NATO PARLIAMENTARY ASSEMBLY

SCIENCE AND TECHNOLOGY COMMITTEE (STC)

SPACE AND SECURITY – NATO'S ROLE

Special Report

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EXECUTIVE SUMMARY

Space technologies and space-based data and services are crucially important for the global economic and financial systems, communication, scientific progress, earth observation and natural disaster management, to name but a few. Moreover, space has emerged as a critical security frontier. Recognising the security implications of the rapid progress of space-related technologies, several Allies have embarked on adapting their armed forces by setting up space commands or created a new military service. Similarly, NATO has agreed on a space policy and recently decided to establish a Space Centre in Ramstein, Germany, and welcomed the creation of a Centre of Excellence in Toulouse (France).

This report sheds a light on the significant increase of actors, both state and commercial, and their activities in space. It briefly describes the advances key space-faring nations, such as the United States, Russia, and China have made in space technology. Special attention is given to Russian and Chinese activities and progress in the development of space-denial technologies. It then discusses possible implications of these developments for the existing space infrastructure of Allied member states. A brief analysis of international agreements on space activities and existing gaps that the international community needs to address is followed by an analysis of NATO's evolving role in space.

The report concludes that the existing space infrastructure of Allied nations is susceptible to attack, and their access to space could be disrupted. Developing a common understanding of the security-related challenges and opportunities of space is an important step towards making existing and future Allied space-based assets more resilient. Member states should use NATO as a forum to discuss the security and defence aspects of space. Moreover, as the use of space for peaceful purposes is in the interest of all nations, the Allies should develop a joint approach towards closing existing gaps in international agreements.

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I. INTRODUCTION

1. Secretary General Stoltenberg noted that "What happens in space is of great importance for what we can do on the Earth: communications, navigation, cell phones, military communications, transmission of data and a lot of activities on the Earth, at sea and on land, is dependent on capabilities in space, not least satellites. So, this is important for our civilian societies, but also, of course, for military capabilities" (NATO Secretary General Jens Stoltenberg) (NATO, 2020).

2. In the past decade, space has emerged as a critical security frontier, and it has steadily risen to the top of NATO's agenda. With the adoption of a space policy and the declaration of space as an operational NATO domain, the Alliance has recognised the need to adapt to this rapidly evolving challenge. The creation of a NATO Space Centre at Allied Air Command in Ramstein, Germany, as well as a Centre of Excellence (CoE) in Toulouse, France[1], are significant first steps in response to these challenges. The Brussels Summit Declaration of 14 June 2021 further signals a shift in NATO's approach to space, particularly regarding the application of Article 5. Although these are noteworthy decisions, though, they can only mark the beginning of a long process for the Alliance. Moreover, the modalities for the implementation of space policy are still under discussion among the Allies. As NATO does not have space capabilities of its own, its policy depends entirely on national capabilities.

3. This report provides a short background on the developments in space and space technology and identifies possible implications for the security of the Alliance. The report concludes that NATO can play an important role in policy coordination and the development of procedures and technologies in space. Your rapporteur also wants to emphasise that cooperation, not confrontation, among all space-faring nations, is needed.

4. This report is an update of the report that was presented at the 2021 online Spring Session to the Science and Technology Committee. It was adopted at the 2021 Annual Session in Lisbon.

II. THE SCRAMBLE FOR SPACE

5. Space technologies and space-based data and services are not only crucially important for security and defence but also for global economic and financial systems as well as scientific progress. Space technologies also play a key role in monitoring the global climate and in natural disaster management. Satellites enhance services for many civilian and security-related activities while also reducing costs and limiting necessary resources for many economic activities.

6. Today, the majority of space investments go to commercial satellite services, satellite manufacturing, and satellite ground equipment (NATO PA, 2020). Operating predominately in low-earth orbits (LEO), satellites provide invaluable contributions to navigation, safety and emergency management, environmental monitoring, and science applications.[2]

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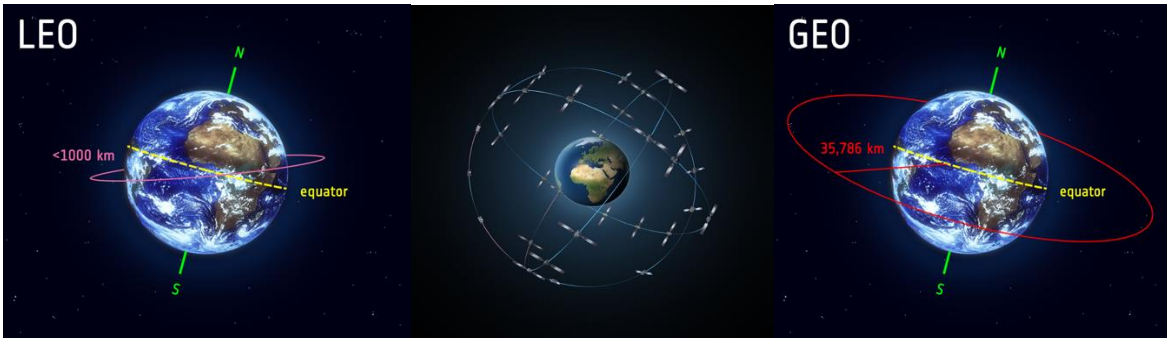
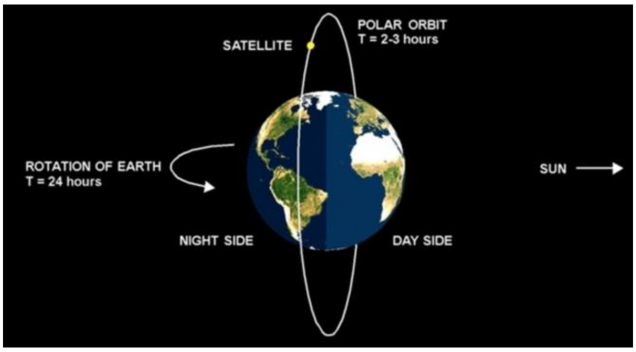
[1] At the time of writing, the creation of the CoE was accepted by NATO Military Authorities (the Military Committee). Final approval by the North Atlantic Council will come when the accreditation process is complete.

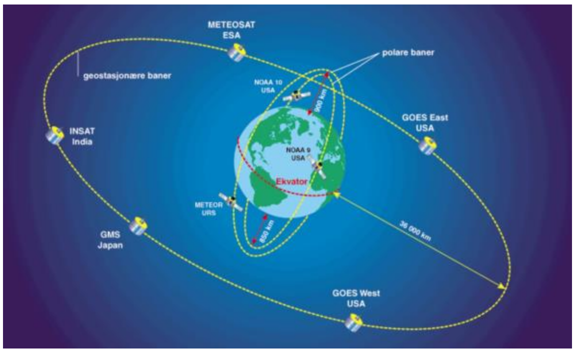
[2] LEO satellites orbit the globe at a comparatively short distance from the Earth's surface of 160 to 2,000 kilometres. They move faster than the Earth's rotation and can only be reached from specific locations on Earth for a limited time. Medium Earth Orbits (MEO) comprises a wide range of orbits between LEO and the Geostationary Orbit (GEO) and is mostly used by navigation satellites. Similar to LEO, satellites in MEO do not require specific paths around Earth. Finally, satellites in GEO are located at the height of the equator, 35 786 kilometres from Earth. Moving at the speed of the Earth's



Source: https://www.esa.int/Enabling_Support/Space_Transportation/Types_of_orbits

7. Polar satellites which revolve around the Earth in a north-south orbit passing over the poles allow for an excellent coverage of Earth's entire surface on a daily basis. Circling about 850 km above Earth, Polar satellites can photograph closer up than the high-altitude geostationary satellites. They are often used for Earth-mapping, Earth observation, reconnaissance, as well as for weather forecasting. Given the increasing strategic relevance of the High North due to climate change, polar satellites can play an important role in monitoring the developments in the region. They can also be used as communication satellites for regions near the poles, where geostationary satellites have no or poor coverage.



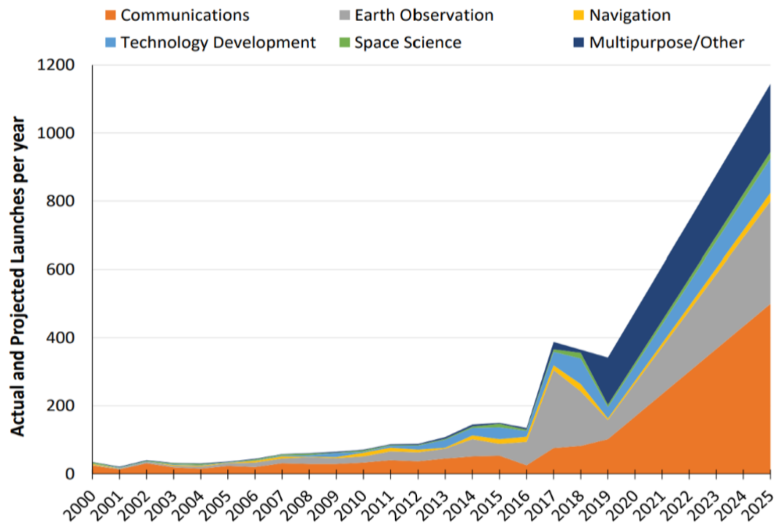


Source: https://www.narom.no/wp-content/uploads/2016/10/Uten-navn-2.jpg

8. Since the first satellite, the Soviet "Sputnik", was launched into orbit in 1957, the space above Earth has become increasingly crowded. More than 30 space-faring nations have emerged in recent years; 84 countries currently operate satellites above Earth (Stewart, 2020). Including launches scheduled through the coming year, close to 3,400 operational satellites will orbit Earth by the end of 2021 (UCS, 2021).[3] Space-based assets are now part of most countries' critical infrastructure (Stewart, 2020). In the meantime, space exploration, including missions into deep space, is becoming a strategic priority for many countries as they develop a robust presence in space.

rotation, they therefore appear to be fixed in the sky when seen from Earth.

3 Broken down by different orbits: LEO (2,612), MEO (139) GEO (562), other (59).



Actual and forecast satellite launches per year (*Source*: MIT Technology Review)

9. Engaging in space activities has become easier and less expensive. Satellite capabilities will expand with technological progress, and new applications will develop. Therefore, space activities will increase as will the dependence of activities on earth on space-based assets. Beyond satellites and scientific exploration, the prospect of access to space resources equally spurs hopes and competition.

10. As resources on earth grow increasingly scarce, space-based mining on celestial bodies (such as asteroids) containing nickel, platinum, iron, or cobalt, will emerge as an issue. Government agencies like the European Space Agency (ESA) have called for new rules to regulate the emerging space mining efforts (Bockel, 2018). For now, these issues are governed by the 1967 Outer Space Treaty (OST), discussed in more detail on the following pages. The Treaty stipulates that celestial bodies are “not subject to national appropriation by claim of sovereignty”[4].

11. Space activities are also less dominated by governments than in the past. A thriving private sector has steadily expanded into what had been almost entirely the province of national governments (Cookson, 2020). Today, government spending accounts only for a total of 22% of all spending on space-related activities globally (NATO PA, 2020). Still, it should be noted that commercial enterprises continue to depend on government contracts.

12. Despite the growing role of the private sector public funds and actors such as the National Aeronautics and Space Administration (NASA) continue to drive commercial research & development (R&D) efforts. Washington has been very successful in integrating private actors into its space activities, which are increasingly attracting innovative start-ups from abroad. As the United States is most advanced in creating public-private partnerships in favour of traditional industrial partners and has the largest market for space, observers have raised concerns that promising younger companies in other Allied nations, like the German specialist for micro-launchers, Isar Aerospace, or engine developer Morpheus Space, might move to the United States to gain access to US funds (Stölzel, 2020). Meanwhile other countries are emulating this approach, taking into consideration their specific scientific and industrial capacities. France intends to capture this short-cycle civilian innovation, notably through its new Defence Innovation Agency

[4] It should be noted, though, that several countries, such as the United States and Luxembourg, have legal frameworks allowing mining which do not contradict the OST.

(Parly, 2021). There is also considerable, and growing, cooperation between space agencies amongst Allies and with partners. For example, NASA is cooperating with the European Space Agency on Earth science, and both have signed an agreement to collaborate on the Artemis Gateway – an outpost orbiting the Moon that will provide support for the return to the Moon and will serve as a staging point for deep space exploration. ESA also cooperates with the Japan Aerospace Exploration Agency (JAXA) on Earth observation, space science and exploration.

A. UNITED STATES

13. The United States are undoubtedly the most advanced space-faring nation and the largest contributor to space programmes worldwide. In 2018, global expenditures for space-related activities were estimated between USD 360 billion and USD 414 billion (European Space Policy Institute, 2020). With around USD 50 billion, including funding for NASA, the United States spent more than all other governments combined that year (NATO PA, 2020).[5] The budget of NASA for 2021 is just over USD 25 billion, representing less than half a percent of the total federal budget (NASA, 2021).

14. While US government spending on space has increased between 9% and 14% between 2016 and 2018 it should be noted that the US percentage of global institutional spending on space has decreased from 75% in the early 2000s to 58% in 2018 (European Space Policy Institute, 2020). This decreasing percentage reflects the emergence of new actors which increasingly challenge the US dominance in space.

15. The Global Positioning System (GPS) symbolised this dominance for a long time. As of January 2021, the GPS constellation comprised a total of 31 operational satellites (NOAA, 2021). Yet, several actors have emerged in recent years and today there are three more operational global navigation satellite constellations: From 2011 the European Space Agency deployed the Galileo system (ESA, 2021) [6], Russia started modernising its Soviet-era Global Navigation Satellite System (GLONASS) in 2012 (IAC, 2021), and China completed the BeiDou constellation with a series of successful launches in 2020 (Howell, 2020).

16. Despite these recent developments, the United States remains the most ambitious nation in space. The total number of US satellites in space is estimated to stay just under 1,900 in 2021 (UCS, 2021). Through the Artemis programme, NASA plans to return humans to the Moon by 2024 (Butow, Cooley, Felt, & Mozer, 2020). The agency views the Moon as a stepping stone to further space exploration. Sustained lunar infrastructures could enable deep space explorations, including to Mars. In February 2021, NASA successfully landed the perseverance rover on the Red Planet (NASA, 2021). In the past years, US commercial companies like SpaceX, Blue Origin, and Virgin Galactic, have emerged on the scene, significantly lowering launch costs while spurring innovation (Schütz, 2021).

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[5] The total budget of all other governments combined was estimated at USD 30.5 billion in 2018, as Dr Stamatios Krimigis informed the joint session of the Science and Technology and Economics and Security Committees during the Annual 2020 session (NATO PA, 2020).

[6] Galileo is now the world's most accurate satellite navigation system, providing metric-scale accuracy to more than 2 billion users around the world. It is also currently preparing a new generation of satellites (ESA, 2021).

B. CHINA

17. The second biggest public investor in space activities is the People's Republic of China (PRC). In 2018 the PRC spent an estimated USD 6 billion on space activities (European Space Policy Institute, 2020), up from USD 4.9 billion only two years earlier. The expansion of China's space budget is also reflected in the growing number of space launches from China. Since 2018, China further increased the pace of its space programme and last year, China had more than 40 successful launches which put over 60 satellites into orbit (Harrison, Johnson, Roberts, Way, & Young, 2020). The total number of Chinese satellites in space is expected to surpass 400 by the end of 2021 (UCS, 2021).

18. In recent years, China's civil space programme has focused on its network of BeiDou positioning, navigation, and timing (PNT) satellites. The constellation is actively promoted to China's regional partners as part of its "Belt and Road Initiative" (BRI) as an alternative to the US GPS system. Thus far, China has directly assisted 60 countries, and recent data shows that 165 out of 195 countries are already more frequently overflown and observed by BeiDou satellites than by GPS systems today (Tsunashima, 2020). This assistance (and the related financing provided by the PRC) allows Beijing to potentially generate dependencies or even control over recipient countries' space sectors (Manson & Shepherd, 2020). To support its growing space capabilities, China has also increased investments in an extensive ground support infrastructure (Harrison, Johnson, Roberts, Way, & Young, 2020).

19. China advances its space capabilities by investing considerable financial resources into this field. More generally, the US National Science Foundation's biennial review reported that from 2000 to 2017, Chinese R&D spending grew at an average annual rate of around 17% (Slaughter, 2020). Between 2000 and 2020, its share of global technology spending has increased from approximately 5% to more than 23% (Darby & Sewell, 2021). In addition to its own R&D efforts, China is conducting sophisticated cyber espionage campaigns in an attempt to catch up in space technology. The U.S. has charged several Chinese nationals with espionage violations, including running multi-year campaigns to steal critical aviation, space, satellite, manufacturing, communications, and computer processor technology (Center for Strategic and International Studies, 2021).

20. Although commercial space activities in China remain primarily driven by state-owned enterprises, the Chinese government increasingly supports private commercial actors in this field as well. In the coming five years, a series of launches are planned to set up China's own space station, the Tiangong-3 (Shepherd, 2020). China's 30-year space goals (2019-2049) include establishing a permanent presence on the Moon, space mining, and developing solar power stations in geo-synchronous orbit (Goswami, 2019). It is also accelerating the modernisation of military space institutions (Broad, 2021).

C. FRANCE

21. France is a major space nation. With EUR 2.3 billion invested per year by the State in space, i.e. 1/3 of institutional space budgets in Europe, France ranks 2nd in the world after the United States in terms of institutional space budget per inhabitant, i.e. nearly EUR 35 annually per capita.

22. France published its defence space strategy in July 2019 and created the Space Command in September of the same year. As the Committee was informed during its virtual visit to France in July 2021, the French Space Defence Strategy emphasises responsible behaviour as a pragmatic and effective way to ensure the continued security of space, thereby clarifying intentions and avoiding escalation following potential misunderstandings (NATO PA, July 2021). The Space Defence Strategy has three pillars. The first aims to take into account emerging threats, which implies developing capabilities to monitor the space environment and even to defend satellites. France will develop space-based protection and active defence capabilities within the strict

framework of international law and the United Nations Charter. The second pillar seeks to strengthen strategic autonomy by exploiting the opportunities offered by the New Space and by reinventing the industrial model. The third pillar involves extending collaboration with allies and partners to the operational domain and seeking new partnerships. In addition to its long-standing action with other EU member states, France is developing various partnerships, both long-standing, such as with the United States and Japan, and more recent, such as with India. An agreement on the exchange of space surveillance data was signed in 2015 with the United States. France also regularly participates in joint military exercises. It also joined the Combined Space Operations (CSpO) in 2020, which brings together the United States, Australia, Canada, New Zealand, the United Kingdom and Germany.

D. RUSSIA

23. After the United States and China, Russia's is the third highest spender in space, with an estimated USD 4.2 billion budget in 2018. Due to its longstanding space experience dating back to the Soviet Union, Russia remains a key player in space. Counting launches planned for 2021, Russia still operates the third-largest number of satellites in orbit, 176 (UCS, 2021), and is engaged in partnerships with many nations in international human spaceflight (Harrison, Johnson, Roberts, Way, & Young, 2020).

24. However, Russia is increasingly at risk of falling behind both the United States and China. Moscow lost its long-standing monopoly on transport flights to the International Space Station (ISS) in November 2020, when SpaceX succeeded its first manned mission (Brown, 2020). Moreover, structural problems in the Russian science and technology sector, poor governance, and misguided allocation of funds are putting Russia's status as a leading space power at risk. Private Russian space companies lag behind and have difficulties to compete against the likes of SpaceX or Blue Origin. State-run space projects have suffered from a lack of innovation and widespread corruption.

25. Russia's response to these trends has been two-fold. On the one hand, recent shifts from the Soviet-era Baikonur Cosmodrome in Kazakhstan to the newly constructed Vostochny Cosmodrome in Siberia illustrate Moscow's determination to renew its space programme. Russia has also increased cooperation with China in recent years, a move which has been largely interpreted as an attempt to diversify its partnerships and counter the US dominance in space (Vidal, 2021).

26. Although Russia's civilian programmes are plagued by structural difficulties, the country has significant military capabilities in the space domain. Taking into the account the infrastructures on the ground as well as costs for personnel, Russia's budget for military space programmes is estimated at USD 1.6 billion (Luzin, 2020).

E. OTHER COUNTRIES

27. Other leading space-faring non-NATO nations include, among others, Japan and India. Tokyo has announced the expansion of its existing programmes in navigation (Quasi-Zenith Satellite System – QZSS) and the development of the next generation of the HTS ETS-3 satellite. If implemented, these announcements would reflect a modest budget growth (2% per year) in the near future. At present Japanese government space expenditures are the fifth highest in the world.

28. India, which launched its first satellite in 1980, has since developed a series of launch vehicles, as well as a range of imaging and communication satellites. Indian space activities are driven by the Indian Space Research Organisation (ISRO), one of the six largest space agencies in the world. Thus far, it has concentrated its activities primarily on earth observation and the utilisation of space to advance India's economic development (Tellis A. J., 2019).

29. Italy, too, is playing a relevant role in space. Italy is the third major contributor to the European Space Agency; the Italian Space Agency has a close and constant working relationship with the NASA. In the security field, the General Space Office of the Italian Armed Forces has been in operation since November 2019 and, in June 2020, the Space Operations Command was established. Its mission is to protect Italy's space assets and to contribute to protecting European and NATO space assets, by developing a full-fledged capability to access and operate in space.

30. Beyond the actors discussed above, many more nations and commercial actors have or will become active in space in the coming years. This development is reflected in the growth rates of investments in space activities – which are twice as high as that of the global economy at large (NATO PA, 2020). Moreover, costs for reaching LEO have declined by a factor of 20 (Space Economy: Rocket fuel, 2020): The cost to launch one kilogram into LEO has decreased from USD 54,500 (on board NASA's space shuttle) to USD 2,720 (with SpaceX's Falcon 9).

Plunge of the Cost of Space Activities will Make Smaller Nations More Ambitious

Country	Acceded to Outer Space Treaty	Acceded to Moon Agreement	Acceded to Artemis Accords	Passed National Legislation on Space-Resource Utilization	Space Mining Activity	Mars Program	Moon Program
USA	+	-	+	+	+	+	+
China	-	-	-	+	+	+	+
EU	-	-	-		+	+	+
UAE	-	-	+	+	+	+	+
Germany	+	-	-	-	+	-	-
France	+	-	-	-	-	-	-
Russia	+	-	-	+	+	+	+
India	+	-	-	-	-	+	+
Japan	+	-	+	+	+	+	+
Saudi Arabia	-	-	-	-	-	-	-

SpaceTech Analytics 18

Source: https://analytics.dkv.global/spacetech/SpaceTech-Government-Activity-Overview-2021.pdf

31. Decreasing launch costs and technology transfers will also progressively enable actors like Iran or North Korea to engage in space activities. Iran launched its first nationally produced satellite (Safir-1) in 2009, while North Korea appears to have launched a satellite in 2016 (Al-Rodhan, Cyber security and space security, 2020). As a consequence, space is not only becoming more crowded, but also risks being increasingly contested.

32. The crowded orbits above Earth create serious challenges. Since the Sputnik launch in 1957, some 9,000 objects have been launched into space. The European Space Agency estimates that more than 3,000 abandoned satellites are in orbit (Cookson, 2020). These and the debris caused by collisions and explosions over the years poses growing risks for satellites and space launches. Approximately 34,000 pieces of debris longer than 10cm, 900,000 between 1cm and 10cm, and 128 million between 1mm and 1cm, are estimated to be in orbit — which could destroy or damage a satellite (Peel, Shepherd, Williams, 2019). Enough debris could lead to a chain reaction known as Kessler syndrome, which could render entire swathes of near-Earth space unusable for decades (The Economist, 2020).

33. Unfortunately, there is no international agreement in place which regulates the removal of non-operational spacecraft from the orbit. The UN and international organisations like the International Telecommunication Union (ITU) have made only partial progress in addressing the issue. The 2007 UN Space Debris Mitigation guidelines are one example for this but fall short of solving the problem (Cookson, 2020).

34. Crowded and contested orbits heighten the vulnerability of space-based infrastructures. Innovations such as reusable and cheaper launchers, CubeSats made access to space easier and cheaper. New states and non-state actors have access to this domain and multiply the presence in the LEO, and thus the risk of malicious interactions (Al-Rodhan, 2020).

III. SPACE AND ALLIED SECURITY

35. “A future conflict may not start in space, but I am in no doubt it will transition very quickly to space, and it may even be won or lost in space,” - UK Air Chief Marshal Sir Mike Wigston, chief of the air staff (Warrell, 2020).

36. Space is essential to the Alliance’s deterrence and defence (NATO, 2020). NATO Allies rely heavily on space for the protection of their homelands and for military operations around the globe. Space is an “enabling domain” as it is closely interconnected with the other security domains relevant for NATO: maritime, air, land, and cyber space. Together with cyber, space will therefore play a critical role for the security of Allied nations.

37. Satellites provide precise information on movements by friend and foe through imagery or via signal interceptions. They transfer huge amounts of data from and to the battlefield: operating a single Global Hawk, for instance, requires roughly 500 megabits of satellite bandwidth per second. This is five times the total amount of satellite communications that US forces used during operations in the First Gulf War (The Economist, 2019).

38. During the 1991 Gulf War, often referred to as “the first space war”, space systems evolved from strategic assets to tactical enablers. Satellites provided near real-time information down to the tactical level throughout operation *Desert Storm* for the first time. Space assets, originally developed to detect strategic missile launches, were transformed into tools that worked “down to do scope reporting” in 1991 (Strout, 2021). The use of satellite-based information contributed to the quick and decisive victory of the US-led forces.

39. Today, many of NATO’s most advanced systems depend heavily on space-based assets. Examples include the Alliance’s Ballistic Missile Defence (BMD) programme, the Airborne Warning and Control Systems (AWACs) and the Ground Surveillance System (AGS) (Moon, 2017). NATO’s Joint Air Power (JAP) is equally dependent on the national capabilities in the space domain of Allied states as they support operations in the air as well as on the ground and on the seas (Bockel, 2018).

40. The Alliance defines five core areas where it heavily depends on space-based assets (NATO, March 2020). These are (1) positioning and navigation: enabling precision strikes, force navigation or combat search and rescue (CSAR) missions; (2) integrated tactical warning and threat assessment: securing force protection, providing crucial information on missile launches and thus allowing attribution; (3) environmental monitoring: enabling meteorological forecasting and sound mission planning; (4) communications for command and control purposes and (5) intelligence, surveillance and reconnaissance (ISR) capabilities: providing intelligence on and off the battlefield and informing targeting decisions. A key benefit of space access is that it increases the ability of the Alliance to respond, thus making it is crucially important for deterrence. Deterrence is largely based upon the adversary knowing that NATO is prepared to act, and to act the Alliance must first Observe, Orientate and Decide, as described by the military strategist John Boyd. Information gained from space can accelerate the OODA loop (OODA loop – Observe, Orient, Decide, Act) and prevent the need for conflict through careful focused action.

41. Free access to space and resilient space infrastructures are essential for operational capability and defence. As a consequence, the dependence of modern armed forces on space has become one of their greatest vulnerabilities. In the early days of space infrastructure, only the U.S. and the Soviet Union were capable of launching satellites into orbit. Space-denial technologies were either non-existent or in their infancy. After the fall of the iron curtain, the threat to Western space assets and capabilities was significantly diminished. The recent evolution of space capabilities, especially on the commercial side, and the increased number of space-faring nations has changed this situation, however.

42. Space denial capabilities of NATO (near-)peer competitors have significantly increased in recent years, and so have the number of tests of such technologies. Several countries possess weapon systems that have the potential to harm space assets at any time. According to CSIS's 2020-Space Threat Assessment there are four types of systems that can be used to damage or destroy space-based assets (Harrison, Johnson, Roberts, Way, & Young, 2020): (1) kinetic physical counterspace weapons, built to directly strike satellites or the ground stations operating them; (2) non-kinetic weapons, including lasers, high powered microwave (HPM) weapons, and electromagnetic pulse (EMP) weapons, that can physically affect space assets without any direct contact; (3) electronic attacks targeting signal transmissions to and from satellites by interfering with radio-frequencies (RF) by creating noise in the same frequencies (jamming) or by falsifying a signal and tricking the receiver into it (spoofing), thus corrupting the data; (4) cyberattacks, that target data instead of transmission frequencies.

43. Kinetic physical counterspace weapons have attracted the most attention by far. Tests of direct-ascent anti-satellite (ASAT) weapons have increased as more countries develop capabilities in this domain (Harrison, Johnson, Roberts, Way, & Young, 2020). The most prominent of these tests has arguably been the destruction of a satellite by China in 2007 which increased space debris in LEO by roughly 10% and was followed by broad international condemnation (Ohlandt, McClintock, & Flanagan, 2021). A more recent ASAT test by China, conducted in 2018, was further evidence of Beijing's growing prowess and ambition in space. Building on extensive experience from Soviet-era ASAT-programmes, Russia has also invested in numerous kinetic physical counterspace capabilities and allegedly has a range of ground-based and air-launched direct-ascent ASAT missiles that could target satellites at its disposal (Harrison, Johnson, Roberts G., Way, & Young, 2020).

44. In addition to direct-ascent systems, co-orbital ASAT-weapons have also already been deployed in space. Their activity is more difficult to detect, however, as it is very similar to on-orbit maintenance or debris removal missions. As most space technologies, co-orbital weapons are a dual-use technology and can be used for both civilian and military purposes. Arguably, any asset in the orbits above earth can be qualified as a weapon just because of its high velocity. With speeds between 11,000 (GEO) and 28,000 (LEO) kilometres per hour, a satellite that changes orbit becomes a kinetic weapon by definition.

45. Some of the most advanced space denial assets have been developed and tested by the People's Republic of China (PRC). The Pentagon's annual China military power report notes that Beijing's space capabilities include orbiting space robots (U.S. Department of Defense, 2020). Similarly, Russia has repeatedly launched inspection-satellites into LEO, which could potentially serve as co-orbital ASAT weapons. Although Moscow has not officially announced any plans to develop space based ASAT weapons, US Space Command accused the Kremlin of testing such weapons-systems under the guise of maintenance in 2020 (US Space Command, 2020).

46. Other than China and Russia, numerous other states are working on counter-space capabilities (Raju, 2020). The threat is also illustrated by the variety of modes of action against satellites: missiles, co-orbital, jamming, directed energy and cyber (Weeden & Samson, 2020). Research and development in these areas is significant, progress is rapid, and some capabilities such as jamming are already in use, in the Middle East (BBC, 2012) or to disrupt NATO exercises

in the High North (Deutsche Welle, 2018). Even civilian systems, such as those intended for rendezvous and proximity operations to dock with a space station or perform maintenance, could be dual-use and pose a threat in the vicinity of military satellites or those providing services essential to our economies and lifestyles.

47. While receiving less public attention than their kinetic counterparts, non-kinetic weapon systems such as lasers and electronic technologies enabling jamming or spoofing have also been increasingly developed and tested. According to the Rand Corporation, China continues to develop space weapons and has developed jamming capabilities and tested them in exercises (Manson & Shepherd, 2020).

48. The development of China's non-kinetic capabilities dates back to the purchase of Soviet-era equipment from Ukraine in the late 1990s (CSIS, 2018). Since then, Beijing's indigenous space industry has made the ability to jam satellite communications one of its priorities (USCC, 2015) and has developed and tested several systems (DIA, 2019). China's electronic warfare capacity includes an ionospheric radar located on the island of Hainan that is able to influence particles up to 2,000 kilometres. In 2020, officials announced an airborne laser which, although developed to target military aircraft or missiles, could potentially be used against satellites (Zhen, 2020).

49. Russia, too, has been consistently enhancing its space denial capabilities. The state armament programme for the period until 2027 lists the development of defensive space-based systems deployed to protect Russian satellites (Zak, 2018). Moreover, Russia is commonly believed to be testing electronic counterspace warfare, jamming and spoofing adversaries' satellites in conflict zones as well as in nearby territories (Harrison, Johnson, Roberts, Way, & Young, 2020) and even on GPS-Satellites within its own state borders (BBC, 2018).

50. Finally, several actors in space have developed substantial knowledge in the cyber realm. As cyber-attacks are significantly cheaper and much harder to attribute than direct-ascent or co-orbital ASAT, they are a compelling alternative to these weapon systems. Russia has demonstrated its cyber capabilities as early as 1998, when it allegedly took control of a US-German satellite, pointed it at the Sun and thus destroyed its instruments (Tucker, 2019). The Chinese government appears to also have tested its cyber capabilities in several instances such as during the 2014 National Oceanographic and Atmospheric Administration (NOAA) hack (Al-Rodhan, 2020). The attack disrupted weather information and impacted end users around the globe (Al-Rodhan, 2020). More generally, research and development in space denial capabilities is significant, progress is rapid, and some capabilities, such as jamming, are already in use, for example in the Middle East (BBC, 2012) or to disrupt NATO exercises in the High North (Deutsche Welle, 2018).

51. These successful tests are only a few examples of a potential "weaponisation" of space. An arms race in this domain would generate considerable geopolitical tensions which will only escalate if the international community will not address it soon (Al-Rodhan, 28/10/2020). The urgency of addressing the potential "weaponisation" of space is amplified by the dual-use character of the majority of space assets: it is very difficult, if not impossible, to verify if space infrastructure launched today is used for civilian purposes of observation, communication, navigation, or for military objectives.

IV. LACK OF SPACE GOVERNANCE

52. These developments are taking place in a virtual vacuum of international law. The legal framework for state action in space is far behind the rapid technological development and commercialisation of space.

53. The Treaty on Principles Governing the Activities of States in the Exploration and Use of Outer Space, the "Outer Space Treaty", remains the bedrock of international space law. The Treaty, dating back to 1967, prohibits the deployment of weapons of mass destruction in space and has been signed by more than 130 countries. Four international agreements reached during the late 1960s and 1970s supplement the Outer Space Treaty. They regulate the rescue of astronauts, liability for damage, registration of launches and lunar activities. No further space treaties have been drawn up since then (Cookson, 2020).

54. While the Outer Space Treaty prohibits the deployment of nuclear weapons, it does not refer to other space-based weapons nor address interference with other countries' space assets. Moreover, they do not ban the use of ground based ASAT missiles. This lack of legal clarity has created a vacuum that many countries, including Russia, the PRC, Iran and the Democratic People's Republic of Korea (North Korea) have exploited (Al-Rodhan, 26/10/2020).

55. The Outer Space Treaty also does not feature a dispute settlement mechanism, nor does it address orbital debris and vehicle collisions. It also lacks adequate provisions to govern satellite mega-constellations or asteroid mining, both of which will become an issue sooner than many observers anticipate. Existing multilateral institutions such as the Committee on the Peaceful Uses of Outer Space (COPUOS) and the Conference on Disarmament have thus far failed to adapt international agreements to the dynamic technological developments.

56. Another example is the International Telecommunication Union (ITU). Since 1959, it has had the mandate to coordinate the use of radio frequencies internationally. This also applies to the radio frequencies earmarked for the new satellite constellations. The ITU also regulates the use of orbits. However, the ITU's coordination function was originally designed for a time when the number of actors in space was limited and the total number of satellites stationed in space was manageable. The development of new applications for satellites and the deployment of mega-constellations threaten to overload the ITU's allocation system.

57. Moreover, although ITU regulations and export controls mechanisms can help in managing the launch of satellites and management of space traffic, military satellites are often not registered. The overall result of this conglomerate of instruments is a loose environment where cooperation is limited (Al-Rodhan, 26/05/2020). However, space security cannot be understood as a zero-sum game. Rather, it has to be approached as a positive sum game where good governance ensures access and safety for all actors (Al-Rodhan, 26/05/2020). As more nations become active in space and increasingly dependent on space assets, they share a common interest in a safe and accessible space. The development and deployment of counterspace weapons could quickly escalate into a global arms race. The pervasiveness of dual-use technologies in space and the according risk of miscalculation and escalation only strengthen this argument (Stewart, 2020). Given the dependence of countries on space-based assets to meet their basic daily needs, any conflict in space – even unintentional – will undermine the space and terrestrial security of all.

58. It is important to emphasise that all space strategies that have thus far been published by space-faring nations underline the need for international cooperation. What is lacking for now is an update of the existing international legal framework that clearly defines the rights and responsibilities of all participants. Actors need to agree on definitions and norms, as this would be an important first step towards building an internationally guiding legal framework. It is therefore necessary to reach an international consensus among the most advanced spacefaring nations to establish long-lasting norms that may be able to lead to distinct arms control measures.

59. Given the dependence on space-based assets for critical services, any conflict in space, even if unintentional, will compromise space and terrestrial security for everyone. However, despite the fact that a growing number of civilian and commercial actors share an interest in establishing norms in space, the Outer Space Treaty and a few associated agreements and conventions from the Cold War era are still the only binding pacts (Ohlandt, McClintock, & Flanagan, 2021).

60. The dual-use nature of space technologies complicates controlling access to these technologies. Therefore, mechanisms to deal with threats to space security and stability should focus on behaviours, rather than technologies. Focusing on responsible behaviour in space, rather than limiting or outright banning certain technologies, is therefore a more promising approach. Encouraging responsible behaviour in space requires a shared understanding among nations of what constitutes responsible behaviour and what constitutes irresponsible behaviour in space. Examples for responsible behaviour include, for example, adherence to legal obligations, being transparent about national space policies, programmes, and activities, prior notifications of launches, or close approaches, etc. Infringing on these actions would constitute irresponsible behaviour, as would not following best practices and standards with regard to orbital debris mitigation or non-registration of space objects with the UN, among others.

61. Developing norms of responsible behaviour has a direct security utility as any breach of these norms by a potential adversary would characterise a malicious act, including a hostile act, and trigger an appropriate diplomatic or even military response. Therefore, your Rapporteur supports UN General Assembly Resolution 75/36, adopted on 7 December 2020 on "Reducing space threats through norms, rules and principles of responsible behaviour". However, agreed norms of behaviour should also identify meaningful penalties that would act as a deterrent against irresponsible behaviour in space by either a nation state or a non-state actor. Responsible behaviour also needs to include the encouragement to avoid, and at least minimise, the creation of orbital debris.

V. NATO'S SPACE POLICY

62. Space-based assets are owned and controlled by NATO member states. Becoming increasingly aware of the importance of and dependence on space-based assets for NATO operations, the Allies have gradually put space on NATO's agenda. Interest has picked up significantly within the last 10 years, due to, among other things, cheaper and more available access to space technology, which resulted in a more contested environment, and the appreciation that more cooperation among Allies is needed.

63. NATO recognised unimpeded access to space as a priority at the Lisbon Summit in 2010 (NATO, 2010). Two years later, the creation of the Bi-Strategic Command Space Working Group acknowledged the crucial role space assets have played in missions like the International Security Assistance Force (ISAF) in Afghanistan (Bockel, 2018). In June 2019, Defence Ministers agreed on NATO's first-ever space policy and in late 2019, NATO Heads of State and Government officially declared space as the Alliance's fifth operational domain after land, sea, air and cyber (NATO, 2019). This decision reflected the recognition of the unique role of space for NATO's deterrence and defence. As a result, NATO planners can now "make requests for Allies to provide capabilities and services, such as hours of satellite communications" (NATO, 2019). Although space is considered a domain of operations, the increased engagement of the Alliance in space is defensive. NATO is looking into ways to protect against attacks or reduce their negative effects, like disrupted communication and navigation systems, on allied forces. The Communiqué of the 2021 Brussels Summit of NATO Heads of State and Government represents a considerable departure from the past. NATO now considers an attack to, from, or within space as potentially equivalent to a conventional attack – which could lead to the invocation of Article 5 of the Washington Treaty (NATO, June 2021).

64. In October 2020, NATO Defence Ministers announced the creation of a new Space Centre which will be located at Allied Air Command in Ramstein, Germany (NATO, 2020). The Centre will help to coordinate Allied space activities and provide support to NATO operations from space, including by using satellite communications and imagery. The NATO Space Centre is still in the phase of being established and is performing functions on a limited basis. A small team of experts

from several Allied nations is assigned to the Centre. It will continue to grow in size and expand its responsibilities and functions over time.

65. The Centre will work closely with Allies' national space agencies and organisations and the NATO Command Structure to fuse data, products, and services (DPS) provided by nations. The Space Centre will streamline the links between NATO and national space agencies through a single entity and provide Alliance commanders with missions critical DPS such as imagery, navigation, and early warning. By strengthening the links between NATO and national space entities, the Centre will increase space domain awareness at all levels. Moreover, The Centre will also help to facilitate training and exercises and sharing of information about potential threats. Thus, in the medium to long term the Space Centre can also offer opportunities for multidimensional integration that can prove to be innovation drivers for the Allied armed forces. It is important to point out, though, that the Alliance does not dispose of any space-based capabilities of its own. NATO receives space related DPS from member nations, whose space capabilities vary widely.

66. In January 2021, NATO endorsed a French proposal to create a new Centre of Excellence (CoE) dedicated to space, which will be established in Toulouse (Dupont, 2021). NATO leaders welcomed the establishment of the CoE at their recent Brussels Summit. As the Committee learned during its virtual visit to France in July 2021, the Centre will be a linchpin for space education, doctrine development and experimentation for NATO space experts. The first establishment conference of the CoE is scheduled for November 2021 with initial operational capacity expected to be achieved in 2022.

67. A longstanding, and important, part of NATO's space activities is played by the NATO Science and Technology Organization (STO), which has been driving NATO cooperation on technology/military related space research. This research includes the use of Artificial Intelligence (AI) and satellite sensing to track maritime vessel traffic, maritime surveillance, space-based sensors, space weather, high performance imaging, operations on Global Navigation Satellite Systems (GNSS) denied environments and transforming space derived data into knowledge.

68. Another concrete example of close cooperation is the STO's project on the management of large constellations of small or cube satellites. This is important to understand space as an operational domain as the management of large numbers of small satellites, or cube satellites, which have no, or only very limited propulsion capability of their own, is very different from managing large, legacy satellites. Related research is done in the STO's Advanced Vehicle Technology (AVT) panels which has done research on propulsion for small satellites.

69. In total, the STO has produced over 50 major reports on space-related issues over the past ten years. Moreover, the STO has identified relevant research areas for space in its "Science and Technology Trends 2020-2040" (Science and Technology Organization, NATO, 2020). For example, among the technologies that will profoundly impact the future intelligence, surveillance, and reconnaissance (ISR) architecture will be space-based quantum sensors which are currently being developed. Although NATO nations conduct most of their space research on a national level, the STO provides a valuable forum for member states to advance space research in areas the nations are comfortable pushing forward together.

70. NATO and the STO serve a crucial function as an information sharing forum. However, under the STO, nations collaborate on the development of space technologies such as novel sensors, data fusion, vehicles, propulsion, and operations. NATO Allies can work together to push forward their national and joint space capabilities. Closer cooperation among NATO Allies, and with partners, is urgently needed to make their space-based infrastructure more resilient. Closer cooperation particularly with the European Union should be pursued to increase resilience of space infrastructure. The European Union faces the same challenges, the same need for a stable and secure space environment and similar issues related to responsible behaviour. The

Spaceways study[7] will contribute to developing a collaborative European vision of space traffic management. As space becomes increasingly competitive, congested, contested and commercial, the challenge of protecting critical space assets will increase, as will the pressure to better understand how to use commercial systems in a security-related context. Protecting Allied space assets and capabilities will require the further development of technical, policy, and legal norms and tools. Moreover, NATO needs to adapt and develop procedures and competencies in terms of personnel, for example through specific training and deployment models.

VI. CONCLUSIONS

71. In an Alliance of 30 member states with widely varied space programmes and capabilities, it is vitally important to develop a common understanding of the security-related challenges and opportunities of space. New actors, both state and commercial, as well as new applications and technologies will profoundly transform the space domain.

72. Creating awareness of the importance of space-based systems for the security of our nations, economies, and societies – and promoting greater understanding and appreciation for safeguarding the use of those capabilities is a crucial first step. Better space domain awareness also requires joint efforts to monitor military and civilian technologies closely so that they can be integrated into a more robust space architecture.

73. As space is becoming much more accessible, making existing and future Allied space-based assets resilient is a priority. More effort is necessary in this science and technology area. Issues that need to be addressed include, among others, how Allies can maintain their military capabilities if space is degraded or denied but also how science can make the enabling of situational awareness from space more environmentally friendly. NATO's STO network helps to leverage the scientific and technological prowess of NATO Allies (and Partners) to promote the joint exploration and development of space S&T. The NATO STO serves as a pivotal platform for Allies to identify risks to space-based assets and to propose solutions to protect these assets. It can coordinate activities among Allies, and with partners, to avoid duplication of efforts. Moreover, the STO activities in space are a first, important step to increase operational capabilities of the Alliance.

74. Although NATO does not play a leading role in defining space policy or priorities, it can influence them by providing a forum for discussion in order to improve critical space awareness and develop common policies and procedures, in particular on interoperability, standards, political consultations, development of Allies' national capabilities, and science and technology activities. With regard to the latter, the STO is an important platform for the Allies and their partners to identify risks to assets in orbit and propose solutions to protect them, while also avoiding duplication of effort. Your rapporteur wants to emphasise the need to include partners, first and foremost the European Union in this discussion. The EU is a strategic partner and a major space actor facing similar issues. Therefore, space is an area in which EU/NATO cooperation must be strengthened.

75. The next step NATO needs to engage in is to define how Allies work together and how they can operate systems together. An effective way to advance critical space awareness and develop procedures and policies to share space-fed data and information could be the creation of a small initial NATO satellite capability. In any case Allies need to provide more resources to NATO to rapidly expand the Space Centre. Given the very limited number of space experts at NATO, personnel development and training need to have high priority. Moreover, given the importance of

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[7] SPACEWAYS is part of the Horizon 2020 European research programme. It includes 15 partners and is coordinated by the FRS. The eighteen-month-project is valued at EUR 1.5 million.

developing skills and a common understanding of space issues among the Allies and of training space experts, the Centre of Excellence in Toulouse (France) must bring together as many Allied contributors as possible, as soon as possible.

76. The use of space for peaceful purposes is in the interest of all nations. As NATO Secretary General Stoltenberg has repeatedly pointed out, NATO has no intention of putting weapons in space. NATO will carry out activities in space in accordance with international law (NATO, 2021).

77. Moreover, using NATO as a forum allows member states to discuss the operationalisation of space, including necessary legal frameworks which need to be put in place. This also expands to the international arena. As nations become increasingly dependent on space-based technologies, the need to maintain space as a peaceful and cooperative environment for technological and scientific progress is ever more paramount. This task is further complicated by the proliferation of actors operating in space, and the potential deployment or use of offensive weapons in outer space. Allies should therefore also consider using NATO as a forum to discuss, and agree, on joint initiatives aimed at updating the international legal framework. A crucial and necessary first step for Alliance members – and indeed for all space-capable nations – will be to develop standard definitions and a common understanding of space-related concepts, enabling the exchange of space data on a voluntary basis. As an organisation, NATO can serve as a central platform for conducting analyses on space standards that would benefit the security interests of the Allies and facilitate consensus among Alliance members and partners on the required standards and definitions.

78. A joint approach is likely to be more effective in closing existing gaps in international agreements on space. The development of responsible behavioural norms is a pragmatic and effective way to introduce confidence-building measures in a strategic context of crucial paradigm shifts, by clarifying intentions and thus avoiding potential escalation. Furthermore, a standard of responsible behaviour should include prohibiting the intentional creation of multiple long-lived debris, as well as encouraging the avoidance, and at least the minimisation, of the intentional creation of short-lived debris.

79. This would also include strengthening relevant multilateral institutions such as the ITU which will be under pressure with the arrival of new mega-constellations and actors. In the absence of a clear international legal framework, individual countries are formulating national laws that allow their companies and citizens to exploit natural resources on celestial bodies. A possible way to help advance international space law is the "Space Law for New Space Actors" project initiated by the UN Office for Outer Space Affairs (UNOOSA). The project is designed to help countries starting to develop space programmes to draw up legislation in line with international space law.

80. Space could be a possible area of cooperation between the Alliance and the European Union. It must be noted, though, that developing cooperation in this area between NATO and the EU will be a longer-term process, due to the different roles and approaches of the two. NATO's role in space remains limited for now and the EU is a different actor focused on commercial programmes and managing large multibillion space programmes like Galileo and Copernicus. Moreover, different EU entities are involved in space from various angles. For example, the European External Action Service is focusing on arms control issues, while the recently established Directorate-General for Defence Industry and Space (DEFIS) focuses on competitiveness and innovation of the European defence industry. The EU Satellite Centre provides early warning and global situational awareness. At this point, there is limited interaction between the EU and NATO at staff level, which offers the opportunity to gradually evaluate areas of possible cooperation which should be exploited.

81. Finally, despite the shortcomings of the Space Treaty, its major principles are still valid and its stabilising effects should not be underestimated. While a revision of the Treaty would be

desirable, it appears unlikely that the verification problem could be solved. Moreover, while NATO Allies might respect a new treaty, other nations might not necessarily do the same as long as the verification issue is not solved. The best way forward is therefore to develop international norms of behaviour that are elaborated jointly and are concrete and immediately applicable.

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