Summary

Over the past two decades, several countries have begun developing rendezvous and proximity (RPO) technologies for non-military purposes such as satellite inspection, refueling, repairs, on-orbit assembly, and debris removal. In addition to government-funded programs, companies have also begun developing, testing, and operationalizing capabilities to provide commercial on orbit satellite servicing capabilities such as life extension, repair, refueling, and inspection. Within the past year, several commercial space services have successfully launched and are testing these capabilities; in January 2020, the first commercial satellite servicing mission successful docked with and repositioned a commercial communications satellite in the geosynchronous region, with the second end-of-life mission occurring in April 2021. Several additional commercial demonstrations and operational missions are planned over the next few years.

RPO and On Orbit Servicing (OOS)

Proximity operations are a series of orbital maneuvers executed to place and maintain a spacecraft in the vicinity of another space object on a relative planned path for a specific time duration to accomplish mission objectives. Rendezvous is a process wherein two space objects (artificial or natural body) are intentionally brought close together through a series of orbital maneuvers at a planned time and place. Taken together, RPO technologies enable a wide range of capabilities to support civil and commercial on-orbit satellite servicing (OOS) capabilities such as inspection, repair, refueling, assembly, and life extension. RPO capabilities can also be used for military and intelligence space activities such as intelligence, surveillance, and offensive weapons such as co-orbital anti-satellites.¹

Civil Robotic RPO and OOS Technology Development and Testing

While RPO capabilities have a long history in human spaceflight, the past twenty years have shown a growing focus on developing robotic versions of these same capabilities. This focus includes government funding to conduct research and development of underlying technologies, technology transfer to industry, and industry efforts to commercialize the technology and identify customers.²

The first robotic RPO mission to be categorized as a civil operation was the November 1997 Japan ORIHIME and HIKOBOSHI test conducted by the Japan Aerospace Exploration Agency (JAXA). As part of the Engineering Test Satellite VII, the servicer satellite (Orihime) orbited the client satellite (Hikoboshi) and became the first successful instance of autonomous robotic rendezvous and docking with another space object.³ While orbiting, Orihime took pictures, inspecting Hikoboshi before redocking and finishing the autonomous test.

On April 14, 2005, NASA launched the DART satellite to conduct an autonomous rendezvous experiment with a U.S. Navy communications satellite, MUBLCOM.⁴ DART ended up “bumping” into MUBLCOM during the test but both satellites were unharmed. An after-action report concluded that the incident was due to a malfunction of the automated rendezvous system, although not all details were released due to export control and classification restrictions.

SECURE WORLD FOUNDATION

PROMOTING COOPERATIVE SOLUTIONS FOR SPACE SUSTAINABILITY
Over the next decade, many more companies and universities began seeing the promise of an on orbit servicing industry. This resulted in many startups investing in the ideas; however, only a few made it through testing phases as the sector was not quite ready for implementation and profit. Projects such as StarTech’s Electrodynamic Debris Eliminator (EDDE) secured funding from NASA in 2012 for initial studies but have not yet been able to conduct in-space demonstrations.

In 2010, Sweden began a RPO mission of their own focusing on autonomous guidance and navigation experiments. The pair of satellites in the PRISMA mission, PRISMA Target and Main, were also commonly known as Mango and Tango. This close-approach experiment also provided GPS navigation testing for future formation flying as well as other technology experiments for various European partners.

January 2016 marked the first university led test of RPO capabilities. BEVO-2 and AggieSat4 were part of the second LONestar mission aimed at testing in-space navigation capabilities built and conducted by the University of Texas and Texas A&M. BEVO-2 was deployed from AggieSat4 after both were released from the ISS. The pair of satellites proceeded to practice communication and data exchange while station-keeping and updating their navigation. This marked a key capability to remotely conduct accurate communication transfer and flying controls with navigation and guidance techniques.

As part of their program to develop OOS capabilities to support future missions, NASA has two missions focused on On-orbit Servicing, Assembly, and Manufacturing (OSAM), dubbed OSAM-1 and OSAM-2. OSAM-1’s primary mission is to demonstrate the ability to refuel a satellite, but also includes a robotic arm known as SPIDER that will demonstrate the ability to assemble an antenna in space. OSAM-2 involves a satellite called Archinaut One that will build, assemble, and deploy its own operational solar array.

Other commercial and civil RPO developments include Italy’s D-Orbit ION launched in September 2020, which offered rideshare opportunities to bring satellites to their operational orbits faster than typical drifting procedures. Additionally, Japanese start-up Astroscale’s ESA-1 servicer launched in March 2021 and plans to demonstrate the ability to inspect, RPO, and capture another object to support future active debris removal missions. The European Space Agency also has a vested interest in space debris removal, awarding the Swiss ClearSpace company a contract to remove a 100-kg ESA upper stage adapter from orbit in 2025.

There have also been two commercial satellite servicing missions. The Mission Extension Vehicle 1 (MEV-1), a satellite developed by SpaceLogistics (a subsidiary of Northrop Grumman), docked with the Intelsat 901 (IS-901) satellite in March 2020 just above the geostationary belt to provide life-extension and repositioning services through 2025. MEV-2 launched in August 2020 and docked with Intelsat 10-02 in April 2021 in the geostationary belt to begin a similar five-year life extension mission.

While there have only been a few commercial missions to date, the advances in technology, changes in national policy, and new regulations could spark a significant increase in the future. Thus far in the past year, multiple start-ups have emerged offering their first clients satellite servicing, active debris removal, and end of life services; this indicates a promising future for the commercial space industry. The Consortium for Execution of Rendezvous and Servicing Operations (CONFERS), created in 2017 with initial funding from the Defense Advanced Research Projects Agency (DARPA), today has more than 40 members from several countries planning a wide range of future commercial OOS missions.
**Dual Use and Transparency**

The growing advances in commercial and civil RPO and OOS capabilities raise important questions about the distinction between their activities and RPO conducted for military or intelligence reasons. Increased transparency is needed, along with establishment of norms of behavior and technical standards, to increase the safety of commercial and civil RPO and OOS and help distinguish them from military and intelligence activities.

<table>
<thead>
<tr>
<th>Country</th>
<th>Date of Activity</th>
<th>Servicer Satellite</th>
<th>Client Satellite</th>
<th>Launch Site</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Japan</td>
<td>Nov. 1997</td>
<td>ORIHEME</td>
<td>HIKOBOSHI</td>
<td>Tanegashima Space Center</td>
<td>• Demonstrated autonomous docking and satellite servicing with onboard mounted robotic system</td>
</tr>
<tr>
<td>USA</td>
<td>April 14 2005</td>
<td>MUBLCOM</td>
<td>DART</td>
<td>Vandenberg AFB</td>
<td>• NASA DART bumped into military satellite during proximity test, unclear if offensive test</td>
</tr>
</tbody>
</table>
| Sweden  | Aug. 2010 - July 2011 | PRISMA Target | PRISMA Main | Dombrovskiy Air Base | • Two launched as a pair and separated  
• Autonomous guidance and navigation experiments while testing GPS navigation |
| USA     | Jan. 2016        | BEVO-2            | AggiesSat4       | Cape Canaveral     | • Pair of satellites deployed from ISS to practice communication and data exchange as well as station keeping and navigation |
| USA     | Jan. 25 2020—present | Intelsat 901 | MEV-1            | Baikonur          | • MEV-1 successfully docked to provide mission extension services for Intelsat by propelling and pointing it |
| USA     | June 15-29 2020  | Aerocube          | Aerocube 10-B    | Wallops           | • AC-10B entered a proximity orbit around AC-10A and used its on-board camera to take resolved images of AC-10A. |
| Italy   | Sept. 3 - Oct 28 2020 | D-Orbit ION | Multiple          | Guiana Space Center | • ION performed rendezvous operations with multiple satellites to bring it to its designated orbit faster than normal drifting |
| USA     | April 12 2021—present | MEV-2            | Intelsat 10-02   | Guiana Space Center | • MEV-2 docked with Intelsat 10-02 after several weeks of RPO and is performing a life extension mission through 2025 |
| Japan   | Summer 2021      | ELSA-D Servicer   | ELSA-D Client    | Baikonur          | • Launched on March 22, 2021, ELSA-d will magnetically dock with the client satellite and demonstrate debris removing capabilities with |

Promoting Cooperative Solutions for Space Sustainability  
www.swfound.org
Endnotes