RemoveDebris mission, from concept to orbit

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Officine orbitali, primo livello di espansione civile nello spazio

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Bologna, Italy

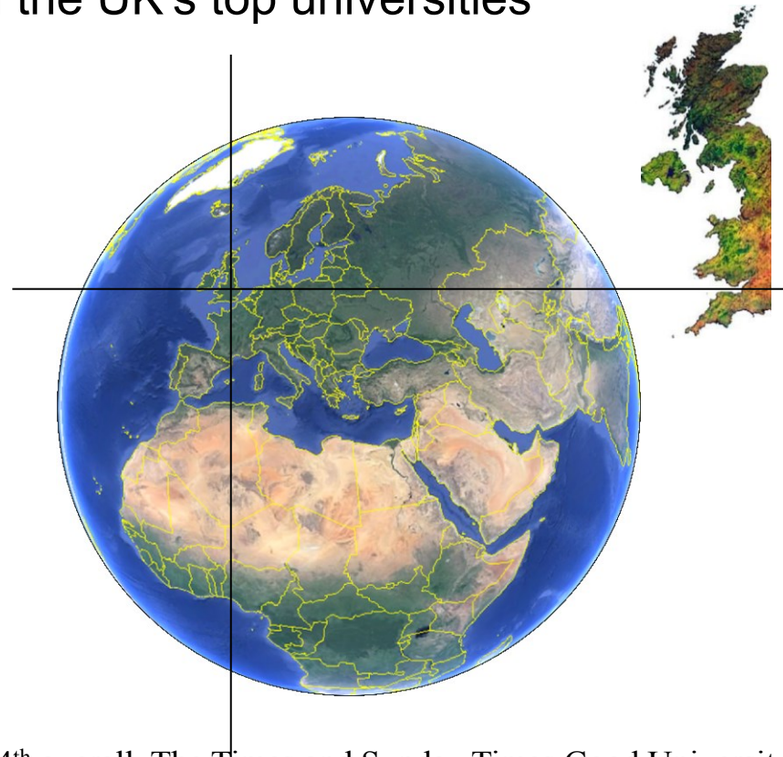
Project funded by the European Union Seventh Framework Programme (FP7/2007-2013) under grant agreement n° 607099

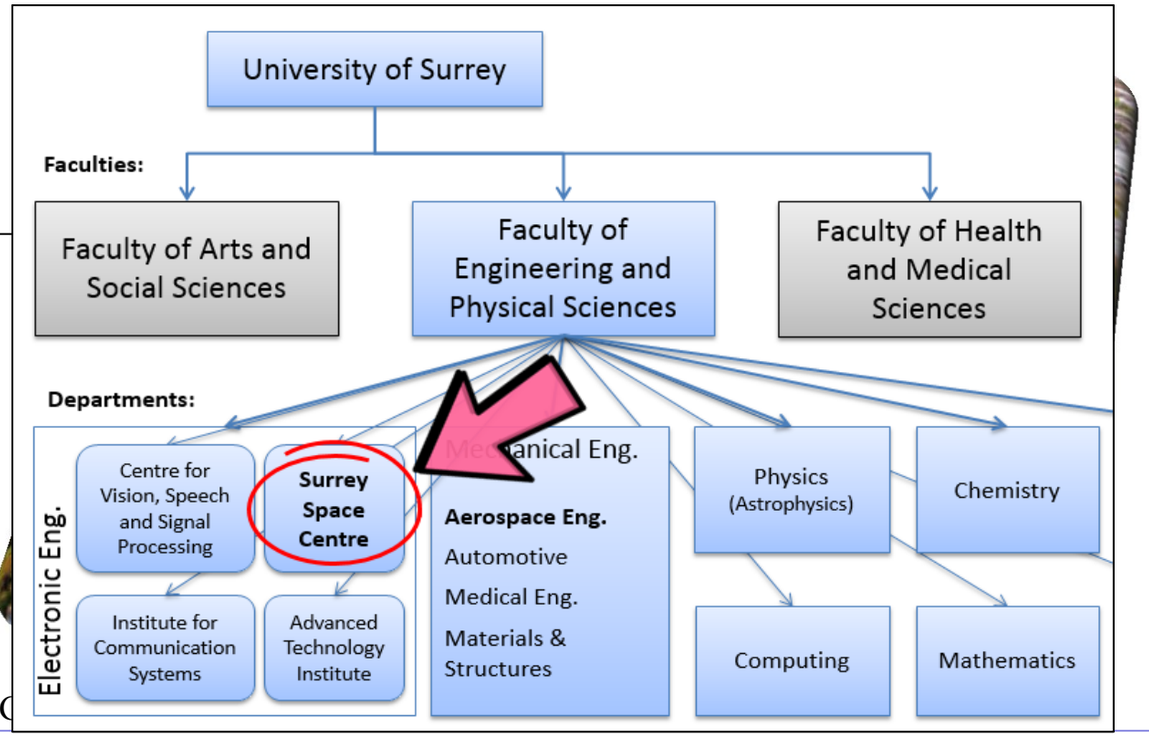
Introduction

Surrey Space Centre

University of Surrey

- Established in 1966 as an evolution of the Battersea Polytechnic Institute (1891)
- We are research-led institution pursuing advancing and disseminating knowledge
- ~3,000 members of staff and ~15,000 students
- One of the UK's top universities*





*The Guardian: 4th overall, The Times and Sunday Times Good University G

Surrey Space Centre

Formed in 1979 to pioneer research in microsatellites & low cost COFS technologies

Largest UK academic centre in Space Engineering, based in the Faculty of Engineering and Physical Sciences

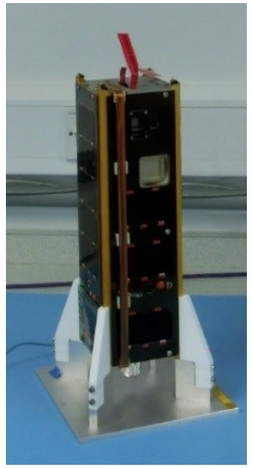
Unique in UK Academia in-house end-to-end capability for Space Missions & Satellite Applications

Strategic partnership with **Surrey Satellite Technology Ltd** (spun out from SSC in 1985)

Cutting Edge **Applied Research** and **Academic Education**

Hands on Space Engineering

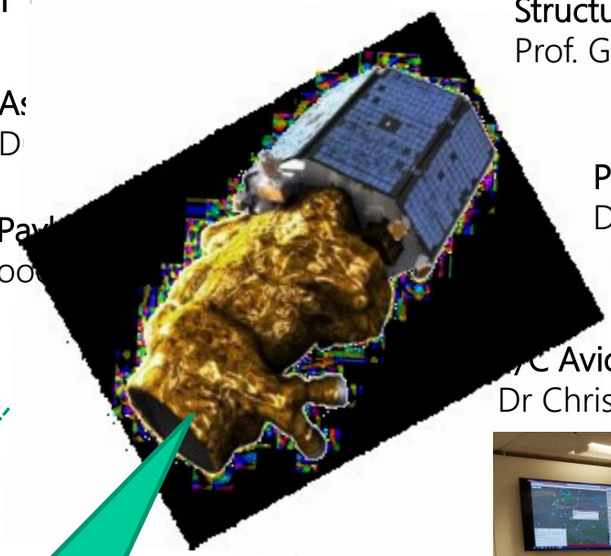
- ✓ Real Engineering Experience
- ✓ **Real Space Missions**



Microsatellites

Supported by
2 x Administration Staff
5 x Engineering Support Staff
45 x PhD Students
20 x Post-Doctoral Researchers

Structures & Mechanisms
Prof. G Aglietti (SSC Director)



Propulsion
Dr Andrea Lucca Fabris

Instrumentation & Pay
Prof. Craig Underwoo

C Avionics
Dr Chris Bridges

AI & Robotics
Prof Yang Gao

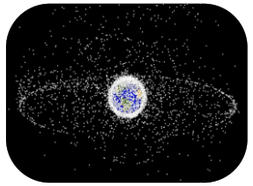
Robotics & Control
Dr Mini Saaj

Space Environment
Keith Ryden

Mission Operations
& Ground Station

Remote Sensing & Applications
Dr Raffaella Guida

Space Debris & RemoveDEBRIS mission



The problem & a possible solution
Video

Space Debris

60+ years of "human" activities in space have brought huge benefits for human kind, but we left behind a certain amount of.... junk (space debris..)

Situation in 2017 (Ref. ESA):

N of rocket launches since 1957: **~5250**

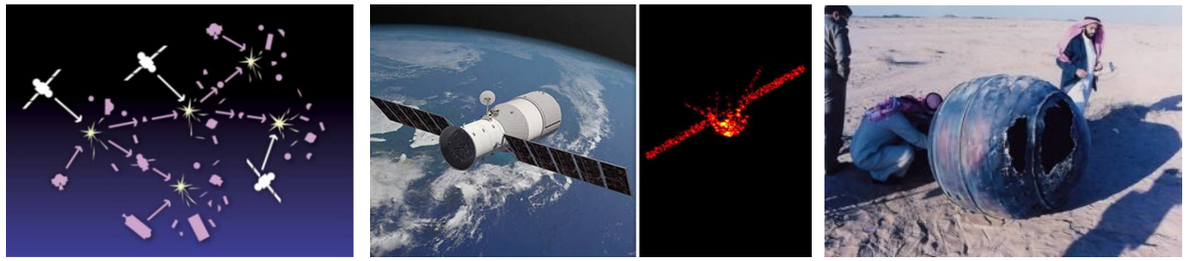
N of satellites placed into Earth orbit: **~ 7500**

N of these still in space: **~ 4300** (still functioning: **~ 1200**)

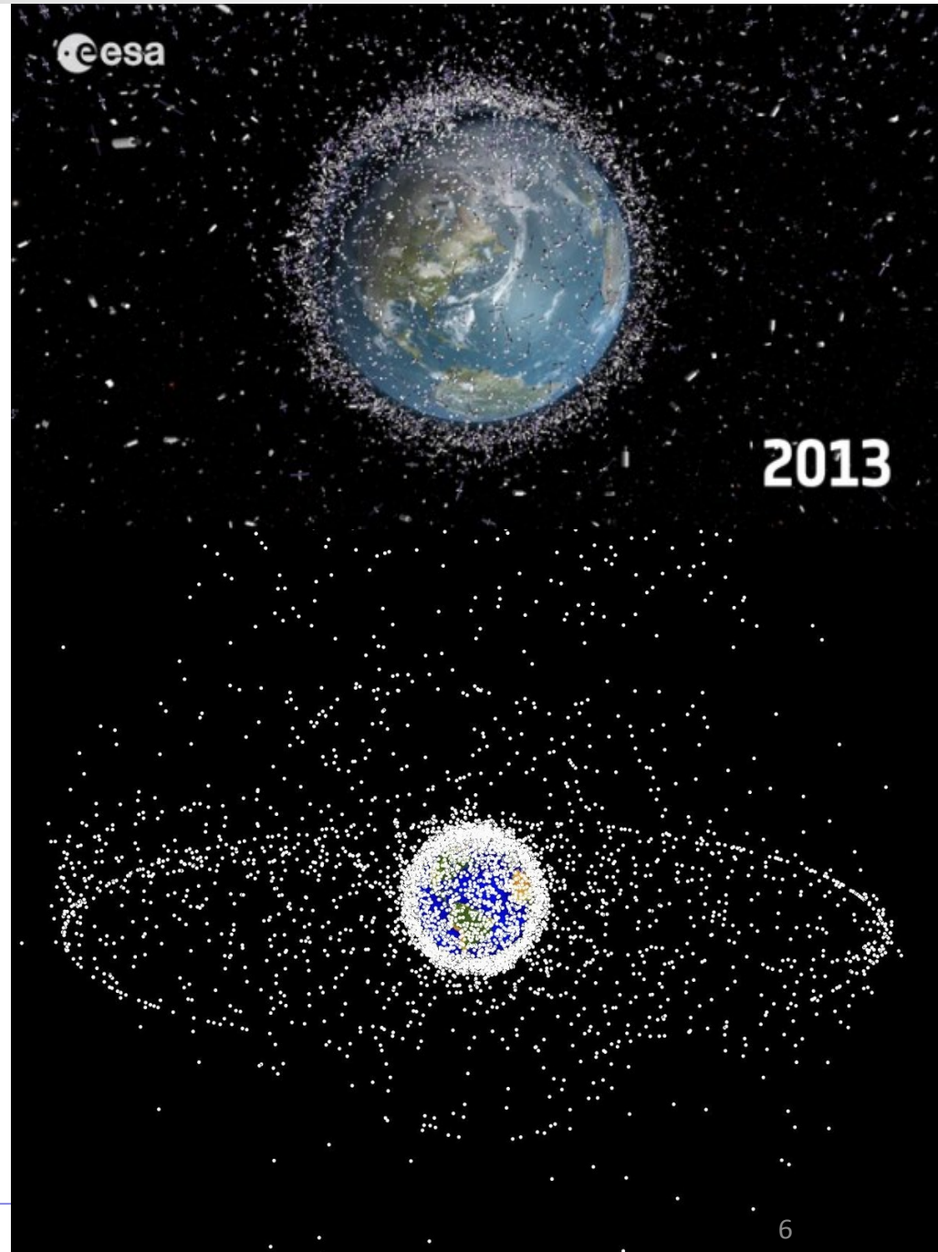
N of debris tracked by the US Space Surveillance Network : **~ 23 000**

Total mass of all space objects in Earth orbit: **~7500 tons**

- **The problem is growing** !
  - New large constellations, OneWeb like (~900 satellites of 150kg)
  - Long duration of objects in orbit:
    - Hubble (600km -> 10 years), Spot (800km -> 200 years !)
- **Fear events**
  - Kessler syndrome -> snow ball effects with loss of all satellites
  - Parts of big debris (>1 tons) impacting ground

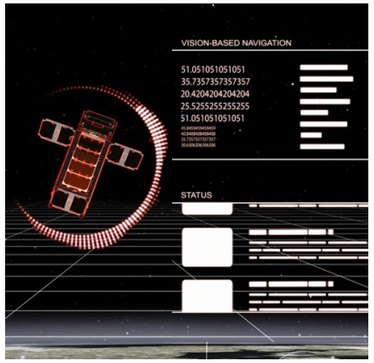


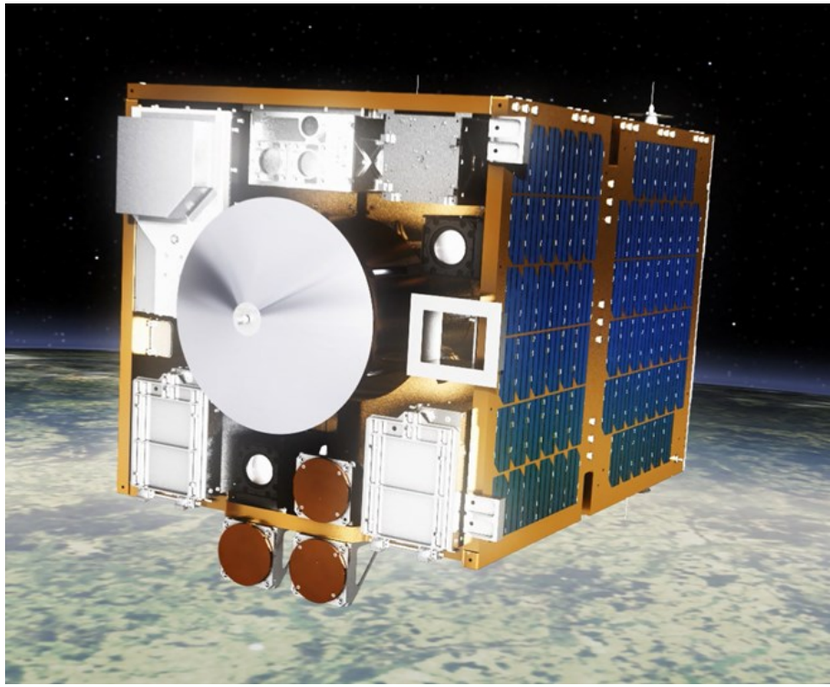
- Possible solution (Prof Liou, NASA): Remove 5/10 large debris/years to stabilize the number of debris (>10cm) in LEO

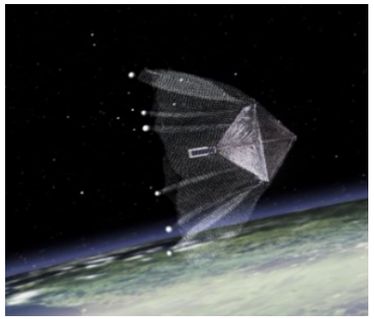


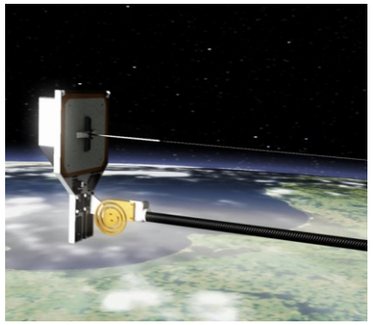
The RemoveDEBRIS mission

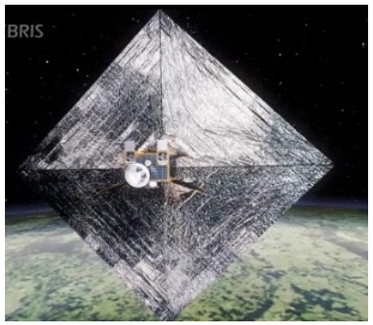
- **Ambitious**
  - First Active Debris Removal demonstration missions of technologies used to
    - ✓ observe (LiDAR camera),
    - ✓ capture (net & harpoon) and
    - ✓ destroy (dragsail) space debris
  - Complete implementation from concept design to in orbit demonstration!
- **High profile project**
  - Space mission significant for the whole space community & society
  - 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

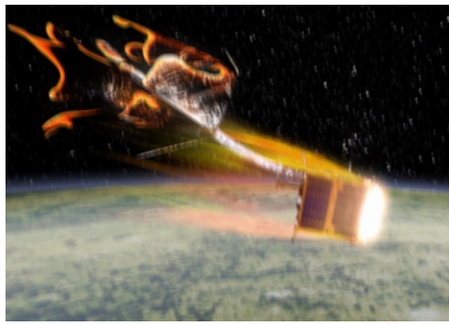


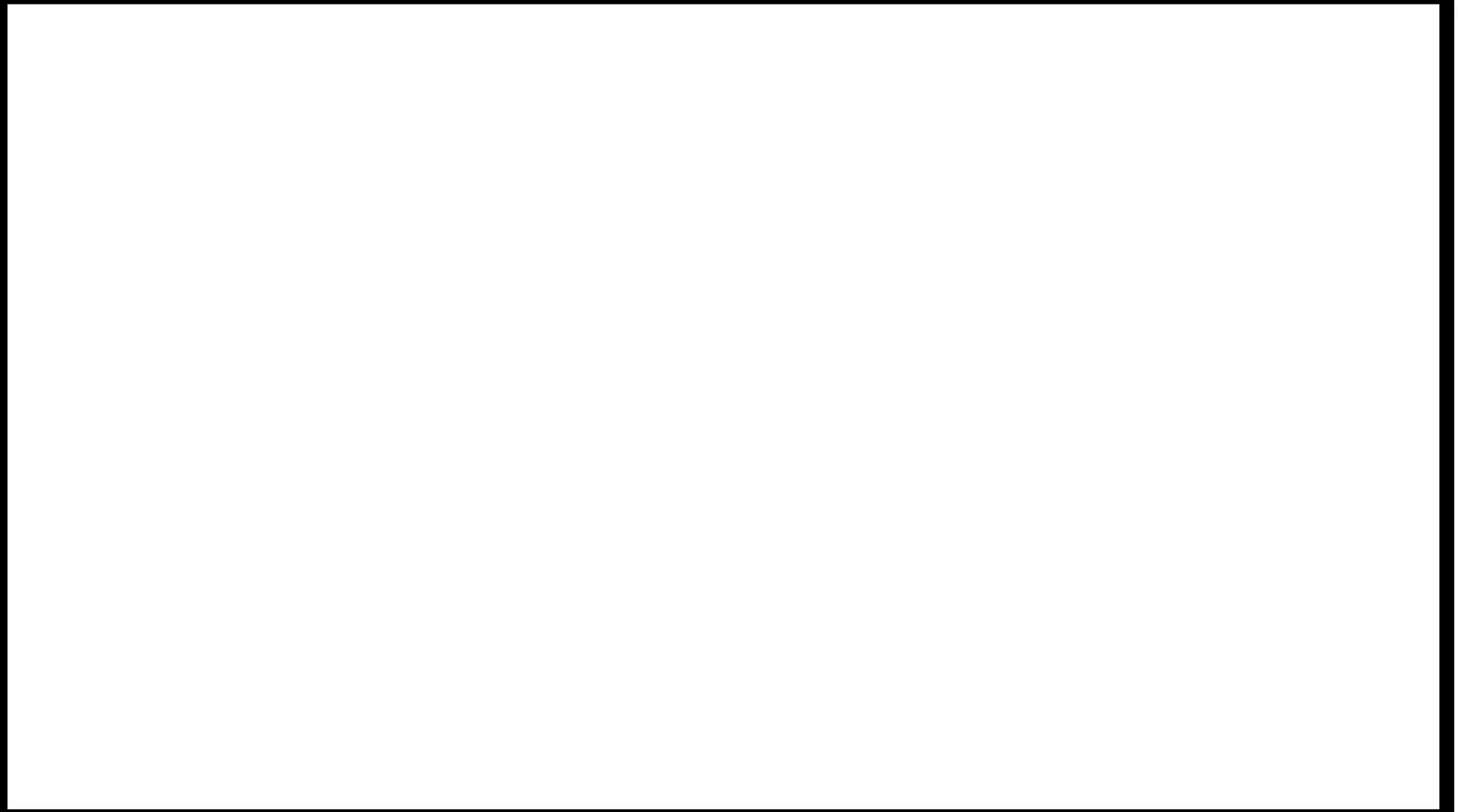




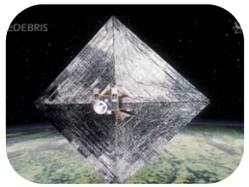








University of Surrey



SSC's contribution to the mission

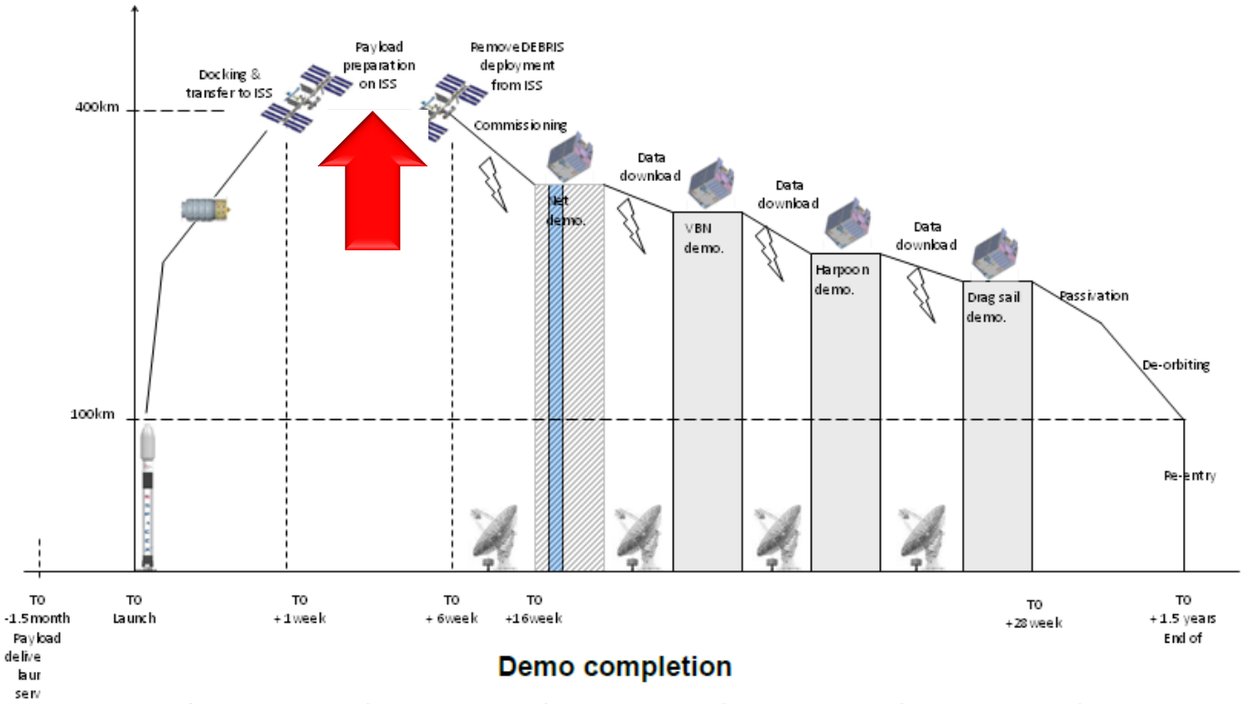
Mission overview & SSC's hardware

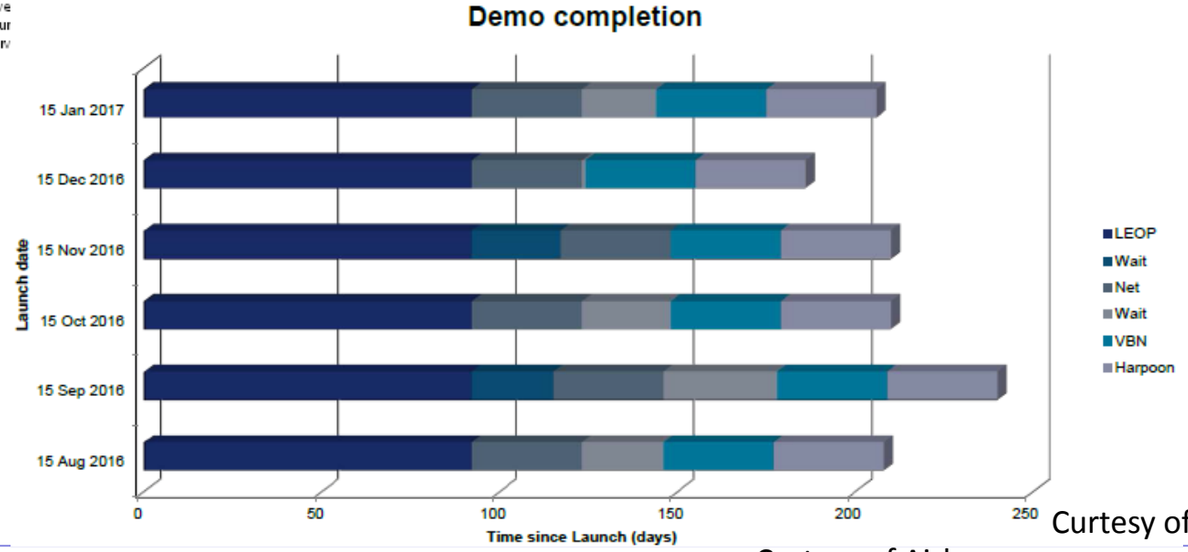
Mission overview

- **Orbital parameter**
  - ISS orbit: altitude [400,430km] 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 > 6 months**
  - Launch + ISS ~6 weeks
  - LEOP + commissioning ~8 weeks
  - On orbit demonstrations ~12 weeks
  - Waiting phases up to ~7 weeks max for having correct lightning conditions (depends on launch date)





Curtesy of Airbus

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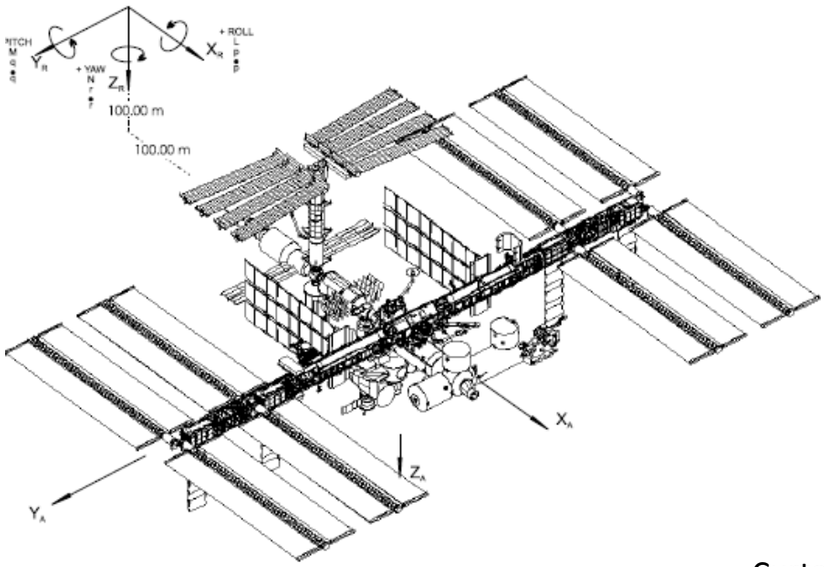
Key design drivers

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 (to get license from UKSA):**
  - Avoid collision risks between platform & targets (fail safe trajectory)
  - All parts must be detectable from ground (no debris < 10cm^2) and re-enter in less than 25 years
- **Relative to ISS environment (to get authorization from Nasa)**
  - Key requirements relative to interface with ISS:
    - Mass < 100kg regarding KABER and SPDM systems
    - Volume compatible of the JEM airlock chamber
  - Key requirements relative to ISS safety:
    - No battery charging done onboard ISS
    - 3 electrical inhibits + 1 mechanical barrier for deployable items (Net, Harpoon, Drag sail and Deployers)
    - Platform "OFF" for 30mn 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



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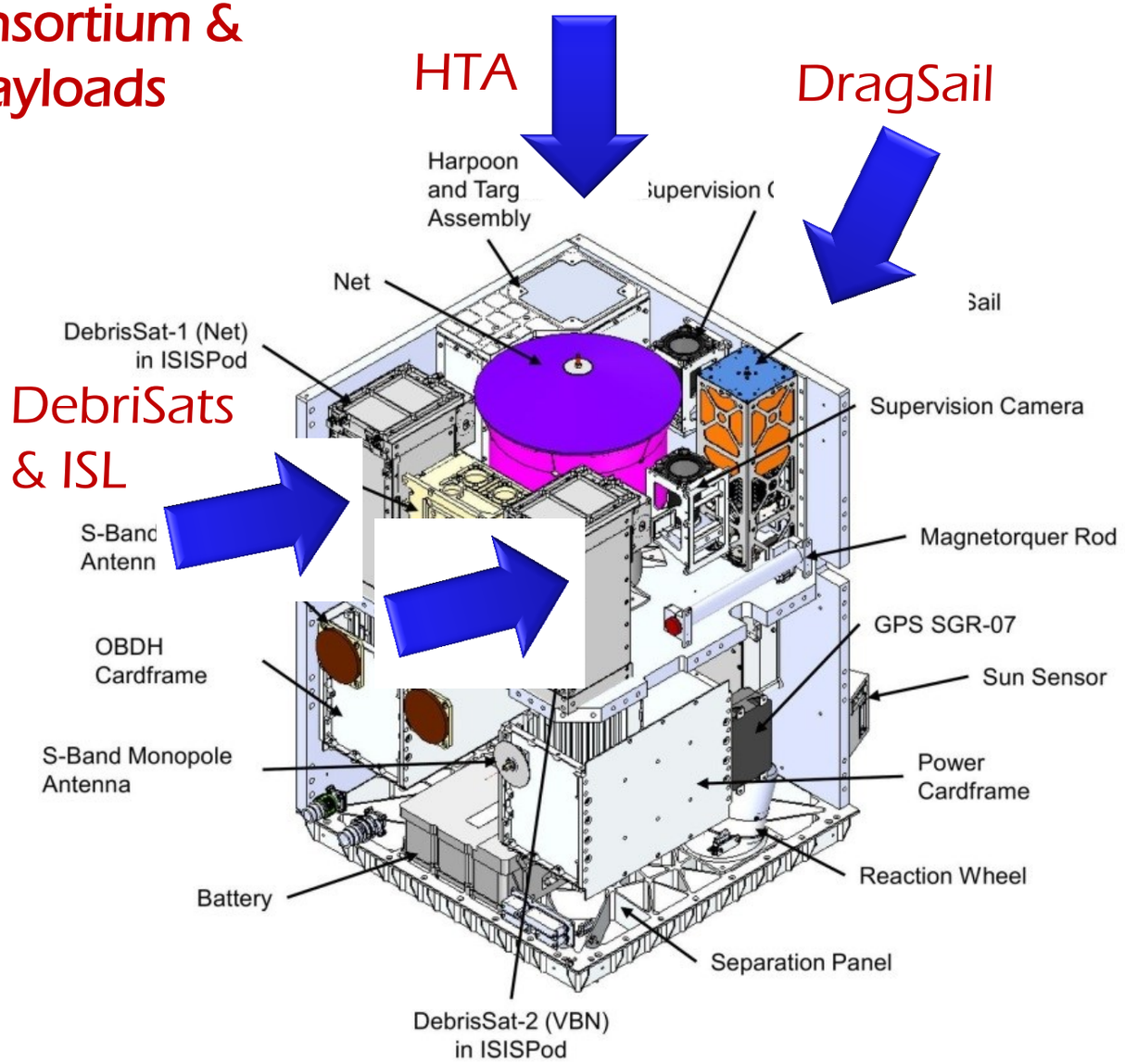
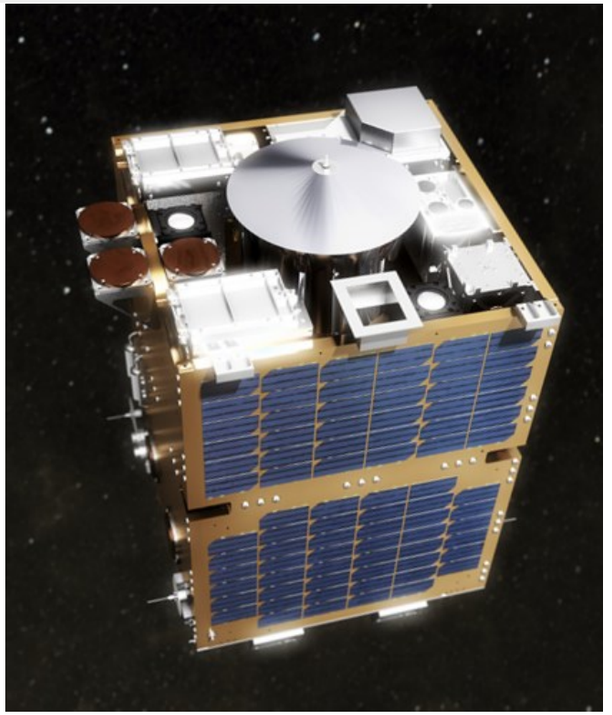
RemoveDEBRIS

SSC leads the consortium & provides some payloads

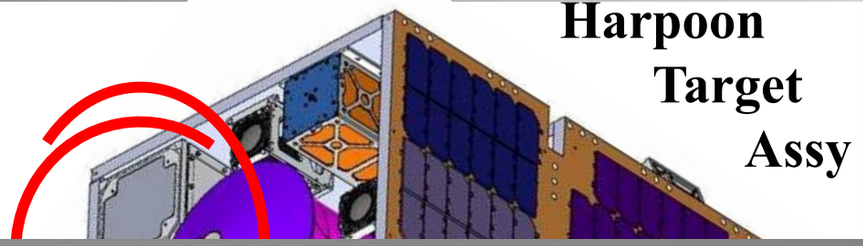




The RemoveDEBRIS Project Partners

	Partner	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

RemoveDEBRIS HTA



Harpoon
Target
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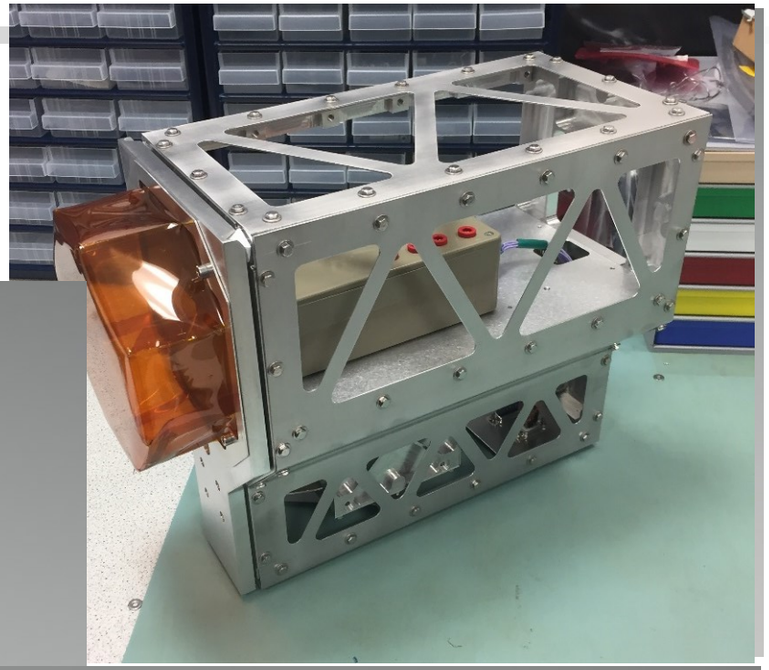

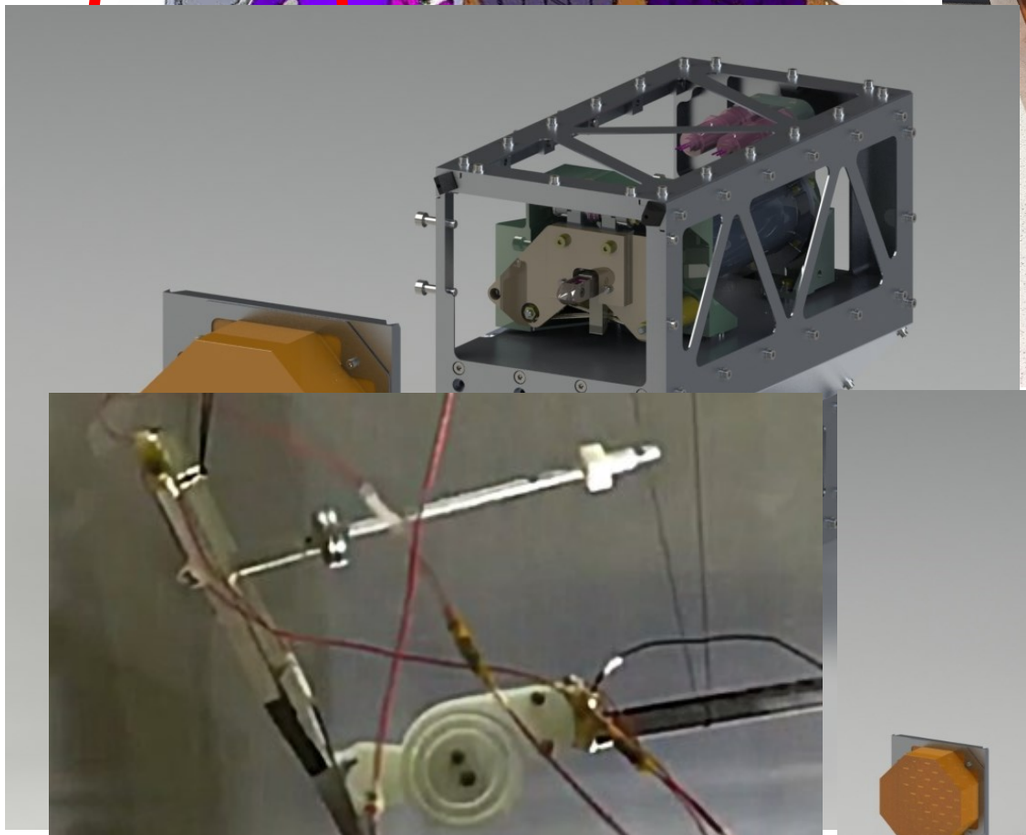

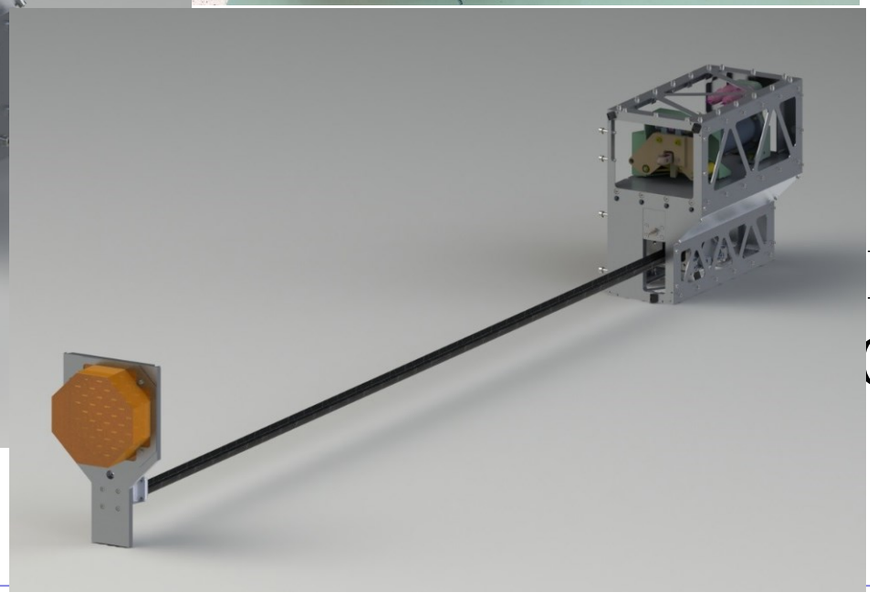

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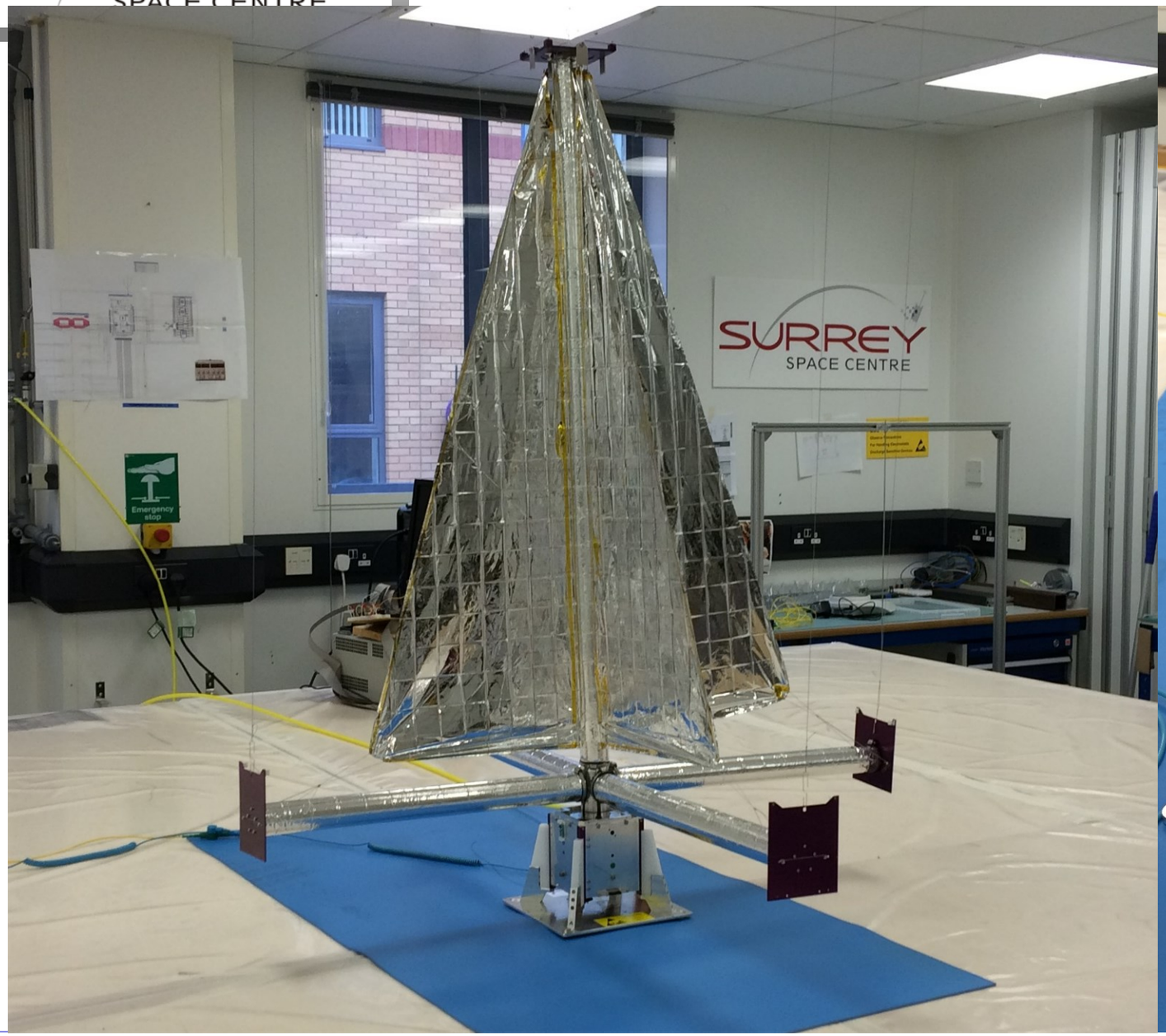
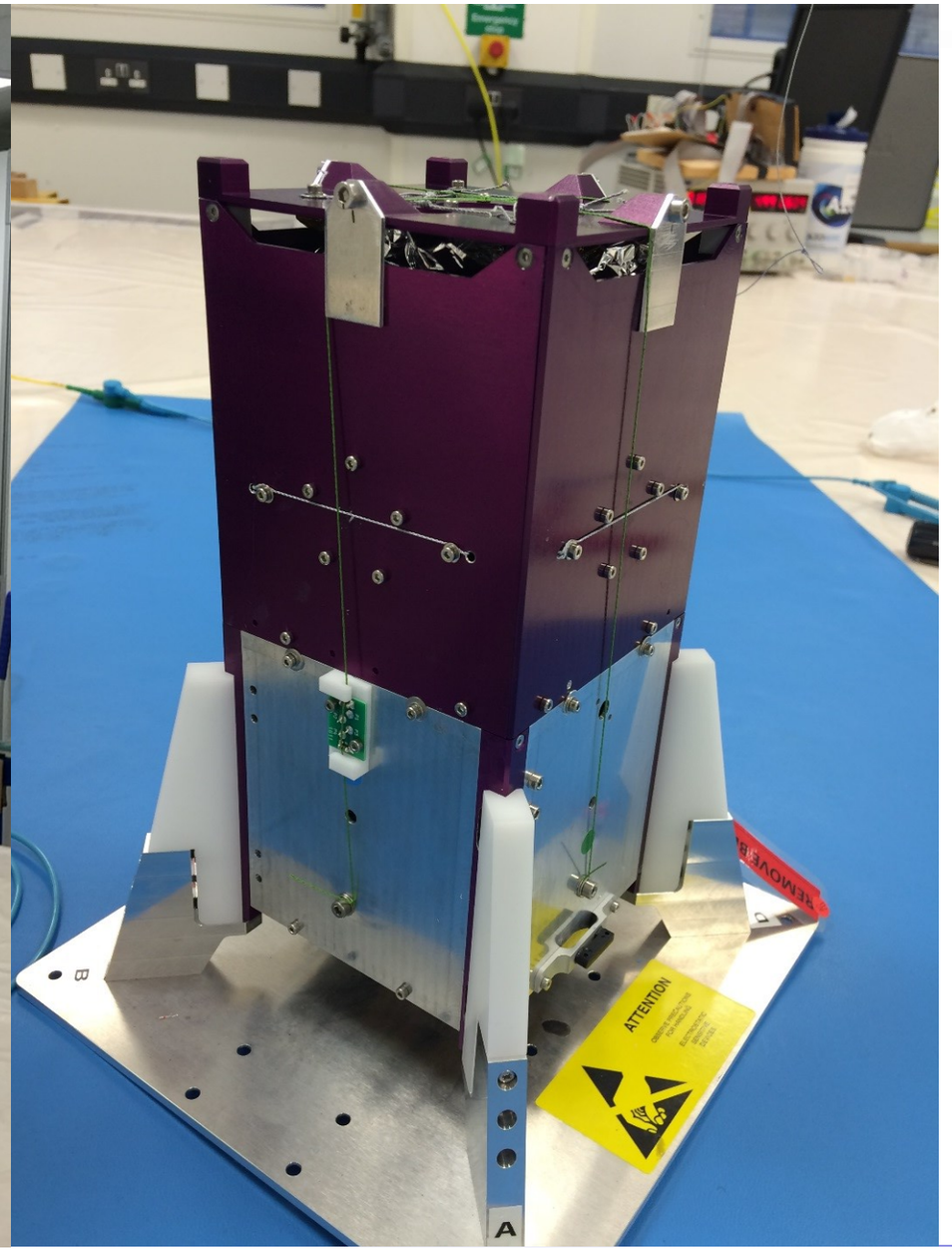
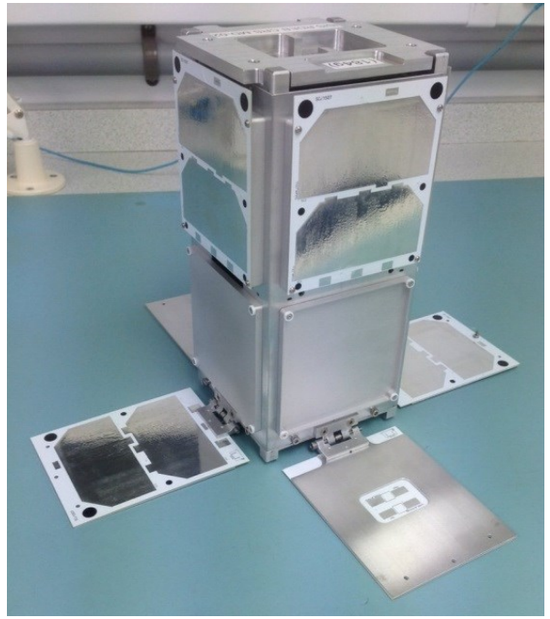
RemoveDEBRIS DS1

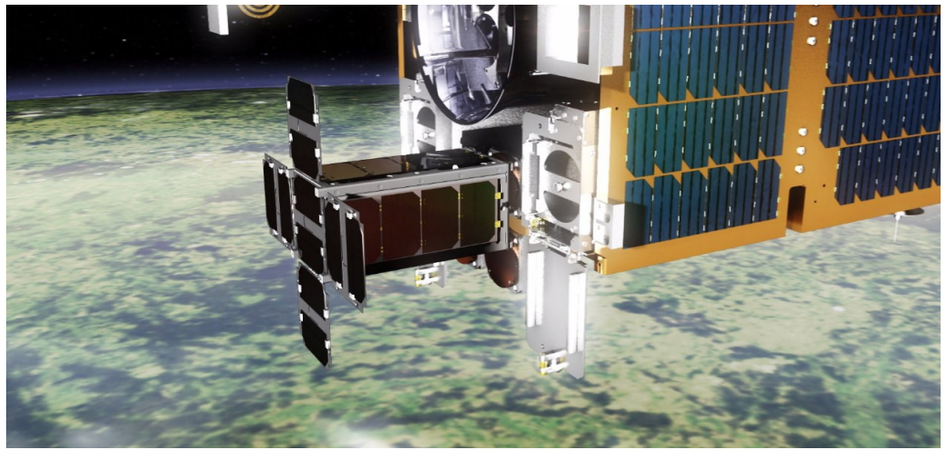


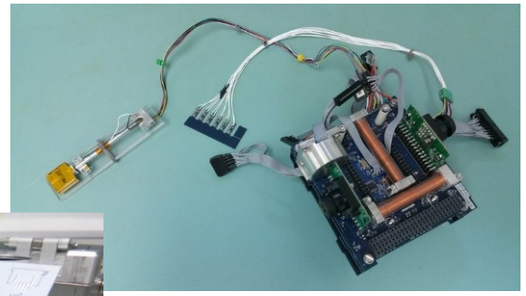


RemoveDEBRIS DS2

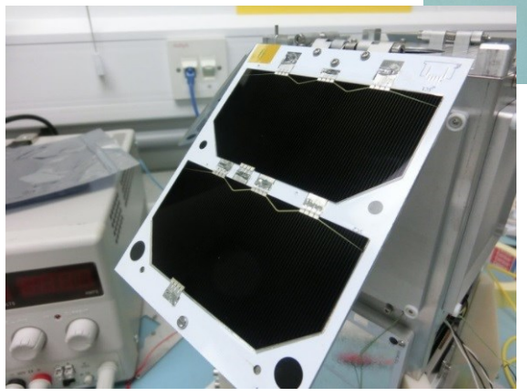
- DSAT-2: Fully active – VBN Experiment (OBC + Power + AOCS + ISL)





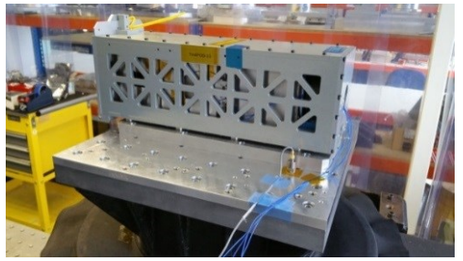


Structure and Solar Panels



Avionics Core

Vibe Testing



RemoveDEBRIS DragSail

Drag sail dem

- Inflatable
- Deployme
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- No need t
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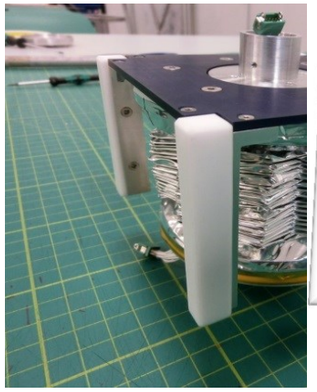
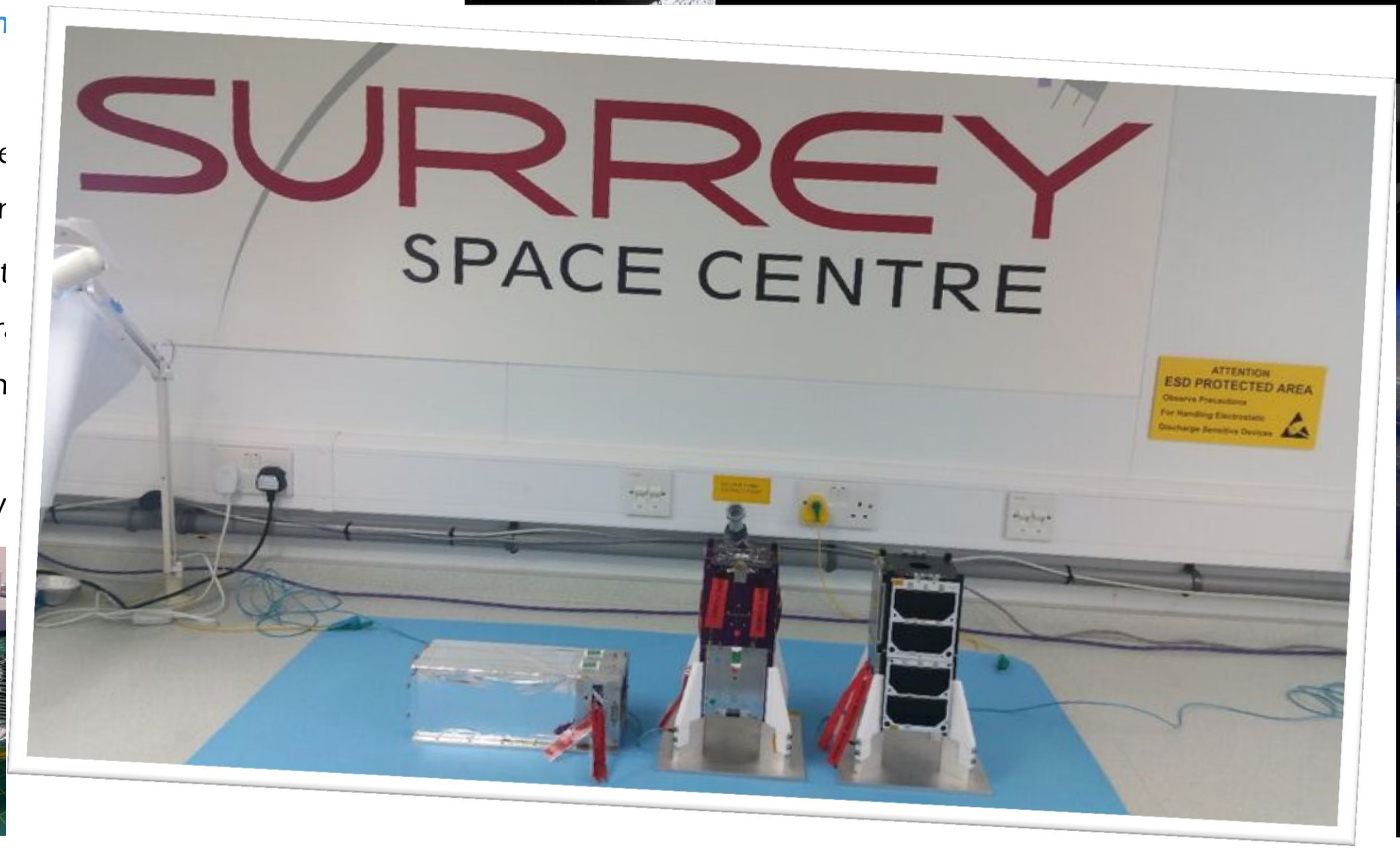
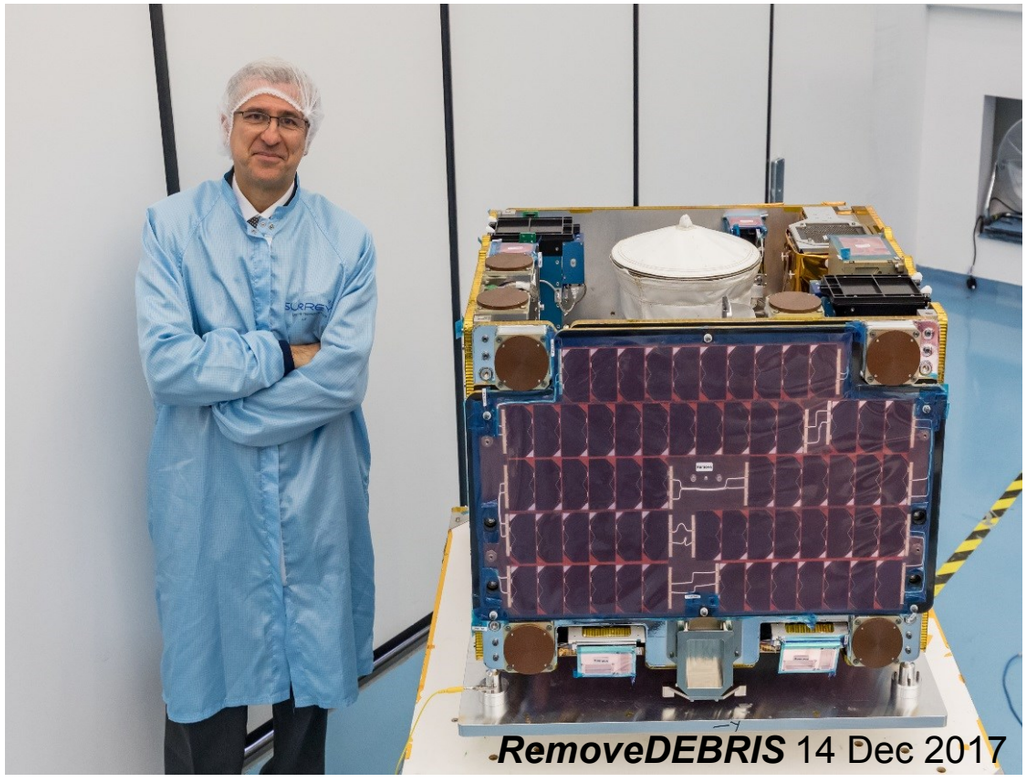
- Based on
  payload v

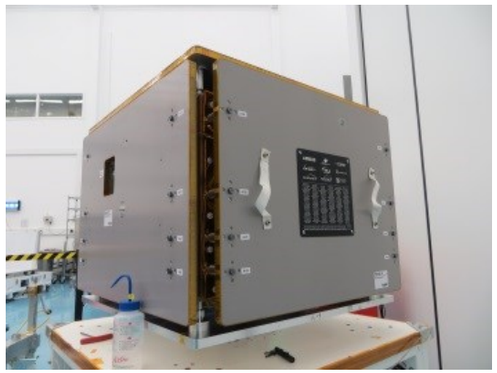




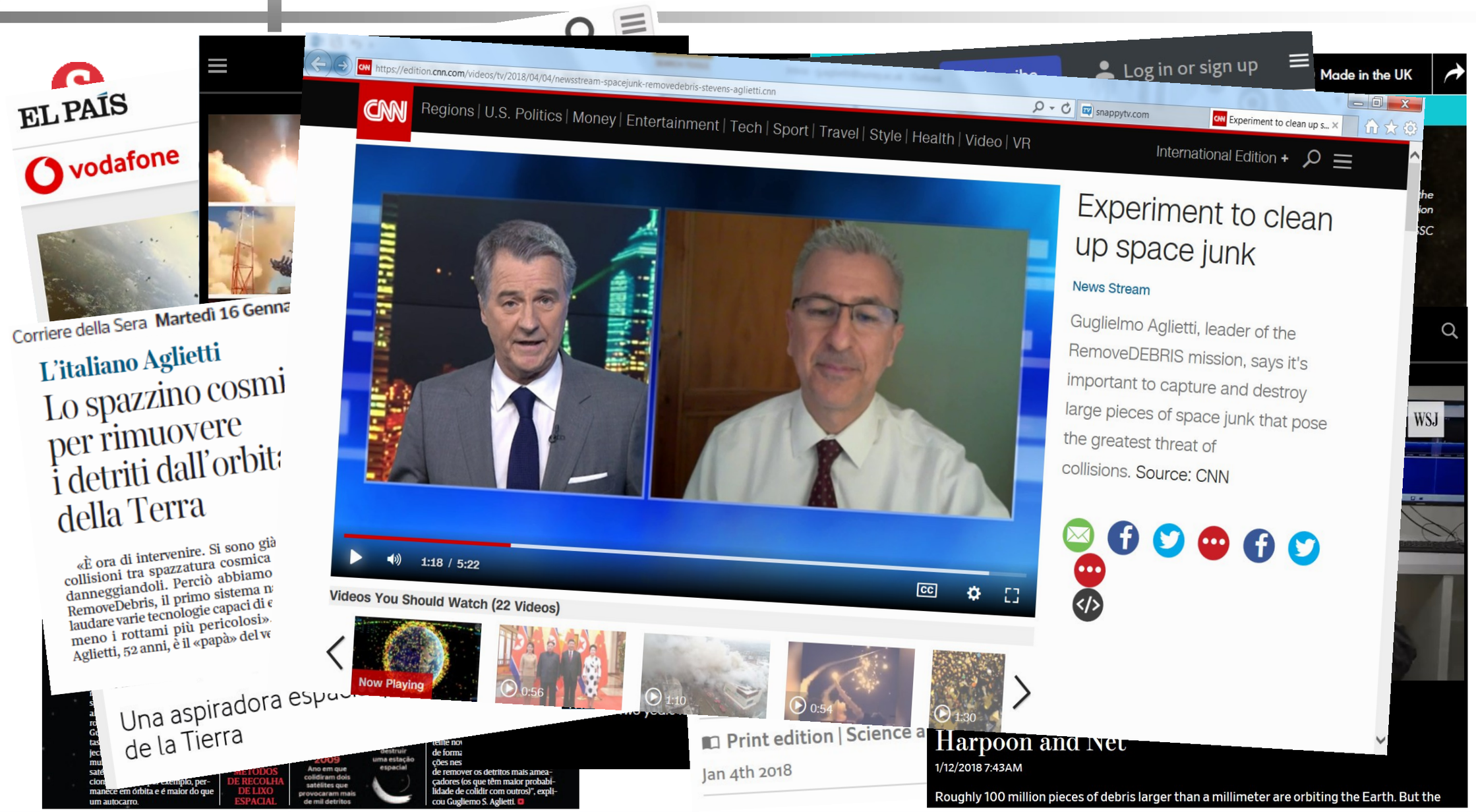
Packaged Inflatable; Combined Inflatable and Deployable Boom Mechanism

RemoveDEBRIS from Guildford to Space





RemoveDEBRIS dissemination



Thank you

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University of Surrey
2018

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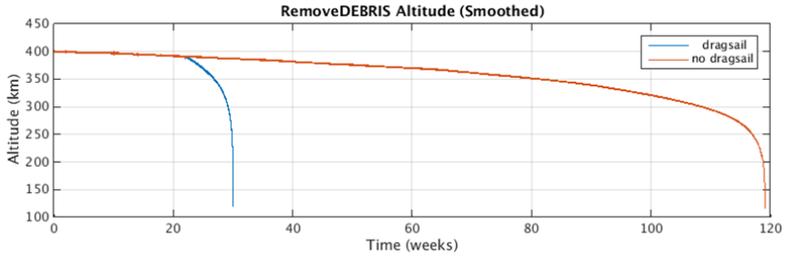
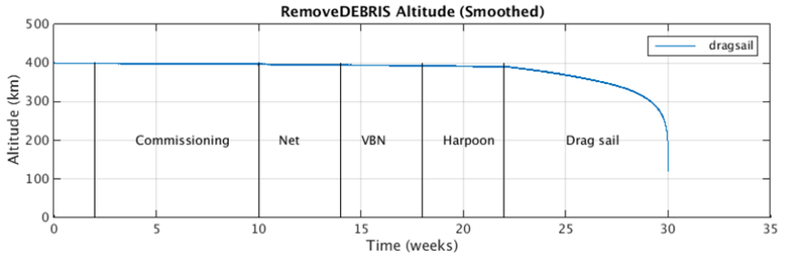
European Commission Seventh Framework Programme (FP7/2007-2013) under grant agreement n° 607099
The members of the RemoveDebris consortium:

- SSTL (UK)
- Airbus Defence and Space (Germany, UK, France/Toulouse),
- Airbus Safran Launchers (France);
- ISIS (Netherlands);
- CSEM (Switzerland);
- Inria (France);
- Stellenbosch University (South Africa).

Mission analyses (1/2)

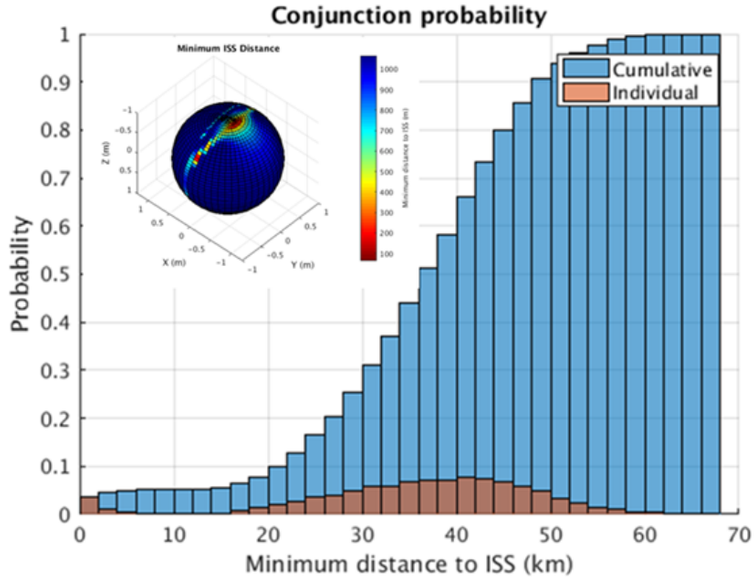
- Decay duration
  - STELA tool used, cross checked with Nasa
  - Specification: Orbit decay < 25 year
    - Sensitive to solar activity, altitude, BN (ballistic number)
    - Decay driven by Platform BN ~140kg/m2 (worst case compared to CubeSat, Net, Harpoon)
  - No issue with regard to decay duration
    - 2.5 years decay without drag sail, 8 weeks after drag sail deployment
    - More than1.5 year margin when deployed from ISS at 400km





- Collision risks with ISS
  - Net collision with ISS feared by Nasa
    - Net ejected at 1.9m/s -> orbit increase ~6.7km (worst case)
    - Risk of collision until 16 weeks after ISS releasing
  - MtC analyses spread in all possible Net directions (sphere) & any time between ISS ejection and 16 weeks
    - 15% probability to come back at a distance <25km around ISS after an undetermined period of time
    - But: probability higher at beginning, and unexpected Net deployment quasi nil !

➔ Accepted by Nasa if Net demonstration not performed before 8 weeks from ISS deployment



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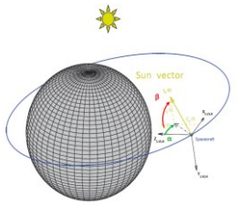
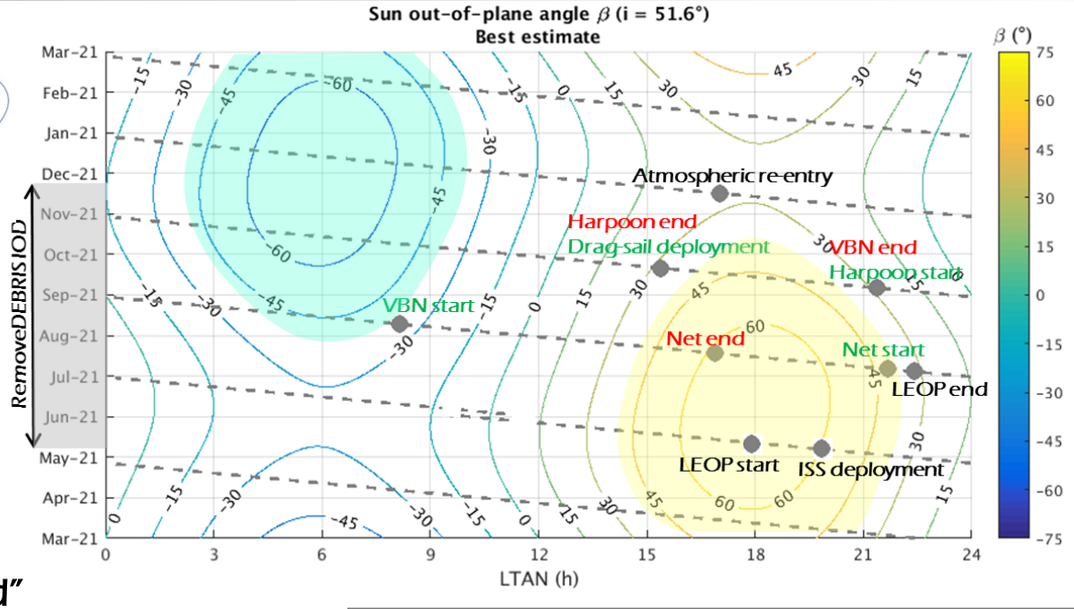
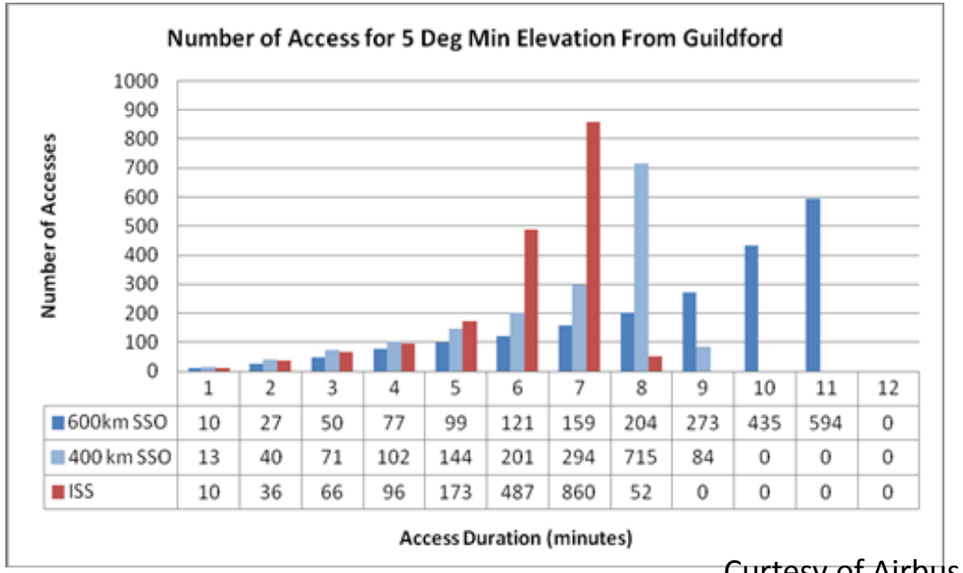
Mission analyses (2/2)

- Lighting conditions
  - Key parameter for supervision cameras for demonstrations success assessment
    - Sun – Target – Platform < 45°
  - Lighting parameters
    - Solar angle (α, β) variations function of orbit & time
    - LTAN not constant (orbit drift ~6° / day) on ISS orbit
  - Deployment directions = best compromise "Lightning" vs "Collision risk" vs "Back ground"
    - Net: AoA +100°, BA +90° -> opportunities for β >40°
    - VBN: AoA +110°, BA +100° -> opportunities for β =40° +/-5°
    - HTA: AoA -90° -> opportunities for β =[20, 45°]

  ➔ Opportunities with correct lighting conditions <u>not</u> all time !







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600km SSO	10	27	50	77	99	121	159	204	273	435	594	0
400 km SSO	13	40	71	102	144	201	294	715	84	0	0	0
ISS	10	36	66	96	173	487	860	52	0	0	0	0

Curtesy of Airbus

- Power & Communication budgets
  - Power budget driven by β angle & eclipses
  - Communication budget (elevation > 5°)
    - Max access duration 7.11mn, 4 to 6 times
    - Average access time per day 27.55mn (0.45Gbyte/days)