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

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• 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

EXAMPLES OF COMMERCIAL RENDEZVOUS AND PROXIMITY OPERATIONS
Chandah Satellite Inspectors

Credit: Chandah Space Technologies
SpaceLogistics Life Extension Service

Credit: Northrup Grumman
SSL Satellite Refueling

Credit: NASA Goddard
iBoss Modular Satellite Assembly

Credit: iBOSS GmbH
EXAMPLES OF NATIONAL SECURITY RPO
### Recent Chinese RPO Activities

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<th>Date(s)</th>
<th>System(s)</th>
<th>Orbital Parameters</th>
<th>Notes</th>
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<tr>
<td>June – Aug. 2010</td>
<td>SJ-06F, SJ-12</td>
<td>570–600 km; 97.6°</td>
<td>SJ-12 maneuvered to rendezvous with SJ-06F. Satellites may have bumped into each other.</td>
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<tr>
<td>July 2013 – May 2016</td>
<td>SY-7, CX-3, SJ-15</td>
<td>Approx. 670 km; 98°</td>
<td>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.</td>
</tr>
<tr>
<td>Nov. 2016 – Feb. 2018</td>
<td>SJ-17, YZ-2 upper stage</td>
<td>35,600 km; 0°</td>
<td>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.</td>
</tr>
<tr>
<td>Jan. 2019</td>
<td>TJS-3, TJS-3 AGM</td>
<td>35,600 km; 0°</td>
<td>TJS-3 AKM separated from the TJS-3 in the GEO belt and both performed small maneuvers to maintain relatively close orbital slots.</td>
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*Image of the SY-7 (lower left, with robotic arm) and its small companion satellite. (Image credit: Liss)*
# Recent American RPO Activities

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<tr>
<td>Jan 2003</td>
<td>XSS-10, Delta R/B</td>
<td>800 x 800 km; 39.6°</td>
<td>XSS-10 did a series of maneuvers to bring it within 50 meters of the Delta upper stage that placed it in orbit.</td>
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<tr>
<td>April 2005 - Oct 2006</td>
<td>XSS-11, multiple objects</td>
<td>LEO</td>
<td>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.</td>
</tr>
<tr>
<td>April 2005</td>
<td>DART, MUBLCOM</td>
<td>LEO</td>
<td>DART did a series of autonomous maneuvers to bring it close to the MUBLCOM satellite and ended up bumping into it.</td>
</tr>
<tr>
<td>March - July 2007</td>
<td>ASTRO, NEXTSat</td>
<td>LEO</td>
<td>ASTRO and NEXTSat were launched together and performed a series of separations, close approaches, and dockings with each other.</td>
</tr>
<tr>
<td>July 2014 - present</td>
<td>GSSAP, multiple objects</td>
<td>GEO</td>
<td>Two pairs of GSSAP satellites have been performing RPO with various other objects in the GEO region.</td>
</tr>
<tr>
<td>July 2014 - November 2017</td>
<td>ANGELS, Delta 4 R/B</td>
<td>GSO</td>
<td>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.</td>
</tr>
<tr>
<td>May 2018</td>
<td>Mycroft, EAGLE</td>
<td>GEO</td>
<td>EAGLE separated from the Delta V upper stage, and Mycroft subsequently separated from EAGLE. Mycroft conducted RPO of EAGLE in the GEO region.</td>
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*Image of the EAGLE with multiple attached small satellites for deployment (Image credit: Northrop Grumman)*
## Recent Russian RPO Activities

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<tr>
<td>June 2014 -March 2016</td>
<td>Cosmos 2499, Briz-KM R/B</td>
<td>1501 x 1480 km; 82.4°</td>
<td>Cosmos 2499 did series of maneuvers to bring it close to, and then away from, the Briz-KM upper stage.</td>
</tr>
<tr>
<td>April 2015 – April 2017</td>
<td>Cosmos 2504, Briz-KM R/B, Briz-KM R/B,</td>
<td>1507 x 1172 km; 82.5°</td>
<td>Cosmos 2504 maneuvers to approach the Briz-KM upper stage and may have had a slight impact before separating again.</td>
</tr>
<tr>
<td>March-April 2017</td>
<td>Cosmos 2504, FY-1C Debris</td>
<td>1507 x 848 km; 82.6°</td>
<td>After a year of dormancy, Cosmos 2504 did a close approach with a piece of Chinese space debris from the 2007 ASAT test.</td>
</tr>
<tr>
<td>Oct. 2014 – Feb. 2019</td>
<td>Luch, Express AM-6, Intelsat 7, Intelsat 401, Athena-Fidus</td>
<td>35,600 km, 0°</td>
<td>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.</td>
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<tr>
<td>Aug – Oct 2017</td>
<td>Cosmos 2521, Cosmos 2519</td>
<td>670 x 650 km; 97.9°</td>
<td>Cosmos 2521 separated from Cosmos 2519 and performed a series of small maneuvers to do inspections before redocking with Cosmos 2519.</td>
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• 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
CURRENT NORMATIVE INITIATIVES
• **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
MILAMOS and Woomera Manuals

The Woomera Manual


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

https://law.adelaide.edu.au/woomera/home
CONFERS Guiding Principles for Commercial RPO and Satellite Servicing (Nov 2018)

CONFERS Recommended Design and Operational Practices for RPO and Satellite Servicing (Feb 2019)
THANK YOU

QUESTIONS?

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