Drag-Augmentation System Modules for Small Satellites

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Overview

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- ✓ Background to Cranfield Drag Augmentation Systems
- ✓ Icarus 1 on TechDemoSat-1
- ✓ Icarus 3 on CARBONITE-1
- ✓ DOM on ESEO
- ✓ Deployment monitoring
- ✓ Next steps – aims of the Building Block activity

Background: Cranfield Debris Mitigation Studies

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Debris mitigation and remediation technologies have been studied at Cranfield for many years

- Particular expertise developed in “air brake” sails for satellites

Increases drag ➔ Shortens life

Satellite burns up in the atmosphere

- For small satellites and orbits up to ~800 km
- Debris hitting the thin sail causes no cascade: reduces “debris-producing” area-time product

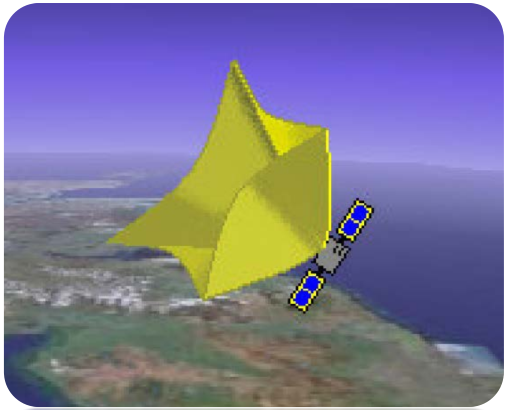
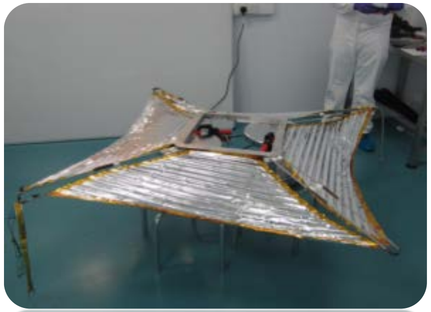


Image: P. Harkness

Image: SSTL

Cranfield Drag Augmentation Systems

- 2 drag augmentation design concepts:
  - "**Icarus**" – frame-based configuration, fits around satellite external panel, 2 units currently in orbit



  - De-Orbit Mechanism (**DOM**) – compact, box configuration, 1 unit currently in production for 2017 launch

Drag Augmentation Systems
Target Classes

DAS Design Approach

- Low-cost
- Simple (both design and interfaces to satellite)
- Safe
- Reliable (but safety takes priority)
- Mass ≤ propellant mass to deorbit
- Minimal impact on host satellite
- Easily testable in 1-g
- No additional debris production
- Tolerates some failures/degradation of host satellite

Icarus-1 on TechDemosat-1

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TechDemoSat-1:

- UK satellite funded by TSB and RDA
- Payloads provided by UK groups with technology needing heritage
- Cranfield: demonstrate technology + help gain launch licence

Initial Cranfield concept: Small module able to deploy autonomously

BUT, too risky:

- Operator trust of the unit
- Tight timescale, low cost

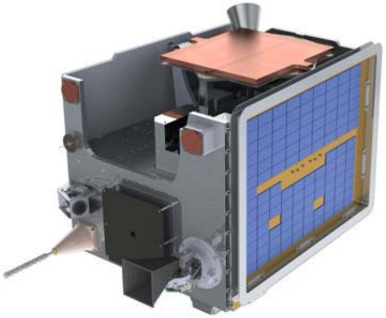
Concept finally delivered:

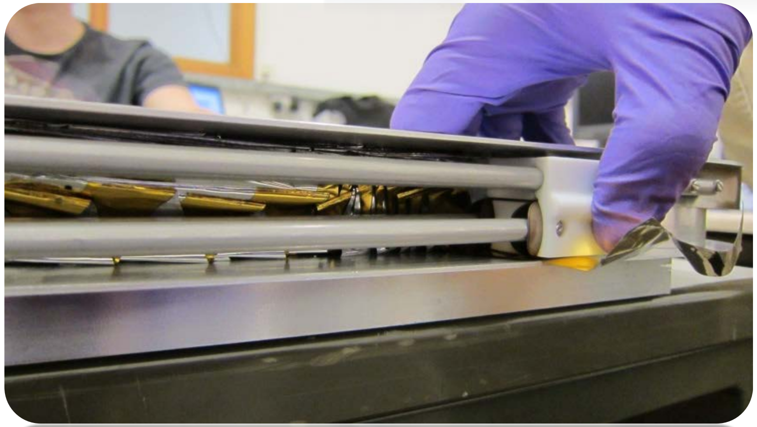
- “Simple”, reliable mechanism, stowed around s/c panel
- Launched July 2014

Images:
Soyuz launch - NASA,
TDS-1 - SSTL

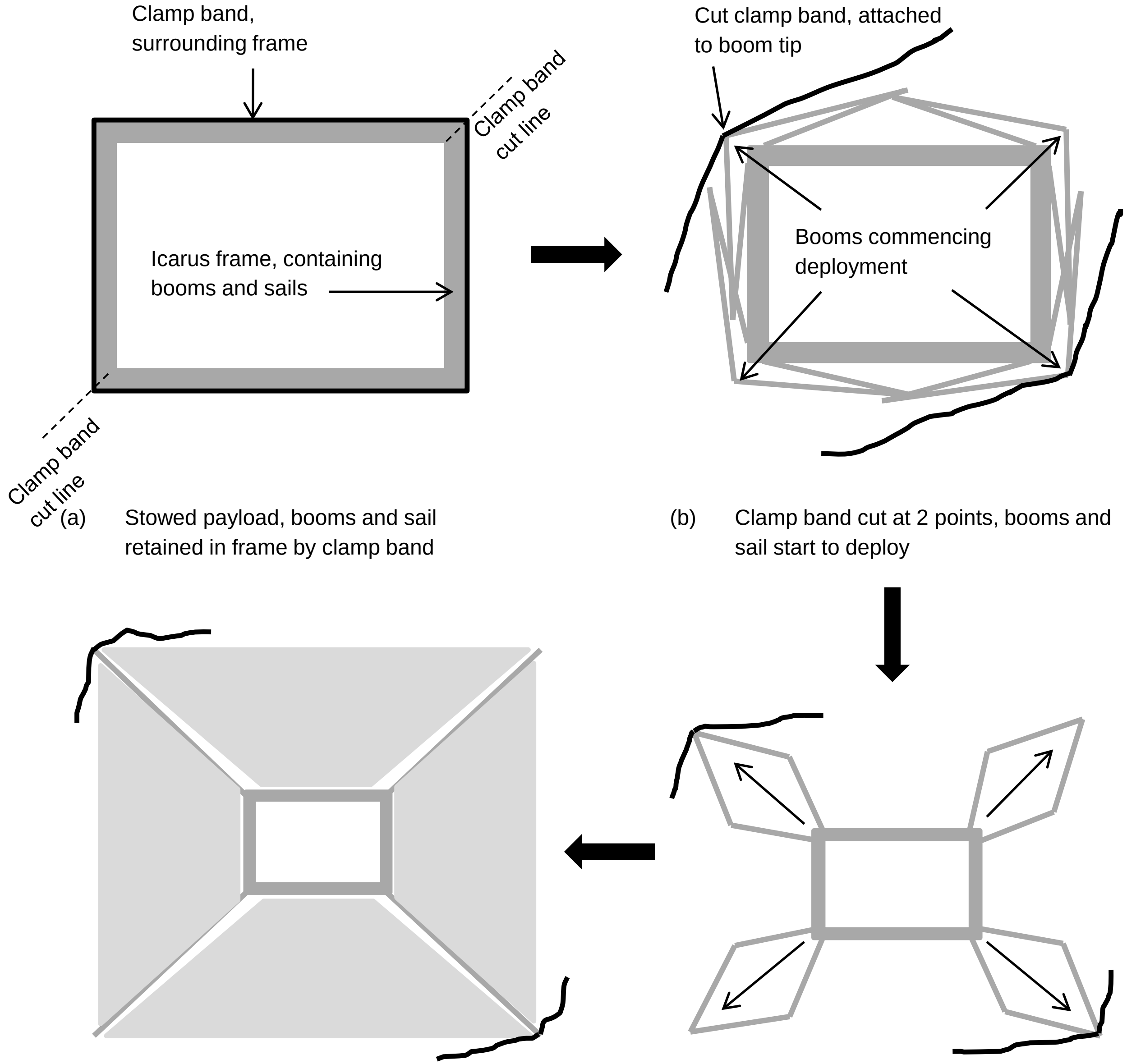
Icarus-1 on TechDemoSat-1: Design Concept

- Lightweight aluminium booms with CuBe tape spring hinges
- Kapton sails
- Booms & sails folded into aluminium frame
- Frame fits around satellite side panel
- Deployment via passive release of stored energy in tape springs
- Booms/sails retained by flexible clamp-band until release
- Simple power connection to satellite (1A current pulse for ~10ms)





Icarus-1: Stowed & Deployed Configuration



(a) Stowed payload, booms and sail retained in frame by clamp band

(b) Clamp band cut at 2 points, booms and sail start to deploy

(c) Booms and sails continue to deploy (sails not shown)

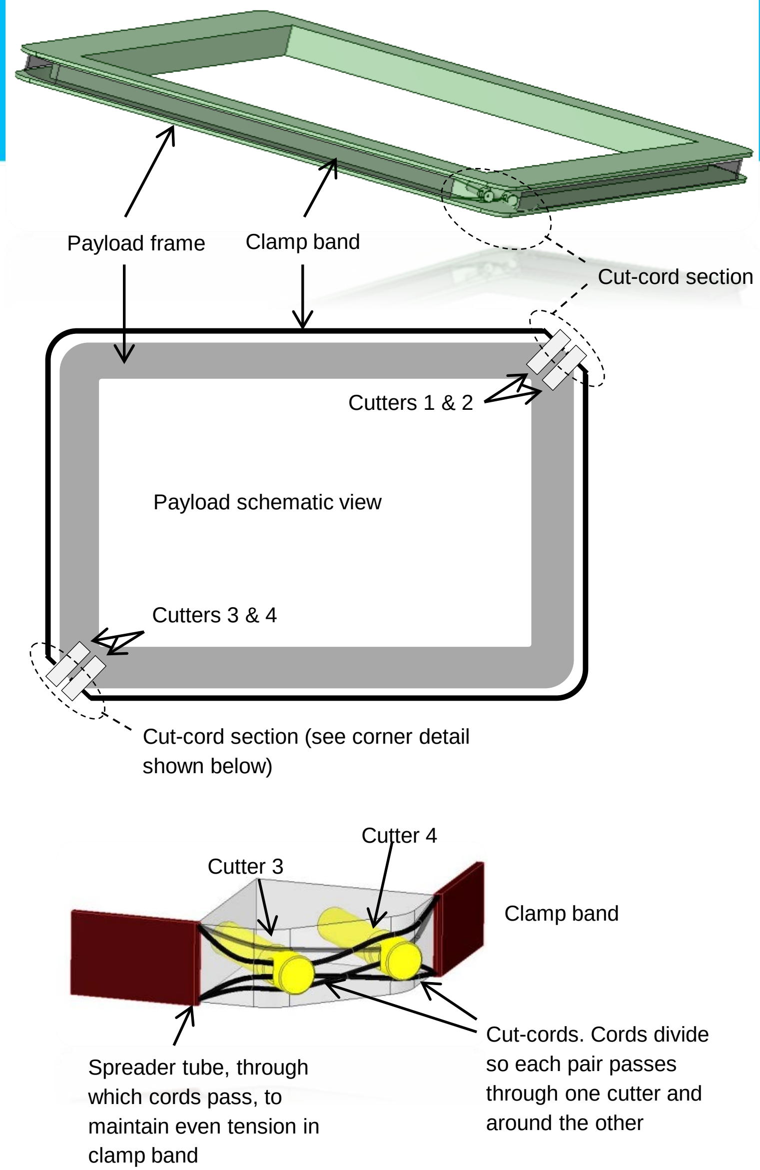
(d) Booms and sails fully deployed. Clamp band sections remain tethered to boom tips

Icarus-1 on TechDemoSat-1: Parts & Materials

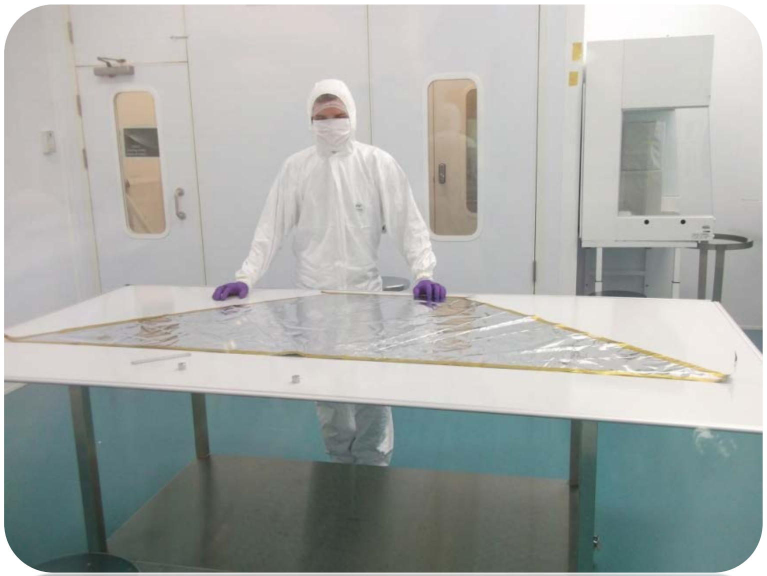
- Machined aluminium – simple, low-cost
- CuBe – more difficult to work with but good performance as tape spring + space heritage
- Teflon spacers – avoid metal-metal contact
- Kevlar – high strength & compliancy for clamp-band, needs shielding from UV
- Kapton – Vapour-Deposited Aluminium coating provides protection from atox
- CYPRES™ EED cutters used for deployment – COTS parts from parachute industry, v high reliability, produce no debris

Icarus-1 on TechDemoSat-1: Hold & Release Mechanism

- Emphasis on safety: avoid premature deployment
- Mechanical & electrical ARM+FIRE
- 3-failures-tolerant
- With minor redesign, can change emphasis to reliability: use paired cutters for redundancy instead
  - Customer decision
- Mechanical testing at component & system level
- Characterisation tests for cutters (thermal, vacuum, no-fire current…)



Icarus-1: Sail Design



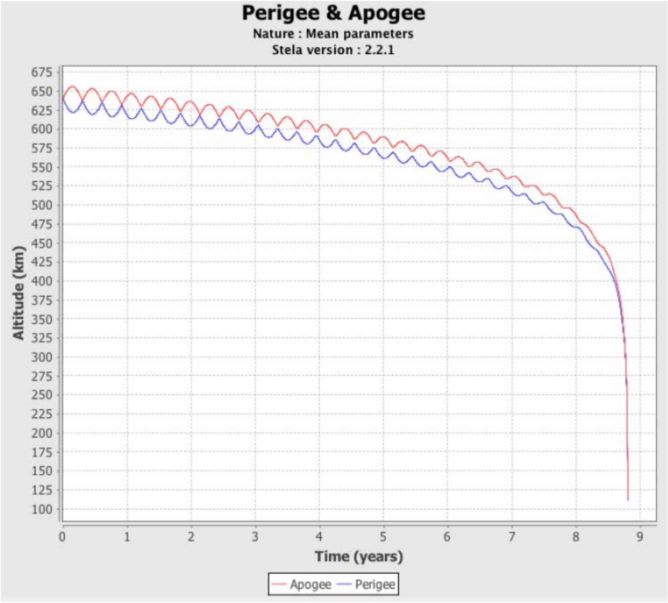
- 25 µm VDA perforated Kapton
- Modified Miura-Ori biomimetic fold pattern

++ Constant deployment force

-- Very complex: lengthy folding & re-stowing process

Icarus-1: Impact on Host Satellite

- "Picture frame" design fits around panel
  - allows equipment mounting/protrusions on the panel surface
  - also maximises useful sail area
- Attitude control not required, only ability to receive commands and provide small amount of power
- Low frame profile minimises shadowing of panel
  - allows solar cell mounting on panel
- Very simple electrical connection
  - 1 A for ~10 ms to fire each cutter pair
- No data connections
- Mass = 3.5 kg for ~5 m^2 sail area
- Allows expected de-orbit in < 9 years



Icarus-3 on Carbonite-1

- **CARBONITE-1**: SSTL technology demonstration satellite
- Launched 10 July 2015
- 80 kg LEO satellite
- Icarus-3 designed, tested and qualified for flight late 2014
- 3 months from go ahead to delivery
- Based on **Icarus-1** for **TDS-1** mission:
  - Trapezoidal Kapton sails
  - Aluminium box-frame structure
  - 2.3 kg, ~2 m^2 drag area

Icarus-3 Configuration

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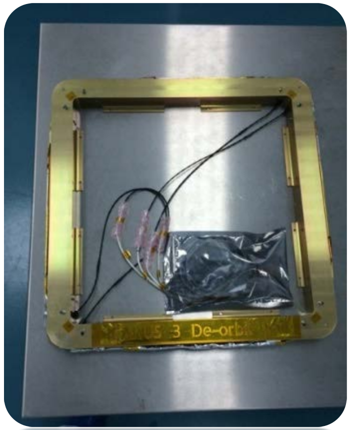
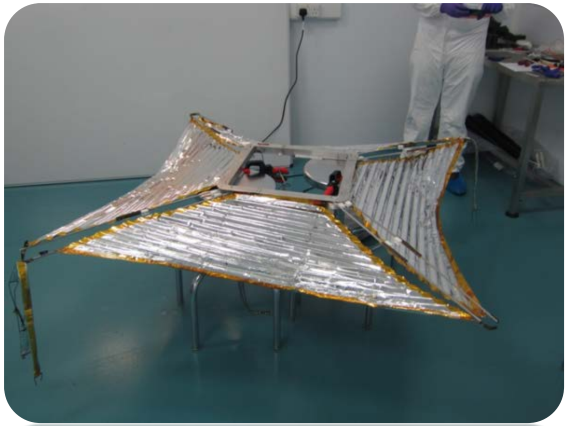


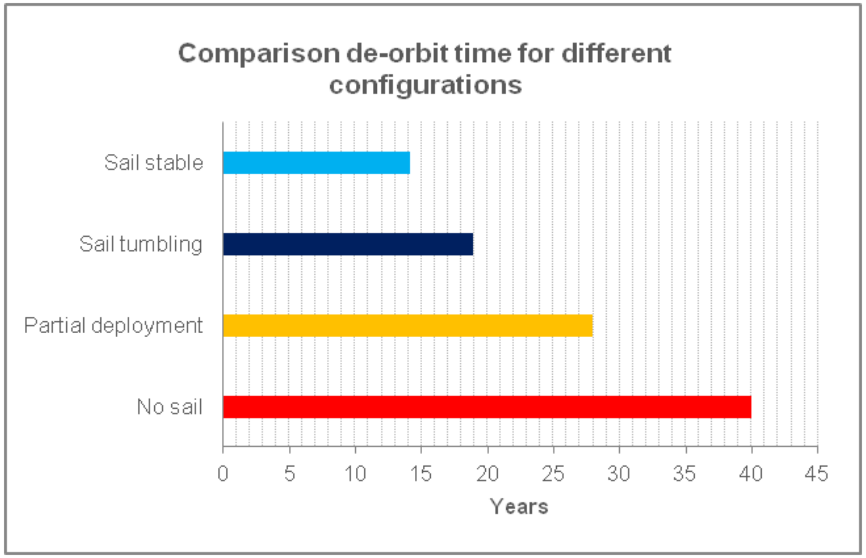


Smaller, Simpler version of Icarus-1:

- Changes to fit smaller size of spacecraft and improve reliability
- No time for detailed analysis, only conservative changes made
- Simplified sail folding pattern

De-orbit analyses with STELA for different sail configuration on orbit:

✓ without sail
✓ partial sail tumbling
✓ sail tumbling
✓ sail stable



De-Orbit Mechanism (DOM) on ESEO: Overview

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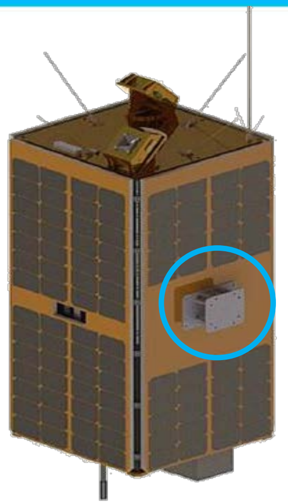
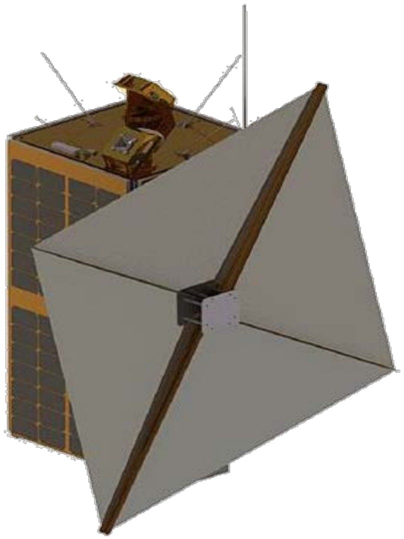
ESEO - **E**uropean **S**tudent **E**arth **O**rbiter

- Micro-satellite mission (m < **45**kg)
- Sun-synchronous Low Earth Orbit (h=**520**km)
- Launch planned for **2016**
- **7** Payloads developed by European Universities Teams
- Current status: CDR closed, EM delivered



Mission Objectives:

- Taking pictures
- Measuring radiation levels
- Testing new technologies



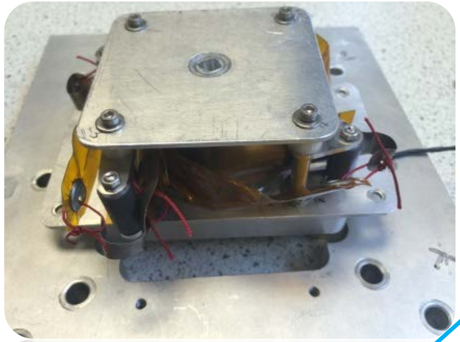
The ESEO Spacecraft

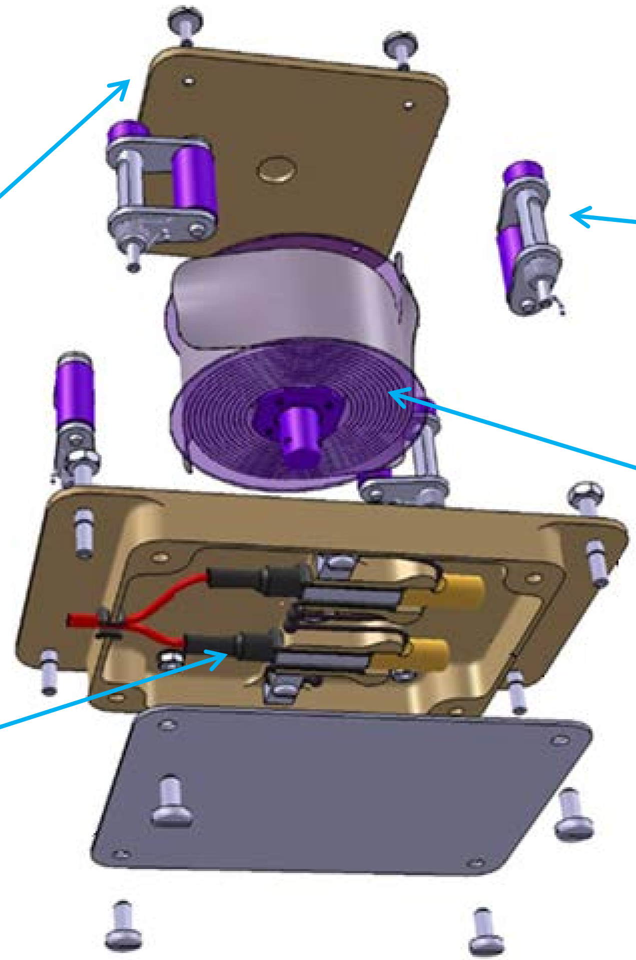
Mission configuration (above), End of mission configuration (left)

Source: ALMASpace System Design Report

esa SITAEL

DOM Configuration

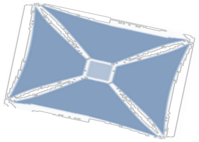




Deployment Monitoring

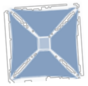
- **TDS-1** end of mission (& Icarus-1 deployment) expected July 2017
- **CARBONITE-1** EOM also expected in 2017
- Interest from Space Situational Awareness community:
  - **Observations** of sail deployment: test observational capability, detect changes in on-orbit objects
  - **Changes** in signature from (pre-deployment) baseline
  - Ground-based laser ranging, radar, optical…
  - **Correlate** with satellite telemetry
  - **Assess** effect of such de-orbit systems on current & future SSA processes
- Interest from Cranfield (also UKSA, industry..)
  - Verify deployment
  - Assess efficacy of DAS (comparison with predictions)
- Discussions currently in progress

DOM-Icarus Comparison



Icarus

- ✓ Currently larger sail area
- ✓ Maximises useful area
- ✓ Allows equipment mounting on panel
- X Boom length related to length of shortest side: constrained scalability, does not scale down well
- X Less mass-efficient (frame structure)



DOM

- ✓ More compact
- ✓ Expected to be more continuously scalable
- X More challenging to manufacture longer booms
- X Panel mounting requires absence of protruding equipment
- X Panel mounting reduces useful area

Further work to be done on optimisation, refinement, combining design elements of both..?

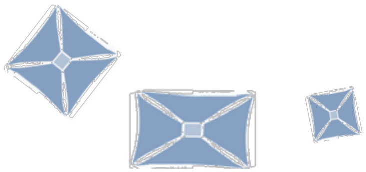
Next Steps – Aims of the Building Block work

Currently we have 2 different but related design concepts

To produce a useful Building Block we need to:

- Fully understand range of user requirements
  - Input from the LSIs
  - More detailed market survey of target host satellites

- Improve scalability & adaptability
  - Enhance applicability to range of host satellites



The CDF activities are expected to enable these improvements & result in a scalable "family" of DAS designs suitable for multiple satellites

Thank You!

Questions?