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Integrated Space Situational Awareness Systems: SDA and SSA – Advantages and Limitations[1]

Abstract: SDA (Space Domain Awareness) and SSA (Space Situational Awareness – SSA) have been defined as comprehensive knowledge of space objects and the ability to track, understand, and predict their future location. The purpose of the article is to present SSA initiatives to protect space systems, which are now recognized as fundamental assets of the sustainable development of each country. The destruction of even a part of the space infrastructure can have severe consequences for the security of citizens and economic activity. These systems assume the combination of all data obtained by various entities operating in space and Earth to create a common database. The SSA system was created based on the US military programme SDA (Space Domain Awareness); SSA and SDA are almost similar, but SDA is a new term replacing SSA, which existed previously. SDA is a better and improved SSA. Increasingly, the SSA programme is part of national and EU space strategies, but it is not yet possible to include it in international space law.

Keywords: *security, satellites, outer space, SDA/SSA, observation programmes*

1. Introduction

Outer space security means safe and permanent access to space and limiting threats flowing from there (Polkowska, 2018, pp. 4-10). This definition also covers the safety aspects of manmade devices sent into space and ground stations. Security in outer space also means protecting human life and the Earth's environment against natural hazards and risks from space (ESPI report, 2020). Space infrastructures can be described as a network of space and terrestrial systems connected by communication channels and allowing access to space.

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There are many challenges related to the security of space infrastructure, such as unintended threats (space debris and accidental disruptions), intentional threats (ASAT anti-satellite weapons, malicious interference, and cyber-attacks), or space weather threats (geomagnetic storms, solar storms, etc. (Chanock, 2020, p. 78).

Because space is so important to many countries, their leaders create policies and strategies for their security and protection. The first task is to secure the results of continuous and substantial investment by public and private entities. The state must protect the economy and society against the risks associated with widespread and significant dependence on space infrastructure. Space policy should enable states to play a significant role in space activities and take advantage of the benefits and opportunities that space offers (Moranta, 2018).

Furthermore, space policy should ensure that the infrastructure can deliver the operational environment upon which space operations depend.

Space Situational Awareness (SSA) has been defined as comprehensive knowledge of space objects and the ability to track, understand, and predict their future location. The destruction of even a part of the space infrastructure can have serious consequences for the security of citizens and economic activity.

Space Domain Awareness (SDA), as an official US new term replacing Space Situational Awareness, appeared only in 2019, and it is mainly used by the US Space Force. The definitions and objectives of the SSA and SDA are almost similar, but the latter is more expansive than the former. The SDA and SSA programme (now also covering the military field) require frequent measuring of objects' positions and precise information about current and future dangers. Measurements can be made from Earth or space using optical sensors, radar, or, in some cases, passive technology (RF radio frequency) (Zimmer & Ackermann, 2020). Increasingly, the SSA programme is part of national space strategies.

As this article explains, SSA (being an operational concept) and SDA (encompassing the whole domain awareness including militarization issue) is a necessary component of stability in space necessary for the whole community to maintain peace and security.

2. Current Situation in SSA and SDA in Global, Regional, and National Level

Due to the rapid development of information technology and related applications to the modern space domain, it becomes imperative that countries maximize their awareness in the field of space. For many decades, space capabilities and services have been essential to support the armed forces and utilities that underpin much of the global economy and technology. However, the threats to these capabilities and services are worrying. Protecting space systems (satellites and terrestrial infrastructure), which provide capabilities and services to users, is a special sovereign responsibility of individual states. It is worth mentioning that private companies are also involved in space security by contributing to SSA, such as LeoLabs.

The operation of these systems and the gathering/acquisition and dissemination of information on space activities are inherently sovereign. These are national systems. There was no need to have standards methods or need for integration.

As outer space has grown in importance as a contentious field expanding human activity, it is a growing problem for global security, security, and sustainable management (Adriaensen, 2020, pp. 701-7040).

In fact, to this day, the SSA (SDA) does not have a reliable scientific and technical system for identifying, assessing, and predicting the threats and dangers of space. There is also no standard method of standardizing data obtained from sensors and other sources. There is also no coherent method for understanding all the causes and effects of space objects and collisions.

Two of the more widespread challenges of integrating data and information from multiple sources that can contribute to increased awareness of space are overcoming the reluctance of various actors to exchange data (including some states and private corporations) and the exact technical combination of such data. Three types of data can be exchanged more often than other more sensitive information (e.g., intelligence). Such limitations are not required by data on 1) space observation and tracking, 2) the state of the space environment, 3) radio frequency interference, and 4) space weather.

In the US, the observations are based on the SSN USSTRATCOM space surveillance network. However, these sensors are often too expensive, even for the wealthiest countries, and the area of space is too vast for them. The US alone cannot cover the entire world and must be assisted by allied countries to ensure security. As already mentioned, the purpose of the SDA (SSA) is to collect observations on the physical states and parameters of objects (e.g., orbit, size, posture, shape), functional characteristics (e.g., thrust, payload), mission objectives (e.g., communication, weather), identifying behavior and predicting specific credible threats and dangers. Currently, the data sets available to the analyst are, in principle, incomplete. Therefore, decisions are made based on simplifying assumptions. A solid and meaningful awareness of outer space requires the analyst to grasp the complexity of the problem and seek to obtain reasonably specific information from space. You should rely on the available precise data and not describe anything other than what the data allows. For "Outer Space Awareness", the correct approach should be to remove ambiguity from the system, and the analyst must try to be biased in the inference and hypothesis process as much as possible and use available data to reject a hypothesis that does not have sufficient evidence.

The so-called complex inputs refer to information from physics-based sensors such as radars and telescopes; soft inputs are information derived from human observation or interpretation. While most tracked space objects (RSOs) are devastated and debris, there is a subset that is actively controlled by humans. Moreover, humans have valuable information that can be fed back to a system that tries to identify, evaluate, and predict the behavior of such objects in space.

Before the collision of the Iridium satellites with the Cosmos in 2009, the perception was that the space was so vast that satellite collisions would be very rare. Only a few satellite operators disagreed and requested space awareness (SDA) services. Such services were provided by the US Air Force based on monitoring data collected using sensor systems. However, these devices were not precise and, as a result, provided only approximate information. Changing the heading of a satellite requires spending on fuel, with each maneuver reducing the life of the device, and a course change based on inaccurate data can increase the risk of collision with another object even later. Moving a satellite's trajectory may also affect its ability to meet the mission's primary objectives (Pelton, Sgobba, and Trujillo, 2020, p. 278).

New US sensors and analysis techniques have emerged over the years, but some satellite operators still felt that this information was insufficient for their needs. Against this background, in 2009, several satellite operators in GEO orbits formed the Space Data Association (SDA) to improve the accuracy and timeliness of possible collision notifications. Through its Space Data Center, the Association supplements catalog data from the US government with the information provided by GEO satellite operators, who generally know exactly where their satellites are and when maneuvers will be performed; they also warn of radio frequency interference.

Currently, some countries in UE (such as France) are developing their warning systems, providing services to the operators of their satellites. However, most of them use the American catalog of space objects as the basis of their services, supplemented by information from their sensors and satellite operators.

Since the beginning of the space age, the primary directory used for SSA/SDA services has been created and maintained by the US Air Force. This catalog of "Resident Space Object" (RSO) is still considered the most complete. Data for this catalog is mainly collected by ground-based radar systems and visual telescope systems operated by US government agencies. The RSO catalog currently contains about 20 000 – 23 000 objects. Due to international cooperation and the activities of commercial entities, soon, the number of observed objects (up to 2 cm) may increase to 200 000 (Ailor, 2020, pp. 306-307).

It is a realistic prospect due to the activities of specialized private companies. For example, one US company currently has two-phase radars in operation and is building a third. The company currently tracks over 14 000 objects in orbit LEO and predicts their increase to 250 thousand. The second company operates a global network of telescopes with over 25 observatories and 250 telescopes and tracks manmade space objects in GEO, High Elliptical Orbit (HEO), and Medium Earth Orbit (MEO). Both of these companies offer a variety of services based on the data they collect.

Continuous data collection on most objects (several times a day) will enable space situational awareness services to be delivered with unprecedented accuracy over the next 10-20 years (William, 2020, pp. 306-307).

A key element in maintaining the resilience of systems and operational perspectives is understanding and responding to threats in the orbital environment in real or near real-time.

By providing useful information on the location and behavior of space objects and natural hazards through a widely recognized image of space and related services (e.g., collision avoidance), SSA is a primary back-end function that enables the protection of critical services such as navigation and surveillance of Earth. Moreover, both in an operational and deterrence context, an SSA is a prerequisite for resolving certain types of anomalies and verifying activities in the spacecraft's vicinity. (unexpected satellite encounters and proximity operations). Finally, as one of the approaches to mitigating the spread of space debris, SSAs are directly related to efforts to make the various orbital systems resilient and durable. A comprehensive understanding of the overall operating environment with an SSA brings significant benefits in terms of burden-sharing. Relying on distributed sensor networks for surveillance and tracking purposes, SSAs are now viewed as a global enterprise. Efforts to exchange and combine information and data from different sources are now gathering pace (Peldszus & Faucher, 2020, pp. 804-991).

2.1. *EU and Other European Space Faring Nations Policies for Space Security and the Role of the Situational Awareness System (SSA)*

Space security is now at the heart of EU diplomacy and promotes a coherent "European way". Security plays an increasing role in commercial space markets and supports the competitiveness of the European industry. The European Space Agency (ESA) is a key element in building the EU's capacity. It has launched many initiatives, including a Cybersecurity Center of Excellence (although it is not an EU institution). Another European institution, EUMETSAT, deals with radio frequency issues, space waste decommissioning, space weather, resource conservation, in situ data provision, cooperation with the Member States and partner organizations (Monham, 2018).

The European Space Policy Institute (ESPI) is also working in this direction (ESPI, 2018). According to the researchers from this institute, in the European Union, at least 10% of GDP depends on the used space potential. ESPI considers space security as one of the key challenges for Europe (Vernile, 2018, p. 61).

Europe is now equipped with a complete and modern space infrastructure, including spacecraft, ground stations, launchers, spaceports, and all the systems and equipment necessary to develop, produce, implement, operate, and use space systems. As a supranational institutional entity, the European Union owns the space infrastructure under the current flagship programmes: Galileo, EGNOS, and Copernicus. Most space technologies, infrastructures, and services can serve both civilian and military purposes. Therefore, they can develop an innovative and competitive European technological and industrial base of the defense sector. These assets need protection in the harsh environment of space.

Space systems contribute increasingly to development and enable the EU's Common Security and Defense Policy (CSDP). But Europe is faced with constantly evolving security threats that are more varied, less visible, and less predictable than before. In order to deal with them, the possibilities of independent political assessment, sound decision-making, and appropriate and effective preventive actions are needed. Space devices contribute to facing these threats thanks to their global monitoring, positioning, and data transfer capabilities. The European Parliament approved the establishment of GOVSATCOM and its budget of EUR 10 million. In 2019-2020, this organization began cooperation with the industry, satellite communications providers, and users (Internal Market…, n.d.). Moreover, EU Space Policy 2021-2027 allocated 442 million EUR for SSA and GOVSATCOM.

The direct operation and use of the EU space infrastructure are entrusted to partner organizations. They deal with this, among others The European Space Agency (ESA), the European GNSS Agency (GSA), EUMETSAT, Frontex, and the European Union Satellite Center (EU SatCen). In addition, EU Member States run both civilian and military programmes; these include space agencies and defense departments that own or operate the national space infrastructure. Commercial entities such as Eutelsat, SES, and Inmarsat own their space infrastructure.

In their well-understood interests, European states cooperate in space policy matters with ESA and EUMETSAT, transferring to them a significant part of their budget sums.

The November 2019 ESA conference (with the participation of ministers from the Member States) decided to increase the funds allocated to the activities of this organization. As a result, a budget of almost EUR 14.39 billion was adopted for 2020. Germany declared the largest sums, EUR 3.29 billion, which made 22.9% of the ESA budget, and France, EUR 2.66 billion (18.5%). Significant sums were also declared by: Italy -2.28 billion (16%), Great Britain –1.65 billion (11.5%), and Spain 0.852 billion (5.9%). The share of other European countries and Canada in the budget was much smaller (ESPI, 2019, p. 6).

In Europe, the number of privately operated satellites (124) exceeds the number of satellites operated by public civil and military institutions (95) (European Radio Navigation Plan, n.d.). It is a direct consequence of the leading position of European satellite operators in world markets, particularly in satellite telecommunications. The satellites operated by the European institutions cover a total of 44 space systems: 17 operated by ESA (including 5 EU Sentinels), five operated by EUMETSAT, and 22 EU-owned Galileo satellites operated by GSA with the support of private operators. Satellites operated by national civilian and military institutions include 45 space systems: 23 operated by national space agencies and 22 by military organizations. The remaining 23 satellites are mainly owned by other private entities, such as Airbus, Skynet (working for the UK Ministry of Defense), or DMC International Imaging. Each European space infrastructure includes earth stations that can operate separately or interact with other systems. Finally, Europe has autonomous access to space, including the required industrial configuration, an operational spaceport (in Guyana), and a wide range of low, medium, and high-capacity launchers (Dependence of the European…, 2017).

Some European capabilities depend on a series of contracts with the US signed by European intergovernmental organizations (i.e., ESA and EUMETSAT), Member State institutions (France, Germany, UK, Italy, Spain, and Belgium), and many European commercial satellite operators and service providers. These agreements were mainly related to the launch and purchase of satellites (or parts for their production) and the use of spaceports, mainly for launching satellites into space. Space security cooperation within an SSA can also bring great benefits.

In 2000, the ESA Council adopted a resolution on the protection of the space environment. This resolution established a task force, coordinated by ESOC (European Space Operations Center) in Darmstadt to define safety standards for satellites in orbit. The task force brought together representatives from ESA and national agencies, and in 2002 introduced preventive measures and the principle of conserving the orbit. In November 2008, ESA established a Space Surveillance Programme (SSA) involving 19 ESA Member States. It aims to support developing an independent European capability to assess space threats to systems in orbit or on Earth.

In March 2018, the European Commission published the first edition of the European Radio-Navigation Plan to identify and reduce the risks of GNSS dependency. Military operations and civil protection also depend heavily on space capabilities for navigation, positioning, communication, and intelligence. Significant progress in implementing EU programmes in 2014-2020 also adds to the importance of a service-oriented space policy aimed at building user confidence, encouraging their use of space services, and, consequently, maximizing the benefits of European space infrastructure.

The growing need to increase the security of space in Europe is due, in the short term, to four key reasons: 1) ensuring continued and substantial investment by public and private actors, 2) protecting the European economy and society from the dangers of its heavy dependence on space infrastructure, 3) ensuring that the infrastructure is capable of delivering services that can be reasonably trusted, in particular to users in the field of defense and security, 4) guaranteeing European autonomy and freedom of action in the field of security in outer space (Johnson, 2017, p. 12).

In addition, equipping Europe with a system that ensures comprehensive and independent SSA capabilities will influence the perception of Europe as a credible interlocutor in the international arena. The EU is aware that security will play an increasing role in commercial space markets. The European Parliament and the Council of the EU, in the communication of April 4, 2011, entitled *Towards a European Union space strategy at the service of citizens* stressed that shared competences in the field of space (entrusted to the Union under the TFEU) are linked to a close partnership with countries member states. The resolution of the European Council of May 2011 on the European Union's Space Action Strategy and the Resolution of the Council of December 6, 2011, reiterated the need to establish effective operation systems in the field of SSA (European Council Decision, 2011). In Europe, the European Space Agency and experienced French, German, and Italian national space agencies play a key role in capacity building in space. These agencies cooperate closely, for example, in the field of the SSA, with military authorities (Villadei, 2020).

The development of European SSA capabilities will underpin the exploitation of European space assets, contributing to autonomous access to (and use) space for Europe. ESA launched an optional SSA programme in 2009, focusing solely on civilian aspects and divided into three segments: space surveillance and tracking (SST), space weather (SWE), and Near-Earth Objects (NEO) (Discussion paper, 2017).

In 2014, the European Commission also made it possible to create the so-called support framework for SST (Space Surveillance and Tracking), also known as EU SST, by implementing relevant decisions to build operational SST capabilities in Europe (16EC, 2016; EC, 2014). Currently, the SSA consists of three main elements and activities: gathering information, systematically organizing the collected information, and issuing reliable aggregate information and forecasts (Kaiser, 2015, pp. 5-12).

The system deals with space weather, the location of natural and manmade objects orbiting the Earth. SSA supports safe, stable, and sustainable space activities (Oltrogge, 2019). In addition, many of the SSA's objectives relate to protecting vital space and terrestrial assets from the adverse effects of outer space (Bonnal, 2016, pp. 2-20).

2.2. Consortium of Space Surveillance and Tracking (EUSST)

The main EU piece of legislation relating to SSAs is the 2014 decision on the management and financing of the Consortium (Decision No. 541/2014/EU, 2014).

The task of the consortium was to connect the resources of European countries to secure the European and national space infrastructure. Member States contribute with their optical and radar sensors. SST services will be implemented in risk assessment, information, and alerts on actual and predicted space events involving artificial space objects based on the processed data. Such events may include, for example, collisions and fragments of objects in orbit or the uncontrolled entry of artificial space objects into the Earth's atmosphere.

The information was shared with interested parties, including the EU institutions, the Member States, and satellite operators. SST services were registered on the EUSST Service Provision Portal operated by EU SatCen (previously European Union Satellite Center-EUSC) (Discussion paper, 2017).

The consortium initially consisted of representatives of the space agencies of leading European countries: Germany, France, Spain, Italy, and Great Britain, represented mainly by national space agencies. At the end of 2018, Romania, Portugal, and Poland joined the group (16EC, 2016; EC, 2014).

In 2018, the European Commission sent the 2014-2017 space surveillance and tracking report to the European Parliament and the Council of Europe. Among the conclusions and recommendations were, among others, issues of formulating a long-term vision of strategic goals and general guidelines at the EU level, further simplification of the subsidy management system for the EU SST, and changes in their management[2].

The European Commission supervises the work of the consortium. The consortium works 24 hours a day; has 12 radars, 34 telescopes, and 4 lasers. The consortium's objectives are pragmatic – to build a network of sensors and transfer data – different consortium member states perform services. Currently, there are 148 users of the system, including 87 organizations and 20 EU member states. The consortium monitors 138 registered satellites (civil, military, and commercial), including LEO 45, MEO 30, and GEO 63. It was concluded that the consortium's activities could be a precursor to the European STM space traffic management system.

The work of the sensors is under the control of the member states; security matters concern not only the Member States but also other EU members and even third countries. The transferred data (data sharing) is available in operational centers, including Poland and Great Britain (Mills & Sharp, 2020). The data will be cataloged (catalogs are currently being created). The consortium has signed many cooperation agreements, including with the US; there are also many bilateral agreements, e.g., Germany-France, Italy-USA. The so-called Security Committee protects sensitive data (Ducaru, 2020).

However, it is not known what will be the future of the consortium – it still does not have full decision-making autonomy – talks about it are currently underway (Becker & Faucher, 2020).

2.3. SSA/SDA in Asia and the Pacific

Asia is undergoing strategic changes due to changing global and regional conditions. Growing political and territorial problems put pressure on the application of hard solutions, also in space. The first successful test in China in January 2007 indicates a new stage in space security competition between Asian powers. Other space states are rethinking their options, strategies, and capabilities, emphasizing the role of security in their space programmes. For example, the Chinese ASAT test in 2007 sparked a new debate in India about their use of these weapons. Eventually, in 2019, India conducted the first successful ASAT.

There is a current growing concern in the Asia-Pacific region about the state of space security. It is possible to use outer space to resolve land conflicts and disputes over the use of space. The former can also lead to the latter. The changing dynamics of development, both in the Asia-Pacific region and at the global level, has a negative impact on the region. Certain powers: China and the Russian Federation are challenging the current geopolitical balance, developing their military capabilities in space, and hinting that they may move to open aggression.

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[2] Proposal for a Decision of the European Parliament and of the Council establishing a space surveillance and tracking support programme /COM/2013/0107 final – 2013/0064 (COD) Document 52013PC0107.

3. The Remedial Steps to Solve SSA/SDA Challenges in Global, Regional, and National Level

SSA (SDA) should be based on properly designed, modeled, and communicated data; it is necessary to develop appropriate standards for this. Thanks to them, data can be easily transferred to a common and properly labeled database, which will make it available to different users. This data also requires detailed information about the assumptions made, where and how they were collected, sensor precision, etc., to be useful. This context or supporting information is often referred to as "metadata". Metadata is simply an assumption or premise from which to draw conclusions. Thus, metadata is the context or information related to the data and is fundamental in providing guidance on using the data set.

Data on the space environment and its objects imported to the SDA (SSA) come from various sources and sensors. To get the most out of this information, we need to combine it. In this context, the term "data fusion", which often is defined vaguely, means that we are looking for precise answers to specific questions. The combined data could create a common database that:

- facilitates the collection of information from the system, guided by the specific needs of a given user,
- defines how to evaluate and process new information and evidence in the system,
- provides an accurate and consistent view of outer space.
- discovers previously unknown elements of space objects and events,
- informs about the behavior of space objects and their movement,
- it facilitates decision-making processes and enables the control and monitoring of devices and services (Jah, 2020, pp. 961-984).

SSA (SDA) programmes should use many other information gathering programmes, including space Earth observation (SBEO) data. They are used, among others, by image (IMINT) and geospatial (GEOINT) collections. Technical and geographic information obtained from satellite systems by interpreting or analyzing images is essential today. Image data from several categories of sensors, including electro-optical, radar, infrared, or laser sensors, can go far beyond the IMINT/GEOINT interview and can be used both in the field of security and defense. SBEO data also supports the monitoring phase, which consists of two complementary functions: early warning and strategic surveillance. In addition, military planning and geospatial support can be delivered with SBEO data and products at the political, strategic, and operational levels.

In recent years, there has been a development of tools and techniques to improve the use of collected image data; however, it is considered that they are still underused. It is, therefore, necessary, staff training, and introduction of better working methods.

The number of SBEO systems and sensors has grown rapidly over the past few years, and their performance and efficiency have improved. In addition, satellite systems have gradually moved from a single-sensor model to a satellite constellation approach. Their efficiency has also been increased through the gradual implementation of the concept of "dual-use" systems, which allows different user groups to manage them depending on the mission. The most recent achievement is launching into the orbit of nano- and micro-satellites and constellations, sometimes with over 100 devices. By lowering the cost of accessing SBEOs, they become more attractive than conventional satellites. Consequently, the amount and access to data obtained as part of space missions increase (Dolce et al., 2020, pp. 705-731).

SDA is the first step in any operations to respond in space and provides the foundation for other activities vital to prosecuting states' interests in the other domains, such as position, navigation, and timing (PNT). The US SDA system works with PNT that has been designed and developed to meet specific defense capability needs. PNT services are recognized as very important factors in supporting defense operations and, as such, must be of the greatest possible robustness and reliability. The operational benefit of having access to such services is significant not only for the armed forces but also for the civilian population. Currently, PNT has become a factor that has a significant impact not only on defense operations but also on the global economy. The US also provides these services to its allies.

Paradoxically, the tension between the Asia–Pacific region states can be reduced, at least in part, by developing Space Situational Awareness (SSA). This system is based on GNNS (Global Navigation Satellite Systems) and allows users worldwide to determine (with high accuracy) the position, speed, and orbital time of satellites. The most famous and most popular GNSS is the American Global Positioning System (GPS). The Russian Federation has the GLONASS system (whose satellites penetrate the Asia-Pacific region). China – BeiDou (also known as KOMPASS) and the European Union – Galileo. These systems rely on information from their satellites. The US Global Positioning System (GPS) currently serves over a billion users and has many applications. The Russian GLONASS system is much weaker and has several million users. China has invested in creating its system (BeiDou), which is expected to achieve the planned capacity in 2021. In addition, India and Japan develop their regional systems based on American programmes, while Australia only uses American GPS. The mentioned countries of the region also decided to join the SSA/SDA systems (Rajagopalan, 2020, pp. 499-513).

4. Global Space Governance (Space Traffic Management STM)

There are different phases of flight in space (e.g., launch, orbital, and return). Hence an STM system would include all of them. Such traffic should be orderly and transparent to each operator. It is worth remembering that spacecraft cannot reach outer space and return to Earth without crossing the airspace used by aircraft. Therefore, an effective traffic management system must not endanger the safety of both aircraft and space objects. In addition, there is a high risk of collision between active and inactive objects in orbit.

Research on STM was reflected in a 2006 report entitled "The Space Study of Space Traffic Management" prepared by the International Academy of Astronautics (IAA). This report defines STM as: "A set of technical and regulatory rules designed to promote safe access to space, outer space operations, and return from space to Earth free from physical or radio frequency interference". Another proposed definition of STM is: "Outer space traffic management covering activities related to the oversight, coordination, regulation, and promotion of outer space activities (including the protection of the outer space environment) during several distinct mission phases – such as launch, outer space operations, and return from outer space" (Dickinson, 2018).

As experts point out, STM data must be properly selected, collected, processed, stored, managed, corrected, combined, used, disseminated, etc. One should be extremely careful when making assumptions and avoid the temptation to achieve more than the data and information allow for. Success requires the ability to do "detective" work and learn as much as possible from the data to improve the predictability of future behavior. Many people can reconstruct events and trajectories, but few can predict them because prediction requires knowledge and understanding of many data variables (Jah, 2020).

In discussions on STM, three possible management regimes are mentioned: high, medium, and low. A higher authority should be created with operational and criminal powers (including the prohibition of operating in orbit and imposing financial penalties). The middle regime takes into account national laws and standards and relies on consensus and soft law. The low regime is based on national law and its institutions. It is recognized that the STM is intended to be purely civilian and the SDA and, to a lesser extent, the SSA, military. So far, only some countries have a national space traffic management policy. The US STM policy is the most developed to support US leadership. Its goals are: 1) to protect the US's vital interests in space, 2) to provide unrestricted access and freedom to operate in space, and 3) to continue leading the world in creating the conditions for a safe, stable, and operationally sustainable space environment. "Moreover, it was concluded that, as space is becoming increasingly crowded and contested today, and this trend is a challenge to the security, stability, and sustainability of US space operations, a new approach to space traffic management (STM) needs to be developed, taking into account current and future operational risks (ESPI, 2020b).

The US STM pilot programme is to be developed by the Space Trade Office (OSC), which is part of the US Department of Commerce. The legal basis for the project is the Directive of June 18, 2018 (National Space Policy Directive No. 3) and the mandate of the US Congress. Primarily US private space companies push for the development of a new STM (Jah, 2021).

Although no other country has formally implemented a national STM policy framework comparable to that of the United States, most countries have already taken various actions that fall under the STM concept. Among them, three main areas of activity should be mentioned:

- Development and operation of space movement monitoring functions by building local SSA capabilities or exchanging data to obtain more accurate and up-to-date information and increase own capabilities. While the United States still maintains the most robust SSA system in the world, other countries such as Russia, China, Japan, and India are in the process of developing own space monitoring programmes;
- Development, implementation, and verification of STM relevant legislation (at the international or national level): e.g., contributing to the development of guidelines for waste reduction measures, development of a national system of laws, regulations, standards, licensing procedures, etc. regulatory framework or specific national space laws that ensure safe and responsible behavior in outer space.
- Strengthen efforts in the field of space coordination, including in particular measures based on bilateral and multilateral information exchange (Rathgeber, 2008).

In 2015, UN COPUOS member states agreed for the first time to include STM in the agenda of the Legal Subcommittee. During the first three years of discussion, 11 countries actively participated in deliberations on the legal aspects of STM (Austria, Germany, Indonesia, Japan, Morocco, the Netherlands, Pakistan, Russia, the United Arab Emirates, and the US). The deliberations concluded that many elements of the STM already exist and that the current international space law already contains relevant provisions for this programme, and the LTS guidelines contain important recommendations in this regard (Long-Term Sustainability…, n.d.).

Europe is also expressing interest in implementing the STM civil space management project, which could regulate space travel, including space access, operation in outer space, and return to Earth. The inclusion of all three steps above will respond to a possible future situation where Member States and private "space airlines" will operate side by side (Rathgeber, 2008). However, it is worth noting that so far, no legal basis for STM has been established (Newman, 2020).

Conclusion

The awareness of the importance of the SDA/SSA system has been discussed since the 1970s. Meanwhile, the space-faring nations must implement it into national law properly. It is especially important for building the system in an international and European environment, with a strong focus on strategic, security, and defense aspects. The problem is that the definition of an SSA does not exist in international law. In this context, some authors suggest creating a new branch of law, such as space security law, that will include SDA/SSA.

As already mentioned, the international space treaties do not establish a general obligation to disclose and share situational awareness data and information. Moreover, national security systems and military space information systems can be considered as obstacles to international cooperation in this field. Therefore, international cooperation in the field of SSA's will be governed by the terms of special bilateral and multilateral agreements. The most important aspect of an SSA is the need to cooperate at different levels through separate legal entities. This cooperation is based on national law. Data exchange policy is essential but must take into account the tension between data protection and SSA objectives.

Due to its dual-use (civil-military) nature, the SSA system is difficult to implement, especially in international relations where states have divergent national interests. Consequently, national regulation will require particular attention from stakeholders. Meanwhile, in most EU countries, research and analysis on the legal aspects of SSAs have not yet started, so legislation on this topic is still insufficient. Despite this, in Europe, it was possible to establish an agreement with 8 EU countries and to create the European Union Space Surveillance and Tracking Consortium (EUSST).

Also, the American SDA programme is defined and its place regulated under the national space traffic management policy. It is confirmed by the presidential document of June 21, 2018, which also announces the creation of the SDA data repository with open access. It will keep space activities safe for everyone and free of charge. As additional data sources for space tracking become available, the United States can include civil, commercial, and other data to serve users better.

Overall, the SDA/SSA programmes are acceptable to all nations involved in space activities; and can reduce tension between states. SSA and STM can create a way forward to create a "rule of the road" for all space users. Perhaps creating an international catalog of space objects will be an important element of efforts to use space peacefully.

References:

Adriaensen, M. (2020). Introduction to Space Applications and Supporting Services for Security and Defense. In K. Schrogl (Ed.), *Handbook of Space Security. Policies, Applications and Programs, Volume II* (pp. 701-704). Springer Nature.

Ailor, W. (2020). Evolution of Space Traffic and Space Traffic Management. In K. Schrogl (Ed.), *Handbook of Space Security. Policies, Applications and Programs. Springer Nature*.

An assessment of the possible EU Space Situational Awareness initiative. (2018). Price-Waterhouse Cooper.

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

Bonnal, Ch. (2016). *Pollution spatiale, l'etat d'urgence*.

Chanock, B. (2013). The problems and potential solutions related to the emergence of Space Weapons in the 21st Century. *Journal of Air Law and Commerce, 78*(4).

Deratti, M., & Dolce, F. (n.d.). *PNT for Defence, Handbook, vol. 2*.

Dickinson, M. (2018, September). *Future STM capabilities*. ESPI conference.

Dolce, F., Domizio, D., Bruckert, D., Rodríguez, A., and Patrono, A. (n.d.). *Earth Observation for Security and Defense, Handbook, vol. 2*.

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

ESPI. (2018). *Report 66*. https://espi.or.at/publications/espi-public-reports

ESPI. (2020a). Space, Policies, Issues and Trends. *Yearbook 2019*.

ESPI. (2020b). *Towards a European Approach to Space Traffic Management*. www.espi.or.at

ESPI. (n.d.). *Report Security in Outer Space: Perspectives on Transatlantic Relations*. www.espi.or.at

European Radio Navigation Plan. (n.d.). https://ec.europa.eu/docsroom/documents/28325/attachments/1/translations/en/renditions/na-tive-

Gleeson, P.K. (2007). Perspectives on Space Operations, Astropolitics. *The International Journal of Space Politics and Policy, 5*(09).

Internal Market, Industry, Entrepreneurship and SMEsi. (n.d.). https://ec.europa.eu/growth/sectors/space/security_en

Jah, M. (2020). Space Object Behavior Quantification and Assessment for Space Security. In. K. Schrogl (Ed.), *Handbook of Space Security. Policies, Applications and Programs, vol. 2* (pp. 961-984). Springer Nature.

Jah, M. (2020). *SpaceWatchGL Opinion: "Houston, we have a Space Traffic Management Pilot program"*. https://spacewatch.global/2021/01/spacewatchgl-opinion-houston-we-have-a-space-traffic-management-pilot-program/

Johnson, Ch.D. (2017). *Handbook for new actors in space*. Space Security Foundation.

Kaiser S.A. (2015). Legal and policy aspects of space situational awareness. *Space Policy, 31*.

Long-Term Sustainability of Outer Space Activities. (n.d.). https://www.unoosa.org/oosa/en/ourwork/topics/long-term-sustainability-of-outer-space-activities.html

Machin, S. (2020, September 3-4). *Space Weather. The MOSWOC in Support of Space Operations*. SMI's Military Space Situational Awareness 2020 Conference.

Machin, S. (2020, September 3-4). *Monitoring space weather as a key enabler for holistic SSA*. SMI's Military Space Situational Awareness 2020 Conference.

Martin, J.-Ch. (n.d.). *Position, Navigation and Timing for Security, Handbook, vol. 2*.

Mills, E., & Sharp, B. (2020, September 3-4). *UKSA (UK Space Agency) lines of efforts within SSA*. SMI's Military Space Situational Awareness 2020 Conference.

Monham, A. (2018). *Securing EUMETSAT's Mission from an Evolving Space Environment*. ESPI report June 2018 Security in Outer Space: Rising Stakes for Europe, report 64.

Moranta, S. (2018, September 27). *Security in Outer Space: Perspectives on Transatlantic Relations*. 12th ESPI Autumn Conference Vienna.

Nakamura, S. (2018, March 8). *Research and Activities on SSA at JAXA*. Tokyo symposium.

Newman, Ch. (2020, September 15-18). *Space law and the Space law Games: legal liability and mapping the future in orbit*. AMOS Conference.

Ogawa, S. (2019, February 25-29). *SSA activities at JAXA*. Tokyo symposium.

Oltrogge, D. (2019). *Marshalling Space Traffic Management requirements and expectations in the international context*. ESPI 12th Autumn Conference.

Peldszus, R., & Pascal, F. (2020). European Space Surveillance and Tracking Support Framework. In K. Schrogl (Ed.), *Handbook of Space Security. Policies, Applications and Programs, vol. 2*. Springer Nature

Pelton, J., Sgobba, T., and Trujillo, M. (2020). Space Safety. In K. Schrogl (Ed.), *Handbook of Space Security, vol. 1* (p. 278).

Polkowska, M. (2018). *Prawo bezpieczeństwa w Kosmosie*.

Rajagopalan, R.P. (2020). Bezpieczeństwo Kosmiczne w rejonie Azji i Pacyfiku. In *Handbook of Space Security*.

Rathgeber, W. (2008). Europe's way to Space Situational Awareness (SSA). *ESPI reports*.

Schrogl, K.-U. (2018, September 27). *Security in Outer Space: Rising Stakes for Civilian Space Programmes*. ESPI Conference.

Su, J. (2010). Use of Outer Space for peaceful purposes: non-militarisation, non-aggression and prevention of weaponization. *Journal of Space Law, 36*.

Vernile, A. (2018). *The rise of private actors in the Space Sector*. Springer.
Villadei, W. (2020, September 3-4). *Italian SSA and STM lines of effort*. SMI's Military Space Situational Awareness 2020 Conference.
Walker, B. (2010). Current international space security initiatives. In W. Rathgeber, K-U. Schrogl, R.A. Williamson (Eds.), *The fair and responsible use of space*. Springer.
Zimmer, P., & Ackermann, M. (2020, September 15). *Telescopes and Optics for Space Surveillance (SSA)*. AMOS Technical Conference Short Course.

Documents

16EC, Commission Implementing Decision of 19.12.2016 on a coordination plan for the space surveillance and tracking support framework and on the procedure for the participation of Member States, C (2016) 8482 final, 19 12 2016; EC, "Commission Implementing Decision C (2014) 6342 final of September 12, 2014, on the procedure for participation of the Member States in the Space Surveillance and Tracking Support Framework", C (2016) 6342 final, 12 9 2014.
2011/199 / EU: Decision of the European Council of 25 March 2011 amending Art. 136 of the Treaty on the Functioning of the European Union with regard to the stability mechanism for Member States whose currency is the euro. L 91, 6.4.2011, pp. 1-2 2011/199 / EU: Decision of the European Council of 25 March 2011 on the amendment of Art. 136 of the Treaty on the Functioning of the European Union with regard to the stability mechanism for Member States whose currency is the euro. L 91, 6.4.2011, pp. 1-2.
42 Decision No. 541/2014/EU of The European Parliament and of the Council of April 16, 2014 establishing a Framework for Space Surveillance and Tracking Support, 27-05-2014; OJ EU L 158/227.
Decision of the European Parliament and of the Council establishing a Space Surveillance and Tracking Support Program COM (2013) 107 final; 2013/0064 (COD).
Dependence of the European Economy on Space Infrastructures Potential Impacts of Space Assets Loss, PwC, 2017, p. 146.
Discussion paper Strategic evolution and possible extension of the EUSST- Ref. GROW (2017) –SSTEG-2-00 2nd meeting of the Space Surveillance and Tracking (SST) Commission Expert Group 27 November 2017.
Lisbon Treaty; 26.10. 2012; C326/47.
Regulation of the European Parliament and of the Council establishing the space program of the Union and the European Union Agency for the Space Program 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).