C03

EOL サービス実現に向けた軌道上技術実証ミッション

An In-Orbit Demonstration Mission Aimed at End-of-Life Service

岡本章, 瀬戸裕基, 藤本浩平, 小林裕亮, 岩井隆, 藤田勝(アストロスケール),
Jason Forshaw(ASTROSCALE LTD.,), ELSA-d project team
Akira Okamoto, Yuki Seto, Kohei, Fujimoto, Yusuke Kobayashi, Takashi Iwai,
Sho Fujita (ASTROSCALE JAPAN Inc.,), Jason Forshaw (ASTROSCALE LTD.,)
and ELSA-d project team

コンステレーションシステムの台頭によって、衛星を始めとする宇宙機の数は急速に増加しつつある中、宇宙環境を持続的に利用し続けるために、最終的な PMD を請け負う end-of-life(EOL)システムの構築が求められる。
ASTROSCALE では EOL サービスのための技術実証衛星 ELSA-d の開発を進めており、2020 年初旬の打ち上げを計画している。ELSA-d は捕獲機(Chaser)とデブリを模擬した衛星(Target)の 2 機の衛星で構成される。また、Target にはドッキングプレート(DP)と呼ばれるプレートを取り付け、それが接近・捕獲に対して補助的な役割を担う。Chaser に搭載した準協力近傍航法誘導技術と磁石を取り付けた捕獲機構によって Target に取り付けた DP を目印に捕獲する。ELSA-d の実証技術は将来の EOL サービスを見据えて構築されており、Chaser は軌道上で Target を分離した後、Target の接近・捕獲を一連の流れで実施する。これらを、Target がタンブリング状態と協力的姿勢制御状態の 2 ケースにおいて行う。
本発表では、ELSA-d の準協力的なデブリ回収技術およびその実証ミッションについて紹介する。

Emerging plans for low Earth orbit (LEO)-based constellations featuring large numbers of satellites mean in the near future, space populations could significantly increase. Systematic spacecraft end-of-life (EOL) management strategies assuring post-mission disposal (PMD) are required to maintain utility of all LEO assets.
Astroscale is developing ELSA-d which is satellite for EOL service demonstration mission, due for launch in 2020.
ELSA-d consists of two spacecraft – a chaser and a target. The chaser is equipped with proximity rendezvous technologies and a magnetic capture mechanism, whereas the target has a docking plate (DP) which enables it to be captured. Each phase of the main concept of operations (CONOPS) will be discussed and how these would align with future servicing missions. Demonstrations include: target search, target inspection, target rendezvous, both non-tumbling and tumbling capture. This paper will provide an overview of the ELSA-d EOL mission, ASTROSCALE's first semi-cooperative spacecraft retrieval technology and capability demonstration mission.

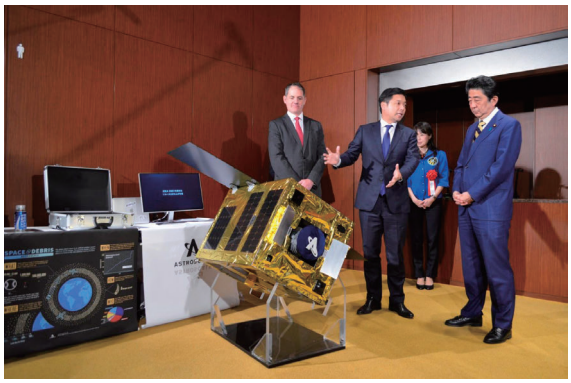
AN IN-ORBIT DEMONSTRATION MISSION AIMED AT END-OF-LIFE SERVICE

EOLサービス実現に向けた軌道上技術実証ミッション

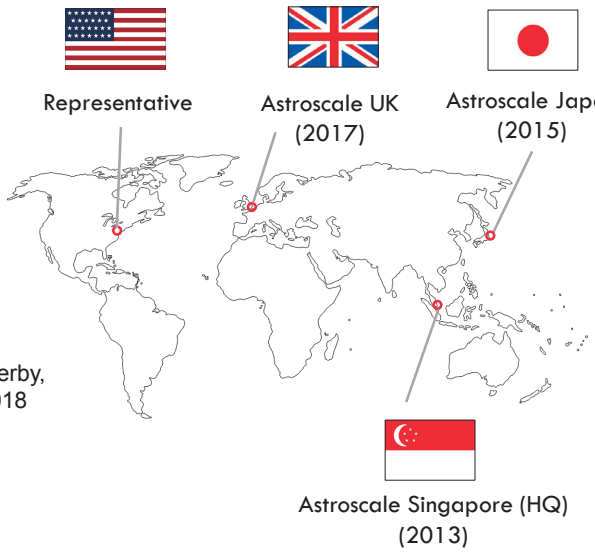
岡本 章、Akira Okamoto, ASTROSCALE JAPAN Inc.,
瀬戸 裕基、Yuki Seto, ASTROSCALE JAPAN Inc.,
藤本 浩平、Kohei Fujimoto, ASTROSCALE JAPAN Inc.,
小林 裕亮、Yusuke Kobayashi, ASTROSCALE JAPAN Inc.,
岩井 隆、Takashi Iwai, ASTROSCALE JAPAN Inc.,
藤田 勝、Sho Fujita, ASTROSCALE JAPAN Inc.,
Jason Forshaw, ASTROSCALE LTD.,
ELSA-d project team

8th JAXA Space Debris Work Shop, 3 - 5 December 2018

Astroscale: An International Company Solving a Global Problem



Founder and CEO, Nobu Okada, and COO, Chris Blackerby, meeting Japanese Prime Minister Shinzo Abe, March 2018



Founded: May 4, 2013
Team: ~55
Capital: $102M during four funding rounds, supported by angel investors, VCs, public-private fund, and private companies.

Mission: Secure long-term spaceflight safety for future generations
Services: End of Life (includes large constellations)
Active debris removal

End-of-Life (EOL) vs Active Debris Removal (ADR)

EOL services are different from ADR in many aspects

	End of Life (EOL) "Don't add any more debris"	Active Debris Removal (ADR) "Remove debris that is already there"
Potential Customers	Constellations, Private Satellite Operators	Governments, International framework
Target Objects	- Satellites that have failed in orbit or reached end of operational lifetime - 50~500kg	- Environmentally critical objects - 500kg+ - Existing debris
Rationale	- Business continuity and maximize revenue - Adhere to best practices and public demands	- Demonstrate commitment to orbital sustainability - Assure spaceflight safety for all operators
	Global Responsibility	
Key Technology	Semi-cooperative approach and capture	Non-cooperative approach and capture
Regulation Authorization	B2B commercial contract following mission approval from launching state	Require international consensus

3

ELSA-d – An Overview

ELSA-d: End of **L**ife **S**ervice by **A**stroscale - **d**emonstration

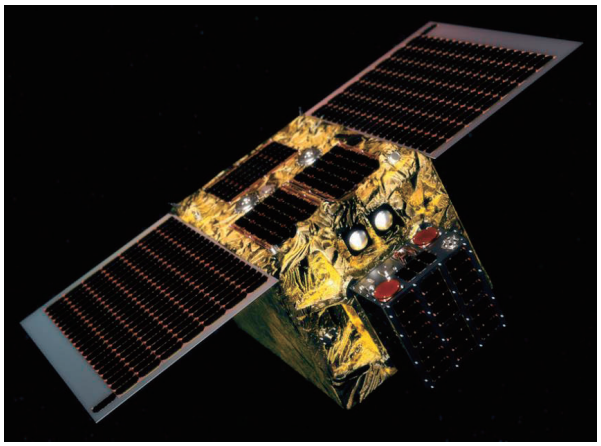
Key Mission Details

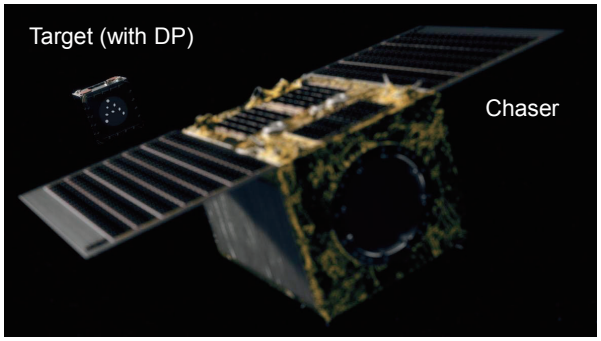
- Chaser: 160 kg
- Target: 20 kg with docking plate (DP)

- Presently in final design stages with AIT to commence Q1 2019.
  - Range of hardware and software prototypes available with testing underway.

- Launch targeting Q1 2020
  - Signed with Glavkosmos/GK Launch Services, Soyuz 2
  - SSO (500-600 km), LTAN 10.30-11.00.

- Full phases of operations that would be necessary for a full EOL service, including target search, inspection, capture, re-orbit and de-orbit.





4

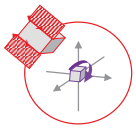
ELSA-d – Key Technologies – I

End-to-end rendezvous solution including far and short-range approach

- Two GNC processors (GNC command, data handling)
- Usual complement of attitude sensing e.g. star trackers, attitude control e.g. RWs and position sensing e.g. GPS
- Specialist rendezvous: ranging system, night navigation cameras (wide and short angle), day cameras (wide and short angle), range finders, illumination device

Advanced operational capabilities

- Search for targets and approach with absolute to relative navigation hand-over.
- Fly-around inspections of target with operator assessment.

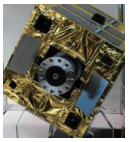


Docking plate to enable semi-cooperative removal

- Designed with constellation customers in mind.

At-night magnetic capture of non-tumbling and tumbling targets

- Capture system is designed to extend and retract and allow multiple captures and releases.



ELSA-d – Key Technologies – II

Flight software designed with ECSS Level-3 autonomy

- Event-based autonomous operations
- Execution of on-board operations control procedures

Re-orbit, de-orbit and passivation capabilities

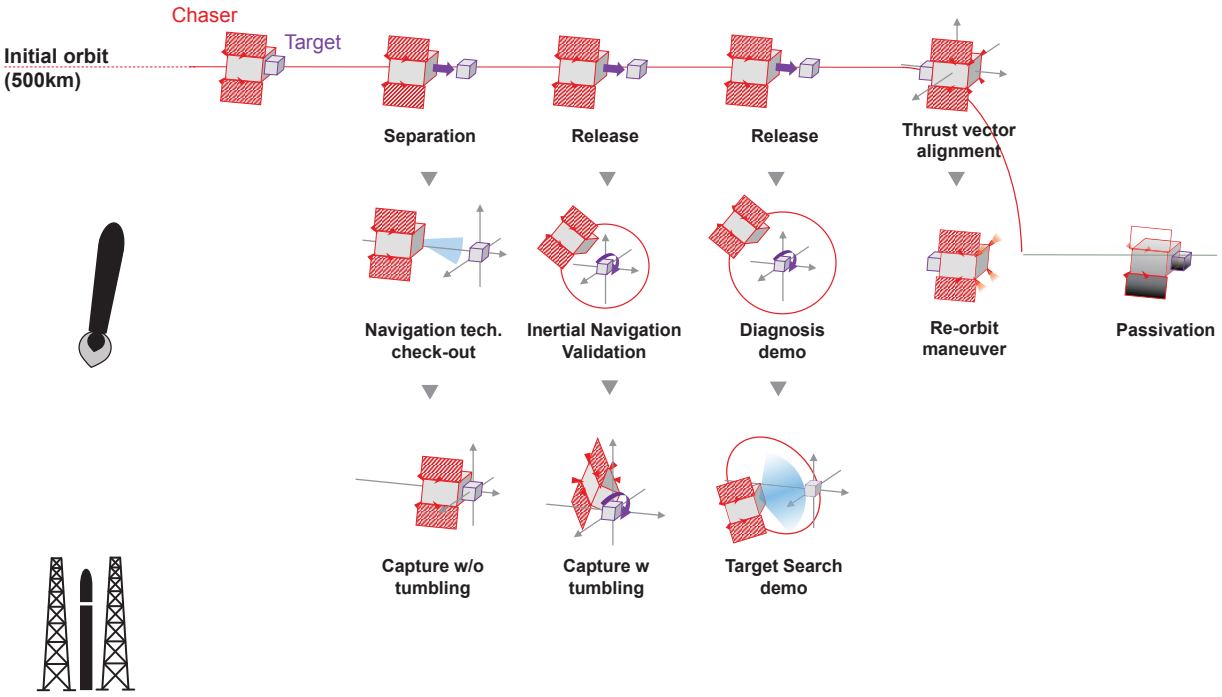
- Green propulsion system with high Isp and compatibility to small launch vehicles

Mission designed with safety evacuations and passively safe trajectories in mind

- Collision avoidance (passive and active abort)
- Movement to evacuation point
- Protected safety ellipse
- Manual experiment abort
- Protected critical functions (including de-orbit)
- Safety critical computing: FDIR and safety tasks
- Architectural redundancy
- High-fidelity ground-based simulation

Ground segment designed specifically for in-orbit servicing

ELSA-d High Level ConOps



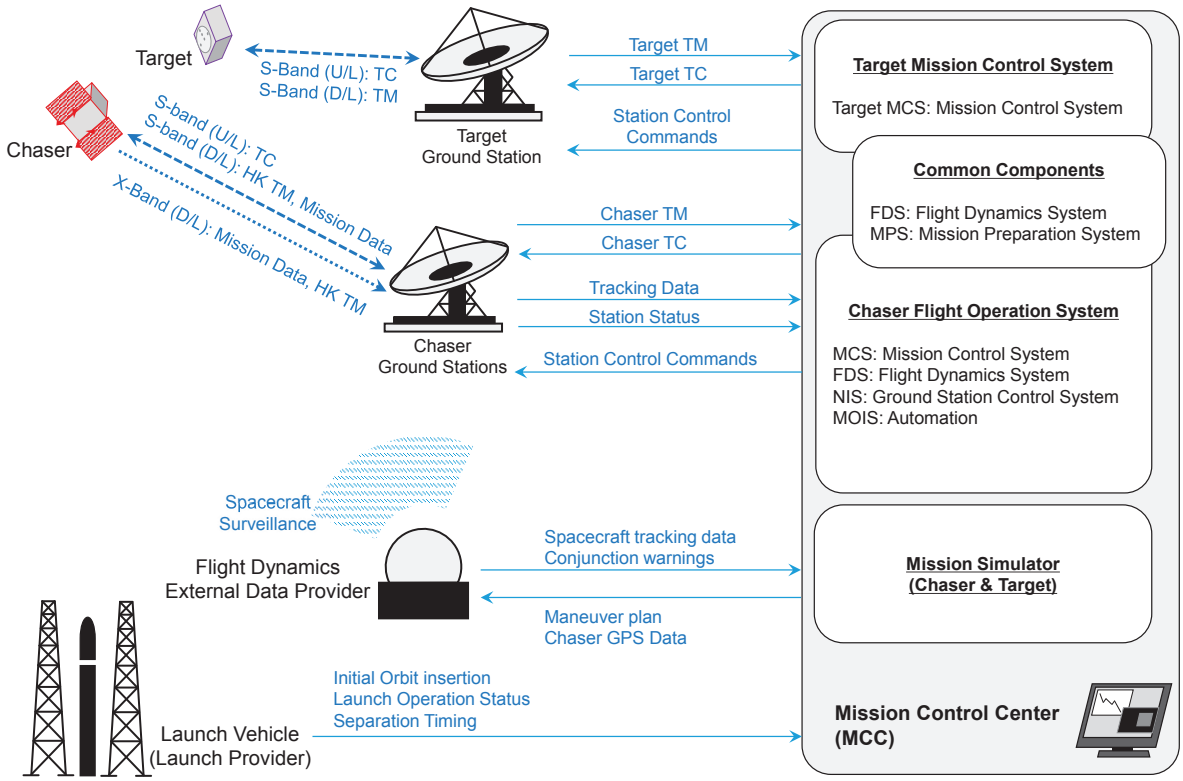
Phase 1	Phase 2	Phase 3	Phase 4	Phase 5	Phase 6	Phase 7
LEOP	Commissioning	Capture w/o Tumbling	Capture w Tumbling	Diagnosis & Target Search	Re-orbit	Closeout

7

ELSA-d ConOps video

https://www.youtube.com/watch?v=IaFHhiOXqlc

ELSA-d Mission Configuration



Path Forward

- From an EOL perspective, Astroscale is engaging large constellation providers to perform an IOD mission.
  - An IOD mission will solidify a partnership and enable technology to be matured.
  - Main driver is minimising cost to Astroscale and cost to the customer.