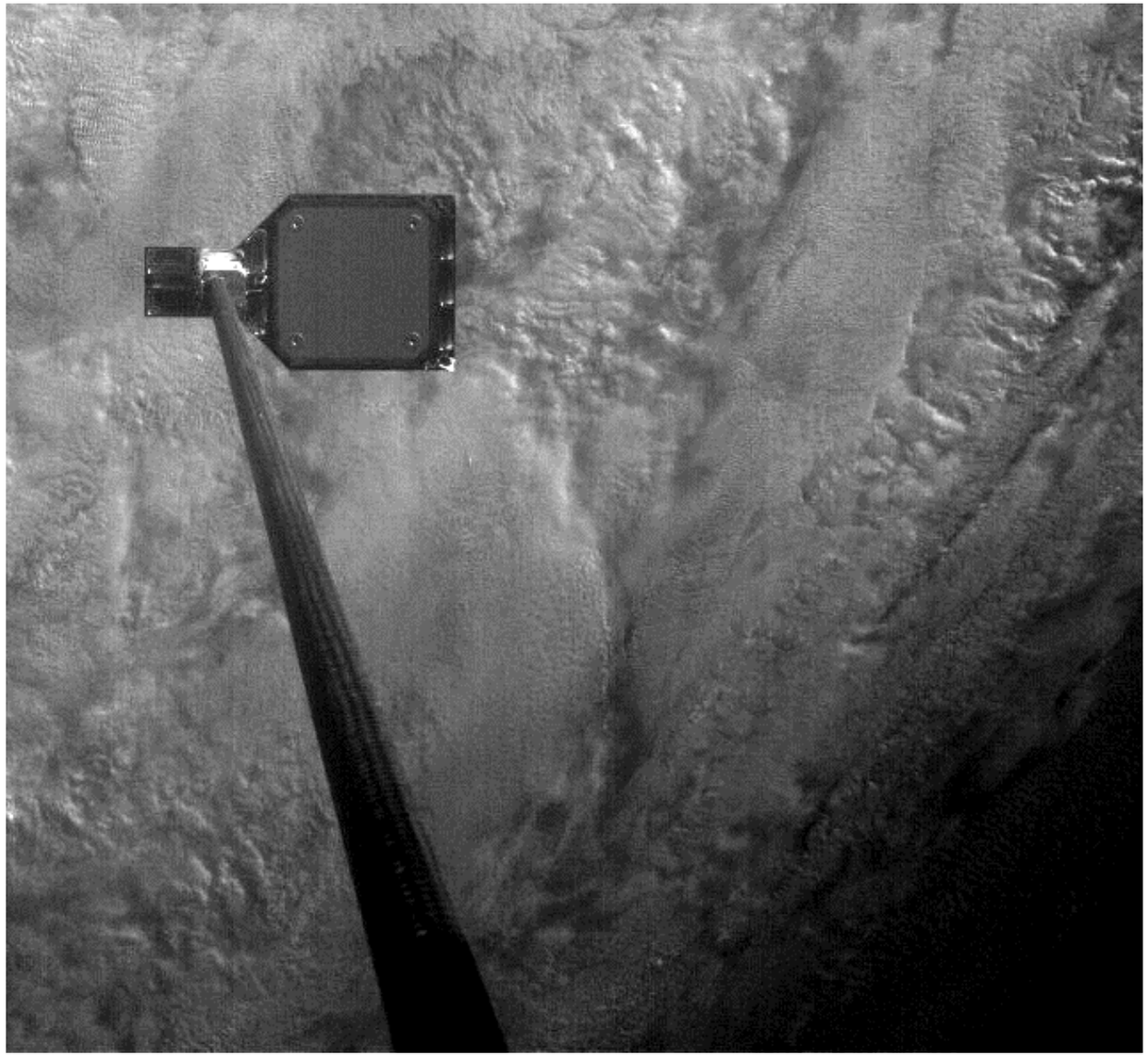


Harpoon experiment

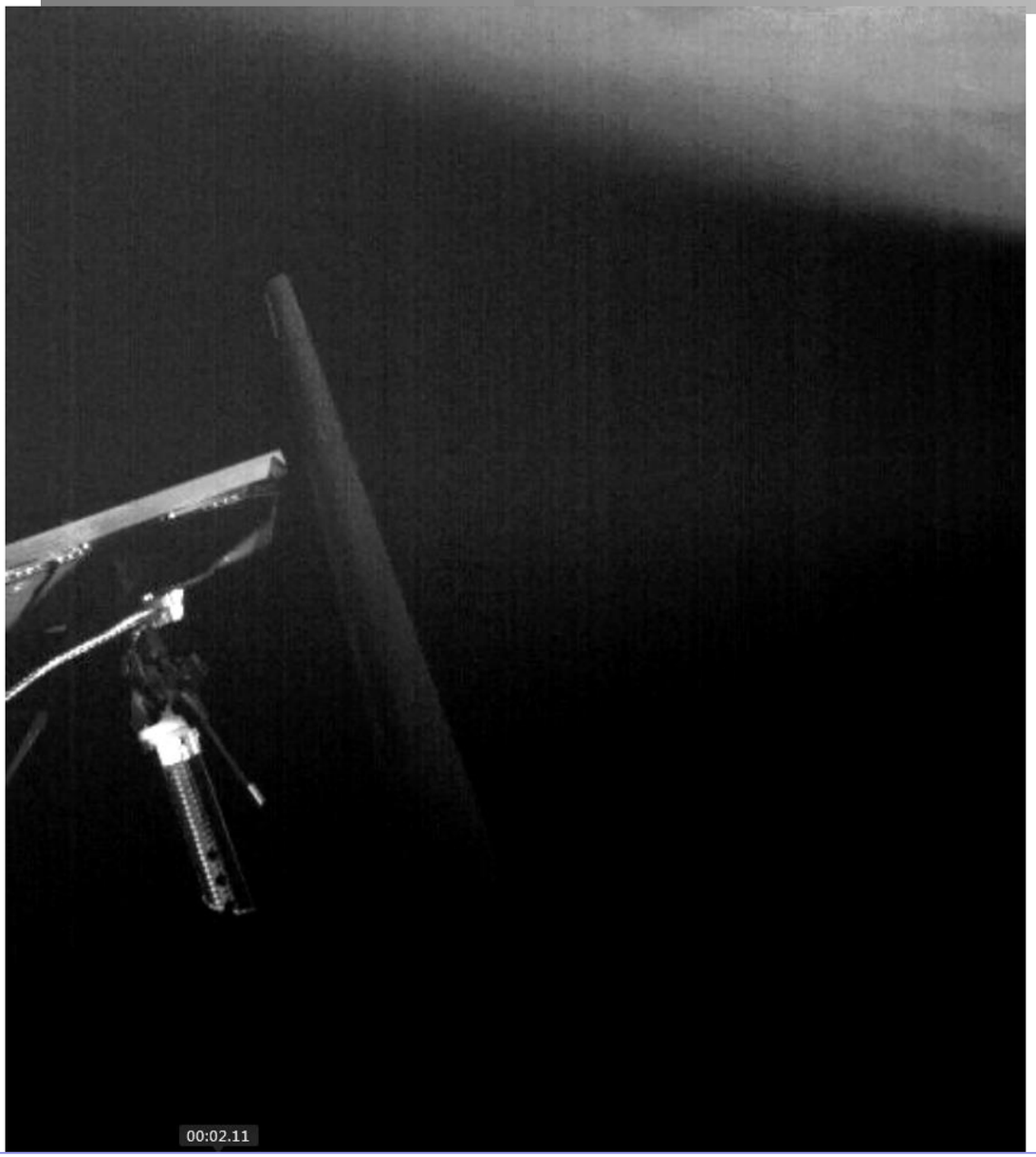
Harpoon successfully fired and imbedded in the target (typical satellite Al H/B panel 8th Feb)



Harpoon experiment - video



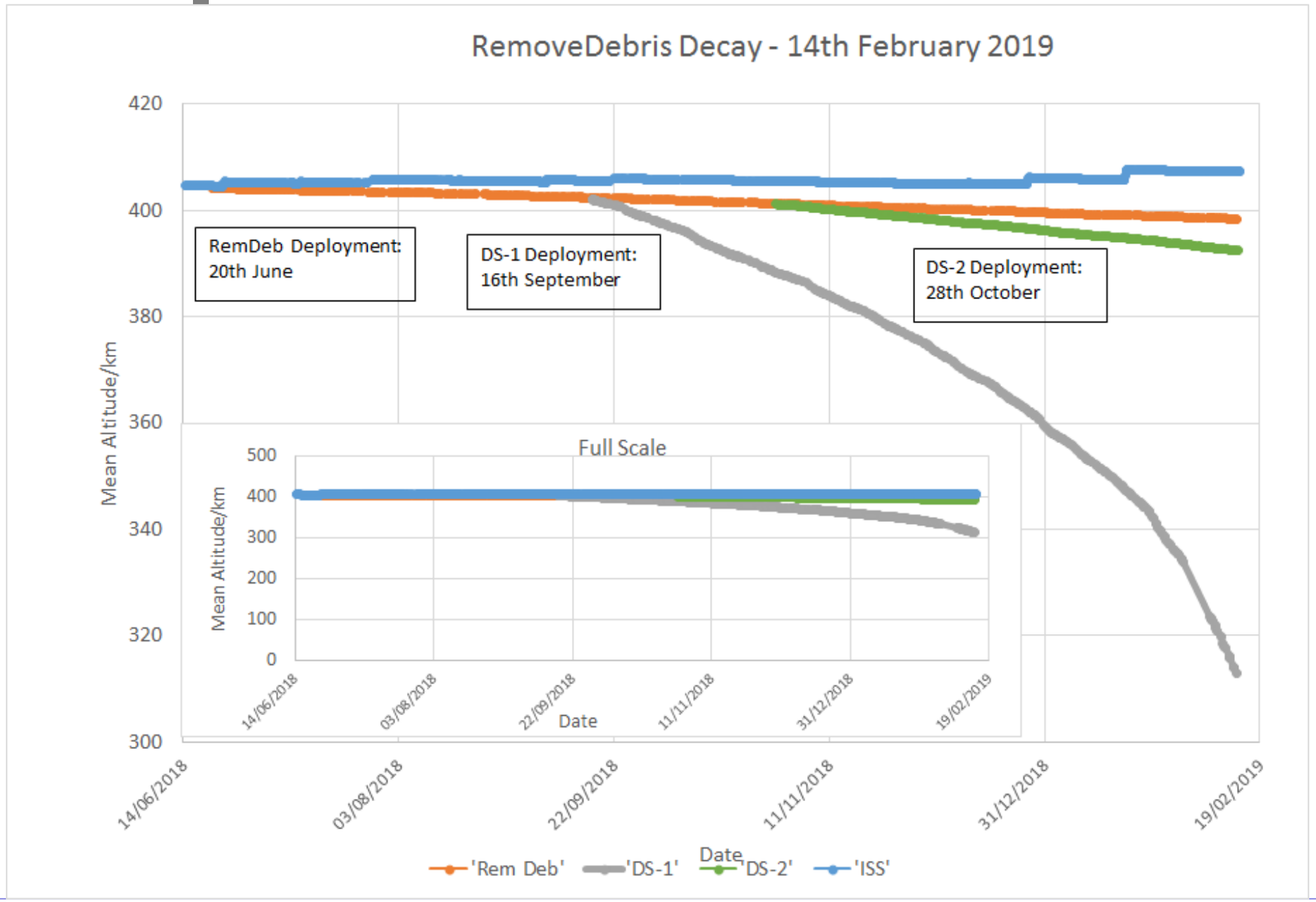
Harpoon experiment – target & boom



Active Debris Removal Demonstrations

Event	NET Date	Description
Net Experiment	September 2018	Deployment and inflation of DS-1 CubeSat Deployment of Net and capture of DS-1
Visual Based Navigation Experiment	October 2018	Deployment of DS-2 CubeSat, transmission of imagery and attitude/position data Observation of departing DS-2 by VBN payload
Harpoon Experiment	February 2019	Deployment of Harpoon Target on end of boom Firing of harpoon into target Retraction of boom, target and harpoon
DragSail Experiment	March 2019	Deployment of Inflatable Boom and Sail Accelerated deorbiting of spacecraft

Objects Decay



ISS

Remove DEBRIS
DS2

DS1 + Net
Final decay predicted
for 4th March 2019

RemoveDEBRIS dissemination/media interest

Conclusions

- Delighted with the progress made so far ! Thanks to all the partners
  - Important stepping for future missions
- Net & Harpoon capture successfully demonstrated as viable options for Active Debris Capture/Removal
- VBN experiment and DS-2 deployment successful.
- Analysis of downloaded data still in progress
- All objects' orbits decaying in line with predictions
- Very happy with extensive media coverage !
- On schedule for the next demonstrations
  - Deorbit sail deployment planned for March 2019
- Important project to raise awareness and propose possible technical solutions to help ensuring sustainability of the LEO environment

Thank you

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University of Surrey
2019

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- CSEM (Switzerland);
- Inria (France);
- Stellenbosch University (South Africa).

& ***Nanoracks***