by **ARTHUR WONG**
Aerospace Engineer
Space Operations
Supreme Headquarters Allied Powes Europe
(HQ SHAPE)

ROBOTIC SERVICING SATELLITE

ENABLER or THREAT ?

"Space makes us safer; makes warfare less likely and less destructive."

General (Ret.) Lance W. Lord
Former Commander, U.S. Air Force Space Command

In-orbit repair

Sending satellites to Space remains an expensive project for both governments and private industries. One of the driving costs for such multi-billion-euro projects is the advanced equipment and systems installed onboard spacecrafts. Additional complications derive from the fact that once the satellite has launched, entered the desired orbit, and began operation, there are very limited repair or maintenance services available. This is contrary to all other warfighting domains; whether it is a cyber firmware update, a maritime dry-dock, an air asset in a hangar or a land capability undergoing preventative maintenance. The spacecraft will orbit in Space until it has reached its end of life. Depending on the severity of the problem, without the possibility of hands-on repair, operators might need to consider abandoning the Space asset resulting in billions of euros lost.

NATO approved its first Space Policy on June 27, 2019.

IN-ORBIT REPAIR IS NOT a new concept; in fact, some of the previous Space shuttle missions were conducted for replacement and repair of satellites, even though sending astronaut crews into Space is both costly and dangerous. The Hubble Space Telescope (often referred to as HST or Hubble) is one of the examples of a Space-based asset that received orbital replacement services in the late '90s and early 2000s. A total of five missions were flown by the United States National Aeronautics and Space Administration (NASA) Space shuttles in order to replace its components, each mission costing hundreds of millions of dollars. As technology has evolved, there are hopes for operators to extend the life expectancy of satellites and provide replacement components directly in orbit for operational satellites, all of this achieved while limiting costs and preventing the need of astronauts conducting risky spacewalks.

Although NATO does not own any operational satellites in Space, it does rely heavily on Space services provided by Nations on a voluntary basis across the full spectrum of Space capabilities: Satellite Communications (SATCOM); Intelligence, Surveillance and Reconnaissance (ISR); Position, Navigation and Timing (PNT); Meteorology and Oceanography (METOC); Space Situational Awareness (SSA); and Shared Early Warning (SEW). These capabilities are critical for modern warfare and provide the most up-to-date information to our warfighters. Considering Space as a force multiplier, it is imperative that nations continue to have operational Space assets, which can be utilized whenever and wherever. Maintaining national satellites at their highest level of readiness and ensuring their survivability will greatly boost the Space capabilities of the Alliance. Military operations can still be conducted without the use of Space-based assets, but military objectives in the 21st Century can be better achieved through utilization of Space.

Modern military operations rely heavily on Space capabilities whether it is SATCOM providing Command and Control, PNT guiding munitions, warning of an inbound missile through SEW, or any of the other capabilities we have come to depend on. Potential adversaries continue to invest into the development of counter Space systems, ensuring Space support to NATO operations is vital to future operations' success.

What is a Robotic Servicing Satellite?

As previously mentioned, manned Space repairing missions are extremely costly and place astronauts at risk. Furthermore, when a satellite malfunctions, it is harder and sometimes impossible to diagnose it using ground-based tools. That is the reason why robotic servicing satellites could present the solution to this problem. Robotic servicing satellites are essentially a satellite tasked with repairing and maintaining other satellites. These maintenance and repair systems will have the ability to image, analyze and provide repair services using a robotic arm. This service allows the terrestrial operator to gain a better understanding of the problem in order to diagnose and repair

the malfunctioning asset. Older satellites may also benefit from this emerging capability with component replacement and upgrade, something that becomes necessary due to aging and exposure to the extreme environment present in Space. The cost of sending satellites orbiting in the Geostationary Orbit (GEO) is generally high, and small repairs from servicing satellites could reduce the cost from further replacement launch and limit the amount of Space debris.

THE FIRST ROBOTIC ARM put into service was the Canadarm installed inside of the Space Shuttle Columbia. The Canadarm was used to assist in the placing of satellites in orbit from the payload bay of the Space Shuttle. With the positive performance of the Canadarm, a second-generation robotic arm was developed and permanently installed on the International Space Station (ISS) as a mechanism to assist with Space docking and Space capsule retrieval. Since the expansion of the ISS, a European Robotic Arm and a Russian Strela crane have also been installed.

The Defense Advanced Research Projects Agency (DARPA), a research and development agency of the U.S. Department of Defense, has been working on a robotic payload, which will eventually inspect and service satellites in the GEO region. If the Robotic Servicing of Geosynchronous Satellites (RSGS) programme proves to be successful, the need of a replacement satellite will be reduced, limiting the cost of the overall satellite programme. This programme, developed by the U.S., is expected to be launched in 2021, while the separate NASA project "Restore-L Robotic Servicing Satellite", aiming to provide robotic services in the low Earth and polar orbit, is expected to enter service by 2022. Other Space-capable nations such as China are also looking into the possibility of developing a similar programme.[1]

During the Gulf War in 1991, for the first time, the U.S. conducted a large military offensive operation using new technologies to fight the adversary. These technologies included the U.S. Global Positioning System (GPS) for precision-guided munition employment and navigation for ground force. This first use of Space-based assets ushered in new reliance and the resulting new potential targets.

The importance of controlling Space and gaining superiority over the opponent through Space did not pass unnoticed. Certain Spacefaring nations have focused on their development of Space capabilities including anti-satellite (ASAT) weapons to deny, degrade and disrupt their adversaries.[2] As technology progresses, other nations have also studied on-

"Maintaining national satellites at their highest level of **readiness** and ensuring their survivability will greatly boost the **Space capabilities of the Alliance**."

BELOW: The International Space Station's robotic Canadarm2. Earth's horizon and the blackness of Space provide the backdrop for the scene. Photo by NASA

Space today is a warfighting domain, similar to the air, land, and maritime domains.

orbit capabilities, such as satellite inspection and repair, to enhance their presence in Space. The concept of robotic servicing satellite will extend the mission life of many Space-based assets, reduce cost and increase their Space capabilities. Due to the capability of the robotic arms, the potential exists to be utilized with a dual-use purpose, making it easy to become a co-orbit ASAT weapon against Allies' satellites without any early warning.

Further to servicing satellites, the robotic arm could also be used as a Space debris removal mechanism to clean up non-functional satellites. With the use of the robotic arm, the defunct satellite will be captured and removed from its current orbit, freeing up spaces for future Space launch. Once the defunct satellites have been removed from its orbit, the robotic arm would either "push" the defunct satellite towards the Earth and burn up in the atmosphere, or for smaller satellite, stored within the cleanup satellite and return to Earth. Both potential options would require the use of robotic arm to grapple and deorbit the target defunct satellite. Despite the usefulness of debris removal, the utilization of the robotic arm for this purpose has been a controversial topic within Space orbital threats. These threats are dangerous as they can act as a dual-use mechanism. In the early stage of being in orbit, the satellite can act as a cleanup satellite and once a target has been spotted it can use it as a co-orbital ASAT.

Do Robotic Arms Pose a Potential Threat to NATO?

Even though satellites with robotic arms are supposed to be used for repair and Space debris removal, there are cases where concerns are being raised on whether the robotic servicing satellites are actually being used for servicing or whether they achieve a different, more nefarious, objective.

China launched a satellite named Shiyan 7 (SY-7) in 2013 for "conducting Space maintenance". According to reports,[3] the SY-7 was equipped with a robotic arm and had remained silent in orbit before making a sudden maneuver and beginning an orbital rendezvous with another satellite. In addition to the rendezvous maneuver, this satellite also tested its robotic arm's grappling capabilities to another object. It is unsure whether this incident and the mission of SY-7 have been used as a testing base for potential sabotaging of foreign satellites. China's state-run news agency reported that the mission of this satellite was to carry out scientific experiments.

After the SY-7 launch, China launched another satellite in 2016, the Aolong-1 Spacecraft, which was also fitted with a robotic arm. According to the official statement,[4] the Aolong-1 was intended to be used as a debris collector. Although the testing of Shiyan 7 and Aolong 1 has not resulted in any damage to other on orbit systems, the ramifications of the capability have raised concerns among many experts regarding China's intention.[5] Both of these missions were conducted by either China Academy of Space Technology (CAST) or China Academy of Launch Vehicle Technology (CALT), a subordinate of the China Aerospace Science and Technology Corporation (CASC). The CASC collaborates closely with the China National Space Administration (CNSA) as it is a state-owned company and the main contractor to the Chinese Space Programme. The CNSA is in charge of all civil Space activities, while military Space activities are run through the People's Liberation Army (PLA). There has been a collaboration between the CNSA and PLA on the development of next-generation Space technologies.

Collaboration between a civil government division and military organization could potentially accelerate research and development as some of the properties overlap between scientific and military area. However, this would create confusion with the blurred line between science or military mission. Furthermore, civil-military collaboration could raise concerns from other nations, questioning the real purpose and intention of the mission, which could further increase the mistrust between nations.

While China has been increasingly interested in using robotic arms on various Space missions, Russia has not publicly announced any major investment, nor has it expressively shown any strong interest in robotic arms. Although there is previous involvement, such as the robotic arm installed on the ISS, research and development activities similar to the ones constructed by China were not mentioned nor detected. However, Russia did conduct Rendezvous and Proximity Operations (RPO) in Space. The Kosmos 2499 satellite was speculated as an experimental orbital ASAT testing. The unexpected and unusual maneuver of a Russian satellite has raised suspicions on whether it is performing "inspection" on foreign Space assets. However, no reports have indicated the Kosmos 2499 has any robotic mechanism attached to the satellite.[6]

The aforementioned incidents all occurred within the Low Earth Orbit (LEO) somewhere between 600–1,500 km range from the surface of the Earth. Some of the communications, and most of the ISR satellites from NATO Nations, are within the LEO. Space-based ISR assets can provide valuable Measurement and Signature Intelligence (MASINT) over areas

ABOVE: TRIDENT JUPITER 2019-1 Main Events List/Main Incidents List Scripting Workshop at the Joint Warfare Centre, Cdr. Robert Kroeger, French Joint Space Command, is briefing. Photo by JWC PAO

ABOVE: The author (left) and Flavio Guidice, TRIDENT JUPITER 2019-1 Main Events List/Main Incidents List Scripting Workshop, Joint Warfare Centre. Photo by JWC PAO

where it cannot be reached using Unmanned Aerial Vehicle (UAV) or without risking the loss of personnel and equipment. Aircrafts entering foreign airspace can be targeted using surface-to-air missile or air-to-air missile, while in Space it is much harder to target it using the ground-based missile.

Furthermore, Space assets do not require authorization to fly over an area. If Space-based ISR assets are disrupted by robotic satellites, it would have a great impact on NATO's gathering of intelligence, surveillance and reconnaissance. Even though NATO troops train in a denied, degraded and disrupted Space operational environment (D3SOE), that training does not eliminate the risk. Space-based assets provide information on all domains, offering data of vital importance for any military operation and exercise in the 21st Century.

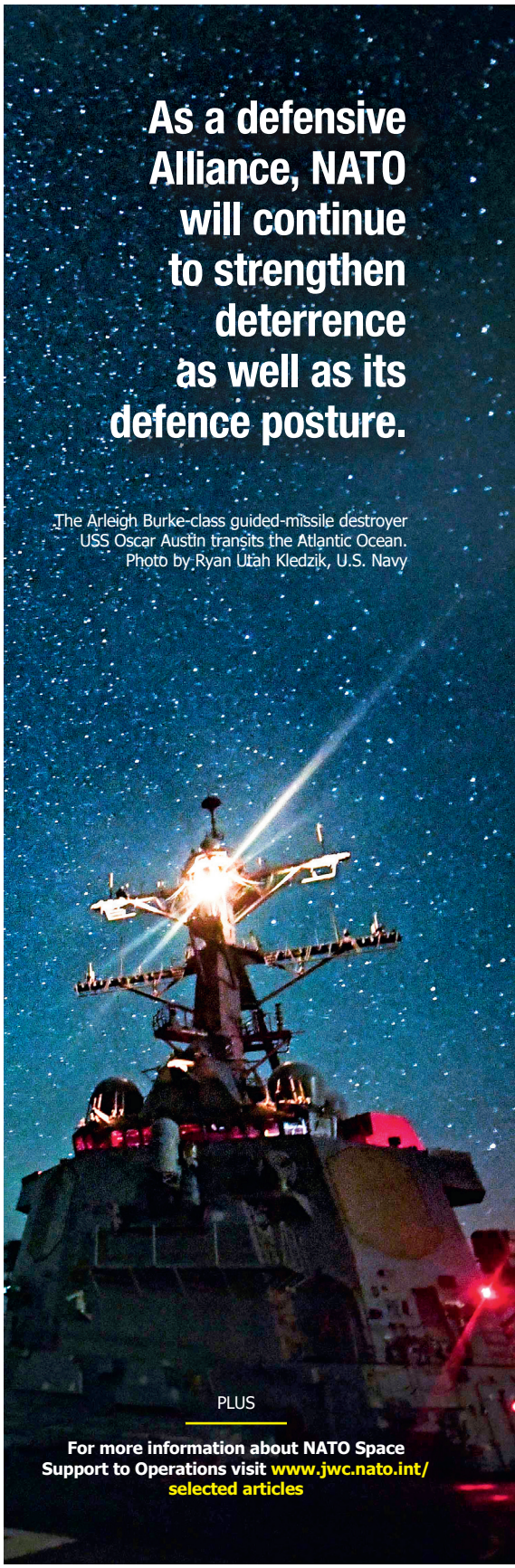
Space Threats Are No Longer Limited to State Actors

During the era of the Cold War, all Space activities were controlled and managed under the authority of each nation's Space administration. However, since the early 2000s, there has been an increase in commercial sponsored spaceflight and Space systems. Furthermore, smaller satellites such as NanoSat[7] and CubeSat[8] can be easily created within a university environment. With non-state actors having the ability to produce and build potential co-orbital threats, it is more difficult for nations to target individual groups or monitor such activities. Additionally, it is hard to determine whether these non-state actors are being sanctioned by their respective states, making non-state actors a second faction in Space activities.

Space and Cyberspace

In the digital age, where almost everything is controlled using computers, the relationship between Space and cyberspace is no different. NATO member states have experienced cyber-attacks where adversaries were targeting the satellite system.[9] These cyber-attacks will impact the defensive capabilities of NATO to react and obtain real-time information. Furthermore, potential adversaries may have the ability to take control of portions, or even the entire satellite, through cyber-attacks, impacting NATO's reliance on these capabilities.

In recent years, Russia and China have been heavily investing to enhance their cyber capabilities.[10 11] In 2008, the NASA Terra Earth observation satellite was attacked by hackers and they "achieved all steps required to command the satellite but did not issue commands."[12] Such attacks have proven the possibility of hacking into robotic servicing satellites and turning them into a co-orbital ASAT weapon. Cyber-attacks are a cheap alternative



"As Space continues to play a prominent role in military operations, an escalation of **Space dominance** will continue to heat up."

to create co-orbital ASAT capabilities. Through cyberspace, potential adversaries only require software and hacking devices and will be able to commandeer foreign national Space assets.

How Can NATO Maintain God's Eye-View

Unlike some Spacefaring nations, NATO does not have a "Space operation centre", which monitors Space activities and the Space situation. NATO is reliant on this Space Situational Awareness (SSA) being shared. Having access to SSA is the key element to gain the upper hand on "Space warfare".

One of the major components of SSA is the study and monitoring of objects orbiting around the Earth, mainly artificial satellites. SSA must include the ability to track an object's activities in Space, thus monitoring suspicious activities such as foreign launch or unusual maneuvers from foreign satellites. Since SSA is a prerequisite for any Space control mission, a nation must have this ability as a complementary requirement to other Space support requirements. NATO's widespread use of Space-based products and services requires SSA products and services as a component of Space support to NATO operations.

The SSA has become more important to NATO over the years, as we encounter more commercial and military Space launches across the world. While most of these launches and the details of the missions are reported, monitoring activities of the spacecrafts is still required, as there could be a "hidden agenda" to the real mission of the spacecraft. If adversaries disrupted Allies' Space capabilities, it could prevent NATO to respond to crises and operations. The 2013 and 2016 robotic arm satellites launched by China, which made unusual maneuvers, and potential orbital ASAT testing are the reasons why NATO utilize SSA to counter offensive Space activities.

A former Commander of U.S. Air Force Space Command, General William Shelton, stressed the importance of Space-based SSA assets to bolster the ability to discern when adversaries attempt to avoid detection and to discover the capabilities they may have, preventing any possible offensive threat against Allies' Space assets.[13] Without them, he said, "we would go back to the way we fought in World War II." Currently, NATO acquires SSA from several Space capable nations through ad-hoc requests, such as previous ASAT missile testing from China and India.

The concept of using a robotic arm as a potential weapon in Space has created a brand-new environment of "Space warfare" that has not been encountered before. Current international and national laws do not prohibit the use of robotic arm, nor prevent satellites conducting RPO, and thereby leaving any potential "attack" on Allies' spacecraft in the legal grey area.

Next Generation Counter-Space

Since the beginning of the 21st Century, the military has adopted the digital age methods and has recognized cyberspace as a future potential "battleground" — a battle without using tanks and fighter jets but still capable of conducting an offensive attack against adversaries. As Space continues to play a prominent role in military operations, an escalation of Space dominance will continue to heat up. However, Space is a unique environment. When objects explode or collide in Space, thousands of smaller pieces of fragments are created. Unlike what happens on Earth, where gravity will keep smaller fragments falling back on Earth, in Space, depending on the direction of the impact and the distance from the Earth's atmosphere, fragments and debris could remain in orbit for many years.

China's ASAT testing in 2007 and India's ASAT testing in 2019 have shown that debris field remaining in orbit increases the chance of collision with other operational satellites. Since the testing in 2007, countries continued to conduct anti-satellite activities. However, none of them have caused a similar scale of Space debris as the one from the 2007 testing. This debris can harm all satellites that are orbiting in the same orbit and is even capable of

ABOVE: U.S. Space Command and NATO Allied Command Transformation at the TRIDENT JUPITER 2019-1 Scripting Workshop at the Joint Warfare Centre. Photo by JWC PAO

damaging satellites in orbit further away from Earth. Due to the outcome of direct ascent attack using missiles, the robotic arm sabotaging could be the next generation "Space weapon" without causing the Kessler Syndrome,[14] which will potentially be damaging all Space-based assets in the nearby altitude. The use of the robotic arm is also more subtle as satellites could hide between the current Space debris field for months as a sleeper satellite and strike when their existence in Space has been forgotten.

Orbital threats in the new Space age are not only bounded by direct kinetic energy threats, but also threats which cannot be easily anticipated. The concept of having sleeper satellites in Space would undoubtedly reduce the reaction time to counter orbital threats. This technology has proven that understanding Space and surveillance of Space are significant to NATO in both defence planning and operations. Without access to Space-based equipment, NATO can still conduct operations, but it would certainly create a more challenging environment to defence planners, field commanders, and warfighters to coordinate, communicate and execute their mission.

Anticipated Space warfare is very different to the Cold War. With this in mind, the U.S. Air Force Space Command has adapted to the rapidly changing Space environment. The disaggregation of Space architectures is one of the strategies to improve the redundancy against any new Space threat. Redundancy can prevent vital Space capabilities from being removed from service by a counter Space threat which can only target one specific satellite at the time. Disaggregation would also be easier to maintain and lower the cost of the production of Space assets due to the lower per-unit production cost. Furthermore, it will help strengthen the deterrence of NATO through new tactics, techniques, and procedures to counter a dispersed architecture.

IN MARCH 2018, U.S. President Donald Trump suggested the establishment of a Space Force to maintain Space traffic and SSA. Former Defense Secretary Jim Mattis also stated that "Space is becoming a contested war-fighting domain, and we have to adapt to that reality", after which Vice President Mike Pence promoted the newly proposed U.S. Space Command.[15] The United States will likely become the first NATO Member Nation to have a dedicated Space Force countering any offensive threat to Space assets and defend against future adversary's Space threat. Furthermore, France has also announced its intention of launching a Space Command, which will further enhance the Alliance's defensive capabilities in Space.

Both China and Russia established dedicated Space Force in 2015 as they saw Space dominance as a vital factor in securing air, maritime, land and electromagnetic dominance. Space dominance will directly affect the course and the outcome of conflicts. By establishing the Space Force, nations have recognized the importance of Space to future conflicts and formally acknowledged Space as a warfighting domain.

While it is unlikely to see any Space-based robotic mechanism targeting NATO nations' Space assets in the near future, these researches and technological advancements from potential adversaries on orbital threats have increased over the past years. Robotic mechanism satellites will revolutionize the Space industry in the coming decades, but also create a harmful orbital threat. Space will continue to be a "heated" environment and is no longer accessible only to state actors. The development of ASAT weapons in the 1980s has already militarized the Space environment. The continuation of dual-use Space assets could potentially weaponize Space in the future. As a defensive Alliance, NATO will continue to strengthen deterrence and its defence posture.


NATO's first RQ-4D Photo by NATO

ENDNOTES:

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5 Harrison, Todd, et al. Space Threat Assessment 2019. Center for Strategic & International Studies, 2019, pp. 13, Space Threat Assessment 2019

6 "Kosmos-2499: Is It a Spy or an Assassin... or Both?" Kosmos-2499: Is It a Spy or an Assassin... or Both?, 30 Apr. 2017, www.russianspaceweb.com/Cosmos-2499.html

7 Miniaturized satellite with a mass between 1–10 kg. CubeSat is classified within the NanoSat category

8 Miniaturized satellite made up of 10 cm x 10 cm x 11.35 cm cubic units. Most CubeSat have a mass less than 1.4 kg and often use commercial off-the-shelf components

9 Harrison, Todd, et al. Space Threat Assessment 2019. Center for Strategic & International Studies, 2019, pp. 13–24, Space Threat Assessment 2019

10 Beech, Hannah. "Meet China's Newest Soldiers: An Online Blue Army." Time, Time, 27 May 2011, world.time.com/2011/05/27/meet-chinas-newest-soldiers-an-online-blue-army/

11 Beckhusen, Robert. "The Russian Military Creates Its Own Cyber Troops." War Is Boring, 28 May 2015, warisboring.com/the-russian-military-creates-its-own-cyber-troops/

12 Harrison, Todd, et al. Space Threat Assessment 2019. Center for Strategic & International Studies, 2019, pp. 16, Space Threat Assessment 2019

13 In 2014, former USAF Gen. Shelton mentioned the importance of Space and Cyberspace at the 30th Annual Air Force Association Air Warfare Symposium and Technology Exposition

14 A scenario proposed by NASA scientist Donald Kessler in 1978. A cascade of collision caused by Space debris remains in the LEO. The initial impact of two objects will increase the likelihood of further collisions. Eventually, the debris in orbit would prevent future Space activities for generations.

15 Stewart, Phil. "Going Where No President Has Gone before, Trump Wants Space Force..." Reuters, Thomson Reuters, 9 Aug. 2018, www.reuters.com/article/us-usa-military-space/going-where-no-president-has-gone-before-trump-wants-space-force-by-2020-idUSKBN1KU209