Rendezvous and Proximity Operations: Friend or Foe?

Victoria Samson, Washington Office Director
Secure World Foundation

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Development of OOS and RPO Capabilities

- On-orbit servicing (OOS) and rendezvous and proximity operations (RPO) are key to enabling future of on-orbit activities
- Benefits and challenges
  - Greatly increase the viability of and benefits from space activities
  - Raises a number of diplomatic, legal, safety, operational, and policy challenges that need to be tackled
- OOS and RPO are not new, and are already international
  - 50+ years of experience in doing it with human spaceflight, but increasingly shifting to robotic/autonomous
  - Multiple countries/companies developing and testing RPO capabilities
- How to develop norms and standards to enable cooperative OOS/RPO and mitigate challenges?

RPO Activities and Counterspace Objectives

- *Global Counterspace Capabilities: An Open Source Assessment,* April 2019
  - www.swfound.org/counterspace
  - Compiles and assesses publicly available information on the counterspace capabilities being developed by multiple countries across five categories: direct-ascent, co-orbital, electronic warfare, directed energy, and cyber
- **China** has conducted multiple tests of technologies for close approach and rendezvous that could lead to a co-orbital ASAT capability, but no evident of destructive intercept of a target
- Since 2013, **Russia** has launched several satellites into LEO and GEO that have demonstrated the ability to rendezvous with other space objects, and in some cases do so after periods of dormancy
- The **United States** has conducted multiple tests of technologies for close approach and rendezvous in both LEO and GEO, along with tracking, targeting, and HTK intercept technologies that could lead to a co-orbital ASAT capability

Recent Chinese Rendezvous and Proximity Operations

Date(s)	System(s)	Orbital Parameters	Notes
June – Aug. 2010	SJ-O6F, 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.

Recent Russian Rendezvous and Proximity Operations

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.

Recent US Rendezvous and Proximity Operations

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.

Current Commercial Activities in OOS & RPO

SATELLITE INSPECTION

Chandah

LIFE EXTENSION

Effective Space solutions

Orbital ATK

SATELLITE REFUELING

AIRBUS DEFENCE & SPACE

SSL

MODULAR SATELLITE ASSEMBLY

NovaWurks

iBOSS

DEORBIT / END OF LIFE SERVICES

ASTROSCALE

D-ORBIT

And future activities and applications, which would leverage technology, norms, and standards

Selected examples of active organizations, not intended as complete listing

DARPA and Satellite Servicing

- The Defense Advanced Research Projects Agency (DARPA) has had a long history with developing cooperative OOS technologies
  - Orbital Express, Robotic Servicing of Geosynchronous Satellites (RSGS)
  - Goal is to develop/demonstrate core technologies, and spin them off to industry
- Establishing norms and standards is essential to creating a vibrant commercial OOS industry
- Consortium for Execution of Rendezvous and Servicing Operations (CONFERS) program is meant to be a forum where industry and other stakeholders can engage to develop standards and norms

CONFERS Objectives

- Leverage best practices from government and industry to research, develop, and publish non-binding, voluntary consensus standards (technical and operations) for cooperative OOS and RPO
- Guiding Principles for RPO and OOS: published Nov. 7, 2018
- Design and Operating Practices: published Feb. 4, 2019
- General Assembly/Global Satellite Servicing Forum: Oct. 3-4, 2019, WDC
- Information on membership application process is available on the CONFERS website at: www.satelliteconfers.org

Contact Information

Questions?

Thanks.

vsamson@swfound.org

1.202.568.6213