



*Promoting Cooperative Solutions for Space Sustainability*

# The Evolution of Space Rendezvous and Proximity Operations and Implications for Space Security

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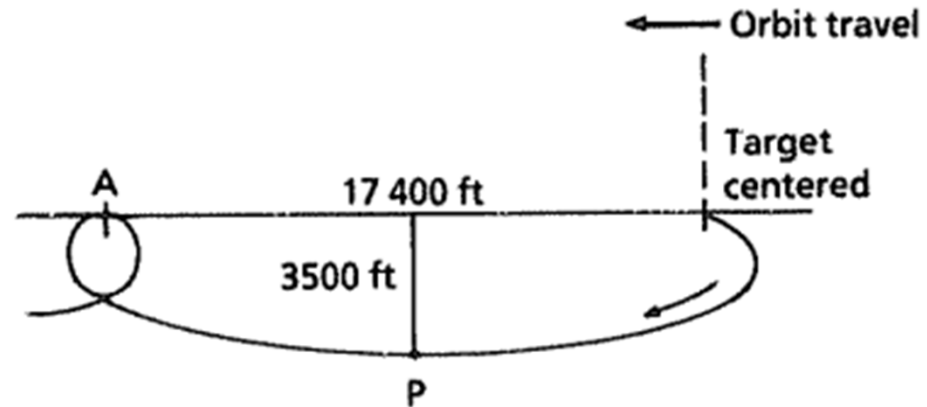
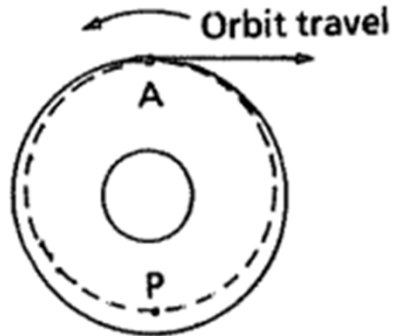
## Overview

- Rendezvous and Proximity Operations (RPO) capabilities are a rapidly evolving and proliferating space technology
- RPO capabilities are being developed and tested for a wide variety of commercial, civil, and national security applications
  - Human spaceflight docking and orbital assembly
  - Satellite servicing, repair and refueling
  - Inspection and intelligence collection
  - Co-orbital anti-satellite (ASATs)
- Key issues that will need to be dealt with:
  - Ways to discriminate between civil/commercial RPO for peaceful purposes and potentially hostile RPO that could be an attack
  - Safety best practices and standards to reduce mishaps and mistakes that could damage satellites and/or generate orbital debris
  - Norms of behavior and TCBMs for military RPO to reduce the risks of misperceptions that could spark crisis or conflict
  - Improved Space Situational Awareness (SSA) for monitoring and verification

## But remember space is different

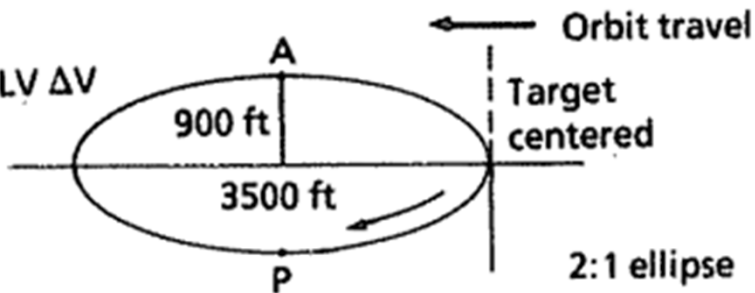
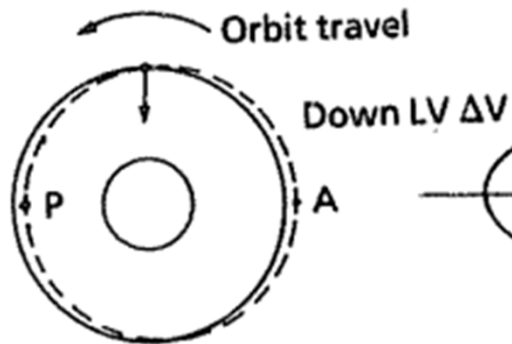
II.

**Retrograde**  
 $\Delta V = -1.0 \text{ ft/s}$



III.

**Radially inward**  
 $\Delta V = 1.0 \text{ ft/s}$



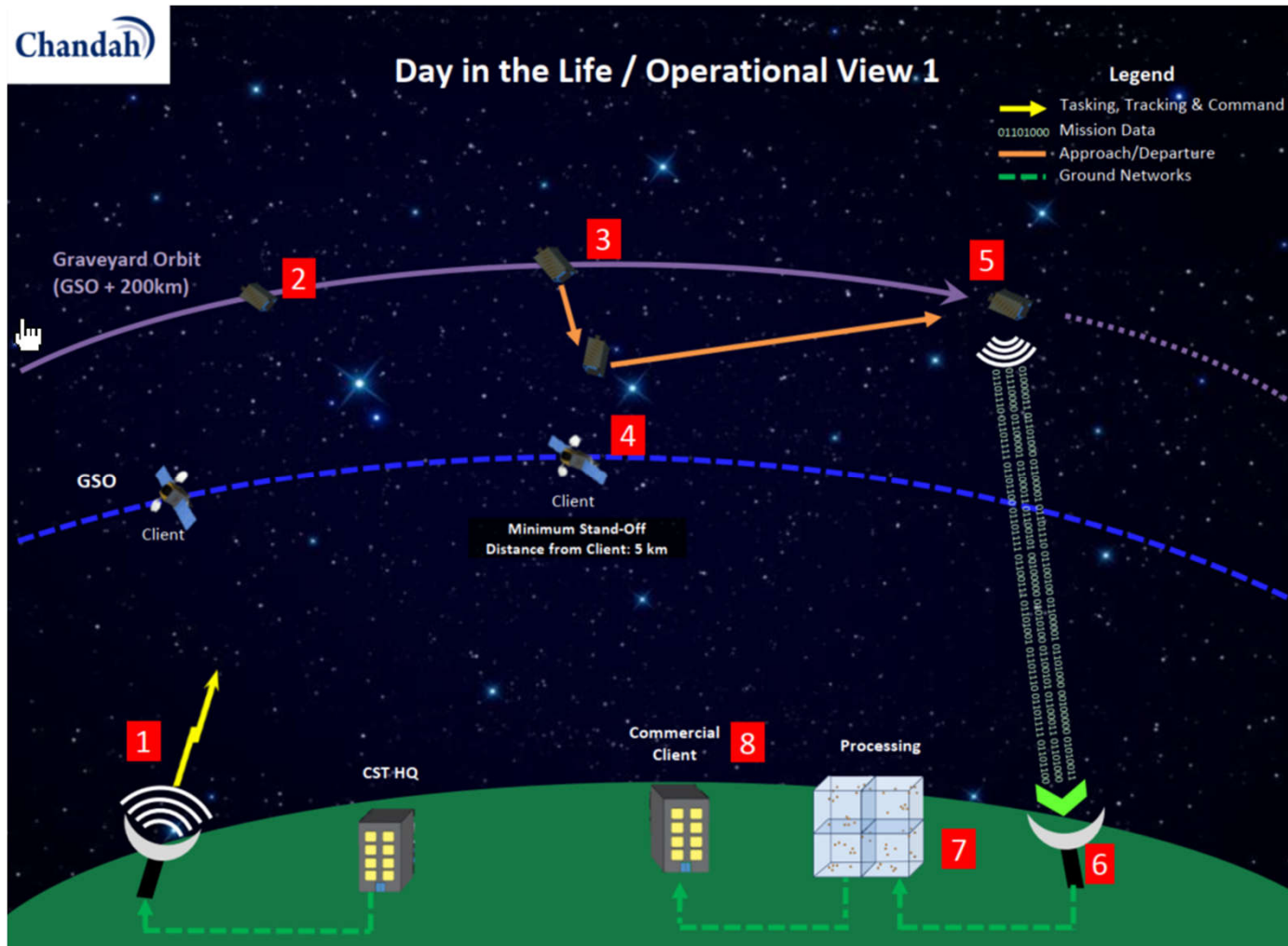
*Credit: NASA Rendezvous and Proximity Operations Handbook (1985)*



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## **EXAMPLES OF COMMERCIAL RENDEZVOUS AND PROXIMITY OPERATIONS**

# Chandah Satellite Inspectors

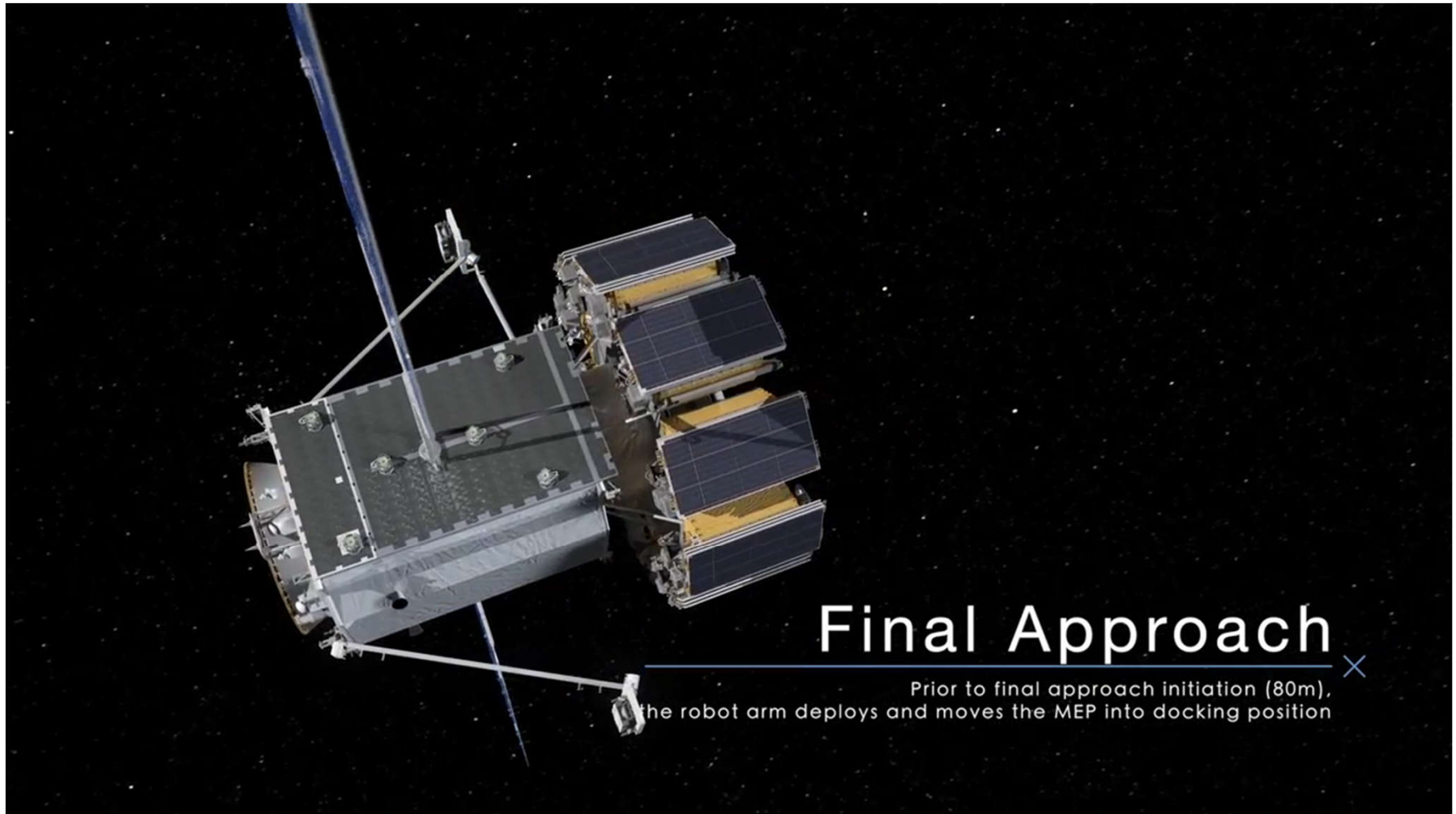


Credit: Chandah Space Technologies



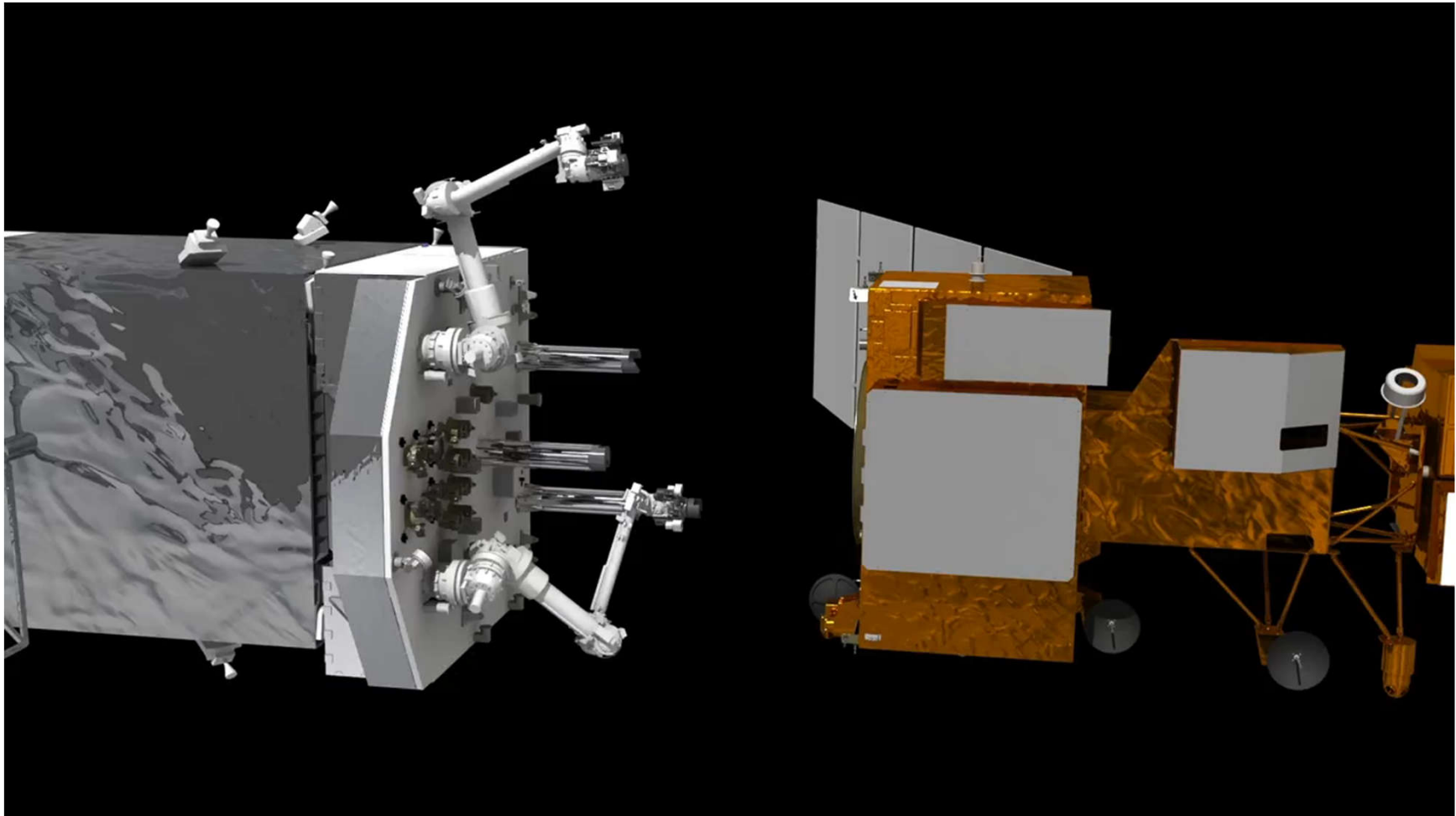
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## SpaceLogistics Life Extension Service



Credit: [Northrup Grumman](#)

## SSL Satellite Refueling



Credit: [NASA Goddard](#)





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# iBoss Modular Satellite Assembly



Modular iBOSS building block (iBLOCK)



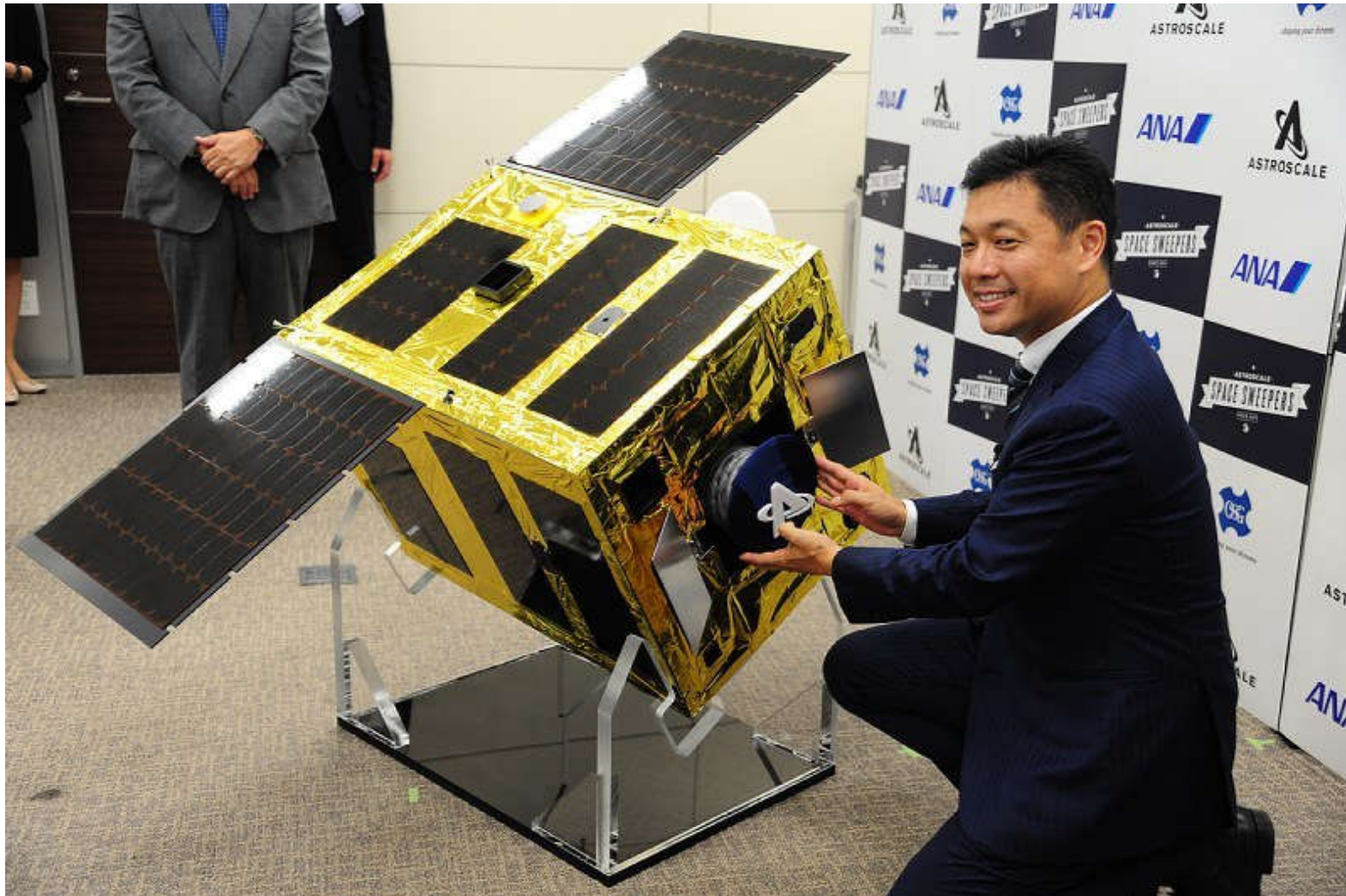
Multifunctional intelligent Space System Interface (iSSI)



Credit: [iBOSS GmbH](http://iBOSS GmbH)



# Astroscale Debris Removal



Credit: [Mainichi](#)



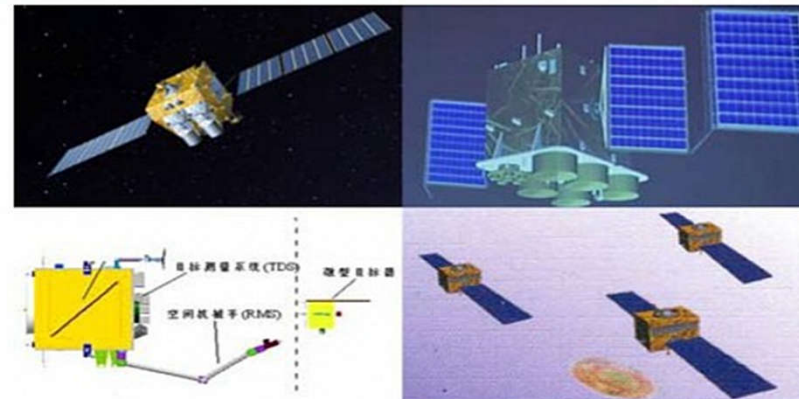
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## EXAMPLES OF NATIONAL SECURITY RPO

## Recent Chinese RPO Activities

Date(s)	System(s)	Orbital Parameters	Notes
June – Aug. 2010	SJ-06F, SJ-12	570-600 km; 97.6°	SJ-12 maneuvered to rendezvous with SJ-06F. Satellites may have bumped into each other.
July 2013 – May 2016	SY-7, CX-3, SJ-15	Approx. 670 km; 98°	SY-7 released an additional object that it performed maneuvers with and may have had a telerobotic arm. CX-3 performed optical surveillance of other in-space objects. SJ-15 Demonstrated altitude and inclination changes to approach other satellites.
Nov. 2016 – Feb. 2018	SJ-17, YZ-2 upper stage	35,600 km; 0°	YZ-2 upper stage failed to burn to the graveyard orbit and stayed near GEO. SJ-17 demonstrated maneuverability around the GEO belt and circumnavigated Chinasat 5A.
Jan. 2019	TJS-3, TJS-3 AGM	35,600 km; 0°	TJS-3 AKM separated from the TJS-3 in the GEO belt and both performed small maneuvers to maintain relatively close orbital slots.

附图 1: 2013 年前三季度公司小卫星产品发射交付概览



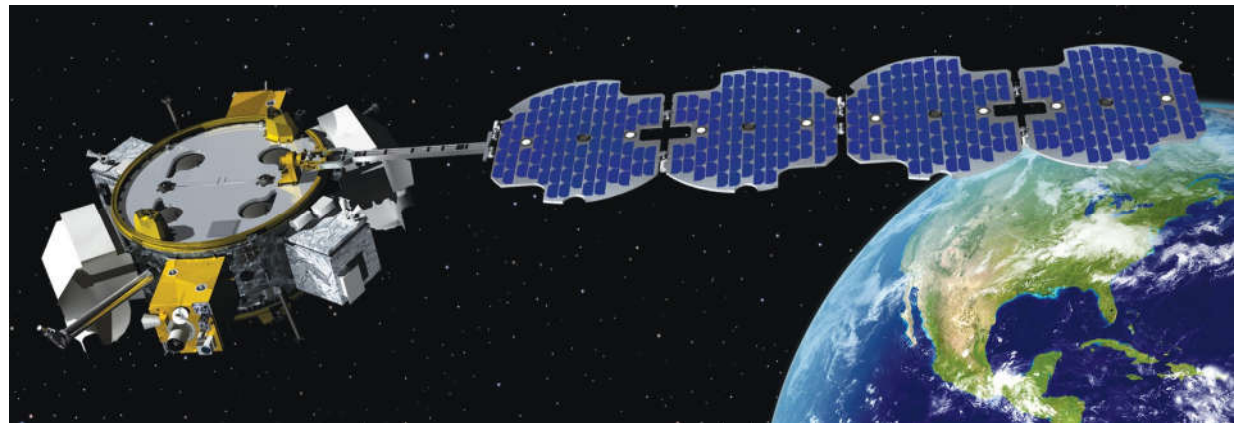
资料来源: 上海证券研究所

Image of the SY-7 (lower left, with robotic arm) and its small companion satellite. (Image credit: [Liss](#))

## Recent American RPO Activities

Date(s)	System(s)	Orbital Parameters	Notes
Jan 2003	XSS-10, Delta R/B	800 x 800 km; 39.6°	XSS-10 did a series of maneuvers to bring it within 50 meters of the Delta upper stage that placed it in orbit.
April 2005 - Oct 2006	XSS-11, multiple objects	LEO	XSS-11 did a series of maneuvers to bring it close to the Minotaur upper stage that placed it in orbit. it then performed additional close approaches to other U.S. space objects in nearby LEO orbits over the next 12-18 months.
April 2005	DART, MUBLCOM	LEO	DART did a series of autonomous maneuvers to bring it close to the MUBLCOM satellite and ended up bumping into it.
March - July 2007	ASTRO, NEXTSat	LEO	ASTRO and NEXTSat were launched together and performed a series of separations, close approaches, and dockings with each other.
July 2014 - present	GSSAP, multiple objects	GEO	Two pairs of GSSAP satellites have been performing RPO with various other objects in the GEO region
July 2014 - November 2017	ANGELS, Delta 4 R/B	GSO	ANGELS separated from the Delta 4 upper stage that placed the first GSSAP pair into orbit and then performed a series of RPO in the GSO disposal region.
May 2018	Mycroft, EAGLE	GEO	EAGLE separated from the Delta V upper stage, and Mycroft subsequently separated from EAGLE. Mycroft conducted RPO of EAGLE in the GEO region.

*Image of the EAGLE with multiple attached small satellites for deployment (Image credit: [Northrop Grumman](#))*





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## Recent Russian RPO Activities

Date(s)	System(s)	Orbital Parameters	Notes
June 2014 - March 2016	Cosmos 2499, Briz-KM R/B	1501 x 1480 km; 82.4°	Cosmos 2499 did series of maneuvers to bring it close to, and then away from, the Briz-KM upper stage.
April 2015 – April 2017	Cosmos 2504, Briz-KM R/B,	1507 x 1172 km; 82.5°	Cosmos 2504 maneuvers to approach the Briz-KM upper stage and may have had a slight impact before separating again.
March-April 2017	Cosmos 2504, FY-1C Debris	1507 x 848 km; 82.6°	After a year of dormancy, Cosmos 2504 did a close approach with a piece of Chinese space debris from the 2007 ASAT test
Oct. 2014 – Feb. 2019	Luch, Express AM-6, Intelsat 7, Intelsat 901, Athena-Fidus	35,600 km, 0°	Luch parked near several satellites over nearly five years, including the Russian Express AM-6, American Intelsat 7 and Intelsat 401, and French-Italian Athena-Fidus satellites.
Aug – Oct 2017	Cosmos 2521, Cosmos 2519	670 x 650 km; 97.9°	Cosmos 2521 separated from Cosmos 2519 and performed a series of small maneuvers to do inspections before redocking with Cosmos 2519.



Analytical Graphics  
@AGItweets

This week [#ComSpOC](#) observed [#Luch](#) Olymp (40258) parked at 60 deg E, marking its 13th stop next to a commercial communications satellite 🌐 since the initial on-orbit checkout next to Russian satellites completed in 2015. [#SSA](#) matters. [#spacesituationalawareness](#)

5:34pm · 22 Feb 2019 · Twitter Web App

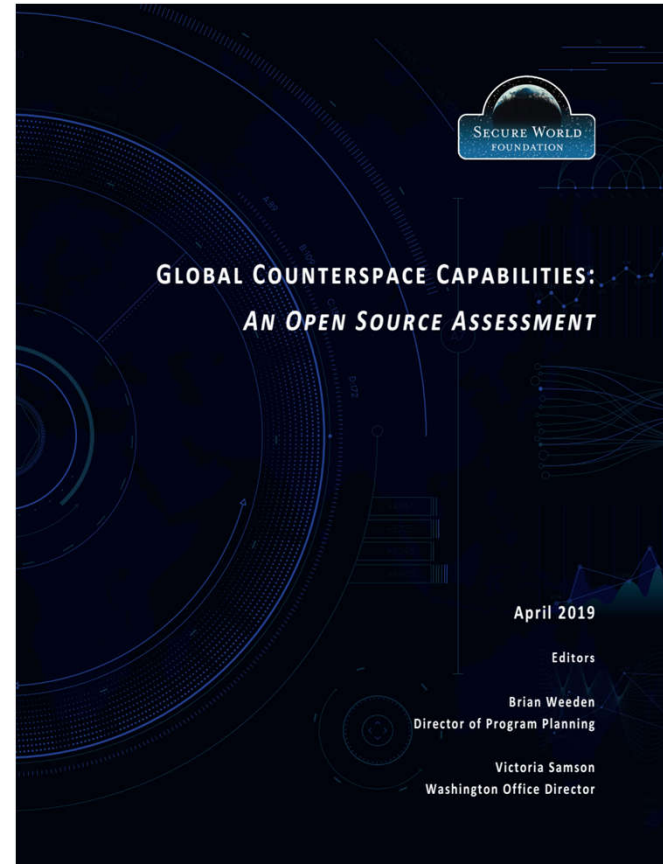




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# SWF Global Counterspace Capabilities Report

- Annual Report of status and development of global counterspace capabilities
  - Direct Ascent ASAT
  - Co-orbital ASAT
  - Directed Energy
  - Electronic Warfare
  - Cyber
- Countries Covered
  - China
  - Russia
  - United States
  - India
  - Iran
  - North Korea



<https://swfound.org/counterspace>



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## **CURRENT NORMATIVE INITIATIVES**

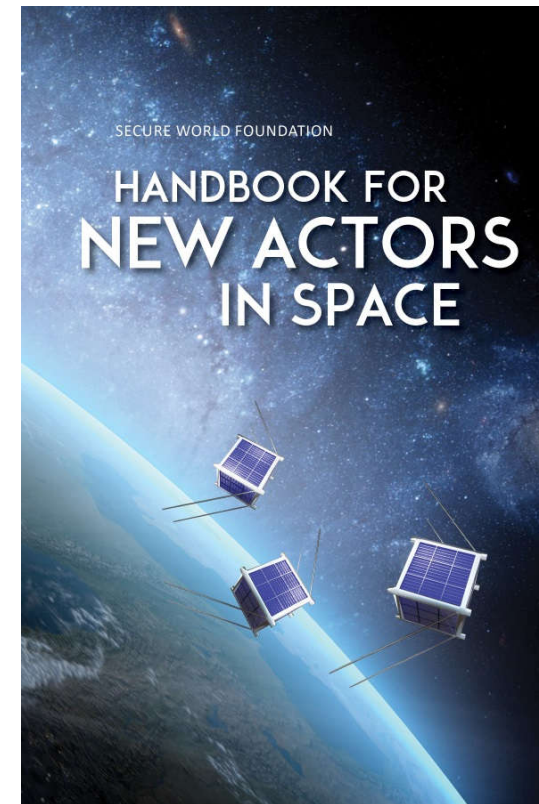




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## SWF Handbook for New Actors in Space

- **Goal:** Create a publication that provides an overview fundamental principles, laws, norms, and best practices for safe, predictable, and responsible activities in space
- **Two specific audiences:**
  - Countries developing space programs and/or having to oversee and regulate their first satellites
  - Universities and start-up companies that are developing/operating satellites



[www.swfound.org/handbook](http://www.swfound.org/handbook)

## The Woomera Manual



<https://law.adelaide.edu.au/woomera/home>

A Manual on the International Law of Military Space Operations

<https://www.mcgill.ca/milamos/>



Manual on International  
Law Applicable to Military  
Uses of Outer Space



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## Commercial RPO Standards



[CONFERS Guiding Principles for Commercial RPO and Satellite Servicing](#) (Nov 2018)

[CONFERS Recommended Design and Operational Practices for RPO and Satellite Servicing](#) (Feb 2019)



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**THANK YOU**

**QUESTIONS?**

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