Research Paper

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The Future of EU–US Cooperation in Space Traffic Management and Space Situational Awareness

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Summary

- Space situational awareness (SSA) and space traffic management (STM) are essential for sustainable near-Earth orbit. International cooperation in SSA and STM is vital with the growing number of satellite operators and the increasingly complex space environment.
- The various definitions of SSA and STM are ambiguous. Understanding the activities that fall under each term can better assist in finding areas for cooperation and collaboration.
- SSA has historically been a military activity, leading to an incomplete public catalogue of its use and barriers to sharing information with other states and the commercial sector. The rise in private space actors has increased the number of commercial STM providers and, with plans in the US to move responsibility for STM to civilian control, there will likely be more opportunities for international collaboration, particularly through the EU Space Surveillance and Tracking (SST) programme.
- Individual EU member states possess developed STM capabilities, but overall these are still some way behind those of allies such as the US. Further investment in STM infrastructure and programmes is required for the EU and individual European states to be an essential partner to the US and add value to the global effort.
- There are worldwide challenges, both political and technical, to providing STM coverage, which may lead to a lack of collaboration and gaps in understanding of activities in orbit. Existing sensors have limitations in terms of the size of objects that can be detected and the precision with which their movements can be predicted. These capability gaps represent opportunities for the EU to contribute.
- The EU can build on its tradition of support for openness and civil society by creating a system that fosters an environment of cooperation and collaboration involving industry, commercial STM providers and the wider international community.
- Although collaboration in STM is vital, the EU should also aim to tackle issues within the wider definition of SSA including space weather, intelligence and the security of ground stations.
- The EU is well placed to become a global leader in SSA and STM. However, it needs to take into consideration the current political and technical landscape when making decisions regarding investment in capabilities and the pursuit of international partnerships.

Introduction

As more state and commercial actors develop and broaden their space activities, there is an increasing requirement for more accurate and comprehensive space situational awareness (SSA) and for these actors to engage in responsible SSA activities. As space technologies advance, owners and operators of these assets require a more comprehensive understanding of Earth's proximity, including phenomena approaching the planet. The potential dramatic increase in the number of active satellites in low Earth orbit (LEO) means that the environment will become more congested, leading to necessary growth in global SSA capabilities to allow continued access to orbits and ensure their sustainability.

The purpose of this paper is to provide an overview of the current landscape in SSA and space traffic management (STM) and expected developments to provide a range of possible scenarios for future EU–US cooperation in this area. The paper is intended to provide an evidence base for EU space policymakers as they look to discuss future collaborative work with their US counterparts. The work has been completed through a review of the available literature and interviews with selected experts in Europe and the US.

The paper begins with a brief overview of the history of SSA and its crucial role in STM, its importance to space operations and the key actors in its development. It then examines the landscape of SSA activities globally, the different providers (government, military and commercial) and their strengths and weaknesses. This section also focuses on the European position, looking specifically at the activities currently undertaken by European providers and their potential to contribute to international partnerships. The paper later outlines the difficulties encountered in providing SSA, both political and technical, and highlights the gaps in capabilities that need to be filled as SSA moves forward.

The final section of the paper identifies scenarios in which the EU and the US could look to collaborate to provide increased joint SSA capability. For the paper to provide as broad a range of scenarios as possible, it treats SSA and STM in their most complete forms, beyond the tracking of objects to include broader intelligence and analysis of the near-Earth orbit environment. These scenarios will take into account the current capabilities of Europe in this area and the gaps that exist among SSA providers. This is intended to enable EU space policymakers to assess ways that they can cooperate with their US counterparts by adding value and being a trusted partner. Furthermore, it is hoped that this paper will contribute to the existing literature on the subject and act as a blueprint for other actors to become involved in SSA activities.

Definitions

The definition of SSA can mean different things depending on context. The European Space Agency (ESA) defines SSA as consisting of three distinct segments:

- **Space weather (SWE):** providing timely and accurate information that supports mitigation of the adverse impacts of space weather.

- **Near-Earth objects (NEO):** observing NEOs, predicting their orbits, producing impact warnings and when necessary involvement in potential mitigation measures.
- **Space surveillance and tracking (SST):** detecting space debris, cataloguing debris objects and determining and predicting their orbits.[1]

The Space Foundation defines SSA as 'the ability to view, understand and predict the physical location of natural and manmade objects in orbits around the Earth, with the objective of avoiding collisions'.[2] This is an example of limiting SSA to cover those activities more accurately defined as STM. As defined by US Space Policy Directive-3, STM '… [means] the planning, coordination, and on-orbit synchronization of activities to enhance the safety, stability, and sustainability of operations in the space environment'.[3] STM activities include tracking active satellites as well as the millions of pieces of debris that are found in orbit, providing data for satellite operators, and preventing collisions that could damage or destroy satellites and cause an increase in debris. While these are in no doubt essential activities for ensuring the sustainability of orbits, they do not cover all the information that is required for a full understanding of the space environment close to Earth and the most frequently used orbits.

SSA is dependent upon surveillance, environmental monitoring, domain analysis, and the status of US satellites and readiness, as well as the importance of understanding the space capabilities and intent of those who may pose a threat.

In its broadest form, SSA refers to knowledge of the near-Earth orbit environment,[4] particularly activities in and phenomena affecting orbits that host space assets upon which much of defence and civil operations depend. This paper has adopted this broad definition as it provides the widest range of opportunities for increased European capabilities and potential cooperation with the US. The US military's Joint Publication 3-14 Space Operations summarized this broad definition as: 'SSA is the requisite foundational, current and predictive knowledge and characterization of objects and the OE [Operational Environment] upon which space operations depend – including physical, virtual, information and human dimensions – as well as all factors, activities, and events of all entities conducting, or preparing to conduct, space operations'. This definition notes that SSA is dependent upon surveillance, environmental monitoring, domain analysis, and the status of US satellites and readiness, as well as the importance of understanding the space capabilities and intent of those who may pose a threat.[5]

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[1] European Space Agency (2017), 'Space Situational Awareness – SSA Programme Overview', https://www.esa.int/Our_Activities/Space_Safety/SSA_Programme_overview (accessed 17 Apr. 2019).
[2] Space Foundation (2018), 'Intro to Space Activities – Space Situational Awareness/Space Traffic Management', https://www.spacefoundation.org/what-we-do/government-and-policy/intro-space-activities#section5 (accessed 17 Apr. 2019).
[3] Space Policy Directive-3 (SPD-3) (n.d.), 'National Space Traffic Management Policy', 83 Federal Register pp. 28969–28971, 18 June 2018, https://www.federalregister.gov/documents/2018/06/21/2018-13521/national-space-traffic-management-policy (accessed 22 Jun. 2019).
[4] For the purposes of this paper, 'near-Earth orbit' is used to describe space out to an altitude of 36,000 km, thereby encompassing low, medium and geostationary Earth orbits (LEO, MEO and GEO), where the majority of space assets orbit.
[5] US Joint Chiefs of Staff (2018), *Joint Publication 3-14: Space Operations*, 10 April 2018, p. II-2, https://www.jcs.mil/Portals/36/Documents/Doctrine/pubs/jp3_14.pdf (accessed 8 Aug. 2019).

Although in one sense SSA began with the launch of Sputnik in 1957, when both the US and USSR were attempting to understand each other's intentions in space, the STM aspect took a step forward with the establishment in the US in 1979 of the Space Defense Operations Center (SPADOC), later called the Space Control Center,[6] the work of which now sits within the Combined Space Operations Center (CSpOC) at Vandenberg Air Force Base in California.[7] Because of the nature of early space operations as state activities, and within the geopolitical environment of the Cold War, SSA activities were traditionally performed within a military setting. However, as space has become more democratic with a proliferation in both state and commercial actors, SSA providers have also diversified to meet the demands of operators. As well as more countries developing indigenous SSA capabilities, commercial companies now also work to provide essential information to satellite operators.

Background

The information received from space assets is essential for the operation of so much of the everyday functioning of modern societies including critical national infrastructure, communication, emergency services, positioning and navigation, air traffic control, maritime control, environmental monitoring, weather prediction, and humanitarian and disaster relief. Space is also vital for military and peacekeeping operations, accurate weapons targeting and intelligence gathering. SSA is fundamental to the safe and secure operations of space-based assets and in preventing scenarios that may cause loss of access to space assets.

It is no coincidence that SSA, and more specifically STM, is increasingly seen as important and more STM data providers are recognizing the value of becoming involved in these activities. It is not just the current reliance on space that is driving the need for increased STM. Recent years have seen a dramatic rise in the number of space actors, both state and commercial. This new reality has increased congestion, particularly in low Earth orbit (LEO).[8] With plans for several mega-constellations of small satellites to be launched into LEO within the next five years, it is imperative their operators have access to STM data. Similarly, states that possess sovereign space assets or that host satellite operators have a responsibility to invest in STM capabilities. As not all states will have the financial or logistical resources to create fully operational and independent STM systems, scenarios need to be identified that will allow such states to contribute to existing capabilities through partnerships, such as hosting telescopes, financing specific aspects or providing personnel. It is therefore equally important for those states with existing capabilities to engage with these new actors and look at how to provide opportunities for cooperation.

[6] Baird, M. A. (2013), 'Maintaining space situational awareness and taking it to the next level', *Air & Space Power Journal*, 27(5), pp. 50–72.
[7] Air Force Space Command (2018), 'Combined Space Operations Center established at Vendenberg AFB', https://www.afspc.af.mil/News/Article-Display/Article/1579285/combined-space-operations-center-established-at-vandenberg-afb/ (accessed 17 Apr. 2019).
[8] LEO covers altitudes of between approximately 100 km and 1,200 km. Satellites in MEO are typically found at about 20,200 km, and those in GEO at 35,800 km. A full discussion of the different orbits can be found in: Ministry of Defence (2010), *The UK Military Space Primer*, Development, Concepts and Doctrine Centre (DCDC), June 2010, https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/33691/SpacePrimerFinalWebVersion.pdf (accessed 8 Aug. 2019).

One of the most significant aspects of space security is the avoidance of collisions with other satellites and space debris. The gradual accumulation of space debris – particularly in medium Earth and geostationary orbits, which are important for navigational satellites (such as GPS and Galileo) and communication satellites, respectively – will continue unless removed deliberately. There are different categories of space debris.[9] The first is natural debris, consisting of small pieces of material from comets and asteroids. The second, artificial debris, is any man-made object in space that is not functioning. This artificial debris can be further sub-categorized, usually by size, to differentiate between defunct satellites, rocket boosters and smaller pieces, which are generally the result of collisions or the break-up of other satellites. Much STM activity is focused on the detection and tracking of debris to warn satellite operators of possible collisions.

It is important to note that information from STM is complicated and there are often several possible and conflicting interpretations of data. For example, in the event of the break-up of a satellite, one set of data may not provide a complete explanation for the cause. This often results in ambiguity and decision-making can take time and be highly uncertain. Additional data sets may provide the necessary missing information and potentially suggest a different reason for its break-up. To provide another example, in the event of a collision warning between two active satellites, one will need to take evasive action to avoid impact. Conflicting data could lead to a disagreement about which satellite should move, particularly when considering the satellite's fuel resources and the potential impact on its function. Global STM data cooperation and analysis can reduce these uncertainties. The more cooperation in STM, in terms of quantity, quality and diversity of data, the better the STM as a consequence.

Current landscape

SSA activities, including STM, have primarily been conducted in a military context, which has influenced the current capabilities of different space actors. At present, the US Department of Defense (DoD) has the most resources, particularly for the tracking of small objects in orbit. STM systems in countries with ballistic missile capabilities also serve as part of the missile early warning systems. As a result, STM and the data it provides is subject to military secrecy and not as easily accessed as it might otherwise be. However, with the advent of new space actors and new technologies, the military's dominance within STM capacities is lessening.

Recent years have seen the emergence of a number of commercial STM providers, particularly in the US, which are rapidly developing impressive capabilities and provide a good source for commercial space operators. These include ExoAnalytic Solutions, which can track nearly all objects larger than 10 cm in geostationary orbit (GEO), and LeoLabs, which tracks over 14,000 objects in LEO.[10] Although these organizations charge for access to the information, in comparison to the data made freely available by governments, it is a vital resource that assists in providing

[9] Australian Space Academy (n.d.), 'Fast Facts on Space Debris', https://www.spaceacademy.net.au/watch/debris/sdfacts.htm (accessed 5 Apr. 2019).
[10] ExoAnalytic Solutions (n.d.), 'Space Situational Awareness', https://exoanalytic.com/; LeoLabs (n.d.), 'Our Data Services', https://www.leolabs.space/. Information on the capabilities of these companies comes from: Christensen, I. and Weeden, B. (2019), 'Commercial Space Situational Awareness', presentation at *Space Situational Awareness Workshop: Perspectives on the Future Directions for Korea*, Seoul, Korea, 24–25 January 2019, https://swfound.org/media/206343/icplusbw_commercial_ssa_for-kari-jan2019.pdf (accessed 4 Jul. 2019).

a more complete picture of the environment.[11] However, the high prices charged make it currently impossible for academic researchers and hobbyist satellite observers, who often play an important role in tracking objects, to gain access to the data. It is possible that the proliferation of these providers will lower the costs and remove the barrier to entry, allowing for the fullest range of actors to be involved in these activities with the best possible data.

As the state that has historically been the leader in space activities, it is no surprise that the US has the most mature SSA capabilities in all aspects from tracking to intelligence. The Space Surveillance Network (SSN), operated by the US military, has the largest number of sensors and the most complete catalogue of objects. It has also been improving its coverage in the Southern Hemisphere.[12] The control centre for the SSN is the CSpOC, which is intended to improve coordination between the US and its allies, in recognition that STM advancement needs to be an international effort.[13]

> The Russian Academy of Sciences organizes the International Scientific Optical Network, with more than 90 telescopes in 16 countries.

Russia is also involved in detection and tracking of space objects and, after the US, has the largest network of capabilities in this area. As part of its Space Surveillance System (SSS), Russia has a number of dedicated radars and optical telescopes, some located in former Soviet states through bilateral agreements. The Russian Academy of Sciences also organizes the International Scientific Optical Network (ISON), with more than 90 telescopes in 16 countries.[14] As with the US, much of the data collected by Russian STM capabilities is not made public, particularly those elements of a military nature.

There is evidence that China, with its increasing space capabilities and activities, has similarly been increasing its STM capabilities, operating a number of tracking stations both in China and in a variety of locations around the globe. For example, in April 2018 operations reportedly began at a Chinese ground station in Argentina.[15] It is thought that China's network is capable of observing and tracking satellites in all orbits, and supports 'intelligence collection, counterspace targeting, ballistic missile early warning, spaceflight safety, satellite anomaly resolution, and space debris monitoring'.[16] Japan has also long been involved in STM. The Japan Aerospace Exploration Agency (JAXA) describes the activities it performs as: monitoring space debris; database compilation of their orbits; analysis of their approach to satellites; and predestination of their re-entry to the atmosphere.[17]

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[11] Lal, B., Balakrishnan, A., Caldwell, B. M., Buenconsejo, R. S. and Carioscia, S. A. (2018), *Global Trends in Space Situational Awareness (SSA) and Space Traffic Management (STM)*, IDA Science and Technology Policy Institute, April 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 (accessed 8 Aug. 2019).
[12] Secure World Foundation (2017), 'Space Situational Awareness Fact Sheet', https://swfound.org/media/205874/swf_ssa_fact_sheet.pdf (accessed 20 Apr. 2019).
[13] Air Force Space Command (2019), 'Combined Space Operations Center established at Vandenberg AFB', https://www.afspc.af.mil/News/Article-Display/Article/1579285/combined-space-operations-center-established-at-vandenberg-afb/ (accessed 4 May 2019).
[14] Secure World Foundation (2017), 'Space Situational Awareness Fact Sheet'.
[15] Seligman, L. (2019), 'U.S. Military Warns of Threat From Chinese-Run Space Station in Argentina', *Foreign Policy*, 8 February 2019, https://foreignpolicy.com/2019/02/08/us-military-warns-of-threat-from-chinese-run-space-station-in-argentina/ (accessed 4 May 2019).
[16] Defense Intelligence Agency (2019), '*Challenges to Security in Space*', https://www.dia.mil/Portals/27/Documents/News/Military%20Power%20Publications/Space_Threat_V14_020119_sm.pdf (accessed 11 Feb. 2019).
[17] Japan Aerospace Exploration Agency (2017), 'Space Situational Awareness (SSA) System', http://global.jaxa.jp/projects/ssa/index.html (accessed 6 Apr. 2019).

Looking specifically at Europe, there is belief among SSA/STM experts that EU member states possess highly capable sensors (albeit there is an opinion that there are too few of them) and expertise. Interviews with individuals in this community show that there is an opportunity for Europe to take advantage of existing capabilities to increase international STM cooperation as well as build new capabilities, and that such activity would be welcome for global efforts. Certain individual European states have the capability and experience to contribute to STM, but others do not. France, Germany and the UK have impressive ground-based STM sensors that contribute to the US SSN through bilateral agreements,[18] thereby enhancing global STM, as the SSN provides data to space-track.org, a forum for sharing STM awareness information and services for US and international satellite operators, academics and other interested parties.[19] There are also a number of highly knowledgeable European small and medium-sized enterprises (SME)[20] and consequently the human capital within the EU that can be brought to bear on STM is significant. As with their US counterparts, the products of European commercial STM data and service providers can rival or dwarf those of individual governments in terms of accuracy, precision and operational relevance. However, there is a weakness in terms of limitation and bias because the information tends to be a result of insular perspectives or capabilities. France, in particular, is highly experienced and capable in conjunction analysis (CA) and support to operators in terms of decision-making. These mature capabilities are used by satellite owners and operators as well as broader STM contributors. France learned from an incident in 1996 in which its Cerise military satellite was hit by a piece of an old Ariane rocket stage[21] and in response has built an effective analytical team and software to support CA operations. This expertise could augment US capabilities in this area through providing an independent assessment of potential conjunctions, decreasing ambiguity and ensuring operators have sufficient information to prevent a collision. Germany is leading the way with its Tracking and Imaging Radar (TIRA), the largest of its kind in the world,[22] which can provide a significant contribution to LEO tracking and object characterization through its high precision and resolution throughout all phases of a space mission, from launch to re-entry.[23] The German SSA centre has developed very effectively and is fast becoming a key contributor to STM activities. Finally, Spain is using commercial experience that is likely to generate greater results in the long run as, unlike governments and militaries, the operators are more consistent and reliable.

The UK has long experience in STM through its partnership with the US, in particular the radar at RAF Fylingdales in Yorkshire. This facility provides ballistic missile early warning and space surveillance and it is a key element in UK–US cooperation in this area. However, according to one expert, there is a gap in tracking and characterization radar capability as a result of its primary mission of missile detection. The UK also operates Starbrook in Cyprus, an electro-optical

[18] Denmark, Italy, Spain and Belgium, as well as ESA and the European Organisation for the Exploitation of Meteorological Satellites, also participate in the USSTRATCOM SSA Sharing Agreement. See, United States Strategic Command Public Affairs (n.d.), 'USSTRATCOM, Denmark agree to share space services', 1 May 2018, https://www.schriever.af.mil/News/Article-Display/Article/1509529/usstratcom-denmark-agree-to-share-space-services/ (accessed 24 Jun. 2019).
[19] Space-track.org (2019), 'Space-track.org', https://www.space-track.org/auth/login (accessed 6 Apr. 2019).
[20] See, for example, Elecnor Deimos: http://www.elecnor-deimos.com/activities/space/space-situational-awareness/.
[21] Ward, M. (1996), 'Satellite injured in space wreck', *New Scientist*, 24 August 1996.
[22] Fraunhofer FHR (2019), 'Space observation radar TIRA', https://www.fhr.fraunhofer.de/en/the-institute/technical-equipment/Space-observation-radar-TIRA.html (accessed 6 Apr. 2019).
[23] Innovations Report (2018), 'Space observation with radar to secure Germany's space infrastructure', 23 March 2018, https://www.innovations-report.com/html/reports/physics-astronomy/space-observation-with-radar-to-secure-germany-s-space-infrastructure.html (accessed 6 Apr. 2019).

sensor for surveillance of high Earth orbits. Of course, when considering the UK the potential implications of Brexit must be taken into account. The capabilities of the UK in STM should not be dismissed when establishing partnerships, but how this will be decided will depend in part upon how the EU intends to move forward in STM activities and cooperation.

The key contribution Europe can make is geographic, as one of the most important needs for effective STM is to have geographically separate tracking systems that are spaced to optimize support to STM. Europe offers a longitude and latitude that is different from US sites. The positions of the Ballistic Missile Early Warning System (BMEWS) radars can be used to illustrate the value of geographic distribution, as they are sited in Alaska, Greenland and the UK (at RAF Fylingdales). In this sense, Europe can also act as a data reception site for space mission data, which is a form of STM. An example is the Maspalomas station in Spain that provided support to NASA's Mercury, Gemini and Apollo programmes and is still in operation, supporting ESA, JAXA and others.

The key contribution Europe can make is geographic, as one of the most important needs for effective STM is to have geographically separate tracking systems that are spaced to optimize support to STM.

STM's 'Achilles heel' is that most of the support and data is behind a military firewall and not readily shareable, including the sensors that are often utilized for another primary mission. One of the key contributions the EU is making is in developing a civil system, which will be significant in the future as it will make data and support more accessible to commercial operations and governments. The SST support framework was established by the European Commission in 2014 and was followed by a consortium of five EU member states (France, Germany, Italy, Spain and the UK) in 2015,[24] which has now increased to eight member states through the inclusion of Portugal, Poland and Romania. Its purpose is to develop EU SST capability through a series of EU-funded projects. As of August 2019, there was no clear understanding of the impact of Brexit on the SST system.

However, there are gaps in European STM capacities. Limited sensor coverage (owing to limited funding and relatively low prioritization in terms of national spending) has led to over-reliance on the US SSN for comprehensive STM. Similarly, limited national space intelligence capabilities are largely reliant on US-provided space intelligence. Another primary EU vulnerability is its lack of experience. The UK has not capitalized on its experience and although there is expertise in the analysts at Fylingdales they are, according to some experts,[25] not effectively utilized, and just one sensor in the UK will not provide full STM coverage.

In addition, European sensors are not as capable as those in the US – they have lower resolution and therefore can only track large objects. To become more complementary and to contribute globally, Europe requires new and dedicated sensors capable of tracking smaller objects. One

[24] Department for Business, Energy and Industrial Strategy (2019), 'Satellites and space programmes if there's no Brexit deal', 27 March 2019, https://www.gov.uk/government/publications/satellites-and-space-programmes-if-theres-no-brexit-deal/satellites-and-space-programmes-if-theres-no-brexit-deal (accessed 20 Apr. 2019).
[25] Author interviews with a number of SSA/STM experts throughout the project, including in person, via telephone and email, and through discussions at conferences, all of whom chose to remain anonymous.

individual with experience both in the military and commercial aspects of STM expressed amazement that the community talks about the significance of STM but provides little funding for dedicated sensors. The current EU funding for future STM support systems was described as 'pitiful' by one expert.[26] For Europe to significantly contribute to STM, at union and member state levels, requires additional funding to develop better capabilities.

Challenges of providing STM

Despite an impressive infrastructure of sensors used for STM and the capabilities of the various actors, there are still significant challenges in creating a full understanding of the space environment that can be used to ensure minimal risk to space assets. And while some of these challenges may seem intractable, recognizing them allows for an assessment of capability gaps that could be proactively addressed. While this would be beneficial to all actors, it could also provide those either wishing to establish relationships with mature STM providers or looking to increase their standing within existing partnerships with a valuable contribution.

> Within the group encompassing the US and its allies, intelligence capabilities in determining the intent and capability of others, specifically Russia and China, is dominated by the US, in part because of its longer history in military space operations and its technical capabilities in classifying non-allied space assets.

The first set of challenges to STM (and, indeed, wider SSA) are political, particularly around the concept of information sharing. As mentioned above, much of STM is carried out by militaries, who are understandably unwilling to share data beyond allies under existing agreements. The US and the UK have an agreement covering the sharing of data gathered through their partnership, which is further shared with other members of the CSpOC. Another type of political challenge relates to space environment intelligence, specifically that referring to the capabilities and actions of potential adversaries. Within the group encompassing the US and its allies, intelligence capabilities in determining the intent and capability of others, specifically Russia and China, is dominated by the US, in part because of its longer history in military space operations and its technical capabilities in classifying non-allied space assets.

The second set of challenges are technical and may be those that are most open to exploitation by STM providers hoping to establish or increase their contribution. Despite the number of sensors and actors, there are still significant difficulties in understanding and predicting the movements of pieces of orbital debris. One of these is related to the size of debris that can be tracked, although the US Air Force will have greater capability in detecting smaller objects following the completion of the Space Fence in 2021.[27] Many of the models used to predict debris movements do not take into account the effects of solar radiation and internal dynamics, such as residual radiation pressure

[26] Ibid.
[27] Lockheed Martin (2019), 'Space Fence', https://www.lockheedmartin.com/en-us/products/space-fence.html (accessed 4 Jul. 2019).

from power sources or whether the object is tumbling. As a result, while it is possible to detect objects over a certain size, it is not always possible to track them. Research is required to further understand the behaviour of certain materials when they are subjected to radiation and to how internal radiation and tumbling affect the orbit of a piece of debris. Technical challenges also relate to the sharing of information. Although more data sources used to create positional information increases reliability, there can be difficulty in incorporating data from these sources if they use different methodologies, lexicons and ways of characterizing objects.

These challenges lead to a range of capability gaps that can be exploited, including:

- Detecting and tracking smaller debris in orbit, due to the threat that they pose to operational space systems. This is expected to lead to a requirement to maintain a far larger catalogue.
- Tracking objects with higher accuracy, to reduce the prediction errors associated with each object and allow conjunction warnings to be calculated with greater precision.
- Tracking objects more frequently, to help maintain custody of specific objects, and to ensure that their error ellipsoids do not increase unacceptably over time.
- Measuring a greater number of parameters associated with a space object, such as ballistic coefficient, albedo and attitude, to correctly predict its orbit in advance.

Future of SSA/STM

While SSA/STM has traditionally sat within a military setting, particularly in the US, in recent years it has become associated with a more diverse set of providers. Private companies now supply commercial data to operators. This change has also been recognized at government level. In June 2018, President Trump signed Space Policy Directive-3, which proposes to shift the responsibility for providing SSA data to satellite operators from the DoD to the Department of Commerce (DoC).[28] The DoC would therefore be responsible for handling the information warning satellite operators of potential collisions. There are a number of benefits that could be felt from this change in policy. First, it will allow the DoD to focus its efforts on national security considerations and not deal with the increasing day-to-day activities resulting from the rising number of satellites and operators. Second, this move creates an opportunity for the DoC to engage with international partners in a way that the DoD was unable to as the data will no longer be behind a military firewall and it has a commercial focus, which alters the opportunity landscape for the EU.

The difficulty in understanding exactly what the impact of this move will be on international STM cooperation is that there is still no firm decision as to how this will be organized in the US. While the proposal is for the work to move to the DoC, the Federal Aviation Administration (FAA) is also fighting for the authority over civil STM, and the debate over which organization will ultimately be successful is still ongoing.[29] Either way, it is unlikely that the DoD will continue to be the main

[28] Harrison, T. and Johnson, K. (2018), *How Does Space Policy Directive 3 Affect Space Traffic Management*, Center for Strategic and International Studies, https://www.csis.org/analysis/how-does-space-policy-directive-3-affect-space-traffic-management (accessed 19 Apr. 2019).
[29] Hitchens, T. (2019), 'Will FAA or Commerce Track Civil Satellites? Congress Must Decide – And Soon', *Breaking Defence*, 15 May 2019, https://breakingdefense.com/2019/05/will-faa-or-commerce-track-civil-satellites-congress-must-decide-and-soon/ (accessed 17 May 2019).

point of contact for STM data. It is also important to recognize the difficulties that could arise during the military-to-civilian transition, particularly in terms of communication and continuity of service over an extended transition period.

Over the next few years there is likely to be an increase in SSA/STM activities by states that are beginning to play a major role in space, whether through the number of satellites in orbit and/or through commercial launch services. An example of such a state is India. In February 2017, India launched 104 satellites on the Indian Space Research Organisation's (ISRO) Polar Satellite Launch vehicle,[30] and as a result it is now one of the leaders in the provision of commercial space launches. It is essential that India and other states entering this arena are included in global SSA efforts and acting responsibly. There are opportunities for Europe to lead in engaging with these actors. Commercial companies operating in this sphere will also continue to grow. Many of these will be looking to increase their geographical coverage to ensure their data is as accurate as possible and could look to partner with European states or companies. The EU could foster an environment that makes such cooperation easy, partnering with both other states and commercial providers to supply more comprehensive SSA. While a European ambition to further SSA cooperation with the US is welcome, this should not be seen in isolation or to the detriment of a move towards a more global coalition of SSA providers. With the US potentially less willing to explore partnership agreements, the EU could act as an intermediary and driver of political will for further international cooperation.

Scenarios for EU–US cooperation

The broad landscape of SSA activities and their importance for orbital sustainability, as well as the changing operators and policy, mean that there are a number of opportunities for EU–US cooperation, and for the EU to increase its capabilities and become a key player in leading the responsible use of space.

The one area in which potential opportunities will be very limited, if not impossible, is military SSA activities. International involvement in the US CSpOC is limited to the UK, Canada and Australia, all members of the Five Eyes community, as well as France and Germany. Any possible involvement of additional European countries would only occur as the result of a larger intelligence and information sharing partnership, although US Air Force Chief of Staff General David Goldfein has stated that he expects the CSpOC to continue to grow.[31] The EU should therefore focus on the civilian aspects of SSA and the changing landscape of providers.

It has been suggested by a number of experts that SSA needs to become a civil mission with the military augmenting and supporting national security programmes as their mission. That will need a significant shift in US operations (which is happening slowly) and a greater sharing of data. Data integrity and data trust are essential. The concept of the EU SST as a civil programme should provide the required momentum to help with this paradigm shift. However, some important issues

[30] Indian Space Research Organisation (2017), 'PSLV-C37 Successfully Launches 104 Satellites in a Single Flight', https://www.isro.gov.in/pslv-c37-successfully-launches-104-satellites-single-flight (accessed 25 Apr. 2019).
[31] Erwin, S. (2019), 'Air Force Chief Goldfein: To win in space, U.S. must work closer with allies', *SpaceNews*, 13 April 2019, https://spacenews.com/air-force-chief-goldfein-to-win-in-space-u-s-must-work-closer-with-allies/ (accessed 4 Jul. 2019).

need to be addressed to support this. First, the civil programme should be the primary goal. Second, EU funds need to be focused on developing sensors, capabilities and experience that complements and contributes to existing activities rather than replicating what is currently available. For Europe that means not spreading funds and resources across a number of countries but focusing on only one or two to support the rest of Europe. Third, sensors dedicated to STM are essential, as one of the difficulties in space tracking for the military is that many of its sensors are primarily focused on missile defence. Fourth, cooperation among EU contributors needs to improve and this must be rectified before Europe can provide an effective support mechanism for global SSA. As a multilateral organization, the EU SST framework also comes with its own set of challenges in cooperation and information integration between member states. It can look to the EU Satellite Centre (Satcen)[32] in Torrejon, Spain, as an example of understanding and dealing with the sensitive nature of aggregating national derived data and distributing it among EU member states.

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Nevertheless, the EU's tradition of support for openness and civil society means that it is well placed to fill the gaps in the other extant SSA systems by being independent, open and free at the point of service. An EU-led open system, with the option for other providers to feed in their data if they wanted to, could rapidly supersede the US SATCAT as the system of choice by virtue of its open availability, and with relatively modest investment. Such a system could also be best placed to increase international cooperation with countries such as Japan and India as well as smaller countries looking to responsibly operate their limited assets and contribute to broader space sustainability. The EU can also look to support and promote initiatives such as the Space Data Association (SDA)[33] and the DARPA-led Consortium for Execution of Rendezvous and Servicing Operations (CONFERS),[34] which provide forums for international operators to exchange data and cooperate to avoid collisions.

One question that Europe needs to address is cooperation with the UK following Brexit. There should still be opportunities to collaborate between the EU and the UK. One aspect that needs to be looked at is any potential UK involvement in the EU SST programme. In whatever way this plays out, Europe should look to the UK for its experience and expertise, and perhaps also to its ability to act as a bridge to the US. Both the UK and EU member states could host commercial sensors. In the UK, radars or passive radio frequency reception sites like Goonhilly Earth Station,[35] a facility in Cornwall that provides commercial tracking in LEO and MEO, are most likely, as the weather is not ideal for optical facilities. It is currently unclear how the transition of space tracking from the US Air Force to DoC in the US will affect the data flows from sensors such as RAF

[32] European Union Satellite Centre (2019), 'Working for EU'S Common Foreign and Security Policy', https://www.satcen.europa.eu/ (accessed 26 Jul. 2019).
[33] Space Data Association (n.d.), http://www.space-data.org/sda/ (accessed 26 Jul. 2019).
[34] The Consortium for Execution of Rendezvous and Servicing Operations (CONFERS) (2019), https://www.satelliteconfers.org/ (accessed 26 Jul. 2019).
[35] Goonhilly Earth Station (n.d.), 'Tracking for Low and Medium Earth Orbit Satellites', https://www.goonhilly.org/satellite-communication-teleport/leo-meo-services (accessed 15 May 2019).

Fylingdales. Currently, data from that radar cannot be shared worldwide due to the provisions of the UK–US treaty (the station is operated under the UKUSA Agreement), which also prevents it being optimized for space tracking. For example, it would be possible to implement a new focused tracking mode at Fylingdales to detect and track smaller objects than it currently sees (albeit with the need for cueing data from the Space Fence) but this is not allowed under the treaty.

There is a need for mutual exchange of STM data between the EU and the US, but there is a problem regarding the classification and accessibility of data (this is largely a problem on the US side). A multilateral data-sharing agreement between the US and one or more EU member state would greatly help, but the US is often reluctant to implement multilateral agreements. This may change with moves to commercialize STM in the US, but with militaries globally increasing their orbital activities, there is likely to remain a significant portion of data that is not considered releasable. Nevertheless, the EU could contribute independent sources of information on all trackable resident space objects and events. As noted above, one of the major problems with SSA is that rarely, if ever, does a single hypothesis explain the evidence. This implies ambiguity on inferred quantities and events and thus clouds or hinders informed and meaningful decision-making. Global SSA data harmonization is therefore critical for curating the required high quantity and diversity of data and information. The EU could help or even lead in this effort.

The broader definition of SSA allows for additional scenarios for collaboration. The first of these is around the issue of space weather. The EU can support and promote the provision of operational weather services as foreseen in the proposed EU space programme. A major space weather event could potentially cause more damage to satellites and ground stations than the other threats and hazards and would render other aspects of SSA obsolete. At present, both NASA and ESA, as well as other international actors, have mechanisms for monitoring solar activity, although current prediction capabilities are limited and there is a need for more missions that increase the ability to understand solar activity and provide longer prediction times. It is also important in this regard to ensure exchange of scientific research outputs and data related to warnings so that all satellite operators, regardless of location, receive the necessary information.

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The second area is intelligence. As European states increase their military assets in space there is a need for intelligence gathering regarding the intentions and capabilities of potential adversaries such as Russia and China. While cooperation in this regard will have the same difficulties as that of military STM activities, if Europe increases its space intelligence capabilities it may prove useful to the Five Eyes states to reach an information-sharing agreement. An increase in European SSA capabilities provides states with additional intelligence and the ability to better track and classify objects that are considered to be a potential danger. As the US and Europe continue close military cooperation, particularly through NATO, possible future EU monitoring of adversarial space activities is likely to be a welcome contribution to SSA by its allies.

A further area of SSA is the security of ground stations that operate satellites as well as the security of manufacturers and the supply chains on which they depend. Even if there is an optimum situation in tracking space objects and a complete, shareable catalogue, if ground stations are at risk from intentional attack or natural hazards the dangers to satellites are still present. Similarly, satellite supply chains are often very complex, and problems with just one component could affect the operations of satellites, creating an additional level of uncertainty. The EU can look to lead the way or partner with others such as the US to ensure adequate levels of security for ground stations of satellite operators and strong regulation of the space industrial sector. This could be done by promoting the best practices of large, multinational corporations that work in both the US and Europe and, often through military contracts, have experience in incorporating such measures. Putting this issue front and centre will help to ensure that ground stations, particularly those run by commercial operators, are aware of the potential risks as well as the mitigation measures that they can put in place.

Overall, there are a number of potential scenarios for collaboration. However, it should be understood that not all within the SSA community see the future of these activities as being state-led. The preferred option of many is that industry, academia and other interested parties lead the work. This is in part because of the timescales involved in government negotiation and decision-making. One suggestion is therefore to build a solution from the bottom-up, forming a consortium to harness and produce transdisciplinary SSA that takes advantage of a broad range of knowledge and expertise. This could be done through the formation of a growing coalition of the willing to demonstrate incremental capability and added value. The EU could play a key role in fostering an environment that would allow such development and advocate a truly international effort that includes the US.

Conclusion

Taking into consideration the anticipated developments in space over the short- to medium-term, it is clear that there are opportunities for increased cooperation between the EU and the US in SSA and that such collaboration is needed. The EU has publicly noted its intention to act as a leader in promoting the responsible use of space, for example through its proposal of an International Code of Conduct for Outer Space Activities.[36] Cooperation mechanisms between the US and the EU would not only improve the individual SSA capabilities of each and the global effort but also act as a blueprint for cooperation with other partners, such as the Five Eyes community, Japan and India.

Cooperation is also essential when considering the possibility that SSA capabilities, rather than space assets, could become a target of adversarial action with the aim of decreasing a state or operator's ability to track objects or otherwise affect their knowledge in such a way as to put their assets in danger. For example, it is possible that that an adversary of the US would target its SSA

[36] European External Action Service (2014), 'EU Proposal for an international Space Code of Conduct, Draft', 31 March 2014, https://eeas.europa.eu/headquarters/headquarters-homepage/14715/eu-proposal-international-space-code-conduct-draft_en (accessed 18 May 2019).

capabilities to gain an advantage by 'blinding' the US to what is happening in orbit. International cooperation in SSA among global partners, which could provide orbital information if it is lost by one partner, would add a layer of resilience to SSA capabilities.

There are obvious challenges to EU–US SSA integration. The first is the issue of secrecy. In this area Europe and the US may not be as far apart as might be initially thought as most state space actors have some military aspect within their capabilities. The key will be to find ways to encourage cooperation in the commercial and civil spheres while allowing individual states to operate and monitor their classified assets as they see fit – sharing what information they are willing to and able to depend upon the military or civilian nature of future EU member state tracking capabilities. As already described, changes within the US government's SSA policy may provide the best mechanism for such activity to move forward. Secondly, the US always wants to be the leader in everything in the space domain rather than be an equal partner. This is becoming even more obvious through the rhetoric of many US military and government leaders, with talk of the need to dominate and lead in space as a reaction to the activities and perceived threats of Russia and China. Therefore, the EU needs to prove its value as a partner in space and advocate for international cooperation as the best way for both parties to achieve state goals and maintain the stability of orbit. Finally, it is important for there to be a cohesive understanding of how EU SSA programmes will cooperate both with member states and with ESA.

The EU needs to increase its capabilities, either through activities that plug existing gaps or through using its geographical situation to augment the activities of other states. This approach will provide it with a platform to become a leading player in this regard and prove it can add value to the global SSA effort. The US will then see it as an indispensable partner in ensuring the sustainability of the near-Earth environment over the coming decades.

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Cover image: Deployment of the NanoRacks-Remove Debris Satellite from the International Space Station. NanoRacks-Remove Debris aims to demonstrate key technologies for Active Debris Removal to reduce the risks presented by space debris.

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