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SPACE SECURITY IN INTERNATIONAL RELATIONS – MILITARY ASPECTS

Abstract: The political and economic competition exacerbated the conflicts between countries. In this situation, Space security and safety covering two significant issues: secure, safe, and sustainable access to space and mitigation of Space hazards, have become more critical. More and more countries are using or planning to use space for military purposes. In addition, more and more civilian satellites are being used for militaristic purposes. There is also a transition from militarization to weaponization of space. Maintaining the principle of peaceful use of space is increasingly more work. In space, there are highly favourable conditions for conducting reconnaissance, maintaining communications, directing the movement of various objects, and many other activities that are not necessary for securing and supporting the activities of military forces. The result of this state of affairs is the appearance in the space of a vast number of objects, without which it is difficult to imagine the functioning of modern armed forces. A significant problem is the multifunctionality of the tasks performed by various satellites, so many problems are associated with the systematization of space objects. International relations and diplomacy are crucial in providing secure and sustainable access to space.

Keywords: Space security, International relations, military aspects, weaponization, monitoring, surveillance, space situational awareness

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1. INTRODUCTION

The most crucial topic in the "new era in Space" is and will be, to an increasingly greater degree, the issue of further provision of security, safety, protection, and sustainability of activities in space. Space systems are exposed to an even greater level of "manmade" hazards and the naturally dangerous Space environment (e.g., geomagnetic storms, solar radiation). The hazards can be unintentional and arise from human activity (e.g., creation of Space debris) and capacities to deliberately disrupt Space systems or services (e.g., antisatellite technologies, signal jamming, cyber-attacks).

2. MILITARY INTEREST IN SPACE

Space applications, including remote sensing, signal intelligence, telecommunication, and positioning/navigation, important for civil economies, have become vital for military operations since the first Gulf War. The threats to Space security, safety, and infrastructure have multiplied, diversified, and intensified over the past decade. Apart from security and safety issues related to the increasingly more congested Space environment, Space systems might also become targets of attacks aimed at physical damage to the system, permanent destruction or temporary disruption of its capabilities, or interception of confidential information. Military and civil satellites are under this threat because boundaries between civil and military domains tend to blur: dual-use equipment has become widespread, and military forces increasingly use commercial Space services.

The cosmos has long been of interest to states, especially the military sector, due to its unique features and capabilities (e.g., the movement of space objects at extreme speeds due to orbital mechanisms or the observation of every point on Earth). During the Cold War, the US and Russia invested enormously in their space programs, developing military technology, resulting in the Space race.

Two concepts developed at that time: militarization and weaponization of the Cosmos. The first of these terms means passive military use of outer space. It includes activities in which satellites are not directly engaged on the battlefield but deal with, among other things, satellite positioning and surveillance systems. "Weaponization" refers to direct involvement in hostilities and assumes using offensive weapons in space. The weaponization of space (via antisatellite weapons) poses a threat, making the idea of space war more accurate. Antisatellite weapons (ASAT) are kinetic weapons, the effects of which pose a significant threat to the environment and space activities.

On 15 November 2021, Russia conducted an antisatellite (ASAT) test in low Earth orbit, where an interceptor of the Nudol ground-based ASAT system was used to destroy one of Russia's derelict satellites, Cosmos-1408. The satellite was at an orbit of about 480 kilometres in altitude; the interception created at least 1500 pieces of trackable debris. This debris field will expand and spread in a ring around the Earth that will likely remain in orbit to threaten other space objects for years. Regardless of the rationale, deliberately creating orbital debris of this magnitude is highly irresponsible. Orbital debris poses an indiscriminate risk to everyone's satellites in orbit, endangering critical space-based services we rely on and human lives on the International Space Station and China's Tiangong Space Station[1].

This is not the first time a country has tested an antisatellite weapon and created debris in orbit; we detail three previous cases by the United States, China, and India. Security World Foundation, in its reports, called upon the United States, Russia, China, and India to declare unilateral moratoriums on further testing of their antisatellite weapons that could create additional orbital debris and to work with other countries toward solidifying an international ban on destructive ASAT testing. The continued testing or demonstration of antisatellite capabilities, including targeting one's space objects, is an unsustainable, irresponsible, and destabilizing activity in which no responsible spacefaring state should engage.

This event also shows that the United Nations' planned Open-Ended Working Group on space threats and responsible behaviour is more critical than ever. It is in the interests of all to refrain from the deliberate creation of space debris that negates the collective efforts of many other space actors to reduce or avoid debris creation during their normal space operations.

The most potent space power was and still is the United States. Russian security strategists believe the struggle for domination in the world will be played out through attacks on infrastructure opponents located in space and on Earth and that this way will gain an advantage in the conflict with the US. However, Russian space targets will come to a standstill soon, facing severe challenges, mainly because of industrial and technological shortcomings in a space program, such as the miniaturization of electronics.

The Cold War between the United States and the USSR for supremacy over the world ended with the victory of the former and the disintegration of the USSR in 1991. This also ended the first space age. On the ruins of the USSR, i.a. The Russian Federation, however, for a long time was not and is not able to continue the Soviet one-space policy. When Vladimir Putin became the head of this state in 2014, the Russian Federation achieved the most significant number of successes in orbital take-offs from all countries. Putin's transition to the development of a policy of aggression towards some states, which emerged on the ruins of the USSR in 2018, the Russian Federation launched only 19 satellites, while the USA – 34 and China – 38.

The introduction of the embargo on the modern one by the European Union and the USA technology has weakened the economy and the Russian

[1] SWF Statement on Russian ASAT Test https://swfound.org/news/all-news/2021/11/swf-statement-on-russian-asat-test (18.11.2021).

space industry. The Russian Federation continues to be a country with great military potential. Although a lot of space devices and systems in the nineties were destroyed in the last century, the Russian government is gradually increasing its financial outlays for the modernization of some of them[2].

Outer space is slowly becoming the arena of future hostilities. This is because some countries, mainly the US, depend on space technologies in civil applications and military. US domination in space may result in other countries, such as China and Russia, not wanting the US to gain too great a military advantage; they will follow suit. It may cause a race of arms in space, similar to the Cold War race in the field of nuclear weapons between the USA and the USSR. The development of space technologies in recent years and carried out by some countries' "space policy" indicates that conflicts in space are still possible. Even observers predict such a situation. Conflicts on Earth can have consequences in outer space, devastating consequences for security in space and all countries on Earth. Some countries with military technologies essential for operations in space may have less interest in protecting the cosmos and being accepted by international standards. The use of kinetic space weapons by China and the US may be considered a precursor of a future conflict or a warning against its dissemination.

The 2015 China Defense White Paper recognized space for the first time as a military domain and linked the development of the situation in international security with the defence of China's interests in Cosmos, which became legally binding in China in 2016, the National Security Act.

In recent years, China has begun reorganizing its army and set up Strategic Support Force (SSF) units as a fifth military service by merging existing space units, cybernetics, and those intended for electronic warfare under a new, unified command that reports directly to the Central Military Commission. The intention is to transform the People's-Liberation into a modern multi-domain army[3].

3. MILITARIZATION OF SPACE AND SPACE OBSERVATION PROGRAMS

Space-Based Earth Observation (SBEO) is one of the primary providers of data for imagery intelligence (IMINT) and geospatial intelligence (GEOINT). Technical and geographical information obtained from satellite systems by

[2] B. Weeden, V. Samson (eds.), Global Counterspace capabilities, an open source, pp. 3–25, https://swfound.org/media/206408/swf_global_counterspace_april2019_web.pdf (22.04.2021).

[3] R.S. Jakhu, J.N. Pelton (eds), op. cit., p. 93; B. Weeden, V. Samson (eds.), op. cit., pp. 1–22; T. Harrison, K. John-son, T.G. Roberts, et al., Space Threat Assessment 2019, https://aerospace.csis.org/wp-content/uploads/2019/04/SpaceThreatAssessment2019-compressed.pdf (23.04.2021), pp. 8–16; J.P. Acuthan, China's Outer Space Programme: Diplomacy of Competition or Cooperation?, https://journals.openedition.org/chinaperspectives/577 (23.04.2021).

image interpretation or analysis is necessary for military purposes. SBEO products, including image data coming from several categories of sensors, among others, electrooptical, radar, infra-red, or laser ones, go well beyond IMINT/GEOINT and are applied in security, safety, and defence. SBEO data also support the monitoring phase, which comprises two complementary functions: early warning and strategic surveillance. Moreover, military planning and geospatial support can be implemented using data and products of SBEO satellites, both on the political, strategic, and operational levels.

US Earth observation (EO) sensors, mounted on Space platforms, are nearly 50 years old. Launched in 1972, Landsat-1 was the first satellite for observation of the whole Earth. SPOT-1 of 1986 was the first satellite to deliver Earth images for commercial purposes. Ikonos, launched in 1999, was the first commercial EO system capable of gathering images with a spatial resolution of 1 m. Changes in the policy of the United States brought about the involvement of private enterprises in the Space management process, which made it possible to create new observation systems, e.g., Digital Globe launched the QuickBird system in 2001.

The number of SBEO systems and sensors has rapidly increased, and their performance and efficiency have improved over the past few years. In addition, satellite systems gradually switched from the model with a single sensor to systems based on sensor constellations. Performance was also increased by the gradual implementation of "dual-use" systems, which allows various users to manage them depending on the mission. The latest achievement is the placement of nano- and microsatellites and constellations composed of even 100 items into orbit. The reduced costs of access to SBEO (with small satellites) increase the quantity of and access to the data acquired during Space missions.

Positioning, navigation, and timing (PNT) services in space were designed and developed in response to the specific needs of military stakeholders. PNT services are regarded as significant factors supporting defence operations, and as such, they must be robust and reliable. The operational benefit from access to such services is significant for the armed forces and the civil population. At present, PNT is a product that exerts a considerable impact not only on defence operations but also on the global economy[4].

Over the last decade, Space-based global utilities have increased considerably. Millions of people can rely on Space applications daily regarding weather forecasting, navigation, surveillance of borders and coastal waters, monitoring of crops, fisheries, forests, disasters, and search & rescue operations[5].

Services related to GNSS (Global Navigation Satellite Systems) are developed by a range of countries. From the operational point of view, such a ubiquitous dependency on GNSS, regardless of the service, creates new weaknesses which

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4 M. Deratti, F. Dolce, PNT for Defence, [in:] K.-U. Schrogl (eds.), op. cit., pp. 821–843.

5 J. West (ed.), Space Security Index 2019, Ontario, October 2019, www.spacesecurityindex.org (23.04.2021).

opponents can exploit efficiently and effectively. This is because GNSS signals are sensitive to various factors. Nevertheless, they enable users worldwide to determine (with high accuracy) the position, speed, and time of satellite travel. The most well-known and popular GNSS is the American Global Positioning System (GPS), an indispensable component in the armies of allies in NATO, from strategic decision-making or operational planning to military operations. Other countries develop their GNSSs: the Russian Federation has GLONASS, China – BeiDou (also known as COMPASS), and the European Union – Galileo. These systems are based mainly on information coming from their satellites.

Every person can use these four constellations (which comprise approximately 120 satellites in total) provided they have a suitable receiver and chip (e.g., in a smartphone). GNSS offers mainly two types of services: an open service available to every entity and a maintenance service, which provides better performance and availability – only for authorised users (mainly military ones).

The US Global Positioning System (GPS) serves more than one billion users at present and boasts a broad range of applications. The Russian GLONASS is considerably poorer and has several million users. China has invested in creating its system (BeiDou), which will achieve the planned performance in 2021. A similar situation occurs in the European Union with Galileo. Furthermore, Europe employs the European Geostationary Navigation Overlay Service (EGNOS), composed of three geostationary satellites and the ground segment, which expands the existing GPS constellation. This system is used primarily by the aviation. The USA has a similar system called WAAS (Wide Area Augmentation System)[6].

4. RULES OF CREATION AND OPERATION OF SDA AND SSA PROGRAMMES

For many years, Space-related services have been a critical component of support for armed forces, public utility enterprises, and the industry, which underlie a significant part of the global economy and technology. However, the development of Space exploitation entails an increased hazard for Space systems (satellites and ground infrastructure). Their defence is a special sovereign obligation of individual countries. The operation of these systems and the gathering/acquisition and dissemination of information about activities undertaken in space are sovereign. As space has gained importance as a contentious field expanding human activity, it is becoming an increasingly more significant problem in global security, safety, protection, and sustainable management. Bearing that in mind, a concept for establishing an SDA/SSA programme and common database emerged.

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[6] J.C. Moltz, Crowded Orbits. Conflict and Cooperation in Space, Columbia University Press, New York 2014, pp. 132–136.

Currently, SSA (SDA) does not have a reliable science and technology system for determining, assessing, and predicting threats and dangers related to space. Moreover, no standard method of standardisation of data acquired from sensors and other sources has been developed. However, attempts at standardisation are still made, e.g., the US Open Architecture Data Repository. There is also no consistent method of understanding all causes and effects related to Space objects and events.

Two of the more widespread challenges related to the integration of information from multiple sources, which might contribute to raising awareness in the field of space, are overcoming the reluctance of various entities to exchange data (these are, among others, certain countries and private corporations) and to aggregate them precisely with the use of technology. Four data groups might be exchanged more frequently than other sensitive information (e.g., intelligence). No such restrictions are required for data concerning 1) Space surveillance and tracking, 2) the state of Space environment, 3) radio frequency interferences, and 4) Space weather. For this reason, the United States rarely disseminates its SDA but is willing to share SSA programme data. Observations in the USA are based on a Space surveillance network (SSN) called USSTRATCOM. However, these sensors are often too expensive, even for the wealthiest countries, and the area of space is too vast for them. Therefore, collaboration with allies is necessary.

As already mentioned, the goal of an SDA (SSA) system is to gather data on the location or position and characteristics of orbital objects or parameters (usually speed, behaviour, shape), functional characteristics (e.g., modes of drive operation, fuel tank capacity), mission objectives (e.g., communication, weather), identification of behaviours and prediction of specific plausible threats and dangers. For the time being, the existing data sets are incomplete. Thus, analysts compiling such data rely on simplified assumptions. An analyst should rely on available precise data and not describe anything beyond what such data allows. The proper approach in the case of "Space Awareness" should eliminate ambiguities from the system. At the same time, an analyst should try to be unbiased in the inference and hypothesising process as far as possible and use available data to reject a hypothesis for which there is no sufficient evidence.

There are two types of data: complex input data refers to information from sensors based on measurements, such as radars and telescopes; soft input data is information from a human's observations or interpretations. Although the majority of Resident Space Objects (RSO)[7] A subset of defunct objects (satellites and Space debris) are actively controlled by humans. Moreover, they have

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[7] G. Escribano, Maneuver Detection via Combined Heuristical and Statistical Methodologies, ESA's Response, 8th European Conference on Space Debris, 20 April 2021 (ESA/ESOC, 20–23 April 2021).

valuable information that can be sent to the system, which attempts to determine, assess and predict the behaviour of such objects in space.

An SSA (SDA) system should be based on appropriately designed, modelled and communicated data, which requires the preparation of relevant standards. They permit easy transfer of such data to a common and appropriately designated base, which will share them with various users. For these data to be valid, they require detailed information about the adopted assumptions, the place and manner of their gathering, the sensor precision, etc. This context or auxiliary information is often described as "metadata". Metadata are simply assumptions or premises from which conclusions can be inferred. Thus, they are the context or information concerning data and are fundamental in guiding the manner of use of the data set.

Data concerning the Space environment and the objects imported to SDA/SSA come from various sources and sensors. In order to make the maximum use of pieces of information, they must be aggregated. In this context, the notion of "data fusion", which is often defined only in a vague manner, means that precise answers to specific questions are sought.

Aggregated data create a joint base, which:

- facilitates acquiring information from the system, guided by the specific needs of a given user;
- permits determination of the manner of assessment and processing of new information in the system;
- provides an exact and consistent image of space;
- enables the discovery of hitherto unknown Space objects and events;
- supplies information on the behaviour of Space objects and their movement;
- supports decision-making processes and permits direction and control of relevant equipment and services.

SSA (SDA) programs must use many other programs that gather information, among others, from data concerning Space-Based Earth Observation (SBEO). Recent years have seen the development of tools and technologies to improve the utilisation of the gathered image data[8].

The key to preserving the resilience of systems and using them for operational purposes is the capability of understanding and responding to threats in the orbital environment in real-time or near real-time. By delivering helpful information concerning the location and operation of Space objects and natural threats with the use of a generally recognisable image of space and the related services (e.g. collision avoidance), SSA constitutes the primary supportive function, which permits the protection of critical services, such as navigation or Earth observation. Furthermore, in the operational and deterrence context, SSA

[8] M. Jah, Space Object Behavior Quantification and Assessment for Space Security, in: K.-U. Schrogl (ed.), pp. 961–984; P. Zimmer, M. Ackermann, J.T. McGraw, op. cit.

is a sine-qua-non condition for understanding certain anomalies and verifying actions near a protected spaceship (unplanned satellite encounters and proximity operations). Finally, as one of the approaches to mitigation of Space debris propagation, SSA is directly related to efforts for resilience and sustainability of various orbital systems. Extensive understanding of the overall operational environment thanks to SSA brings considerable benefits in the division of costs related to Space operations. Relying on distributed networks of surveillance and tracking sensors, SSA is perceived as a global undertaking. Efforts for exchanging and aggregating information and data from various sources have recently gained momentum[9].

During the AMOS (*Advanced Maui Optical and Space Surveillance Technologies Conference,* 15–18 September 2020), Danielle Wood delivered a speech titled "Contribution from SSA data to the definitions of a Space Sustainability Rating". Instead of establishing official regulations, the author proposes introducing a system for recognising operators' activity in Space objects (detection, identification, data sharing, collision avoidance). All operation phases would be examined, from registration to documentation, operation, and final evaluation. SSR is a regulatory updated scoring system (either "SSR certified" or degrees: silver, gold and platinum). A significant role in SSR is played by SSA, which controls whether the operator transmits up-to-date data, publishes them, or exchanges them with other operators (e.g. as regards collision avoidance)[10].

As mentioned, the United States and its Combined Space Operations Center (CSpOC) currently hold the most significant operational capacities in Space surveillance. This means that various countries cooperate there. This facility manages a global network of 30 surveillance sensors used for space object surveillance, including ground radars, optical telescopes, and optical Space sensors. Ground radars, such as Globus II, AN/FPS-85 Space track radar, and Haystack Ultrawideband Satellite Imaging Radar (HUSIR), ensure a high probability of detecting objects at long and very long distances, with the capability of cloud penetration. These features are required for assessing the situation in space, the physical characterisation of Space objects, and the risk that objects re-enter Earth's airspace. Phased array radars can track multiple satellites simultaneously and scan large space areas in a split second. Conventional radars with mechanically controlled reflector antennas can precisely track only one or a few objects. The newly constructed S-band ground radar system located on Kwajalein Atoll in the

[9] R. Peldszus, P. Faucher, European Space Surveillance and Tracking Support Framework, in: K.-U. Schrogl (ed.), op. cit., pp. 883–904; R. Peldszus, Foresight methods for multilateral collaboration in Space Situational Awareness (SSA) policy and operations, JSSE 2018, no. 5(2), pp. 115–120.

[10] AMOS (Advanced Maui Optical and Space Surveillance Technologies Conference), 15–18 September 2020; D. Wood, speech titled: Contribution from SSA data to the definitions of a Space Sustainability Rating, 11th ESSCA Space Policy Workshop, 29 October 2020; speech by M. Borowitz.

Marshall Islands, Space Fence, is supposed to provide unprecedented range and precision. This is the first step of CSpOC in the process of upgrade of the primary radar systems. The new system is expected to track approximately one hundred fifty thousand Space objects, even as small as a golf ball.

Optical systems are also necessary to pursue an SSA programme besides ground radars. The Ground-Based Electrooptical Deep Space Surveillance (GEODSS) system plays a significant role in tracking Space objects. The Air Force Maui Optical and Supercomputing (AMOS) observatory boasts state-of-the-art electro-optical equipment for detecting and tracking orbital debris. AMOS has, among others, a 1.6-metre telescope and a 3.67-metre Advanced Electrooptical System (AEOS) with an adaptive optics (AO) system[11].

Russia (Russian Federation) has the second-largest SSA radar network after the USA[12]. Similarly to the USA, the Russian system relies mainly on anti-missile warning systems. Some of the first Russian systems stopped working or were dismantled. Other radars are deployed in the area of the former Soviet Union; about half of them are located in bases outside the Russian Federation and are leased by that country. Russia has two bistatic Daryal-type radars: Pechora, Russia, and Gabala, Azerbaijan. Each of these facilities is composed of a receiver and a VHF transmitter. The radar in Baranovichi in Belarus is another bistatic phased array facility operating near 3 GHz. Known in the West as a Pill Box, the Don-2N radar is a part of the ABM system, which protects Moscow[13].

For now, Europe does not have a uniform network of SSA sensors, although individual countries serve a few significant radar installations. The French Army owns the Grande Reseau Adapte à la Veille Spatiale (GRAVES) radar. This facility combines the bistatic and phased concepts, which enhances surveillance frequency and precision.

Other critical European radars include the German Tracking & Imaging Radar (TIRA), supported by the Research Institute for High Frequency Physics and Radar Techniques. TIRA is a monostatic mechanical device that can track objects sized 2 cm at an altitude of 1,000 km; an additional 100-metre antenna enhances its surveillance capabilities of objects sized 1 cm. The system is also capable of imaging objects in Low Earth Orbit (LEO) with the use of an imaging radar with a higher frequency of 16.7 GHz and a resolution of 15 cm.

Thanks to the cooperation with the USA, Norway has the GLOBUS II radar. A mechanical radar tracks objects in the Geostationary Orbit (GEO). Also, a part of the Incoherent Scatter (EISCAT) European radar system, used above

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11 See https://fas.org/spp/military/program/track/amos.htm (22.04.2021).

12 B. Weeden, V. Samson (eds), Global Counterspace capabilities, an open source, pp. 3–25. https://swfound.org/media/206408/swf_global_counterspace_april2019_web.pdf (22.04.2021).

13 T. Harrison, K. Johnson, M. Young, Defense against the dark arts in space – a Report of the CSIS Aerospace Security Project, Protecting Space Systems from Counterspace Weapons CSIS (Center for Strategic and International Studies), February 2021, p. 27.

all for scientific research on the interaction between the Sun and Earth, is located in Norway. EISCAT radars (located in Tromsø and Longyearbyen) are also employed to research Space debris.

Many observers assume that China has radars used for monitoring the hazards to the natural environment, but little information on this topic is publicly available. Chinese SSA sensors and the employed technology are similar to those in the USA, Russia and Europe. This country is believed to have a network of phased array radars, each of which probably has a range of 3,000 km and 120° azimuth. China does not have radars outside its territory so it can observe only the areas in East Asia. To extend the radar's range, two Yuanwang-type tracking satellites were launched[14].

5. ROLE OF THE USA IN THE DEVELOPMENT OF SDA AND SSA PROGRAMMES

The official Space policy of the United States has remained relatively consistent over the past 60 years. Beginning with President Eisenhower, every administration emphasized international cooperation, peaceful intentions and Space management for the common good of humankind. Notably, every policy also reserved the right of countries to self-defence in space. In practice, the USA interpreted this policy rather broadly, particularly as regards military activity. A significant change was made to the National Security Strategy (NSS) in 2017 after President Donald Trump stated that the USA intended to gain an advantage in space. In March 2018, Trump's administration issued four Space Policy Directives (SPD), the last of which ordered that a "New Space Force" be established. The change to the American Space policy is the reason why space is currently regarded as a domain of combat, and the USA is preparing to fight and win military conflicts which might occur there[15]. It can be presumed, though, that the administration of the new President, Joe Biden, will introduce new changes in this regard[16], but it is argued by some that not all actions of the previous administration in the field of Space security and safety deserve criticism[17].

[14] Ch. Eun-Jung, S. Cho, J. Hyun Jo, J. Hyun Park, T. Chung, J. Park, H. Jeon, A. Yun, Y. Lee, Performance Analysis of Sensor System for Space Situational Awareness, JASS 2017, vol. 34, no. 4, pp. 303–313.

[15] E.C. Dolman, War, Policy, and Spacepower: US Space Security Priorities in: K.-U. Schrogl (ed.), pp. 367–384.

[16] Space Policy and Sustainability. Issue Briefing for the Biden Administration. Secure World Foundation, December 2020, https://swfound.org/events/2020/space-policy-and-sustainability-issue-briefing-for-the-incoming-biden-administration (access: 24 April 2021).

[17] B. Bowen, Biden-Harris Space Policy: Building on the Space Force and Artemis, https://spacewatch.global/2021/01/spacewatchgl-column-biden-harris-space-policy-building-on-the-space-force-and-artemis/?mc_cid=f2071aabe6mc_eid=UNIQID (access: 29 April 2021).

Space Situational Awareness (SSA) refers to the capability of detecting, tracking, identifying and cataloguing Space objects, such as Space debris or active and defunct satellites, as well as to the observation of Space weather and surveillance of space, spaceships and payloads for manoeuvres and other events. SSA increases the capacity to distinguish attacks of foe satellites from technical failures or interferences caused by Space weather and thereby might contribute to stability in space by preventing misunderstandings and false accusations of hostile acts. SSA data, available to all countries, might help enhance transparency and conformity of actions in space, which might strengthen the overall stability of the Space system. The Space environment must be secure and safe for the International Space Station (ISS) and the existing and future Space infrastructure related to human Space exploration[18]. The growing number of prominent constellations and the accelerating pace of launches drive the global demand for more precise knowledge (including determination of orbits) and improved, automated Space Situational Awareness services[19]. Hence, cataloguing objects and the systems performing them are vital for maintaining security and safety in space.

The American Space Surveillance Network, SDA (which means situational awareness in the Space domain, i.e. a broader term than SSA), significantly outpaces the rest of the world regarding SSA capacities. There is no global Space surveillance or data-sharing system, partly due to the sensitivity of the gathered data. Commercial entities also develop end-to-end tracking services. SSA is also crucial to security and safety joint activities in space and is necessary for developing a Space Traffic Management (STM) system, which could considerably reduce congestion in space. Although generally regarded as significant, STM is still at the stage of discussion[20].

Before the collision of "Iridium" and "Kosmos" satellites in 2009[21] the conviction prevailed that space was so huge that such collisions would be rare.

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18 A. Białkowski, Automated processing chain for sensor data sharing, The Space Debris Challenge, ESA's Response, 8th European Conference on Space Debris, 20 April 2021 (ESA/ESOC, 20–23 April 2021).

19 M. Popp, Towards Secure De-centralised Management and Exchange of Space Surveillance and Tracking Data, The Space Debris Challenge, ESA's Response, 8th European Conference on Space Debris, 20 April 2021 (ESA/ESOC, 20–23 April 2021); M. Schubert, Analysis of different process noise models in typical orbit determination scenarios, ESA's Response, 8th European Conference on Space Debris, 20 April 2021 (ESA/ESOC, 20–23 April 2021).

20 J. West (ed.), op. cit. STM is also discussed in the context of the Cislunar space (the space between Earth and the Moon), see C. Frueh, Cislunar Space Traffic Management: Surveillance Through Earth-Moon Resonance Orbits, The Space Debris Challenge, ESA's Response, 8th European Conference on Space Debris, 20 April 2021 (ESA/ESOC, 20–23 April 2021).

21 The collision above Siberia (at an altitude of 790 km) occurred between the derelict Russian Kosmos-2251 satellite and the American Iridium 33 telecommunication satellite (one of 66 satellites of the global telecommunication network). The quantity of debris created due to this

Only a few satellite operators had a different opinion and used the Space Situational Awareness (SDA/SSA) services. The US Air Force provided such services based on surveillance data gathered using sensor systems. However, these devices could have been more precise, and as a result, they provided only approximate information.

Even a change in the satellite heading requires expenses on fuel, though, and each manoeuvre reduces the service life of the equipment. The change of heading based on inaccurate data may sometimes increase the risk of collision with another object even later and affect its capacity to accomplish the primary mission objectives.

Over the years, new American sensors and analysis technologies emerged, but some satellite operators still believed that such information needed to be improved for their needs. In such a situation, several operators of satellites in GEOs founded the Space Data Association (SDA) in 2009 to improve the accuracy and timeliness of notifications about possible collisions. Using its Space Data Center, the Association supplements the catalogue data from the US government with the information supplied by GEO satellite operators, who generally know precisely where their satellites are located and when manoeuvres will be performed; they also warn against radio frequency interferences.

At present, certain countries (e.g. France) develop warning systems that provide services to the operators of their satellites. In fact, however, most of them use the American catalogue of Space objects, supplemented with information from their sensors, as the basis for their services. The primary catalogue, *Resident Space Object* (RSO), used for SSA/SDA services, was created and is maintained by the US Air Force. This catalogue has still been regarded as the most complete one. Data are gathered mainly by ground radar and visual telescope systems served by US government agencies. The RSO catalogue contains data about 20–23 thousand objects; thanks to international cooperation and actions by commercial entities, the number of the objects (sized up to 2 cm) under surveillance can rise to 200 thousand shortly.

This is a realistic prospect given the activity of specialised private companies. For example, one American company now operates two-phased radars and is constructing a third one. That company currently tracks over 14 thousand objects present in LEO and anticipates that the number will increase to 250 thousand. Another US company operates a global network of telescopes (with over 25 observatories and 250 telescopes). It tracks artificial Space objects in GEO, Highly Elliptical Orbit (HEO), and Medium Earth Orbit (MEO). Both these companies offer various services based on the data they gather. The continual gathering of data on the tracked objects (several times a day) will make

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disaster was higher than that caused by the Chinese ASAT test in 2007, see J. Pelton, T. Sgobba, M. Trujillo, Space Safety, in: K.-U. Schrogl (ed.), op. cit., p. 278.

it possible to provide end-to-end Space Situational Awareness services with unprecedented accuracy in the coming 10–20 years[22].

Until recently, the US Department of Defense (DoD) was the only holder of Space Situational Awareness (SSA/SDA) information. Today, DoD has contracts which allow it to share data (mainly open ones) with 15 governments and 66 international and private organisations. In 2018, numerous countries collaborated with the USA in military SSA (SDA). They included in particular: Australia, Brazil, France, Japan, Canada, South Korea, Germany, Poland, Thailand, the United Kingdom, Italy and the United Arab Emirates. The Russian Federation, China, and India have recently been developing their SSA programmes.

A range of allied countries contribute considerably to SSA (SDA) and purchase American sensors, software and services. This is why SSA programme financing is dynamically growing, e.g., in Australia and Japan; the expenses on this goal are much lower in other countries, such as Poland and Thailand.

At the same time, governments, the industry, the academic community and other entities want broader access to these data to perform their analyses. This distrust of the accuracy of the American data is one of the reasons why some allied countries want to develop their own SSA systems. Apart from that, they fear that American data transmission might suddenly stop. Indeed, the American SSA system does not supply information necessary for secure and safe operation in space because the number of objects there increases, and the actions performed by operators need to be coordinated. Consequently, data coming from EU member states are sometimes more accurate and more usable for civil purposes[23].

The United States strives to expand international cooperation, enhancing the stability and international partnership in space following the national Space policy. Guided by this strategy, the United States Space Command (USSPACECOM) signs data exchange contracts as part of the SSA programme. Such documents were concluded with many countries and their entities by November 2019. In Europe, such contracts were concluded by Belgium, Denmark, Finland, France, Spain, the Netherlands, Germany, Norway, Poland, Romania, the United Kingdom, and Italy, as well as the European Space Agency and the European Organisation for the Exploitation of Meteorological Satellites. In South America, such a contract was signed by Brazil; in North America – by

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22 W. Ailor, Evolution of Space Traffic and Space Traffic Management, in: K.-U. Schrogl (ed.), op. cit., pp. 306–307.

23 B. Lal, A. Balakrishnan, B.M. Caldwell, R.S. Buenconsejo, S.A. Carioscia, Global Trends in Space Situational Awareness (SSA) and Space Traffic Management (STM), IDA, Alexandria, Virginia 2018, https://www.ida.org/-/media/feature/publications/g/gl/global-trends-in-space-situational-awareness-ssa-and-space-traffic-management-stm/d-9074.ashx (access: 29 April 2021).

Canada; in Asia and Pacific – by Australia, Israel, Japan, South Korea, New Zealand, Thailand and the United Arab Emirates. In total, 80 entities participate in SSA data exchange, including commercial owners and operators of satellites, non-governmental organisations and scientific institutions[24].

It comprises three primary components and actions: gathering data, ordering it systematically, and issuing credible collective information and forecasts[25]. This system also handles Space weather and the location of natural and artificial objects circling Earth[26]. Moreover, multiple SSA objectives refer to protecting important Space and Earth resources against adverse effects of the impact of space[27].

6. EUROPEAN CONSORTIUM FOR SPACE SURVEILLANCE AND TRACKING (EU SST)

Space Situational Awareness (SSA) is a dual-use mission by nature. As space becomes busier and busier, the exact knowledge of the domain is crucial to all satellite operators, regardless of whether these are military, civil or trade matters. In order to protect Space infrastructure objects in orbit, including active and defunct satellites, it is necessary to track as many objects in orbit as possible. Many technologies used for measuring and tracking objects in space originate from an anti-missile defence system, and military entities are still using sensors for Space surveillance worldwide. This double dimension of SSA has also been in the European support framework for Space object surveillance and tracking (EU SST). Over the past decades, the major European countries have actively participated in global efforts towards improvement of Space operations security, Space security and space infrastructure resilience. However, it was not until 2014 that the European Union prepared a unique model of multilateral action of EU member states in Space surveillance and tracking, which would not prejudice their sovereignty. The joint efforts at the national, intergovernmental and supranational levels aimed to live up to the challenge posed by the growing scale and complexity of the use of space by developing operational, technical and normative approaches to detection, description, understanding and mitigation of the risk related to the growing number of objects in Earth's orbit[28].

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24 See https://www.spacecom.mil/News/Article-Display/Article/2047780/usspacecom-expands-key-allied-space-partnerships-through-multi-nation-operations/ (access: 23 March 2020).

25 S.A. Kaiser, Legal and policy aspects of space situational awareness, SP 2015, vol. 31, pp. 5–12.

26 D. Oltrogge, Marshalling Space Traffic Management requirements and expectations in the international context, ESPI 12th Autumn Conference; https://espi.or.at/downloads/category/58-presentations (access: 29 April 2021).

27 Ch. Bonnal, Pollution spatiale, l'état d'urgence, Belin, Paris 2016, pp. 21 ff.

28 R. Peldszus, P. Faucher, European Union Space Surveillance Tracking (EU SST) – State of Play and Perspectives, 71st International Astronautical Congress (IAC) – The CyberSpace Edition, 12–14 October 202; IAC-20-E3.4-56723.

The primary legal act of the EU regarding the implementation of an SSA programme is the Decision of 2014 on managing and financing the Consortium for Space Surveillance and Tracking – EU SST (541/2014/EU)[29].

The Consortium's task was to combine European countries' resources to secure the European and national Space infrastructure. The member states contribute to their optical and radar sensors. Based on the processed data, such SST services will be implemented to assess risk, information and warnings concerning actual and predicted Space events involving manufactured objects. Such events include satellite collisions, orbiting fragments of objects, or uncontrolled entry of manufactured Space objects into Earth's atmosphere.

This information was to be shared with the interested parties, including EU institutions, member states, and satellite operators registered in the EU SST Service Provision Portal and handled by the EU SatCen (previously European Union Satellite Centre – EUSC).

Initially, the Consortium was composed of representatives of national Space agencies of the leading European countries: Germany, France, Spain, Italy and the United Kingdom. Romania, Portugal and Poland joined this group at the turn of 2019[30].

In 2018, the European Commission sent a report on Space Surveillance and Tracking in 2014–2017 to the European Parliament and the Council of Europe. The requests and recommendations included particular issues regarding preparing a long-term vision of strategic objectives and general guidelines on the EU level, further simplifying the EU SST subsidy management system and changes in the subsidy management[31].

The works performed by the EU STT are supervised by the European Commission. Operating 24/7, the Consortium has 12 radars, 34 telescopes and four lasers. The goals of the Consortium are pragmatic: to build a network of sensors and to transmit data (services are provided by various Consortium member states). Currently, the system is used by 148 entities, including 87 organisations and 20 EU member states. The Consortium performs surveillance of 138 registered (civil, military and commercial) satellites, of which 45 are located in LEO, 30 in MEO and 63 in GEO. It was decided that the Consor-

29 Decision No. 541/2014/EU of the European Parliament and of the Council of 16 April 2014 establishing a Framework for Space Surveillance and Tracking Support, OJ L 158 of 27 May 2014, p. 227.

30 N. Antoni, C. Giannopappa, M. Adriaensen, Space and Security Programs in the Largest European Countries in: K.-U. Schrogl (ed.), op. cit., p. 1316.

31 Decision No. 541/2014/EU; 2013/0064 (COD); Proposal for a Regulation (EU) 2021/696 of the European Parliament and of the Council of 28 April 2021 establishing the Union Space Programme and the European Union Agency for the Space Programme and repealing Regulations (EU) No. 912/2010, (EU) No. 1285/2013 and (EU) No. 377/2014 and Decision No. 541/2014/EU, COM/2018/447 final – 2018/0236 (COD).

tium's activity might be pioneering for the European Space Traffic Management (STM) system.

The member states control the operation of the sensors; the security matters concern not only the member states but also other EU member states and even third countries. The shared data are available in operational centres in Poland or the United Kingdom[32]. The Consortium has signed numerous cooperation agreements, including with the USA; there are also multiple bilateral agreements, e.g. Germany-France, Italy-USA. A Security Committee was established within the Consortium for sensitive data protection[33]. However, the later fate of the Consortium is unknown: it still does not have full decision-making autonomy. Talks concerning the Consortium are in progress[34]. Despite that, in April 2019, it was decided to upgrade the database, which was to become a starting point for constructing and maintaining a European catalogue of Space objects[35].

Since its establishment, the EU SST Consortium has gradually developed SST capabilities with support from the European Union using various financing lines (H2020, Galileo and Copernicus programmes). Sensors belonging to the Consortium member states (including radars, telescopes, and laser measurement stations) serve for examining and tracking Space objects located on all levels of Earth orbit: LEO, MEO, HEO and GEO. Every day, thousands of measurements from EU SST sensors are shared via a joint database available to the operational centres (OC) and supplied to the users via the SST Service Provision Portal (SST Portal). These data underlie the future EU SST catalogue to be compiled by Germany.

The Service Provision Portal (managed by SatCen, which acts as a front desk) is responsible for providing three SST services: collision avoidance (CA), re-entry analysis (RE) and fragmentation analysis (FG). French and Spanish OCs are currently responsible for the CA service; the Italian OC handles the RE and FG services. The collision avoidance service assesses the risk of collision between spaceships or between a spaceship and Space debris (warnings

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32 E. Mills, B. Sharp, UKSA (UK Space Agency) lines of efforts within SSA, SMI's Military Space Situational Awareness 2020 Conference (virtual), 3–4 September 2020; S. Machin, Space Weather. The MOSWOC (Met et al.) in Support of Space Operations, SMI's Military Space Situational Awareness 2020 Conference (virtual), September 3–4, 2020. The United Kingdom withdrew from the Consortium as a result of Brexit.

33 S. Ducaru, Security from Space and Security in Space – an operational perspective, SMI's Military Space Situational Awareness 2020 Conference (virtual), 3–4 September 2020.

34 M. Becker, P. Faucher, European Space Surveillance and Tracking, SMI's Military Space Situational Awareness 2020 Conference (virtual), 3–4 September 2020.

35 P. Faucher, R. Peldszus, A. Gravier, Operational Space Surveillance and Tracking in Europe, document for the first international conference devoted to orbital debris (December 2019). Abstract available on: https://www.hou.usra.edu/meetings/orbitaldebris2019/orbital2019paper/pdf/6165.pdf. (access: 23 February 2021).

are sent). This service is tailored to the user's needs; it includes messages and reports enabling the user to assess the future risk.

Re-entry analysis (RE) refers to the possibility that artificial Space objects re-enter Earth's atmosphere. The RE service routinely monitors all bodies and objects weighing more than 2,000 kg or, if there is no information about their mass, provides their area (if it exceeds 1 m^2). When such objects are close to a predicted re-entry into Earth's atmosphere, a request is sent to all EU SST sensors to acquire additional data to make the data more specific and accurate. The service is tailored to the user's needs as it allows them to select areas of interest in the territories of EU member states (and the associated territories).

The fragmentation analysis (FG) service ensures the detection and characterisation of the disintegration of objects in orbit. The short-term FG aims to quickly confirm such an event and its characteristics (e.g. object and event type, quantity of detected fragments, position in orbit). The medium-term FG provides further details of the event based on the orbital parameters of the catalogued fragments. This analysis covers visual information of the fragments. The long-term FG supplements the earlier analyses with information concerning a simulation of an event with the use of an appropriate model of disintegration or collision, which contains data on the ratio of the object's area to mass and density and on the predicted number of fragments[36].

A meeting between the management staff of the EU SST and the researchers interested in this topic was held in late 2019. It was communicated that the Consortium undertook a range of research & and development works to improve SST results on the European level in the future. For this purpose, "architectural" studies were established to simulate various scenarios composed of one or more sensors (existing or in development) as to their individual or collective performance level. The preliminary results of these studies reveal that by 2021, the Consortium will be able to catalogue most objects sized above 35 cm in GEO. As regards LEO, various surveillance radars with various performance levels depending on the updates to be performed, which were proposed by the member states, were examined. The upgraded network will detect over 16 thousand objects with a size greater than 7 cm. All radars, in total, will deliver more than 40 thousand "traces" (observations) daily, which will make it possible to catalogue over 6 thousand objects, including 35% of objects with a size greater than 10 cm.

Moreover, the performance of several networks studied in the perspective of 2028 covers a simulated orbital population, considering the inclusion of constellations and CubeSats based on current forecasts. In this scenario, the network will detect more than 32 thousand objects with a size greater than 7 cm. All radars, in total, will deliver more than 200 thousand traces daily, which makes it possible to catalogue over 19.5 thousand objects, including 65% of ob-

[36] See www.eusst.eu (access: 15 February 2021).

jects with a size greater than 10 cm. Mega-constellations will be taken into account in the next step[37].

On 16 November 2020, the second remote seminar with 400 registered participants was held. The session was opened by Pascal Faucher, the Chair of EU SST, who presented the hitherto achievements of the Consortium and outlined the plans for its further development. María A. Ramos, the SST Technical Chair, presented the current work organisation in the Consortium and the network of sensors composed of 4 lasers, ten radars (3 surveillance, seven tracking ones), and 32 telescopes (17 surveillance, 15 tracking ones). Solaris telescopes for the EU SST observatory in Chile were manufactured in Poland.

Rodolphe Muñoz informed the attendees about the coming changes in the Consortium's activity, including the planned introduction of a Space debris removal programme, the increased importance of expert teams from various member states, and the extension of cooperation with military and civil entities. Furthermore, Muñoz notified the participants of the United Kingdom's withdrawal from the Consortium's works. The United Kingdom participates neither in the EU Space Object Surveillance and Tracking programme nor in the service provision as part of the programme; moreover, it does not take part in science and technology groups that make up the programme.

The Consortium's success is an argument confirming the necessity for societies to prepare for the coming changes in the Space environment. Better access to the technologies, more equipment launched into orbit, miniaturisation of Space assets, the emergence of prominent constellations and new operational concepts, such as satellite services or technologies of satellite removal from space, are only some of the changes and events that will contribute to the further increase in the complexity of the human use of the Space environment. In order to mitigate the risk to which they are routinely exposed, such entities dealing with space whose primary goal is to secure their assets and maintain access to orbit are involved in activities using the Space environment (SSA).

Space Situational Awareness constitutes operational monitoring and understanding of the orbital environment and the behaviours of entities being its part. Surveillance and tracking sensors (e.g. radar, optical, laser ones) acquire data on objects (active and defunct satellites, debris, fragments, Space weather and NEOs), which are processed and incorporated into the database (catalogue). Thus, obtained data are aggregated and create a Space image, serving, among others, for warning operators against possible collisions of objects. At present, SSA constitutes a critical operational domain. Given the pace of the situation in orbit and the growing importance of space as critical infrastructure, the significance and scope of this area will increase in the coming decades.

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37 P. Faucher, Operational Space Surveillance and Tracking in Europe (EUSST), webinar, 16 November 2020.

In line with the changes in the environment to which SSA will have to adapt shortly, the traditional paradigms of operation and management, originating from the legacy of the Cold War anti-missile defence, are changing. They have transformed to a considerable extent recently, for example, through the fact that private entities have joined the process. Therefore, the SSA system prepares for future actions, which are to be planned and taken by assemblies of many heterogeneous organisations rather than single entities. The tendency of sovereign democratic countries to develop cooperation in this field is noticeable this decade[38].

An example of the fact that the international community is concerned about the use of kinetic ASAT weapons is the Outer Space Institute's Open Letter of 2 September 2021 [International Open Letter on Kinetic Antisatellite (ASAT) Testing] addressed to the Chairman of the Assembly General UN on the need to prepare a treaty banning the use of this type of weapon in space[39]. The letter has been signed by famous world experts and several politicians. Let us hope that diplomacy in space security will play a significant role today and in the future.

7. CONCLUSIONS

The most crucial use of satellites is space reconnaissance (one may wonder if it is legal under existing treaties). In some countries, space agencies take on the challenges of space activities for civil and military use. Hence, their activities are based on using space for these two domains. The militarization of space is slowly entering a new phase: from passive satellites, supporting military operations through the collection and transmission of various necessary information, to active satellites, which, equipped with anti-missile systems, can destroy designated targets. The existing space treaties need a more relaxed and adequate definition of space weapons. This leads to a problematic situation connected with an unambiguous classification of some means of destruction. The greatest hopes of the military are pinned on laser weapons. Work on this type of weapon is carried out on a vast scale. Work is also underway on particle gas pedals, which will be to destroy objects in space and kinetic and radiation weapons. All this indicates that soon, military conflicts will be able to take place not only on land, sea and air but also in space. In the struggle for the best use of space for military purposes, in addition to the US and Russia (which throughout the Cold War were the only space powers), China, India, Japan, North Korea, Iran, Israel and others are also joining in. This state of af-

38 R. Peldszus, Foresight methods..., op. cit., pp. 115–120.

39 http://outerspaceinstitute.ca/docs/OSI_International_Open_Letter_ASATs_PUBLIC.pdf (access 18-11-2021)

fairs raises the question of whether a "space Cold War" may be waiting for us soon and whether it will not turn into a global military clash this time. The continuous development of space technology, connected with military means, may lead to a rapid acceleration of the arms race. Today, unlike during the Cold War, when enemies and threats were more clearly defined, and diplomacy had urgent challenges to intervene (mainly in nuclear weapons and missile proliferation), space threats seem less critical.

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