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Introduction

On-orbit satellite servicing (OOS) refers to the ability to repair, refuel, reposition or otherwise maintain satellites in space (Duke, 2021). As orbital infrastructure has become increasingly strategically relevant for both commercial and military purposes, this capability has gained heightened attention in recent years. Since major nations have accelerated OOS projects in recent years, servicing technologies experienced a steep evolutionary trajectory (Garretson, 2021). From a strategic perspective, OOS not only helps to maintain and maximise the efficiency of space-based defence applications in a support role, but also servicing technology, such as tracking, targeting and repositioning capabilities, has itself been increasingly shown potential for weaponisation in an anti-satellite capacity (Samson & Cesari, 2025). However, European servicing capacities have historically lagged behind major global powers such as the United States (Reuters, 2025).

Recently, the European Union has re-committed itself to achieving European strategic and defence autonomy. In March 2025, the European Commission published the White Paper for European Defence - Readiness 2030, a milestone framework designed to bolster European defence spending (Montinari, 2025). Within the framework, space has been recognised as a key domain to achieve this autonomy and is mentioned more than any other strategic theatre, with a total of 20 mentions across the paper (European Commission, 2025). On this path towards strategic sovereignty, the development of European on-orbit servicing capabilities is emerging as a paramount strategic necessity.

This research article explores how servicing technologies can serve as a resource for and cost-effective accelerator on Europe's path towards space autonomy. In the context of this essay, "Europe" refers to the constellation of nations forming part of the broader European security architecture, encompassing EU member states, European NATO members, and associated European-based partners within the Euro-Atlantic security order as defined by Hyde-Price (2007). This article first establishes the contemporary strategic relevance of on-orbit servicing by providing an overview of its historical development, before examining the global state of current and emerging servicing technologies. These findings are then used as a basis of comparison to Europe's own capabilities, deficits and opportunities for future development in this domain.

1. The History of On-Orbit Satellite Servicing

The concept of on-orbit servicing emerged alongside the ascent of commercial satellite technologies in the 1960s, when the issue arose that maintenance or repair was impossible once a satellite had been launched (Garretson, 2021). However, tangible progress in on-orbit servicing technology only began to materialise in the 1980s with NASA's Space Shuttle program. In 1984, astronauts performed the first on-orbit satellite repair when they retrieved the Solar Maximum Mission SolarMax satellite and successfully repaired its malfunctioning electronics, marking "a new era of the human enterprise in space" (Wilford, 1984, p. 40). This was followed by a series of high-profile Space Shuttle servicing missions to the Hubble Space Telescope in the 1990s and 2000s (Garretson, 2021). While these early missions were entirely human-operated, focus increasingly shifted to robotic and autonomous servicing technologies. The Engineering Test Satellite VII (ETS-VII) mission launched by Japan in 1997 achieved the world's first autonomous rendezvous and docking between two unmanned spacecraft (Yoshida, 2003).

Throughout the 2000s and 2010s, technological developments further refined on-orbit servicing operations. In 2007, the United States' Orbital Express mission, developed by the US Defense Advanced Research Projects Agency (DARPA) in partnership with the Air Force and NASA, achieved the first-ever autonomous refuelling and component replacement using a pair of satellites, one servicer and one client, in low Earth orbit (Garretson, 2021). The International Space Station (ISS) became the primary testing field for servicing technology, for instance, with NASA's Robotic Refuelling Mission in the early 2010s, which practised robotic handling of fuel valves and satellite interfaces (NASA, 2013). Canada and Europe also contributed robotic arms to the ISS, namely Canadarm2 and ERA. By the late 2010s, the main technological components for modern on-orbit servicing, including autonomous guidance, navigation and control (GNC), robotic manipulators, and refuelling technology, were established.

The late 2010s and early 2020s were further marked by a shift in the balance of the space technology market, as private enterprises increasingly evolved from merely being suppliers of components to government-led space missions to building their own spaceflight and satellite servicing capabilities (Duke, 2021). A significant breakthrough came with Northrop Grumman's Mission Extension Vehicle (MEV) programme, in which, for the first time, two private satellites docked in space to provide orbital servicing; a landmark that proved private companies could provide orbital maintenance as a service (Howell, 2020). MEV-1 launched in 2019 atop a Russian Proton rocket and in early 2020 autonomously docked with an aging Intelsat-901 communication satellite in a high-altitude graveyard orbit, successfully restoring it to a geostationary slot and extending its operational lifespan by five years (Jones, 2025). A second Mission Extension Vehicle (MEV-2) soon followed, docking to another Intelsat satellite in 2021.

2. Current Global On-Orbit Servicing Capabilities

By the mid-2020s, on-orbit servicing has transitioned into a heavily commercialised field with actors around the world developing a range of capabilities. Globally, the United States is leading the development of operational on-orbit servicing. Northrop Grumman's Space Logistics division, through its MEV missions, has demonstrated the commercial viability of life-extension services for satellites in geostationary orbit (GEO) (Jones, 2025). In the US, the success of MEV-1 and MEV-2 since sparked a rise in investments in similar servicing concepts by commercial ventures and space agencies alike. In the private sector, Northrop Grumman has been working on a new Mission Robotic Vehicle carrying multiple small Mission Extension Pods that can be attached to clients for life extension (Erwin, 2021). Notably, most commercial efforts are not purely private. As US-governmental interest in servicing capabilities has increased drastically, many American commercial servicing projects are either directly funded by government projects or regard the military as their key future customer. For instance, the Space Force has allocated funds specifically for in-space servicing and logistics services from commercial providers (Samson & Cesari, 2025). Additionally, following their past successes with the Orbital Express servicing programme, DARPA has been developing the Robotic Servicing of Geosynchronous Satellites programme (RSGS), which was initiated to develop a government-owned robotic servicer for inspection and repair of US military satellites in GEO, specifically for usage onboard commercial spacecrafts developed in the private sector (Garretson, 2021). Meanwhile, the US Space Force and Defense Innovation Unit are developing programs to add fuelling ports to satellites (Erwin, 2021). To facilitate uniformity in future servicing technologies, American companies have also proposed technical standardisation projects, such as Lockheed Martin's Mission Augmentation Port standard, to make satellites compatible with servicing by different providers (Lockheed Martin, 2025). On the international stage, the US has facilitated the private sector-led initiative Consortium for Execution of Rendezvous and Servicing Operations (CONFERS), which aims to introduce global common standards for satellite servicing and debris removal activities (Weeden, 2022).

Strikingly, US governmental interest in developing on-orbit capabilities through defence projects have highlighted their strategic support value in increasing operational efficiency of American orbital entities. However, US on-orbit servicing technologies have increasingly been proven as active capabilities for space defence purposes: The 2025 Global Counterspace Capabilities Report (Samson & Cesari, 2025) found that the numerous tests carried out by the US of technologies for close approach and rendezvous both in low Earth orbit (LEO) and GEO, as well as systems for tracking, targeting, and hit-to-kill (HTK) interception, could all potentially be used in a co-orbital anti-satellite (ASAT) capacity.

Other space powers, most notably Russia and China, have simultaneously been developing their own strategic on-orbit servicing technology capabilities. Between 2021 and 2022, China launched Shijian-21, officially described as a 'space debris mitigation' test satellite (Jones, 2022). Shijian-21 successfully docked to a defunct Chinese navigation satellite in GEO before towing it to a higher graveyard orbit, exhibiting orbital asset relocation capabilities previously only displayed by the US (Jones, 2022). This advancement in de-orbiting capabilities has received critical responses from US analysts, since although space debris removal technology has become an urgent necessity to ensure sustainability of the space domain, the same procedure could instead be used to disable or remove an adversary's satellite (Jones, 2022).

Meanwhile, Russia has pursued similar dual-use orbital manoeuvring programmes. In a notable incident in July 2020, the US Space Command reported that a Russian inspection satellite, Cosmos 2543, covertly released a sub-satellite object in proximity to another Russian satellite – a manoeuvre effectively constituting a space-based anti-satellite weapon test. The exercise was condemned by US and UK officials as evidence of Russian developments of co-orbital anti-satellite weapons, although Russia denied such accusations (Reif & Bugos, 2020).

Such developments have demonstrated how leading global space actors have not only accelerated their development of on-orbit servicing technologies in recent years but also expanded their strategic utility through practicing the use of servicing capabilities with clear military implications in counterspace roles. These dual-use application abilities are set to further proliferate the future strategic importance of on-orbit servicing technology.

3. European On-Orbit Servicing: Capabilities and Deficits

As space is increasingly recognised as a contested strategic domain, it has become evident that in a defence scenario, domestic European space capabilities are vital to assure control of this novel theatre of operation (European Commission, 2023). However, European efforts in space defence have historically lagged behind those of the US and other major space nations (Reuters, 2025). This includes on-orbit servicing technology. As of 2025, Europe has yet to deploy an operational satellite servicing mission (European Space Agency, 2024), while earlier projects, such as Germany's on-orbit servicing mission DEOS, have been discontinued (Krebs, 2025). This deficiency can be attributed largely to past policy and funding choices related to not only space as a domain, but also, notably, defence (European Commission, 2025). A key deficit has historically been the limited involvement of defence sectors in European space technology efforts. Unlike the US, where the Space Force and DARPA actively invest in servicing for military satellites (Garretson, 2021), Europe's mostly European

Space Agency (ESA) and EU-research funded projects have been almost entirely civil and were grounded on sustainability and commercial competitiveness projects (Sagath et al., 2019). In this, France has been a notable outlier, as the country's 2019 national space defence strategy explicitly called for developing "active defence" capabilities in orbit (Ministère des Armées, 2019). Following through, in 2024, the French Space Command announced project 'Toutatis', including a demonstrator satellite named Splinter that is supposed to be highly manoeuvrable in LEO and potentially able to target and impact other satellites using a laser (Ruitenberg, 2024).

However, a drastic change of course in common EU defence policy materialised in the EU Strategic Compass for Security and Defence, published in May 2022, which, following an exhaustive threat assessment, concluded with formulating the necessity of a common strategic culture towards European strategic autonomy (Fiott, 2022). This rethinking towards European autonomy also became apparent in the space domain. The 2023 EU Space Strategy for Security and Defence highlighted the need to protect European space assets and to regard space as a "strategic domain" (European Commission, 2023). As a result of this attention, the European space budget has increased significantly over recent years, with the ESA having approved €16.9 billion for space investments from 2022 to 2025, a 19% increase from the previous period (Tani, 2022). Still, public space-related funding remains significantly behind budgets of other space powers, in particular the US and China (Francica, 2025).

As part of the ReArm Europe plan, the 2025 White Paper for European Defence – Readiness 2030 presented a landmark plan to bolster European defence, including loosening regulations and fiscal rules to mobilise up to €800 billion for defence investments (Tidey, 2025). The initiative particularly emphasises incentivising the mobilisation of private capital to accelerate defence technology development and close the gap in military development and production capabilities (European Commission, 2025). This call for contributions from within the European private sector particularly targets Small and Medium Enterprises (SMEs) As the White Paper strategy concludes, one of the most potent paths for European strategic autonomy is for European governments to partner with emerging commercial companies to boost capabilities quickly (Montinari, 2025). By expanding defence-related public funding opportunities, the EU and national agencies can increase investment incentives by ensuring increased contract certainty for private companies. This approach not only accelerates technology development but also helps close strategic capability gaps short-term, without having to build missing resources anew, but instead utilising existing private sector capacities. Private innovations can hence bolster governmental defence efforts in a more cost-effective way, as the existing market can provide, and thus compensate for, crucially lacking space technology and infrastructure, while absorbing parts of the development risk and cost (Poirier et al., 2023).

Although less advanced than their international competitors, European on-orbit servicing projects have made significant progress in recent years, many of which are already profiting from an increase in such public-private partnerships. One flagship project is the ClearSpace-1 mission (ESA, 2020). In 2020, the ESA contracted the Swiss startup ClearSpace SA to launch the world's first active debris removal mission, scheduled for the mid-2020s. ClearSpace-1 is projected to rendezvous with an ESA-owned Vega rocket debris in low Earth orbit, capture it with four robotic arms, and de-orbit it (ESA, 2020). Although its primary concern is debris removal, the mission is effectively also a demonstration of all other core technologies required for general on-orbit servicing missions, including autonomous rendezvous, the capture of an uncooperative object, and controlled de-orbiting.

Beyond debris removal, Europe is also now directly targeting the development of satellite servicing technology in geostationary orbit. In October 2024, the ESA announced the in-orbit servicing mission RISE, partnering with the Italian company D-Orbit to build Europe's first life-extension servicer for GEO (ESA, 2024). Supported by a €119 million ESA contract, RISE is projected to demonstrate safe rendezvous and docking with a client satellite in geostationary orbit, using a mission design similar to Northrop Grumman's MEV. Following the initial demonstration, which is planned for the late 2020s, D-Orbit intends to operate the servicer commercially for life-extension services (ESA, 2024). Simultaneously, France, through its space agency Centre National d'Études Spatiales (CNES) and with funding from the France 2030 investment plan, is supporting a mission called Endurance by the startup Infinite Orbits, which aims to be France's and Europe's first GEO satellite servicing mission (Dawn Aerospace, 2024). Announced in 2024, Endurance will carry a Dawn Aerospace propulsion system and is intended to dock with a geostationary satellite to extend its life (Dawn Aerospace, 2024).

In the research and technology domain, the EU and various national agencies have also initiated a series of projects to develop autonomous robotics for servicing. Under the EU's Horizon 2020 programme, a Strategic Research Cluster on Space Robotics was established, including flagship projects such as EROSS (European Robotic Orbital Support Services) and its successor EROSS+ (Thales, 2021). These projects, led by Thales Alenia Space alongside other private European partners, have been integrating servicing technologies into a ground demonstrator for on-orbit servicing tasks. Its primary aim is to achieve a fully autonomous capture and servicing in an in-orbit demonstration by the mid-2020s (Thales, 2021). European agencies have also shown interest in developing European-standardised servicing interfaces to increase modularity and interoperability (ESPI, 2023). For instance, iBOSS (Intelligent Building Blocks), a German-led initiative, is working on modular interfaces for satellites that could help simplify future repairs (Kortmann et al., 2015).

However, while the White Paper presents a wide range of new funding opportunities from various sources, it also reveals the still prevalent regulatory confines preventing quick progress in approving and distributing investments for defence-related spending, including, for instance, a lack of clarification of the application of the EU's Sustainable Finance Disclosures Regulation for defence-related financing (European Commission, 2025). The more European private and public organs are prevented by bureaucratic hurdles from cooperating efficiently with one another across national jurisdictions, the more difficult it will be for European space efforts to rival the efficiency and output of the more centralised agencies of other space powers, such as the US and China (Poirier et al., 2023). Future collective European servicer missions should thus be able to profit from streamlined legislation facilitating transnational cooperation, as it is already materialising in projects such as EROSS+, where France, Italy, Germany, Spain, Poland and others each contribute sub-systems (Thales, 2021).

European space capabilities, including on-orbit servicing, have previously been behind international competition. However, following the recent European paradigm shift, which declared European defence autonomy a strategic imperative, orbital defence has received increased attention. To fill previous and current capability gaps, Europe's best opportunity revolves around utilising the continent's already existing industrial and entrepreneurial resources. By better supporting joint civil-military projects and facilitating cooperation across member states, the EU has the chance to significantly enhance its space defence capacity, which would not only translate directly into greater resilience of European space assets, but also improve strategic autonomy by reducing dependency on non-European services. Additionally, it would ensure Europe increases its competitiveness in the growing global market for in-orbit services, which is expected to expand as satellites proliferate and the urgency of space sustainability grows (Toral García, 2025).

Conclusion

On-orbit satellite servicing has evolved into an increasingly critical capability within the rapidly developing space domain. Major global actors, such as the US, Russia, and China, have significantly advanced these technologies, developing their strategic value not just for satellite maintenance but also for concrete military purposes. While Europe has historically fallen short of its competitors in developing similar capabilities, recent policy shifts towards European strategic autonomy offer Europe a crucial opportunity to address and overcome these limitations, as the development of its own on-orbit servicing capabilities becomes increasingly paramount for achieving strategic autonomy. The emergence of a more unified European approach, characterised by increased public-private cooperation and an emphasis on leveraging existing industrial capacities, represents the most promising opportunity to close the capability gap with immediate effect. Transnational private-public partnership initiatives such as ClearSpace-1, RISE, and EROSS+ demonstrate the increased attention servicing technologies, in particular, are receiving on this European path towards operational readiness. Nevertheless, realising the full potential of private European capacities for developing servicing technologies will require Europe to overcome its persistent regulatory and structural challenges, particularly in regard to transnational cooperation and the integration of civil and defence efforts. If the legislative obstacles can be effectively addressed, European-made on-orbit servicing technologies may not only be a short-term cost-efficient tool to significantly enhance the sustainability and security of European space infrastructure but serve as a strategic multiplier for future European ambitions of technological and strategic sovereignty.

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