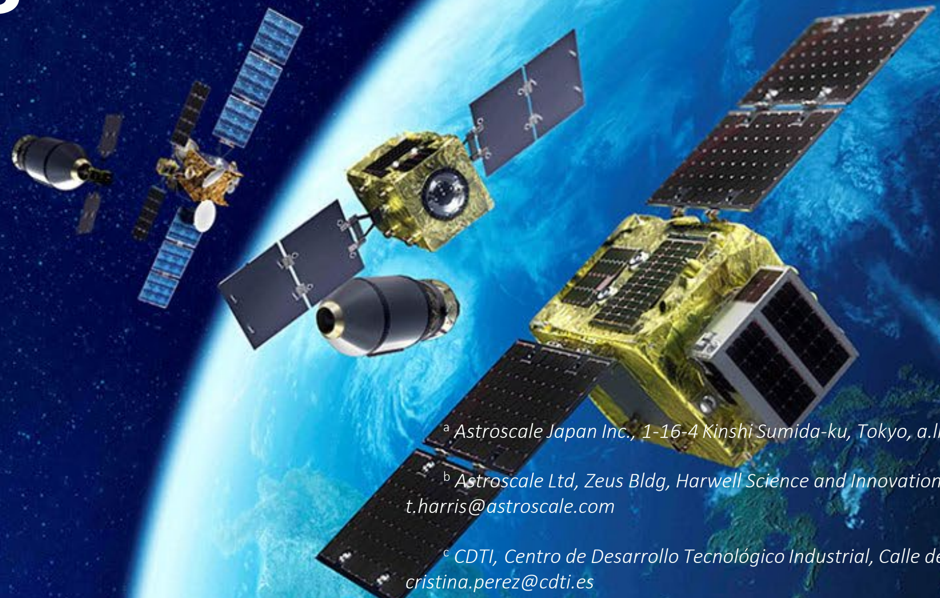
IAC-22-A6.9.8

SSA observation campaign of the ELSA-d mission



Aleksander A. Lidtke [a]*, Toby Harris [b]*, Cristina Perez Hernandez[c], Florian Delmas[d], Cassien Jobic[e], Alexis Petit[f], Daniel Saez[g], Jorge Humberto Fonseca[h]

[a] *Astroscale Japan Inc., 1-16-4 Kinshi Sumida-ku, Tokyo, a.lidtke@astroscale.com*

[b] *Astroscale Ltd, Zeus Bldg, Harwell Science and Innovation Campus, Didcot, OX11 0DF, t.harris@astroscale.com*

[c] *CDTI, Centro de Desarrollo Tecnológico Industrial, Calle del Cid, 4, 28001 Madrid, Spain, cristina.perez@cdti.es*

[d] *CNES, 18 avenue Edouard Belin, 31400 Toulouse, France, florian.delmas@cnes.fr*

[e] *CNES, 18 avenue Edouard Belin, 31400 Toulouse, France, cassien.jobic@cnes.fr*

[f] *ShareMySpace, 14 rue Crespin du Gast, Paris, alexis.petit@sharemyspace.space*

[g] *GMV, Calle Isaac Newton 11, Tres Cantos, 28670, Spain, dsaez@gmv.com*

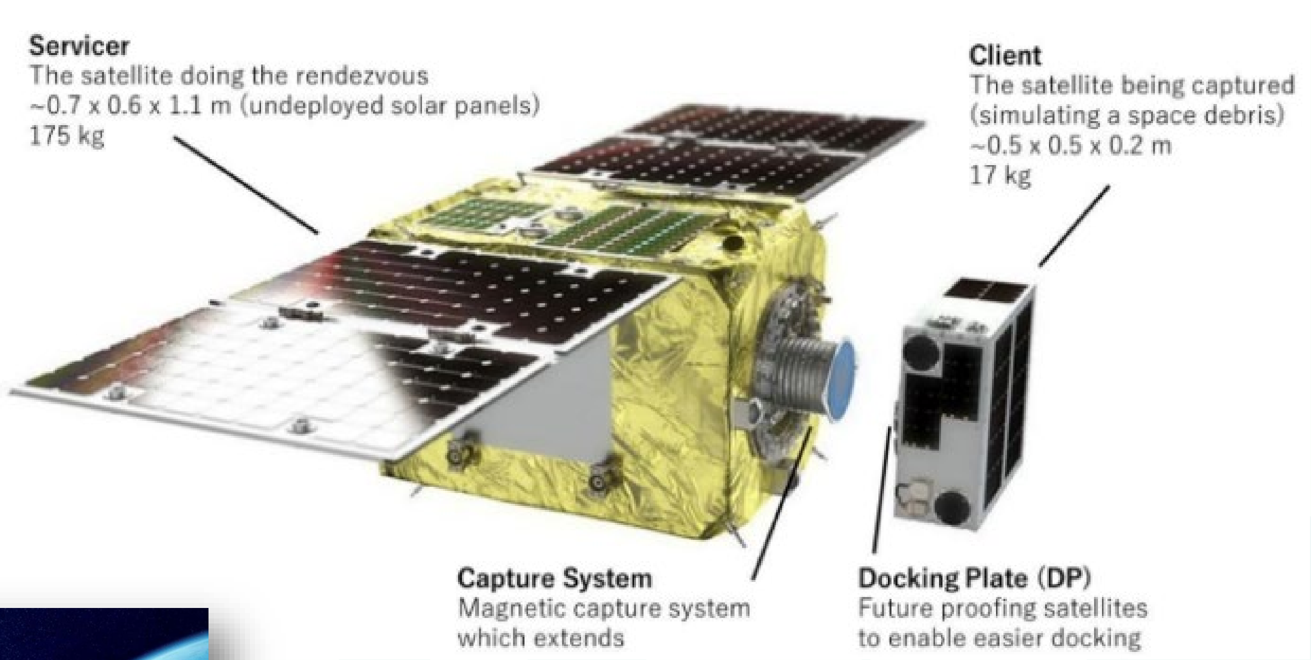
19th September 2022

Overview

- ELSA-d Mission
- SSA observation campaign
- Mission timeline from SSA perspective
- SSA events of interest
- Analysis and discussion

ELSA-d Mission

- Consisting of two spacecraft: a **Servicer** and a **Client**
- A ferromagnetic **Docking Plate** allows prepared servicing of Client using the proprietary capture system.
- Successfully launched on March 22nd 2021 to ~533kmx560km, 97.5 degrees
- Designed to explore the full phases of operations necessary for a EOL service, including client search, inspection, capture, re-orbit and de-orbit.
- Licensed through the UK Space Agency.
- Operated from the National In-Orbit Servicing Control Centre – based at Satellite Applications Catapult, Harwell Campus.



Detailed presentation on ELSA-d at A6.5 session on Wednesday

SSA observation campaign

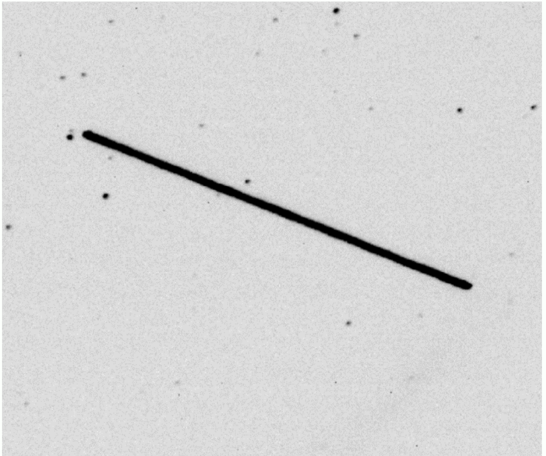
- SSA support is crucial to ensure safe and successful mission operations.
- Many service providers were also involved in making observations and analysis during the mission

Mission operations:

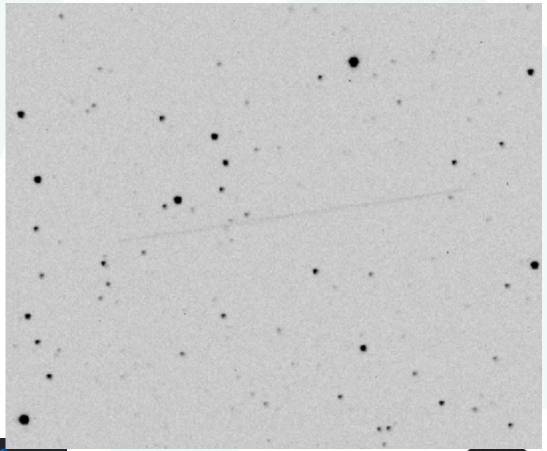
- ESA
- SpaceNav
- ILRS
- US 18SDS
- Leolabs

Mission observers:

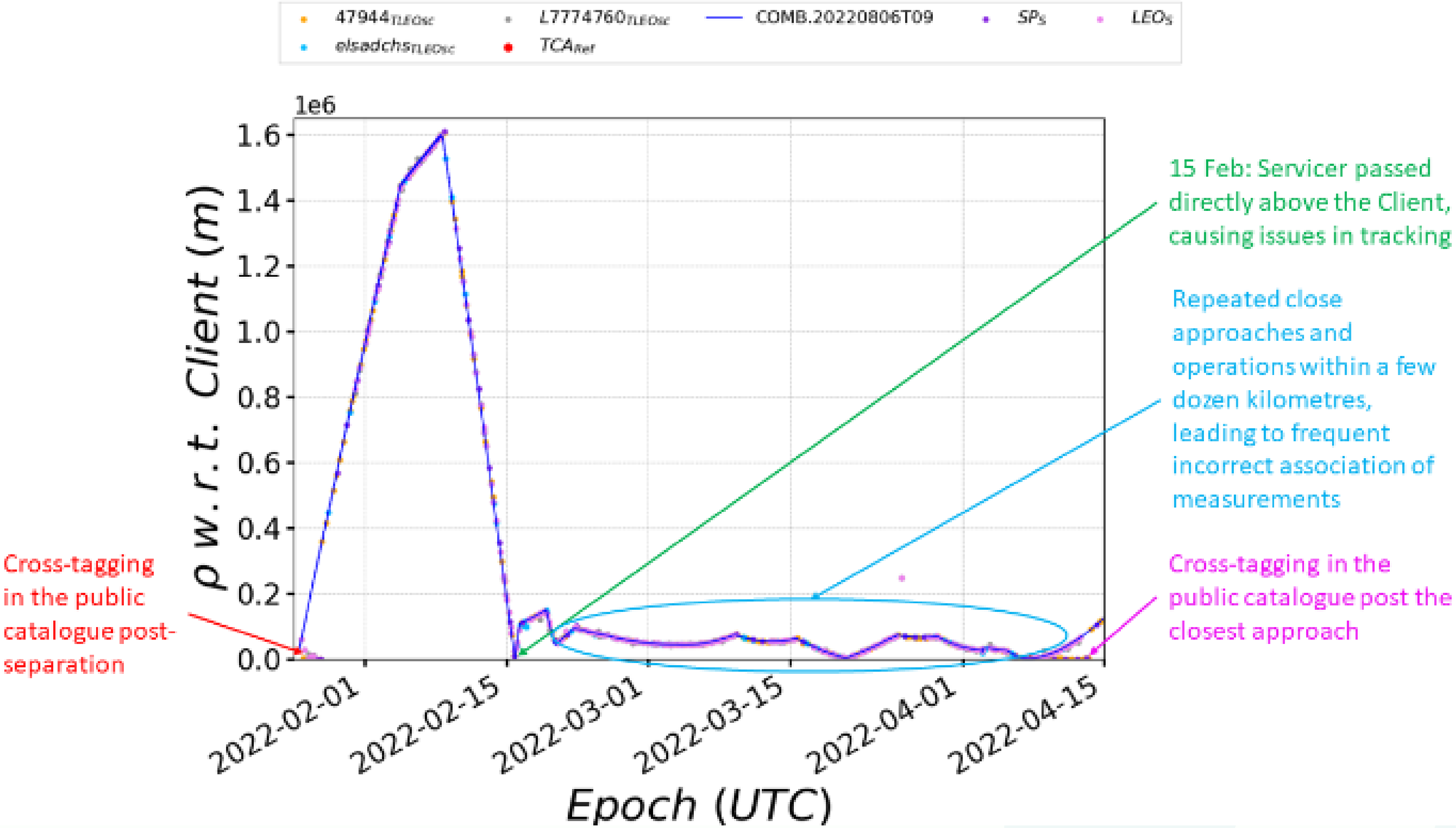
- EU-SST (CNES/DLR/CDTI/ASI)
- ShareMySpace
- Austrian academy of science (Graz)
- University of Bern
- NORSS
- HEO Robotics
- COMSPOC (AGI)
- UK NSpOC /CIC
- US NSDC
- US NRO



Ground-based optical tracklets of ELSA-d Servicer (above) and Client (below) - (Images courtesy of ShareMySpace)



Mission timeline from SSA perspective



Relative distance between the Servicer and Client, indicating key SSA-related events that occurred during the mission. Other ephemerides (TLEs and SP_VECs from 18th SDS, and LeoLabs state vectors) shown as dots at their respective epochs

SSA events of interest

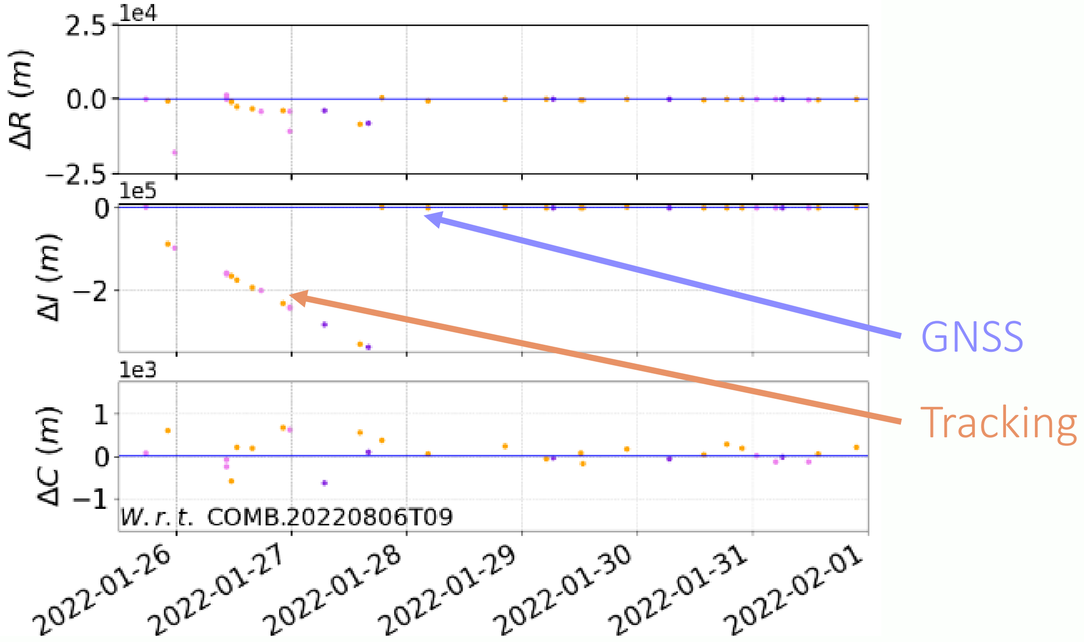
We now consider events relevant to the tracking of the two spacecraft:

1. Jan 25: Servicer/Client separation
2. 15 Feb: Cross-tagging event due to overhead fly-by
3. 2 Mar – 10 Mar: Repeated mis-associations of Servicer and Client observations
4. 28 Mar – 10 Apr: Mis-association of measurements in EU SST observations
5. 7 Apr: Closest approach and cross-tagging
6. [N/A]: Loss of attitude and its effects on the orbit
7. [N/A]: Attitude rate estimation from ground

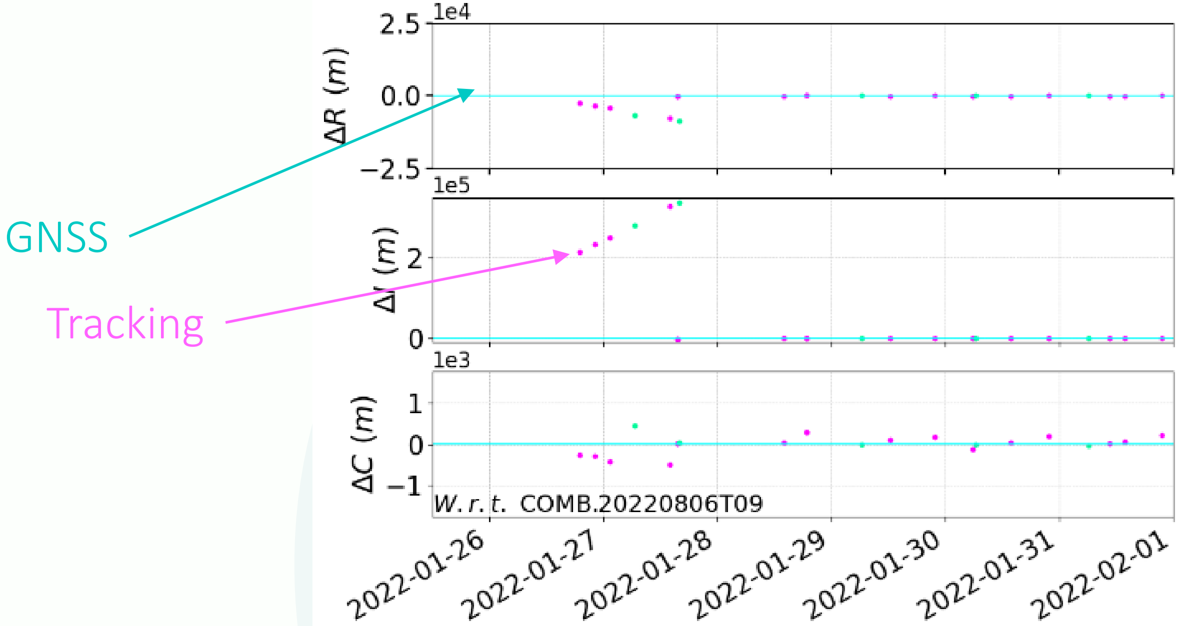
1) Servicer/Client separation and cross-tagging (25 Jan)

- Client separation occurred on 25 Jan'22, followed shortly after by an active abort
- The magnitude, direction and epoch of this abort manoeuvre were not immediately known by Astroscale
- For a period of time, the two spacecraft were swapped in the public catalogue, or "cross-tagged"

Servicer

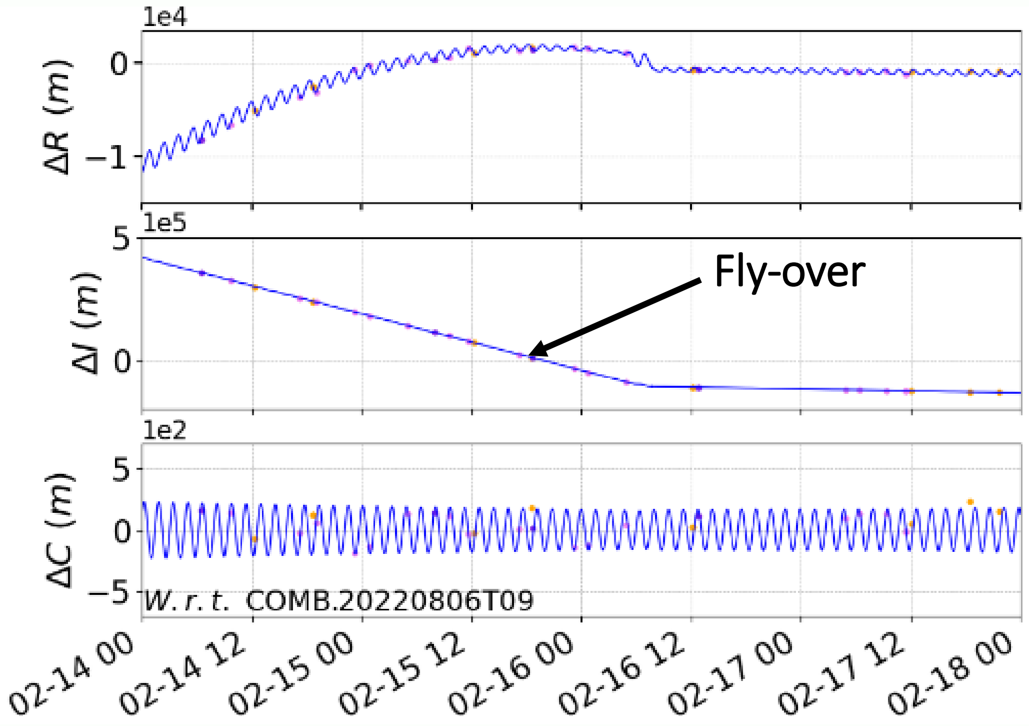


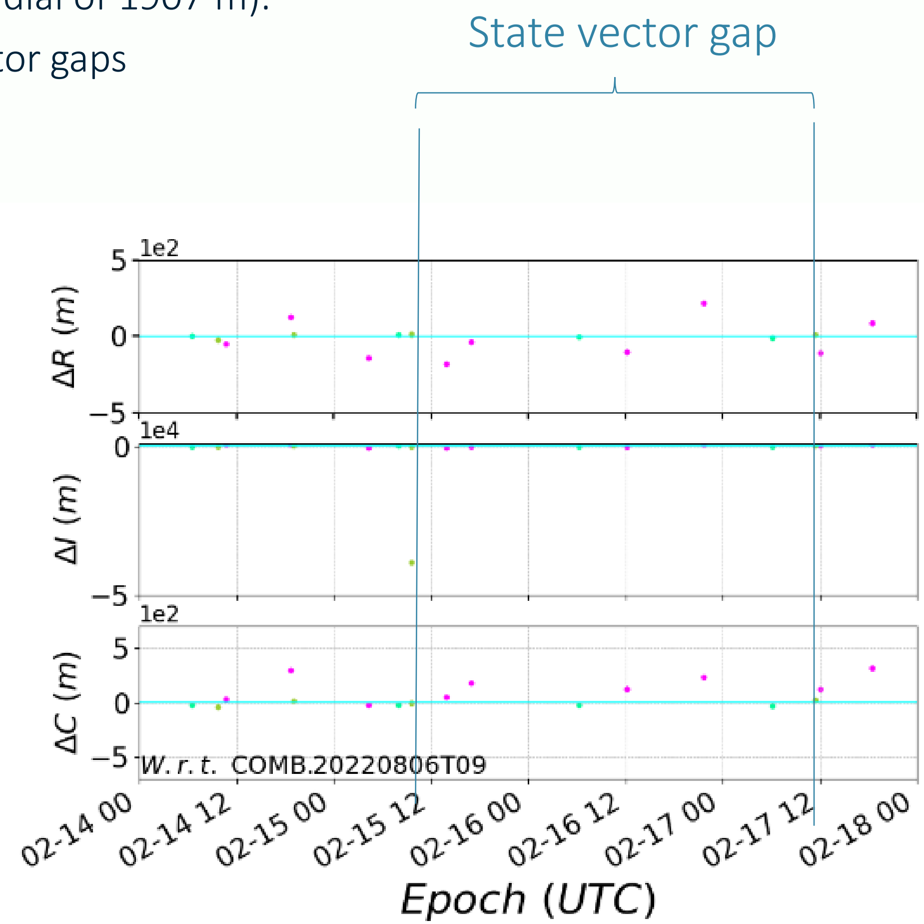
Client



2) Cross-tagging event due to overhead fly-by (15 Feb)

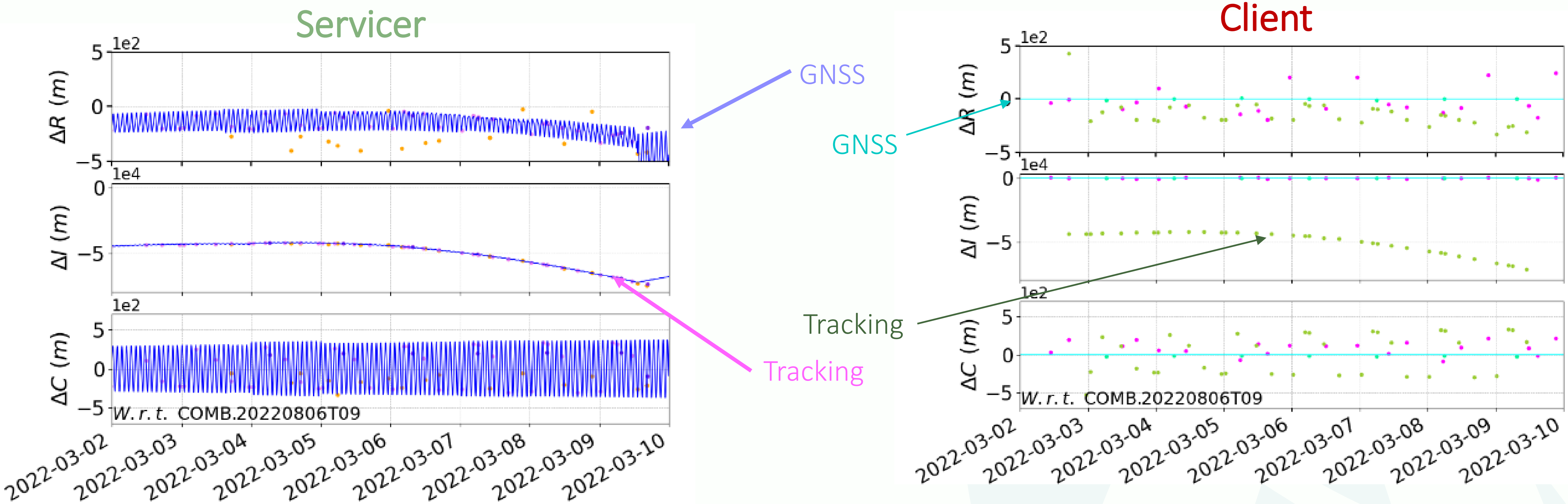
- While the Servicer was moving to reapproach the Client along the V-bar after the abort ΔV on 25 Jan 2022, it passed directly above the Client on 15 Feb 2022 19:43:39 (cross-track separation of 60 m, radial of 1907 m).
- This ‘fly-over’ disrupted radar tracking of the Client and resulted in state vector gaps
- No disruption in Servicer tracking occurred for 18SDS, Leolabs or EU-SST





3) Mis-associations of Servicer and Client observations

- Several times during the mission, when the Servicer and Client were in close-proximity (<10km), mis-association of the Client sometimes arose
- This is distinct from cross-tagging as the ID’s were not swapped.
- The larger radar X-sec of the Servicer (0.15m2) compared to the small Client resulted in automated association algorithms pick up the stronger signature.



4) Mis-association of measurements in EU SST observations

- EU SST investigated the presence of mis-associations in their own observations.
- Measurements were obtained with the following between 28 Mar and 10 Apr '22:

  - GRAVES radar, France
  - S3TSR radar, Spain,
  - TIRA radar, Germany,
  - GRAZ laser ranging, Austria,

  - The weighted RMS of the residuals was used as Figure of Merit (FoM) for each track

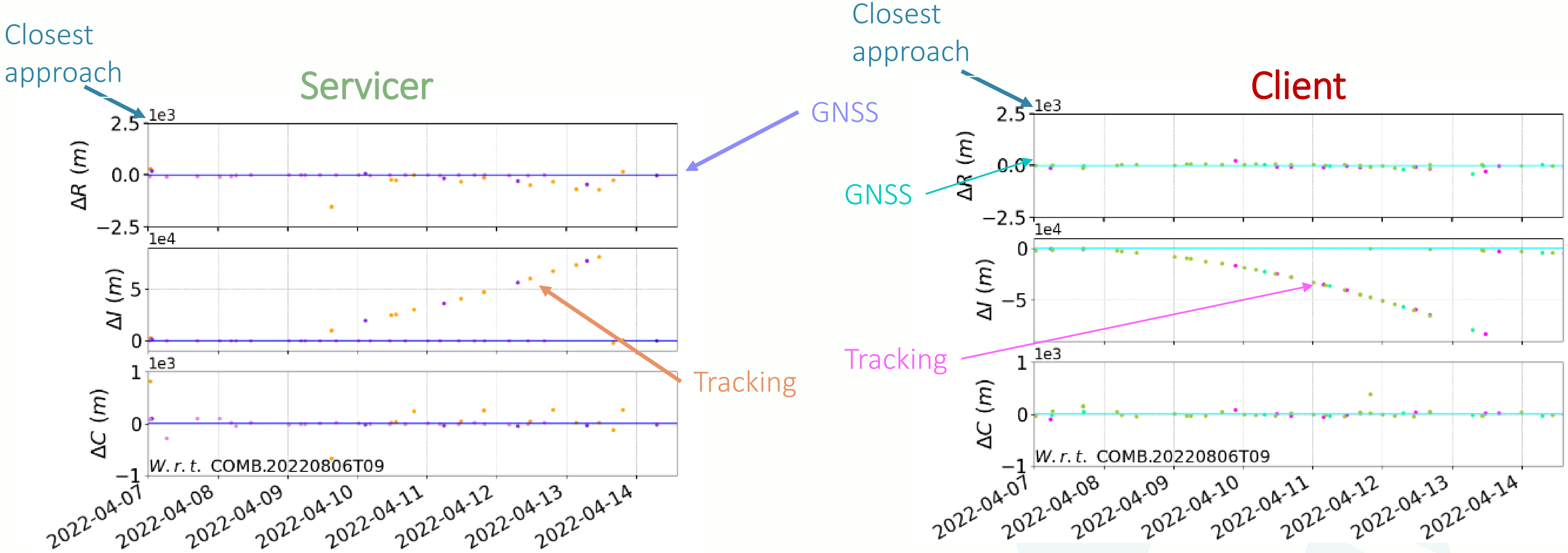
- Associations were compared to Astroscale ephemeris and revised:

	Number of associations	
Object	**Original**	**Revised**
Servicer	31	28
Client	5	8

- Several mis-associations between the two ELSA-d craft have been detected
- Even though mis-associations are present, they would typically be identified and rejected at the orbit determination stage

5) Closest approach and cross-tagging (7 April)

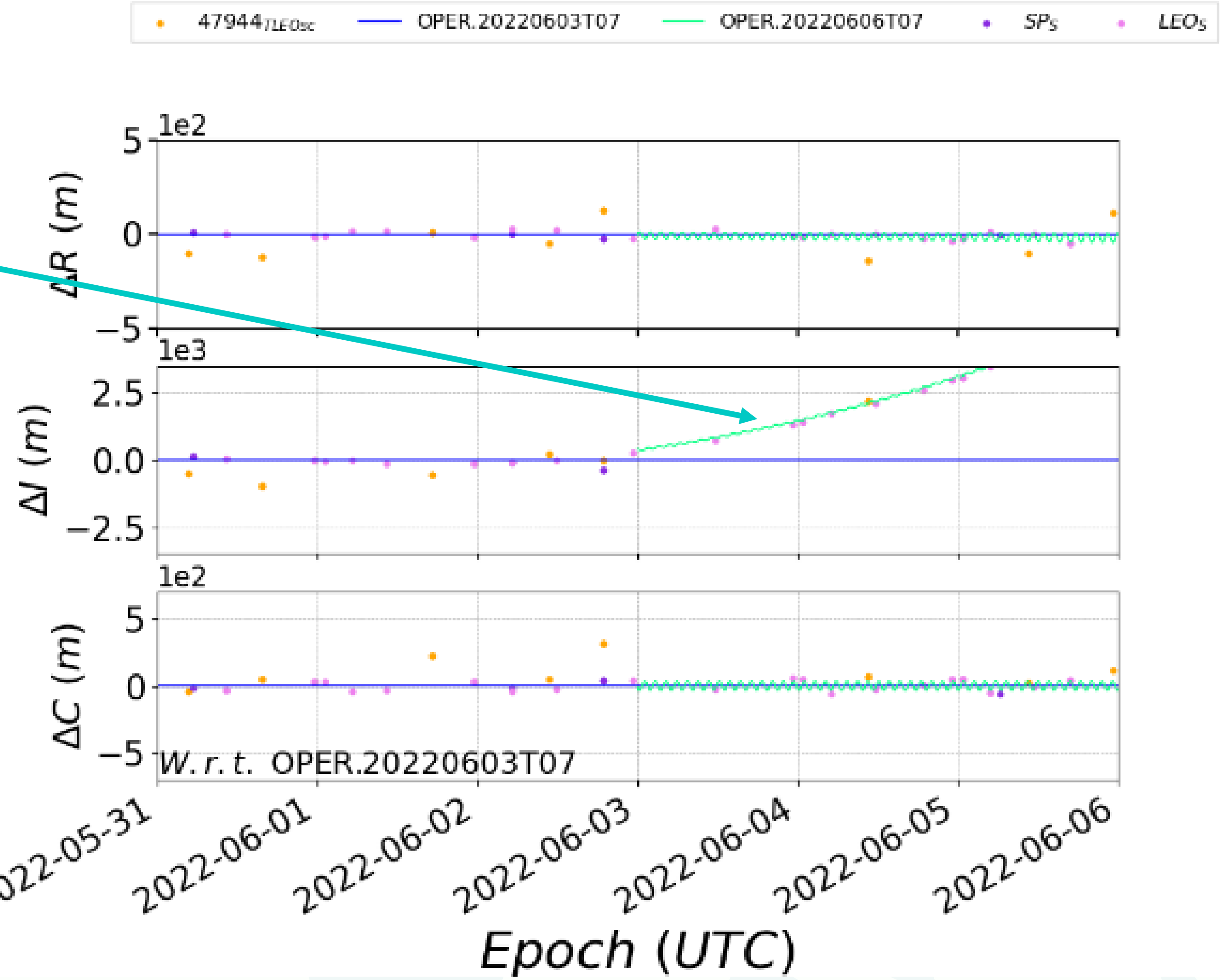
- The two spacecraft approached to within 159 metres from each other in the afternoon on 7 Apr 2022
- Whilst planned, the close approach caused a cross-tagging between the Servicer and the Client in the 18th's catalogue,



6) Loss of attitude and its effects on the orbit

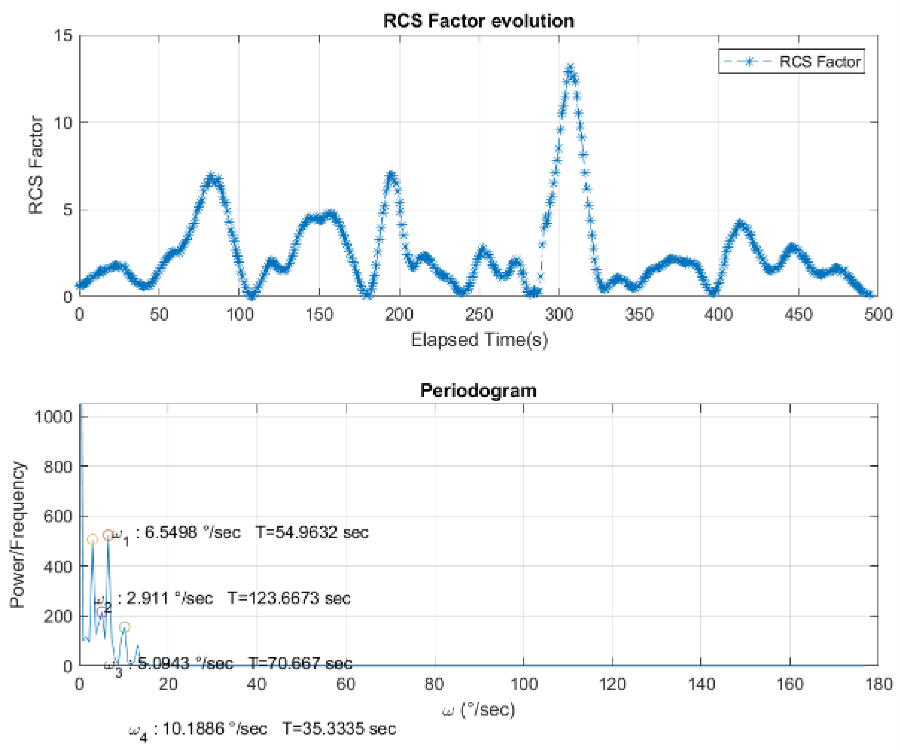
- Atmospheric drag is the second dominant force in LEO after gravity
- Differential drag between satellites flying in the same formation needs to be controlled – this is a key aspect of ADR missions
- Varying ballistic coefficient due to mass/size and attitude affects ephemeris predictions
- For example, the change from RIC-aligned to sun-pointing Servicer attitude resulted in significantly different predicted ephemeris
- Differential drag, if well characterised, is a potential mechanism to efficiently go from rendezvous to close-proximity

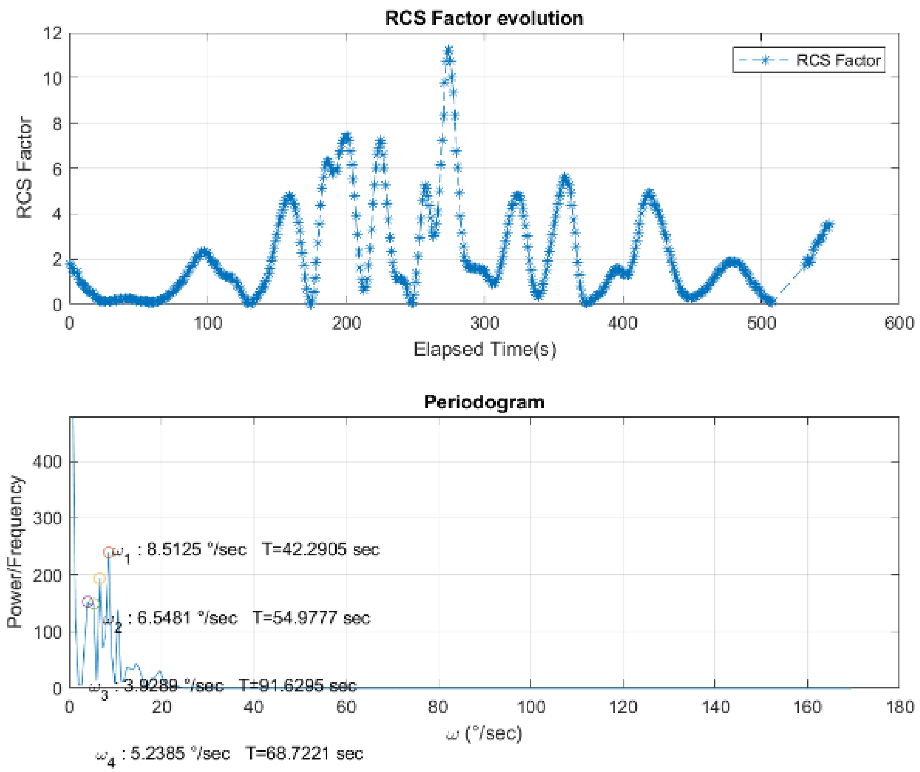
In-track drift between two different attitude states



7) Attitude rate estimation from ground

- Attitude rate assessments for Client objects is essential for fuure ADR missions.
- To explore this, observations were made to understand how ground-based analysis of ELSA-d's attitude motion would compare to body-rate telemetry
- Radar cross-section (RCS) of the servicer was observed using SATA and TIRA, then analysed to extract attitude rate data.





Analysis and discussion

- The ELSA-d mission has offered a valuable insight into the demands and issues with SSA observations regarding RPO missions
- Several distinct SST-related issues have been discovered during the ELSA-d demonstration and described herein.
- These are predominantly issues that can arise when two spacecraft operate close together, including:
  - disruptions to automated tracking;
  - measurement (mis) associations;
  - orbit determination processes that.
- For future ADR/EOL missions, when approaching a defunct spacecraft, any disruptions in tracking could cause operational difficulties or even result in an elevated risk of collision
- This highlights the importance of ELSA-d in the context of SSA, and underscores the value of identifying SST algorithm issues in a controlled setting.

Acknowledgements

Astroscale would like to acknowledge the generous and valuable support of various groups that have made ELSA-d operations.

This list includes, but is not limited to, the ESA Space Debris Office, US 18th SDS, the ILRS community, Leolabs, SpaceNav and UK Space Command's Commercial Integration Cell.

Contact Astroscale

Toby Harris
Global Head of SSA
t.harris@astroscale.com

Aleksander A. Lidtke
Senior Missions and Systems Engineer
a.lidtke@astroscale.com

www.astroscale.com