Trends in Global Space Situational Awareness

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Introduction

On February 10, 2009, a defunct Russian military communications satellite, called Cosmos 2251, collided with an active U.S. commercial communications satellite, Iridium 33. This was the first accidental collision of two satellites in orbit and the incident produced almost 2,000 pieces of space debris, many of which still orbit LEO today.[1] The conjunction warning data provided by the U.S. Air Force showed that there were 37 other possible conjunctions for the Iridium constellation during that week, and one had an order of magnitude higher likelihood than this incident. The data that was provided to the Iridium satellite operators was not sufficient to distinguish the many false conjunction warnings they had become accustomed to from the more serious risks, and in this instance the operators did not choose to alter the satellite's orbit.[2] This incident gave commercial space companies a compelling reason to find, or become involved in, alternative sources of SSA data and analysis that would protect their assets in space and improve the accuracy of conjunction warnings.

The Iridium Cosmos collision is not the only reason to be concerned. As more satellites enter orbit, collision warnings between objects in space have become more common, and many of the objects involved have been orbiting the Earth for decades and are not capable of avoidance maneuvers. For example, in early April 2021, a defunct meteorological satellite was on a trajectory to possibly collide with a rocket body that had been in orbit since 1973.[3] The two missed each other this time, but this won't always be the case. The possibility of debris-creating collisions poses a great threat to space assets and national security as nations continue to grow more reliant on space systems for both military and civilian operations.

The ability to track active satellites and other objects in orbit is becoming increasingly important, a mission area known as space situational awareness (SSA). SSA capabilities are vital to protect assets in space, and they play an important role in security as many businesses, governments, and militaries rely on space systems for essential functions. Reliable SSA allows space operators to have a better understanding of what others are doing in space, and this information can be used to better protect their own space assets. As SSA capabilities have continued to increase, so have the number of SSA providers. Many commercial SSA companies have emerged in the last decade or so that are now major players in the field, selling SSA data to other commercial firms or working with governments for collision avoidance. This paper focuses on the growing activities and capabilities of commercial and international SSA providers and the trends expected to emerge in the coming years.

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[1] Brian Weeden, "2009 Iridium-Cosmos Collision Fact Sheet," Secure World Foundation, November 10, 2010,https://swfound.org/media/6575/swf_iridium_cosmos_collision_fact_sheet_updated_2012.pdf
[2] Glenn Peterson, Marlon Sorge, and William Ailor, "Space Traffic Management in the Age of New Space," Aerospace Corporation, April 2018 https://aerospace.org/sites/default/files/2018-05/SpaceTrafficMgmt_0.pdf
[3] EUSST, @EU_SST, "#EUSST contributes to protecting the safety & security of European economies, societies & citizens. Our Operations Centres are monitoring…" April 7, 20201, Twitter, https://twitter.com/EU_SST/status/1379828862478131201

Definition of Terms

Space situational awareness, or SSA, is the term used to describe the activities involved in classifying, tracking, and predicting the movements of objects in Earth orbit.[4] This specific term describes the cataloging of bodies in space and estimating how they will move. Within SSA, there are three subcategories of focus: space weather, near-Earth object tracking, and space surveillance and tracking. Space weather monitors activities from the Sun, solar wind, and Earth's magnetic field that can have effects on satellites, ground stations, and the health of humans in space.[5] Near-Earth object tracking most often refers to other space objects that may enter an Earth-orbit, such as asteroids or comets.[6] Space surveillance and tracking is what most think of with the term SSA: tracking human-made space objects including operating satellites, decommissioned satellites, and various types of space debris.[7] Although these categories are distinct, many sensors and telescopes used for SSA can serve more than one purpose. With the growing reliance on space systems for military operations, SSA is considered an important military enterprise. In 2018, the U.S. Air Force defined SSA as part of the Space Battle Management mission area that "enables the continuous preparation of the battlespace in order to fight and win a war in space."[8]

Space domain awareness (SDA) is a broader term that includes the characterization of the overall space domain, which includes SSA. The U.S. military defines SDA as "the effective identification, characterization, and understanding of any factor, passive or active, associated with the space domain that could effect [sic] space operations."[9] In 2019, the U.S Air Force announced its official switch of terminology from SSA to SDA, indicating that SDA would be used to give a more complete picture of the space domain and SSA would be reserved to distinguish more specific space warfighting awareness. It has become more common for military users to refer to their systems as SDA, while commercial and civil systems are most often referred to as SSA.[10]

The term space traffic management (STM) is also sometimes used in conjunction with SSA and SDA. Defined here by the International Academy of Astronautics (IAA), STM is the "set of technical and regulatory provisions for promoting safe access into outer space, operations in outer space and return from outer space to Earth free from physical or radio-frequency interference."[11] STM is necessary in all three basic phases of space flight (launch, in-orbit operation, and re-entry).

This paper uses the term SSA because the primary focus is on non-military operators in the SSA field. It surveys the SSA capabilities belonging to both private commercial companies and those owned or controlled by international governments. The study also addresses current challenges in the space domain, focusing on the growing number of actors in space and plans for a large increase in the number of operating satellites. It explores the services offered by commercial operators, including trends in the market, types of services provided, how private operators interact with

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[4] Prof. Marcus J. Holzinger, "Space Situational Awareness," http://holzinger.gatech.edu/?q=SSA
[5] "Space Weather at ESA," European Space Agency, https://swe.ssa.esa.int/ssa-space-weather-activities
[6] "Near-Earth Objects - NEO Segment," Safety & Security, the European Space Agency, https://www.esa.int/Safety_Security/Near-Earth_Objects_-_NEO_Segment
[7] "Space Surveillance and Tracking - SST Segment," the European Space Agency, https://www.esa.int/Safety_Security/Space_Surveillance_and_Tracking_-_SST_Segment
[8] Maj. Erin Salinas, "Space Situational Awareness is Space Battle Management," Air Force Space Command (Archived), May 16, 2018, https://www.afspc.af.mil/News/Article-Display/Article/1523196/space-situational-awareness-is-space-battle-management/
[9] Theresa Hitchens, "New SMC Focus: Space Control, 'Domain Awareness'," Breaking Defense, October 21, 2019, https://breakingdefense.com/2019/10/new-smc-focus-space-control-domain-awareness/
[10] Sandra Erwin, "Air Force: SSA is no more; it's Space Domain Awareness'," SpaceNews, November 14, 2019, https://spacenews.com/air-force-ssa-is-no-more-its-space-domain-awareness/
[11] Corinne Contant-Jorgenson, Petr Lala, and Kai-Uwe Schrogl, "Space Traffic Management," The International Academy of Astronautics Cosmic Study, June 2006, https://www.unoosa.org/pdf/pres/copuos2006/06.pdf

government customers and regulators, and capability projections for the next decade. Finally, this paper explores other countries' SSA strategies, including international agreements and data sharing activities. As more actors enter the space domain, SSA will continue to become increasingly essential to monitor satellites for collision avoidance, space weather events, and hazardous pieces of debris.

Challenges

According to the Union of Concerned Scientists, as of January 2021 there are 3,372 active satellites orbiting Earth, although the number is growing rapidly each month as companies continue to deploy large satellite constellations. Over half of these satellites (1,897) are registered to the United States, followed by China with 412 satellites, and Russia with 176 satellites.[12] The roughly 900 other satellites in orbit are registered to almost 70 different countries for a range of civil, commercial, and military purposes.[13] In addition to these satellites, NASA estimates there are some 500,000 pieces of debris in orbit that are the size of a marble or larger.[14] As more objects enter the space domain, there is a greater risk for collisions and a greater need for accurate and reliable SSA data to avoid the creation of even more debris.

As commercial companies seek to advance telecommunication services across the globe, large satellite constellations in LEO are becoming more economically viable.[15] In the past few years, many companies have announced plans for large commercial satellite constellations, each at different stages of readiness. The most notable yet is the internet-providing Starlink constellation designed, launched, and operated by SpaceX. As of June 2021, there are over 1,800 Starlink satellites in orbit, and SpaceX has announced plans for tens of thousands more satellites to expand its coverage and capacity.[16] Its website boasts a low latency network, helped by the fact that its "satellites are over 60 times closer to Earth than traditional satellites."[17] The satellites are equipped with an AI navigation system, which is intended to automatically monitor and avoid collisions. However, this system has not been used in two recent collision warnings, which both resulted in close calls.[18]

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[12] Union of Concerned Scientists Excel Sheet, "UCS-Satellite-Database-1-1-2021.xls"

[13] Ibid.

[14] Mark Garcia, "Space Debris and Human Spacecraft," NASA, May 26, 2021, https://www.nasa.gov/mission_pages/station/news/orbital_debris.html

[15] "Curbing space debris in the era of mega-constellations," The European Space Agency, July 18, 2018, https://www.esa.int/Enabling_Support/Preparing_for_the_Future/Discovery_and_Preparation/Curbing_space_debris_in_the_era_of_mega-constellations#:~:text=Over%20the%20next%20decades%2C%20many,that%20is%20already%20highly%20congested.

[16] Richard Bednarski, "SpaceX satellites soaring across Nevada night sky leave many curious," Reno Gazette Journal, June 14, 2021, https://www.usatoday.com/story/tech/2021/06/14/spacex-starlink-satellites-night-sky-lights/7682738002/
Amy Thompson, "SpaceX launches 60 new Starlink internet satellites, nails latest rocket landing at sea," Space, March 24, 2021, https://www.space.com/spacex-starlink-22-satellites-launch-rocket-landing-success

[17] Starlink, https://www.starlink.com/

[18] Joey Roulette, "OneWeb, SpaceX satellites dodged a potential collision in orbit," The Verge, April 9, 2021, https://www.theverge.com/2021/4/9/22374262/oneweb-spacex-satellites-dodged-potential-collision-orbit-space-force

OneWeb plans to deploy another megaconstellation. After filing for bankruptcy, it received an investment of over $1 billion from the UK government and Bharti Global in 2020.[19] Its initial proposal called for almost 48,000 small satellites, however in 2021 the company greatly reduced the constellation size to just over 6,300 satellites.[20] In the filing stating the reduced number, the company noted that the change was an attempt to "support the long-term use of space for all by preserving the orbital environment." This statement came just two months before a Starlink satellite came close to colliding with a OneWeb satellite. The two operators coordinated and the OneWeb satellite was able to maneuver to avoid collision.[21] Currently, OneWeb is in the process of building out its initial 650-satellite constellation.

Similarly, Amazon has received approval to launch its own low latency broadband internet satellite constellation called Kuiper, which is planned to include some 3,236 satellites. If launched as planned, this constellation alone would almost double the amount of satellites currently in orbit. The first satellites have yet to be launched.[22]

China has also announced plans for a national megaconstellation to provide satellite-based internet services. Current plans suggest this will be broken up into two separate LEO constellations totaling just under 13,000 satellites, although nothing has been launched yet.[23]

Telesat, a Canadian communications company, LeoSat, an American telecommunications company, and Boeing also filed to launch large constellations of 292, 108, and almost 3,000 satellites, respectively. However, Boeing and LeoSat have since abandoned these plans.[24] Telesat, an already expansive satellite operating company, is expected to complete financing and initial contracts for its constellation in 2021. The Telesat constellation, named Lightspeed, is estimated to cost $5 billion in total, and the company has contracted Thales Alenia Space, a jointly owned French and Italian company, to build the system.[25]

United States SSA Policy and Practice

The most relied upon source for SSA data currently is the U.S. Space Surveillance Network (SSN). The SSN is a system of almost 25 sensors located around the world and operated by U.S. military personnel. Though operated by the U.S. military, the data collected is available to users worldwide through Space-Track.org.[26] There are three types of sensors used in the SSN: conventional radars, phased-array radars, and the Ground-Based Electro-Optical Deep Space Surveillance system (GEODSS). The SSN maintains a catalog of all objects larger than 10 cm known to be orbiting the Earth. Less than 10% of these objects are operational satellites, and the vast majority of objects tracked

[19] Martyn Warwick, "Troubled OneWeb satellite system now fully owned by the UK government and Bharti," Telecom TV, November 23, 2020, https://www.telecomtv.com/content/access-evolution/bankrupt-oneweb-satellite-system-now-fully-owned-by-the-uk-government-and-bharti-40288/
[20] Jeff Foust, "OneWeb slashes size of future satellite constellation," SpaceNews, January 14, 2021, https://spacenews.com/oneweb-slashes-size-of-future-satellite-constellation/
[21] Roulette, OneWeb, SpaceX satellites dodged a potential collision in orbit.
[22] Elizabeth Howell, "The FCC has approved Amazon's plan for its Kuiper satellite constellation. Here's what that means," Space.com, August 20, 2020, https://www.space.com/amazon-kuiper-satellite-constellation-fcc-approval.html
[23] Andrew Jones, "China is developing plans for a 13,000-satellite megaconstellation," SpaceNews, April 21, 2021, https://spacenews.com/china-is-developing-plans-for-a-13000-satellite-communications-megaconstellation/
[24] Caleb Henry, "Amazon Planning 3,236-Satellite Constellation for Internet Connectivity, Space.com, April 5, 2019, https://www.space.com/amazon-plans-3236-satellite-constellation-for-internet.html
[25] Jeff Foust, "Telesat completing financing for Lightspeed constellation," SpaceNews, April 7, 2021, https://spacenews.com/telesat-completing-financing-for-lightspeed-constellation/
[26] Spacke-track.org, https://www.space-track.org/auth/login

are old rocket bodies that delivered these satellites to orbit, inactive satellites, and pieces of space debris.[27] Currently, the SSN tracks over 25,000 objects in orbit, and this number is expected to grow significantly in future years.

The most recent addition to the SSN is the Space Fence, known as the world's most advanced radar. Operated by the U.S. Space Force in the Marshall Islands, the Space Fence detects, tracks, and measures space objects in LEO. The Space Fence replaced the Space Surveillance Radar, and with the advanced sensors it possesses the catalog of objects is expected to grow at a rapid pace. The Space Fence is the most sensitive radar in the SSN, and it is able to detect objects in LEO the size of a marble.[28]

The U.S Space Force (and previously the Air Force) is the initial gatekeeper for SSA data since the United States' SSA infrastructure is developed and operated by the military. However, there is an ongoing shift of these responsibilities to the Department of Commerce (DoC) that was mandated by a White House Space Policy Directive.[29] DoC will be responsible for the "publicly releasable portion of the DoD catalog" and partnering with industry and academia to provide STM data and resources, but the Space Force will continue to collect SSA data. The transfer of responsibility from a military to civilian agency is intended to create a better interface with commercial companies and international actors who will be deploying more satellites and large constellations. This change is estimated to be complete by 2024. Although it is likely the government will be heavily involved in SSA capabilities in the foreseeable future, commercial companies and international actors are increasing capabilities at a rapid pace.

Commercial Operators

Current Market

According to Verified Market Research, the global market for SSA "was valued at USD 1.16 Billion in 2020 and is projected to reach USD 1.63 Billion by 2028."[30] The report attributes this growth to a growing reliance on space for national security purposes, and projects that commercial companies will account for a large portion of the compound annual growth rate of the sector in the next decade. As many countries around the globe continue to rely on space for everyday civilian and military operations, assets in the domain have become part of the critical infrastructure that must be monitored and protected.

While SSA services were historically dominated by the U.S. government (and the military's Space Surveillance Network in particular), commercial companies are making significant strides in providing independent SSA data to satellite operators. Commercial operators started to come together in the late 1980s to fill holes they saw in the government system. Individuals from the government and commercial sectors began to work together to improve SSA collection and ensure widespread access to the data that accompanies it. As noted below, some SSA companies collect their own SSA data from privately owned and operated sensor networks, while others provide SSA analytic

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[27] Dr. T.S. Kelso, "Space Surveillance," Satellite Times, Fall 1997, https://celestrak.com/columns/v04n01/
[28] "Space Fence," Lockheed Martin, https://www.lockheedmartin.com/en-us/products/space-fence.html
Sandra Erwin, "Space Fence surveillance radar site declared operational," SpaceNews, March 28, 2020, https://spacenews.com/space-fence-surveillance-radar-site-declared-operational/
Erica Blanton,"Swinging for the Space Fence," Space Force News, April 7, 2020 https://www.spaceforce.mil/News/Article/2142648/swinging-for-the-space-fence/
[29] Sandra Erwin, "U.S. Space Command eager to hand over space traffic duties to Commerce Department," SpaceNews, November 17, 2019, https://spacenews.com/u-s-space-command-eager-to-hand-over-space-traffic-duties-to-commerce-department/
[30]"Space Situational Awareness Market Size and Forecast," https://www.verifiedmarketresearch.com/product/space-situational-awareness-market/

services using data collected by others. And some companies provide a fully integrated capability from data collection to analysis and mission planning.

Major Commercial SSA Providers

The following section provides summaries of the major commercial SSA providers in the United States and abroad. Because the industry is rapidly growing and evolving, it is not intended to be a comprehensive listing of all companies providing SSA services but rather serves as a snapshot of the major companies involved in SSA at this time.

Analytical Graphics, Inc. (AGI)

AGI is a U.S. technology company which has a longstanding history of providing SSA through its Commercial Space Operations Center (ComSpOC). ComSpOC started as an initiative within AGI, but is now a separate entity that provides SSA services and data for space operators.[31] It processes data from over 20 optical sensor sites, one radar site, and three RF sites, though they do not operate these facilities. This network of sensors is operated by ComSpOC partners and is used to maintain an active catalog by tracking all satellites in GEO.[32] The SSA products are put into a web service known as SpaceBook that customers can interact with.[33] And AGI experts within COMSPOC have created the Center for Space Standards in Innovation (CSSI), a team of research and subject matter specialists that work to develop space standards including how commercial operators share orbit data, planned maneuvers, and physical characteristics.

AGI also runs the Space Data Center (SDC) for the Space Data Association. The SDC is able to collect data from private satellite owners and operators and the U.S. government. It shares operational data provided by satellite operators and supplements this with data in the public catalogue. The SDC is able to issue conjunction warnings to satellite operators in the case of a possible collision with greater accuracy than using only the publicly available data.[34] The SDC is funded completely by 31 core commercial members as well as associated participants, such as NASA.

ClearSpace

ClearSpace is a Swiss company formed in 2018 for on-orbit servicing and space debris removal. Though a new company, in 2019 ClearSpace was selected by ESA for an orbit-removing operation in 2025.[35] A 2020 consulting report states that the company offers tracking, capture, and removal services for defunct spacecraft, able to track objects 10cm and larger in LEO and GEO, by buying optical and radar networks from other providers.[36]

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[31] Comspoc, https://comspoc.com/#about
[32] Josh Poley, “AGI and business partners announce new milestones for ComSpOC,” AGI, September 10, 2014, https://www.agi.com/blog/2014/09/agi-and-business-partners-announce-new-milestones
[33] Sarah Chow, “ComSpOC: A Space Situational Awareness Facility that Tracks Satellite from a Global Network of Commercial Sensors,” Cesium, March 29, 2018, https://cesium.com/blog/2018/03/29/comspoc/
[34] Space Data Center, https://www.space-data.org/sda/space-data-center-3/
[35] Clearspace Today, https://clearspace.today/
[36] “Commercial Space Surveillance & Tracking,” Euroconsult, March 17, 2020, https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/917912/Euroconsult_-_Commercial_SST_Market_-_for_publication.pdf

Elecnor Deimos Group

Spanish company Elecnor Deimos has its own optical and radar tracking systems, capable of tracking objects from 10 to 15 cm in LEO, MEO, and GEO.[37] The company also offers supplemental services for its customers, including orbit determination, maneuver tracking, antenna calibration, and conjunction analysis support.[38]

etamax space GmbH (Germany)

etamax space GmbH is headquartered in Germany and specializes in space debris analysis. etamax is a partner of ESA and has helped to develop the ESABASE2 tool, used to study the effects space debris may have on a space mission. The company is furthering this research focusing on tools that simulate orbital collisions and developing models to understand the aftermath of orbital impact. etamax also contributes space weather services to ESA.[39]

ExoAnalytic Solutions

ExoAnalytic Solutions is a U.S. commercial SSA provider that specializes in tracking high-altitude space debris and satellites using a rapidly growing network of 350 telescopes located at more than 30 observatories across the globe. This network gives global coverage of all GEO, HEO, and MEO orbits, and with post-processing it can track near GEO objects as small as 10 cm with an astrometric error of 30 m.[40] The ExoAnalytic Global Telescope Network is currently the largest optical telescope network that provides commercial satellite operators with SSA data, focusing on defense and intelligence.[41] The company is able to provide orbit determination, correlate orbit position to tracked objects, and produce automated conjunction warnings, new objects discovered alerts, and other monitoring alerts.

In 2019, the company announced a partnership with Canadian satellite company Northstar E&S to develop and launch on-orbit optical cameras which can monitor orbits in LEO and GEO. According to a press release, NorthStar will begin the operation of its 40-satellite constellation for SSA services in 2023. The sensors on this proposed constellation will collect precise observations and increase the frequency of observations per object.[42] Adding space based sensors to its large ground network will give the company increased data, speed, and ease of observations.[43]

GlobVision

GlobVision is a Canadian technology company that has developed software that interprets space data and performs conjunction analysis of the objects. The software, called SSAVision, can report conjunction risks and environmental factors to spacecraft operators.[44] The company does not operate its own sensors but acquires data and catalogues to

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[37] Ibid.
[38] "SST Services for Orbit Determination," https://elecnor-deimos.com/wp-content/uploads/2020/08/SSA_DeSS4SatOp_EN.pdf
[39] Etamax, https://etamax.de/topics/?lang=en/#tab-77c0633fb262d897861
[40] https://www.satelliteconfers.org/wp-content/uploads/2018/12/Mark-Jeffries-ExoAnalytic-Solutions.pdf
https://spacenews.com/exoanalytic-video-shows-telkom-1-satellite-erupting-debris/
[41] Exoanalytics, "Who We Are," https://exoanalytic.com/about/
[42] "ExoAnalytic Solutions and NorthStar Earth & Space expand collaboration to protect satellites," Press Release, April 28, 2021, https://exoanalytic.com/exoanalytic-solutions-and-northstar-earth-space-expand-collaboration-to-protect-satellites/
"ExoAnalytic Solutions and NorthStar Earth & Space join forces to combat growing space debris threat, protect satellites in orbit," April 1, 2019, https://www.newswire.ca/news-releases/exoanalytic-solutions-and-northstar-earth-amp-space-join-forces-to-combat-growing-space-debris-threat-protect-satellites-in-orbit-802015126.html
[43] Caleb Henry, "ExoAnalytic, NorthStar E&S team up on space situational awareness," SpaceNews, April 1, 2019, https://spacenews.com/exoanalytic-northstar-es-team-up-on-space-situational-awareness/
[44] Globvision, https://www.globvision.com/space/

create its analysis. GlobVision provides SSA services such as space weather data monitoring, conjunction warnings, collision analysis, and re-entry prediction to its customers, commercial and military operators alike.

GMV Innovating Solutions

GMV is a private business group headquartered in Spain which contributes to the European Space Agency's SSA and SST programs. Almost 70 engineers at the company work on SSA activities, making this the largest SSA team in Europe.[45] In early 2021, the company was selected by the European Commission to lead a Coordination and Support Action for a future European Space Traffic Management capability. GMV is leading and coordinating a group of 18 European institutions in this effort as well as leading working groups on available SST technology that can be used for the program.[46] GMV does not currently have any sensors of its own, but it acquires data and uses it to provide innovative services. As of 2020, GMV products can track objects 10 cm and larger in GEO.[47]

Kratos Defense & Security Solutions, Inc.

Kratos is an American company that provides SSA data through radio frequency (RF) monitoring data. The company has a global RF network which includes over 80 sensors and antennas at 21 global locations used for high-speed RF signal measurement and collection.[48] It offers RF satellite surveillance, RF interference mitigation, RF situational awareness, predictive analytics, and bandwidth utilization to government and commercial customers.[49] Kratos also boasts that its RF data can detect and locate satellite interference and identify anomalies in payload performance, as well as analyze satellite behaviors and maneuvers.[50] In April 2021, the company took part in a multi-national Joint All Domain Command and Control (JADC2) demonstration where it was able to provide real-time SSA capabilities in an operationally secure data environment. Capabilities included spectral data, real-time link and equipment status, and interference detection.[51]

L3 Harris Technologies

L3 Harris is an American company that operates government owned optical sensors which are able to track objects in LEO 20 cm and larger.[52] These sensors are part of the U.S. SSN and L3 sustains the sensors that provide data to

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[45] "GMV to upgrade GSSAC Mission System for German Space Agency at DLR," May 26, theGPStime,https://www.thegpstime.com/german-space-situational-awareness-centre-gssac/

[46] "GMV-led consortium EUSTM is shaping the future of European Space Traffic Management," SpaceDaily, February 17, 2021, https://www.spacedaily.com/reports/GMV_led_consortium_EUSTM_is_shaping_the_future_of_European_Space_Traffic_Management_999.html

[47] Commercial Space Surveillance & Tracking, https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/917912/Euroconsult_-_Commercial_SST_Market_-_for_publication.pdf

[48] "Kratos Introduces New Spectral Services to Enhance Space Situational Awareness," Kratos Defense & Security Solutions, Inc., April 12, 2018, https://www.globenewswire.com/news-release/2018/04/12/1469093/224/en/Kratos-Introduces-New-Spectral-Services-to-Enhance-Space-Situational-Awareness.html

[49] "RF Monitoring Services," https://www.kratosdefense.com/products/space/signals/rf-management/rf-monitoring-services

[50]"RF Space Domain Awareness," https://www.kratosdefense.com/video/rf-space-domain-awareness

[51] "Kratos Demonstrates SATCOM Situational Awareness to an Operationally Secure Environment Using Commercial Resources," April 26, 2021, https://www.globenewswire.com/en/news-release/2021/04/26/2216789/224/en/Kratos-Demonstrates-SATCOM-Situational-Awareness-to-an-Operationally-Secure-Environment-Using-Commercial-Resources.html

[52] Commercial Space Surveillance & Tracking, https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/917912/Euroconsult_-_Commercial_SST_Market_-_for_publication.pdf

other customers.[53] In 2018, L3 Harris acquired Applied Defense Solutions, a leader in command and control SSA capabilities.[54] In February of 2021, L3 Harris was awarded a second year contract to continue maintenance and infrastructure modernization to track objects in space for the U.S. Space Force and U.S. Space Command. The initial contract was awarded in 2020 for the Maintenance of Space Situational Awareness Integrated Capabilities (MOSSAIC) program to upgrade and maintain radar and optical sensors as well as command and control systems for military, civil, and commercial users.[55] L3 Harris works frequently with the U.S. government, and is upgrading DoD ground and space-based sensors including the Ground-based Electro-Optical Deep Space Surveillance (GEODSS) system.[56]

LeoLabs

LeoLabs is a prominent commercial operator in the U.S. commercial market for SSA services.[57] LeoLabs' network is composed of ground-based, phased array radars that can catalog thousands of objects in space. Its main tracking radars are located in Alaska, Texas, New Zealand, and Costa Rica. The data from these radars are provided to customers as a web-based subscription service, and its network of radars can currently track over 16,000 objects in LEO down to 2 cm in size.[58] In June of 2021, LeoLabs announced plans to expand its radars to the Azores archipelago off the coast of Portugal. Scheduled to come online in 2022, this new S-bad radar will offer coverage over Europe and the North Atlantic and better track small pieces of space debris.[59]

In May of 2020, the company announced the start of its collision avoidance system, a global network of "space-scanning radars" which will track space debris in orbit. One of the biggest features of this new system is the ability to safely plan a satellite maneuver without the need to contact the U.S. Space Force. The LeoLabs system will be able to check the safety of a maneuver, and once committed, the radar will be able to track the satellite to ensure the maneuver was accomplished as intended.[60] Although it has not been well documented how well this currently performs or when the system will be fully operational, it is an example of how responsibility for SSA and STM is shifting from the government to commercial providers. The company currently has four radars that cover a majority of the Earth's orbit, and they are investing in two more to expand how often satellites are viewed and tracked.[61]

Another program announced by LeoLabs is LeoTrack, which is tailored to smallsat and cubesat operators. According to a 2019 press release, LeoTrack is a "web-based subscription, offer[ing] satellite operators a full range of monitoring capabilities, including precision tracking of satellites, orbital state vectors, predictive radar

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[53] Interview with L3 Harris

[54] "L3 Strengthens Space Mission Capabilities With Acquisition of Applied Defense Solutions," Press Release, July 2, 2018, https://www.l3harris.com/newsroom/press-release/2018/07/l3-strengthens-space-mission-capabilities-acquisition-applied

[55] "L3Harris Technologies Awarded Second Year of Space Object-tracking Modernization Contract," Press Release, February 25, 2021, https://www.l3harris.com/newsroom/press-release/2021/02/l3harris-technologies-awarded-second-year-space-object-tracking

[56] "Space Superiority Solutions," L3Harris, https://www.l3harris.com/sites/default/files/2020-06/l3harris-space-superiority-solutions-sell-sheet-sas.pdf

[57] LeoLabs, https://www.leolabs.space/

[58] Ibid.
"LeoLabs Tracking and Monitoring," LeoLabs, https://www.leolabs.space/wp-content/uploads/2021/06/LeoLabs-Tracking-and-Monitoring.pdf

[59] Debra Werner, "LeoLabs to expand radar network to Europe," SpaceNews, June 16, 2021, https://spacenews.com/leolabs-azores-radar/

[60] Devin Coldewey, "LeoLabs launches its global satellite monitoring and collision avoidance service,' TechCrunch, May 13, 2020, https://techcrunch.com/2020/05/13/leolabs-launches-its-global-satellite-monitoring-and-collision-avoidance-service/

[61] Ibid.

availability, scheduled passes, and real-time orbit visualization for constellations as well as individual satellites."[62] CEO Dan Ceperly stated publicly that "We're the largest data provider for LEO in the world now … we've stepped beyond anybody in the public or private [sectors]."[63]

Lockheed Martin

In 2017, Lockheed Martin unveiled its iSpace program which provides solutions to customers through optical, radar, and RF sensors that monitor space objects. Lockheed Martin doesn't operate any of its own sensors, but uses data collected from government, commercial, and academic systems to provide its SSA solutions to customers. iSpace uses data from commercial companies ExoAnalytics, Kratos, Numerica, LeoLabs, the U.S. Space Fence, the Australian co-developed FireOPAL system, and observational sensors placed in Italy, France, and Germany.[64] As of 2021, iSpace can track nearly 300,000 objects and is highly automated. Lockheed Martin was selected to build the U.S. Space Fence surveillance radar and was able to use that mission software for its own commercial product.[65]

Numerica

Numerica is an American defense company with a focus in SSA solutions for government and commercial operators. The Numerica Telescope Network is a privately built and operated system that tracks objects in LEO, MEO, HEO, and GEO. The network consists of more than 130 telescopes positioned in over 20 sites across the globe. The company also boasts six sites that are capable of the only commercial LEO to GEO daytime satellite tracking service on the market.[66] In 2019 Numerica was awarded a contract by the U.S. Air Force for real-time satellite tracking.[67]

Parsons Corporation

Parsons Corporation is an American corporation headquartered in Virginia focused on defense, intelligence, and critical infrastructure markets. In May 2021, it was awarded a contract for SSA support for the Space and Missile Systems Center Special Programs Directorate (SMC/SPG) to provide operational, technical, and space domain awareness expertise. In 2018, Parsons acquired Polaris Alpha, an SSA company which developed orbit solutions for government customers.[68]

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[62] "LeoLabs Unveils First Commercial Satellite Tracking Service for SmallSat and CubeSat Operators," Press Release, August 5, 2019, https://www.prnewswire.com/news-releases/leolabs-unveils-first-commercial-satellite-tracking-service-for-smallsat-and-cubesat-operators-300896081.html

[63] Michael Sheetz, "Space debris tracker LeoLabs raises $65 million as satellites launch to orbit at unprecedented rate," CNBC, June 3, 2021, https://www.cnbc.com/2021/06/03/space-debris-tracker-leolabs-raises-65-million.html

[64] "Inteligent Space," https://www.lockheedmartin.com/content/dam/lockheed-martin/rms/photo/ispace/ispace-brochure.pdf

[65] Sandra Erwin, "Germany's space agency selects Lockheed Martin's traffic management software," SpaceNews, April 6, 2021, https://spacenews.com/german-space-agency-selects-lockheed-martins-traffic-management-software/

[66] "Numerica Telescope Network Overview," https://s11967.pcdn.co/wp-content/uploads/2021/04/Numerica-SDA-NTN-One-Pager-04072021.pdf

[67] "Numerica awarded U.S. Air Force contract for real-time satellite tracking," Geospatial World, July 19, 2019, https://www.geospatialworld.net/news/numerica-u-s-air-force-contract-real-time-satellite-tracking/

[68] "Parsons to Acquire Polaris Alpha," Press Release, May 21, 2018, https://www.parsons.com/2018/05/parsons-acquires-polaris-alpha/
Anusuya Datta, "The only way to solve data breach is by spreading awareness, believes Marcus Featherston, Polaris Alpha," Geospatial World, May 21, 2018, https://www.geospatialworld.net/blogs/the-only-way-to-solve-data-breach-is-by-spreading-awareness-believes-marcus-featherston-polaris-alpha/

Peraton

Peraton is an American company focusing on national security missions. In October of 2020, the company finalized a $10 million five-year contract from the U.S. Space Force for orbital analysis services. This was an extension of a project that Peraton was first awarded in September of 2015. Peraton will provide SSA services, such as collision avoidance analysis and support during daily operations and any operating anomalies.[69] Peraton operates a number of satellites and telescopes with NASA, but it is unclear if those are used for SSA purposes or unrelated missions. The company has been public in stating that it will take a combination of data from all sensor types to enhance SSA.[70]

SpaceNav

SpaceNav is an American company based in Colorado which supplies services through its AdvancedSSA network to commercial, civil, and military operators. It is a monthly subscription service that allows unlimited simultaneous users to have real-time access to mission analytics. The platform provides orbit determination, collision risk management, maneuver planning, maneuver reconstruction, and covariance assessments to satellite operators.[71] SpaceNav does not have its own network of sensors.[72] The company has cataloged over 44,000 objects in the space environment and has alerted its customers of 1,916 high risk events.[73]

Satellite Data Association

One of the largest commercial SSA organizations is the Space Data Association (SDA).[74] The Space Data Association was created in 2009 by four large commercial satellite operators as an international organization that aims to bring satellite operators together to share data and protect the safety of the space environment from space debris. The main goal of the SDA is to administer a space where operators can provide their own information to add to US and European catalogues to increase the accuracy of the catalogues. This information is also used by the association to provide collision warning notifications and improve capabilities around the globe.[75] The catalogue created by SDA is meant to complement the catalogue released through Space-Track.org and cross-checks that data to identify any biases, errors, or updates in operator information. The SDA does not operate any sensors of its own and instead uses supplemental information from members on the status and orbital parameters of their own satellites. Member companies also supply information from more than 50 sensors located across the globe giving SDA the ability to detect objects 1m and larger.[76] Members operate 276 GEO satellites as well as 479 LEO and MEO satellites. The SDA is able to share its collected data with its member operators as well as governments.

Overall Findings for Commercial Providers

Through interviews with some of the major commercial SSA providers, it is evident that state actors are not always sure how to best leverage commercial capabilities. Many governments prioritize working with domestic commercial

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[69] Sandra Erwin, “Space Force extends Peraton’s contract for orbital analysis services,” SpaceNews, October 27, 2020, https://spacenews.com/space-force-extends-peratons-contract-for-orbital-analysis-services/

[70] “Six National Security Space Issues to Confront in 2020,” Peraton, https://www.peraton.com/six-national-security-space-issues-to-confront-in-2020/

[71] “Space-Nav,” https://www.space-nav.com/

[72] Commercial Space Surveillance & Tracking, https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/917912/Euroconsult_-_Commercial_SST_Market_-_for_publication.pdf

[73] “Advanced SSA,”https://www.space-nav.com/products/#orbit-determination

[74] “Space Situational Awareness,” Space Foundation, https://www.spacefoundation.org/space_brief/space-situational-awareness/

[75] “Space Data Association,” https://www.space-data.org/sda/

[76] Interview with SDA

companies, which limits their opportunities to work with foreign firms. In the current market, only a small number of state actors require broad access to SSA data, so commercial companies must tailor the products they offer to the specific government buyer. Trade restrictions also vary by country, so there is no one size fits all approach for building government relationships and service offerings

Over the coming decade, commercial companies plan to continue developing capabilities that rival those of large governments to improve the quality of the SSA data they provide. Major providers like LeoLabs and ExoAnalytics are building more sensor sites to further enhance their capabilities. The prevailing trend is that independent SSA companies are able to produce data with accuracy and timeliness that meets or in some cases exceeds the data publicly provided by large government operators. The commercial SSA industry is continuously recognizing gaps in SSA services and moving quickly to fill them. Commercial companies are able to have such success because they are able to act on gaps and issues in the domain quickly and at a lower cost than a government would be able to.

Commercial companies plan to reduce the size of objects they are able to detect, and how frequently they can maintain data on small objects. These companies will also rely on automation to improve the collection of SSA data.[77] ExoAnalytics is an example of how well this can be done, as the company places an emphasis on automating many repetitive tasks.[78] An interview with the company confirmed this and that the team that manages their 350+ telescope network with just a handful of individuals. Lockheed Martin's iSpace solution is similarly automated, and as its program manager for space command and control said, "it doesn't require a lot of human interaction with the catalog."[79]

Possible points of contention between states and private entities

In speaking to commercial operators, a main point of contention is with the governments that are providing SSA data for free, namely the United States-run Space-Track.org and the European Union Space Surveillance and Tracking (SST) program. These free resources are a direct competition to commercial providers of SSA data, and some commercial companies would prefer far less free government information than is currently available.[80] However, the availability of these free data sources forces commercial firms to differentiate themselves by providing higher quality data, more frequent updates, or more innovative and useful services to attract paying customers.

Another possible point of contention between states and private entities is release of data for sensitive objects in orbit. Currently government operators omit SSA data on certain objects that may be classified or otherwise deemed sensitive for national security reasons. Within the U.S. government there is a policy that distinguishes what to share and what to keep private, but the data can be inconsistent. The U.S. military has made an effort to declassify or downgrade some of this data since 2017.[81] Omitting sensitive objects from the catalog was a common practice for the U.S. Government that was successful until recently and now commercial SSA providers are able to locate and track objects that are not in the data provided by governments. If located independently, there is nothing stopping commercial operators from publicizing or selling this data, which can be of concern to state actors because it undermines the ability of governments to shield these objects from public view. Companies like AGI that frequently work with governments can create a security guide, however each commercial operator ultimately can decide for

[77] Interview with ExoAnalytics
[78] "Space Domain Awareness Solutions," ExoAnalytic, https://exoanalytic.com/space-domain-awareness/
[79] Sandra Erwin, "Germany's space agency selects Lockheed Martin's traffic management software," SpaceNews, April 6, 2021, https://spacenews.com/german-space-agency-selects-lockheed-martins-traffic-management-software/
[80] Interview with ExoAnalytics
[81] Joe Pappalardo, "The Pentagon is Declassifying Lots of Info About What's in Orbit," Popular Mechanics, December 13, 2018, popularmechanics.com/space/satellites/a25562991/pentagon-declassifying-space-traffic-data/

themselves which data to publish. While commercial SSA companies have the capability to track some classified objects, there are different levels of willingness to share data that may be more sensitive even if it is not derived from classified sources. At the same time, government users may not be sure how to best use commercial capabilities that are available. This grows more complicated when dealing with multiple classification levels across allies, partners, and commercial industry.

Foreign SSA Capabilities

The following section provides an overview of the latest SSA developments and capabilities of other nations and the commercial firms that support these efforts. While it is not an exhaustive list of capabilities for every nation, it provides an overview of the capabilities, significant partnerships, and data sharing agreements for SSA around the world.

Australia

The largest recent development in Australian SSA capabilities is a new Space Surveillance Telescope (SST), a joint effort between the United States and Australia. Originally constructed in New Mexico, the telescope was successfully relocated to Western Australia in early 2020 and is a dedicated sensor in the U.S. Space Surveillance Network. The SST can image objects in GEO using 12 large sensors consisting of 96 million pixels in total. Locating the SST in Australia helps fill a gap in the Space Surveillance Network's coverage, and when fully operational in 2022, the network will have a complete coverage of orbits. It will be operated by the Australian Air Force in conjunction with the U.S. Space Force 21st Space Delta 2.[82]

Researchers in Australia also use a large radio telescope, the Murchison Widefield Array, to detect and track satellites. It was initially developed for astrophysical surveys, which capture deep-space phenomena, and in recent years researchers developed a new concept known as Dynamic Signal to Noise Radio Spectrum (DSNRS) to detect and track satellites.[83]

Australia also has an Advanced Instrumentation and Technology Centre (AITC), part of the Australian National University, which was created in 2006 "to support the development of the next generation of instruments for astronomy and space science."[84] The AITC has numerous partnerships across Australia and the globe with universities and private companies. Its current projects include improving tracking capabilities with lasers in addition to radar,[85] using adaptive optics to observe satellites in LEO,[86] and improving the imaging of objects in LEO.[87]

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[82] Dorothy Ryan, "The Space Surveillance Telescope in Western Australia captures its first image," Lincoln Laboratory, February 2, 2021, https://www.ll.mit.edu/news/space-surveillance-telescope-western-australia-captures-its-first-image

[83] Rami Mandow, "Outback Radio Telescope Utilised for Space Situational Awareness," Space Australia, February 10, 2020, https://spaceaustralia.com/news/outback-radio-telescope-utilised-space-situational-awareness#:~:text=Australian%20researchers%20have%20showcased%20the,situational%20awareness%20(SSA)%20capability.

[84] "About," Australian National University, https://rsaa.anu.edu.au/aitc/about

[85] "Established Projects," Australian National University, https://rsaa.anu.edu.au/research/established-projects/adaptive-optics-demonstrator-space-debris-tracking

[86] "Adaptive Optics for Satellite Imaging," Australian National University, https://rsaa.anu.edu.au/research/established-projects/adaptive-optics-satellite-imaging

[87] "Freezing-out atmospheric blurring with Lucky Imaging," Australian National University, https://rsaa.anu.edu.au/research/established-projects/freezing-out-atmospheric-blurring-lucky-imaging

In 2018, Lockheed Martin partnered with Curtin University to form a project called FireOPAL which uses a range of sensors to track space objects. The project is testing SSA sensors to explore how data can be combined from different sensor types.[88] If fully developed, the system aims to be cost effective by creating an expanded network for the same price as a traditional 1 m telescope.[89]

Brazil

In August of 2018, Brazil's Ministry of Defense signed an agreement with U.S. Strategic Command to share information and services for SSA. The agreement aims to "enhance each nation's awareness within the space domain increasing the safety of their spaceflight operations," and represents Brazil's commitment to the sustainable use of space by all nations.[90] In January of 2019, an officer from the Brazilian Air Force took a two-week Global Space Situational Awareness Course at Peterson Air Force Base which covered the services enabled by the signed agreement and how to best use the SSA services.[91]

Canada

Canada has been involved in SSA efforts since the 1960s, when it installed two Baker-Nunn telescopic cameras for NORAD. Though discontinued shortly thereafter, the country continued to look for ways to contribute to SSA. In 2012, Canada signed a bilateral SSA data sharing agreement with the United States and opened the Canadian Space Operations Centre (CANSpOC).[92] With allies and partners, CANSpOC reports threats of debris and collision, space weather, status of space mission systems, and missile warnings.[93] Canada had success with its first Near-Earth Orbit Surveillance Satellite (NEOSSat), dedicated to searching for near-Earth asteroids. NEOSSat was able to observe nearby spacecraft uninterrupted by terrestrial weather, such as cloud cover.[94] Today, Canada is adding SSA to its defense policy starting with a new Strong, Secure, and Engaged initiative. In 2020, the Canadian National Department of Defense selected seven proposals for a future space-based surveillance system.

Chile

On October 29, 2020, representatives from the Chilean Air Force, U.S. Space Force, U.S. Southern Command, and U.S. Space Command met virtually to discuss increased collaboration between the countries focusing on space situational awareness, integration and interoperability, commercial space partnerships, and research and development.[95] Additionally, The Air Force Research Lab is currently working with the Chilean Air Force to test an

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[88] "Lockheed Martin and Curtin University partnership develops world-class space tracking system," Media Release, June 15, 2018, https://news.curtin.edu.au/media-releases/lockheed-martin-curtin-university-partnership-develops-world-class-space-tracking-system/

[89] "Industry," Space Science and Technology Centre, https://sstc.curtin.edu.au/engagement/industry/

[90] "USSTRATCOM, Brazil sign agreement to share space services, data," U.S. Strategic Command, August 20, 2018, https://www.stratcom.mil/Media/News/News-Article-View/Article/1607213/usstratcom-brazil-sign-agreement-to-share-space-services-data/

[91] Andrea Barretto/Dialogo, "US and Brazil Share Information on Space," Dialogo-Americas, May 30, 2019, https://dialogo-americas.com/articles/us-and-brazil-share-information-on-space/

[92] Major C.J. Marchetti, "Canada and Space Deterrence: The Space Situational Awareness Impact," Canadian Forces College, https://www.cfc.forces.gc.ca/259/290/298/286/marchetti.pdf

[93] "Operations," Government of Canada, http://www.rcaf-arc.forces.gc.ca/en/space/operations.page

[94] Marc Boucher, "Canadian Space Agency Opens Neossat Science Guest Observation Program," SpaceQ, February 1, 2021, https://spaceq.ca/canadian-space-agency-opens-neossat-science-guest-observation-program/

[95] "Southcom Hosts U.S.-Chile Space Engagement Talks with U.S. SPACECOM and U.S. Space Force," U.S. Southern Command Public Affairs, October 29, 2020, https://www.southcom.mil/MEDIA/NEWS-ARTICLES/Article/2398543/southcom-hosts-us-chile-space-engagement-talks-with-us-spacecom-and-us-space-fo/

OmniSSA camera, which uses frame-stacking techniques to improve the resolution of images and the ability to detect and track objects in space.[96]

China

Though China currently possesses the world's largest radio telescope, it is used for deep-space research rather than SSA capabilities.[97] China has a large network of radars, including multiple large phased array radars (LPARs) that are used for missile warning and to track objects in LEO.[98] China also has maritime SSA capabilities in a fleet of ships outfitted with radars and antennae, which gives it the ability to have dispersed tracking sites without requiring the cooperation of partner nations around the world. The fleet is composed of four "spacecraft tracking ships," and two ships used to transport launch vehicles, such as the Long March 5.[99] The ships first went to sea in the late 1970s and were used to track domestic launches of communications satellites before being upgraded to track international launches. These vessels tracked the launch of China's Shenzhou spacecraft as part of the country's crewed spaceflight program.

Together with partners, in 2015 the China National Space Administration created a Space Debris Monitoring and Application Center to organize SSA capabilities. This was followed by a 2018 announcement which outlined a space debris monitoring base that would include telescopes, optical sensors, and radars.[100] To further develop its SSA capabilities, China has constructed a 16-story antenna in Argentina for space observation. According to state media, this facility played a role in the successful Chang-e 5 lunar mission.[101] It is managed by the China Satellite Launch and Tracking Control General who reports to the military branch of the country focused on space, the People's Liberation Army's (PLA) Strategic Support Force (SSF). The agreement with Argentina lays out broad terms for China's use of the facility, stating that China has full control of the area and can solely operate facilities. The initial agreement did not state a definitive purpose for the technology and data use.[102]

China is also a leading member of the Asia-Pacific Space Cooperation Organization (APSCO), which is headquartered in Beijing and exists to facilitate resource sharing and cooperation among its member states. Members include: Bangladesh, China, Iran, Mongolia, Pakistan, Peru, Thailand, Indonesia, and Turkey. Part of this data sharing is a Ground-Based Space Object Observation (APOSOS) Network, based on three Chinese-provided

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[96] "Omnissa-Camera for Space Situational Awareness," Air Force Research Lab, https://afresearchlab.com/technology/future-technologies/successstories/omnissa

[97] Chelsea Gohd, "China is opening the world's largest radio telescope up to international students," Space.com, December 18, 2020, https://www.space.com/china-fast-radio-telescope-open-international-scientists

[98] "7010 Phased-Array Missile Warning Radar Large Phased-Array Radar LPAR," Global Security, https://www.globalsecurity.org/wmd/world/china/lpar.htm#:~:text=Large%20Phased%2DArray%20Radar%20LPAR,-Huangyang%20Mountain%2040&text=An%20integral%20part%20of%20China's,manned%20by%20Second%20Artillery%20forces.

[99] Li Yan, "China's spacecraft tracking ships depart for missions," ECNS.cn, November 11, 2011, http://www.ecns.cn/news/sci-tech/2019-11-11/detail-ifzqrxfh5726934.shtml

[100] Peter W. Singer and Peter Wood, "Keep Tabs on China's Growing Space Situational Awareness," DefenseOne, May 26, 2021, https://www.defenseone.com/ideas/2021/05/keep-tabs-chinas-growing-space-situational-awareness/174309/

[101] Cassandra Garrison, "China's military-run space station in Argentina is a black box'," Reuters, January 31, 2019, https://www.reuters.com/article/us-space-argentina-china-insight/chinas-military-run-space-station-in-argentina-is-a-black-box-idUSKCN1PP0I2

[102] Erin Watson-Lynn, "The gravity of China's space base in Argentina," The Interpreter, June 9, 2020, https://www.lowyinstitute.org/the-interpreter/gravity-china-s-space-base-argentina

telescopes located in Iran, Pakistan, and Peru.[103] China and Turkey have been tasked to lead this project, which is currently able to track most objects from LEO to GEO.[104] The observation data from APOSOS goes to the Chinese Academy of Science's National Astronomical Observatory of China before it is accessible to member states.[105]

European Union (EU)

In 2014, the EU established its Space Surveillance and Tracking (SST) Support Framework with the help of five member states: France, Germany, Italy, Spain, and the United Kingdom. Portugal, Poland, and Romania later joined the project in 2018. The SST program gives the EU "the capability to detect, catalogue and predict the movements of space objects orbiting the Earth."[106] This focuses on pulling the information from existing radar, telescope, and laser networks run by member states. The data from these sensor networks is then collected into the same European SST database.[107] According to a 2019 document, "the sensor network is composed of 5 surveillance radars, 7 tracking radars, 4 laser stations and an optical network of 35 telescopes providing coverage for all orbital regimes (LEO, MEO, HEO, GEO)."[108] Most of these sensors are located on mainland Europe, though some optical sensors are located on other continents.[109] All member states involved in the SST have security data sharing agreements in place with each other, and all either have or are in the process of finalizing similar SSA data sharing agreements with the United States.

The SST works together with the European Union Satellite Centre (SatCen) to sustain this capability, and a set of SST services are provided to all countries, institutions, and spacecraft operators in the EU. The SST provides collision avoidance, re-entry analysis, and fragmentation analysis. Over 100 organizations receive these services which protect over 200 European satellites from the risk of collision.[110] At the end of 2019, the services were provided to 106 individual users coming from 18 EU member states and 60 individual organizations. It is predicted that by 2028 the SST will be able to catalogue almost 20,000 objects.[111]

European Space Agency (ESA)

ESA has created a Space Debris Office to define guidelines for keeping LEO as debris-free as possible, largely by tracking the satellites and debris already in orbit to prevent accidental collisions. Specifically in response to the many mega constellations planned in the next few years, ESA has stated that "collision avoidance maneuvers and space debris mitigation efforts, requiring new technologies and procedures to be developed, are becoming more urgent."[112]

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[103] "About APSCO," http://www.apsco.int/html/comp1/content/WhatisAPSCO/2018-06-06/33-144-1.shtml
[104] Guo Xiaozhong, "Asia-Pacific ground-base Optical Satellite Observation System," Center for Research and Application of space Debris, October 2011, https://swfound.org/media/50867/guo_aposos.pdf
[105] "Challenges to Security in Space," Defense Intelligence Agency, https://www.dia.mil/Portals/27/Documents/News/Military%20Power%20Publications/Space_Threat_V14_020119_sm.pdf
[106] "What is EU SST?" EUSST, https://www.eusst.eu/
[107] Lucia Marta, "The European Space Surveillance and Tracking Service at the crossroad," Fondation pour la Recherche Strategique, October 2015, https://www.frstrategie.org/en/publications/defense-et-industries/european-space-surveillance-and-tracking-service-crossraoad-2015
[108] Pascal Faucher, Regina Peldszus, Amelie Gravier, "Operational Space Surveillance and Tracking in Europe," First International Orbital Debris Conference, 2019, https://www.hou.usra.edu/meetings/orbitaldebris2019/orbital2019paper/pdf/6165.pdf
[109] Ibid.
[110] EUSST, https://www.eusst.eu/services/
[111] https://www.hou.usra.edu/meetings/orbitaldebris2019/orbital2019paper/pdf/6165.pdf
[112] "Curbing space debris in the era of mega-constellations," the European Space Agency, June 18, 2018, https://www.esa.int/Enabling_Support/Preparing_for_the_Future/Discovery_and_Preparation/Curbing_sp

ESA has created an SSA Programme, but it is optional for its 19 member states to financially participate in the program. The program had 95 million euros in funding from 2009 to 2020, with a focus on Space Weather (SWE), Near-Earth Objects (NEO), and Space Surveillance and Tracking (SST).[113] ESA's SST project is separate from the EU's SST Framework and is based at the European Space Operations Centre in Germany. ESA works with experts and satellite operators across Europe to maintain this capability.[114]

ESA also has a premiere space weather programme headquartered in Belgium that monitors solar weather, ionospheric weather, space radiation, geomagnetic conditions, and eventually heliospheric weather.[115] These space weather occurrences can impact telecommunication, radio communication, and some navigation sources, so being able to understand the patterns and most likely effects of space weather is of the utmost importance. SSA information is also used to better predict and understand space weather occurrences. Though it is an important aspect of SSA monitoring, this is a service that takes a large amount of funding and resources, so is currently most publicly provided by civil government actors like ESA, NASA, and NOAA.

France

A contributing member of ESA's SSA program, France has spent decades developing its own SSA capabilities as well. The GRAVES system, a radar system using directional information to track the orbits of satellites, became operational in 2005. The system can only detect objects that are larger than 1m, and relies on only two telescopes for higher orbits. The 2019 space defense strategy outlined a replacement to the system that would allow it to detect cubesats in LEO and expand its domestic network of telescopes. Though as of 2019, France relies on the GRAVES space surveillance radar for SSA data in LEO.[116]

India

In late 2020, India's civil space organization, the Indian Space Research Organisation (ISRO) stood up a Directorate of Space Situational Awareness and Management (DSSAM) to enhance SSA in the country.[117] The DSSAM is the country's first step in creating a network of its own, focusing on radar and optical telescope facilities.[118] Previously, India was able to use TLE's supplied from NORAD to provide collision avoidance analysis before launch, space object proximity analysis, and space debris modeling. India boasts six domestic optical-infrared observatories, but

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ace_debris_in_the_era_of_mega-constellations#:~:text=Over%20the%20next%20decades%2C%20many,that%20is%20already%20highly%20congested.

[113] "SSA Programme overview," the European Space Agency, https://www.esa.int/Safety_Security/SSA_Programme_overview

[114] "Space Surveillance and Tracking - SST Segment," the European Space Agency, https://www.esa.int/Safety_Security/Space_Surveillance_and_Tracking_-_SST_Segment

[115] Juha-Pekka Luntama, Alexi Glover, "ESA SSA Space Weather Services - Federated Service Concept," ESA SSA Programme Office, April 8-11, 2014, https://www.swpc.noaa.gov/sites/default/files/images/u33/Luntama_ESA_SSA_SWE_Federated_Services.pdf

[116] "France's new space defense strategy," SatelliteObersvation.net, July 27, 2019, https://satelliteobservation.net/2019/07/27/frances-new-space-defense-strategy/

[117] Sidharth MP, "Explained: All about ISRO's new center dedicated to Space Situational Awareness," ZEENews, December 16, 2020, https://zeenews.india.com/india/explained-all-about-isro-s-new-center-dedicated-to-space-situational-awareness-2331190.html

[118] "ISRO sets up dedicated control centre for Space Situational Awareness," The Economic Times, December 16, 2020, https://economictimes.indiatimes.com/news/science/isro-sets-up-dedicated-control-centre-for-space-situational-awareness/articleshow/79763690.cms?from=mdr

only two have been used for SSA purposes.[119] Though no agreement has been signed, after an India-U.S. strategic dialogue in late 2020, the ministers released a joint statement calling for future cooperation on SSA.[120]

Italy

Italy is home to the BIRALES radar sensor that is used for LEO observations. This system has both government and commercial users, including Lockheed Martin.[121] OHB Italia S.p.A., an Italian prime contractor for ASI and ESA missions, operates a telescope for ESA called Flyeye. Flyeye is used for SST purposes and to observe objects in high LEO that are 8 cm or larger.[122]

Iran

In 2017, the Iraninan Minister of Communications and Information Technology stated "Iran has already installed a telescope in collaboration with APSCO."[123] This was confirmed in late 2018, when an Iranian military officer claimed that the country has domestic SSA radar capability, an optical telescope, that can track satellites in LEO, although few other details have been publicly disclosed.[124]

Japan

Japan is heavily investing in SSA capabilities, largely through its civil space program, the Japan Aerospace Exploration Agency (JAXA). JAXA has three domestic SSA facilities, one for radar, one for optical observation, and another focusing on data analysis.[125] Together these systems are capable of tracking objects from LEO to GEO. The country invested $17 million U.S. dollars in SSA initiatives in 2018 and is working towards a deep-space radar center to be fully operational in 2024.[126] This new system will be led by the Ministry of Defense, and the Self-Defense Forces will be charged with the development of further space-based telescopes to be incorporated into the system.[127]

JAXA and the Ministry of Defense are working together to update these SSA systems, and they are sharing personnel when necessary for the mission. They are also working with the United States to maintain the databases

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[119] Mrunalini Deshpande, "Space Situational Awareness: Indian Perspective," National Institute of Advanced Studies, https://swfound.org/media/206344/india-ssa-perspective-mrunalini-d.pdf
[120] Rajeswari Pillai Rajagopalan, "India and the US are expanding their space cooperation," Observer Research Foundation, October 31, 2020, https://www.orfonline.org/research/india-and-the-us-are-expanding-their-space-cooperation/
[121] Lt Col Andrea Console, "Command and Control of a Multinational Space Surveillance and Tracking Network," Joint Air Power Competence Centre, June 2019, https://www.japcc.org/wp-content/uploads/JAPCC_C2SST_2019_screen.pdf
[122] "SSA/SST," OBH-Italia, https://www.ohb-italia.it/space-situational-awareness/
[123] "Iran Plans to Join 2 APSCO Projects," Financial Tribute, July 1, 2021, https://financialtribune.com/articles/economy-sci-tech/72519/iran-plans-to-join-2-apsco-projects
[124] "Iran Claims to have SSA Radar Capabilities of Detecting Satellites in LEO," Spacewatch.global, https://spacewatch.global/2018/12/iran-claims-to-have-ssa-radar-capable-of-detecting-satellites-in-leo/
[125] "Space Situational Awareness (SSA) System," JAXA, https://global.jaxa.jp/projects/ssa/index.html#:~:text=Space%20Situational%20Awareness%20(SSA)%20is%20a%20key%20for%20such%20understanding.&text=In%20addition%2C%20JAXA%20will%20set,at%20contributing%20to%20SSA%20activities.
[126] "Global Space Situational Awareness (SSA) Industry," CISION, https://www.prnewswire.com/news-releases/global-space-situational-awareness-ssa-industry-301179623.html
[127] Robert S. Wilson, "Japan's Gradual Shift Toward Space Security," The Aerospace Corporation, May 2020, https://aerospace.org/sites/default/files/2020-05/Wilson_JapansGradualShift_20200428_0.pdf

and share orbit information.[128] Japan and the United States have had an agreement to share SSA data since 2013, and the two countries have participated in multiple joint SSA workshops and security exercises.[129] The U.S. military plans to launch SDA payloads on the next generation of Japanese QZSS navigation satellites in 2023, which will be the first time a foreign country has launched hosted payloads for U.S. national security missions.[130]

New Zealand

New Zealand has announced plans to build a radar antenna for the LeoLabs Collision Avoidance system, which focuses on small objects in LEO that are 2 cm or larger. The company has called this move the "future of commercial SSA," and has joined the government in an Innovative Partnerships programme aimed to enhance New Zealand's space contributions.[131] In another partnership with LeoLabs, the New Zealand Space Agency has contributed to the development of the Space Regulatory and Sustainability Platform, a tool which helps the country oversee its space activities.[132] The tool tracks objects launched from the country and alerts the space agency if a satellite is a collision risk with another object or has travelled outside its planned path.[133] Additionally, New Zealand has enforced a regulatory act ensuring that before a payload can be cleared for launch from the country the company has met certain standards, including that the "satellites operate in a manner that avoids collision risk and minimizes orbital debris."[134] It does not seem that the country has any public SSA systems in place independently from LeoLabs or with any other partners, though the University of Auckland is conducting research in this area.[135]

Peru

As previously mentioned, Peru is part of the Chinese-led APOSOS network. In May of 2020, Peru and the United States also entered into a data sharing agreement focused on SSA data to be executed between the Peruvian Space Agency and the U.S. Space Force's 18th Space Control Squadron.[136] Peru is also home to the Jicamarca Radio Observatory, a leading facility for studying the equatorial ionosphere and the effects of space weather.[137]

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[128] "Space Situational Awareness Workshop: Perspectives on the Future Directions for Korea," International Symposium on Ensuring Stable Use of Outer Space, January 24-25, 2019, https://swfound.org/media/206349/susumu-yoshitomi-ssa-workshop-in-seoul-20190124.pdf
[129] "The First Meeting of the Japan-U.S. Comprehensive Dialogue on Space," March 11, 2013, https://www.mofa.go.jp/files/000001829.pdf
[130] Ibid.
[131] "New Zealand to host LeoLabs phased array radar for commercial SSA," https://spacewatch.global/2018/10/new-zealand-to-host-leolabs-phased-array-radar-for-commercial-ssa/
[132] "Implementation of the Guidelines for the Long-term Sustainability (LTS) of Outer Space Activities of the Committee on the Peaceful Uses of Outer Space," UNOOSA, March 15, 2021, https://unoosa.org/documents/pdf/PromotingSpaceSustainability/PresentationsCaseStudies/CaseStudies/Event3_Regulators/New_Zealand_Case_Study.pdf
[133] "NZ Space Agency launches new tool to track satellites, combat space debris," 1 news, June 25, 2019, https://www.tvnz.co.nz/one-news/new-zealand/nz-space-agency-launches-new-tool-track-satellites-combat-debris
[134] Implementation of the Guidelines for the Long-term Sustainability (LTS) of Outer Space Activities of the Committee on the Peaceful Uses of Outer Space.
[135] "Spacecraft microvibrations and stable structures," The University of Auckland, https://space.auckland.ac.nz/research/
[136] Sandra Erwin, "U.S. Space Command signs space data sharing agreement with Peru," SpaceNews, May 20, 2020, https://spacenews.com/u-s-space-command-signs-space-data-sharing-agreement-with-peru/
[137] "Jicamarca Radio Observatory," http://jro.igp.gob.pe/english/

Poland

In late 2018, the Polish Space Agency signed an agreement to join the EU's SST Consortium, and the country will contribute a network of telescopes and establish a national operational center.[138] In April 2019, the Polish Space Agency signed an agreement with U.S. Strategic Command to share SSA services and data.[139] The formation and eventual operation of the domestic network is a top priority for the country's National Space Program.[140]

Russia

The former Soviet Union had a highly capable space and missile tracking network. The sensors that composed this network were spread across former Soviet satellite states, and thus Russia was not able to keep all of the assets after the Soviet Union's dissolution. Russia currently has a small network of facilities around the country that double as missile warning radars.[141] Russia also has its own domestic network, called the Russian Military Space Surveillance Network or Main Centre for Reconnaissance of Situation in Space (SKKP). The SKKP maintains a Russian catalogue of objects in space, and is used to help support Russian launches, ASAT programs, and intelligence collection. The data in the catalogue comes from a system of domestic radar stations.[142] Russia also leads the International Scientific Optical Network (ISON), a network which includes 33 facilities and 60 telescopes in 14 countries (including the United States) aimed at tracking and learning more about space debris in GEO. ISON is managed by the Russian Academy of Sciences.[143]

South Africa

South Africa is home to the South African Large Telescope (SALT), the largest single optical telescope in the southern hemisphere situated at the South African Astronomical Observatory. The telescope has been fully operational since 2011 and is funded by South Africa, the U.S., India, Poland, and the UK. The South African National Space Agency (SANSA) constructed an Optical Space Research Laboratory in 2016 with a main focus on space weather research. Additionally, SANSA partnered with Germany's DLR to create a debris tracking station at the laboratory. This debris tracking station would be part of the global SMARTnet, a network of small robotic telescopes used to track orbital regimes in GEO and MEO to help build ESA's catalogue.[144]

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[138] "Poland has joined the Space Surveillance and tracking (SST) Consortium established to track space debris," Polish Space Agency, https://polsa.gov.pl/en/events/events/15-latest/943-poland-has-joined-the-space-surveillance-and-tracking-sst-consortium-established-to-track-space-debris

[139] "USSTRATCOM, Polish Space Agency sign agreement to share space services and data," U.S. Strategic Command Public Affairs, April 11, 2019 https://www.afspc.af.mil/News/Article-Display/Article/1815260/usstratcom-polish-space-agency-sign-agreement-to-share-space-services-and-data/

[140] "POLSA and the US sign an agreement on the exchange of space situational awareness data," Science in Poland, https://scienceinpoland.pap.pl/en/news/news%2C33738%2Cpolsa-and-us-sign-agreement-exchange-space-situational-awareness-data.html

[141] "Russian Space Surveillance System (RSSS), GlobalSecurity.org, https://www.globalsecurity.org/space/world/russia/space-surveillance.htm

[142] V. Dicky et all, "The Russian space surveillance system and some aspects of spaceflight safety," ScienceDirect, 1993, https://www.sciencedirect.com/science/article/abs/pii/027311779390564R?via%3Dihub

[143] "International Scientific Optical Network activities on highly elliptical orbit, geosynchronous orbit and Near-Earth objects observation and analysis in 2013,: Russian Academy of Science, February 10-21, 2014, http://unoosa.org/pdf/pres/stsc2014/tech-26E.pdf

[144] "Projects and Partnerships," SANSA, https://www.sansa.org.za/projects-partnerships/ "Zimmerwald Small Aperture Robotic Telescope" The European Space Agency, June 5, 2010, https://www.esa.int/ESA_Multimedia/Images/2010/05/Zimmerwald_SMall_Aperture_Robotic_Telescope_ZimSMART

South Korea

The South Korean Defense Ministry and the U.S. Department of Defense have had an SSA data sharing agreement in place since 2014. As part of this agreement, the South Korean Ministry of Defense agreed to provide satellite position and radio-frequency information to U.S. Strategic Command.[145] Additionally, the Korean Astronomy and Space Institute (KASI) has multiple ongoing SSA projects, which includes the detection, tracking, identification, and cataloging of space objects.[146] KASI is involved in the operation of the South Korean component of the Optical Wide-field patroL Network (OWL-Net), a system of autonomous telescopes in South Korea, Israel, Mongolia, Morocco, and the United States.[147] KASI is also involved in initial research aimed at building a radar surveillance system.

Thailand

The Royal Thailand Air Force signed an agreement with U.S. Strategic Command in late 2018 to share SSA data.[148] The following year an agreement was signed with Japan's National Institute of Information and Communications Technology to work on space weather monitoring and forecasting in Thailand.[149] 2019 also saw the stand up of the Thai Air Force's Space Operation Centre (Spoc), an effort to improve the country's space security. SSA is one of the stated main missions of the Spoc, as it has ground-based sensors installed at two space surveillance stations in the country.[150] In 2018 the country announced a proposal to build an indigenous SSA satellite, but there is no public record that this proposal was approved.[151]

Overall Findings for Foreign SSA Capabilities

In the next decade, more foreign governments will continue to invest in SSA capabilities—including data collection, data sharing, SSA analysis and services, and commercial partnerships. As they have already done, large multinational agreements on SSA data sharing will likely continue to be led by the three main space powers, the United States, Russia, and China. These three countries have strong existing ties with other space faring nations and have already begun expanding data sharing agreements with new space actors, some of which overlap.

Commercial companies are likely to continue making and expanding agreements with foreign governments, similar to LeoLabs with the New Zealand government and Lockheed Martin with the Australian government. Commercial companies will need approval to operate more land-based monitoring equipment, specifically space radars in the southern hemisphere, and can offer high-tech jobs and access to data that some countries may not be able to attain otherwise.

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[145] "DoD Agrees to Share Space Data with South Korea," U.S. Strategic Command, September 5, 2014, https://www.stratcom.mil/Media/News/News-Article-View/Article/983783/dod-agrees-to-share-space-data-with-south-korea/

[146] "Space surveillance technology overview," Korea Astronomy and Space Science Institute, https://www.kasi.re.kr/eng/pageView/322

[147] "OWL-Net development," Korea Astronomy and Space Science Institute, https://www.kasi.re.kr/eng/pageView/325

[148] "USSTRATCOM, Thailand sign agreement to share space services, data," U.S. Strategic Command, October 11, 2019, https://www.stratcom.mil/Media/News/News-Article-View/Article/1659776/usstratcom-thailand-sign-agreement-to-share-space-services-data/

[149] "Signed MoU with Thai space agency 'GISTDA'" https://www.nict.go.jp/en/global/lde9n2000000bbjo-att/Sec4E-01_20191129_MOUwithGISTDA.pdf

[150] Wassana Nanuam, "New air force satellite 'aims to prevent foreign spying," Bangkokpost, June 16, 2020, https://www.bangkokpost.com/thailand/general/1935908/new-air-force-satellite-aims-to-prevent-foreign-spying

[151] "Thailand to build its own space situational awareness satellite," spacewatch.global, https://spacewatch.global/2018/02/thailand-build-space-situational-awareness-satellite/

Other countries use SSA data to protect their space assets, in civil, commercial, and military operations. In recent decades, space capabilities have rapidly grown from being a nearly impossible barrier to entry for small nations to an increasingly common component of national infrastructure. As foreign governments continue to rely more heavily on the safety and security of their space assets, SSA data, tracking, and space weather monitoring capabilities will become further ingrained as a national security priority.

Through interviews with commercial SSA companies, governments are driving a more international SSA market. Foreign commercial companies have indicated that governments prefer to support and rely on indigenous technology, and this factor might be driving the creation of smaller SSA companies with niche capabilities to serve the smaller government markets.

Conclusion

The SSA landscape has changed rapidly over the last decade and will likely continue to evolve significantly in the decade to come. While initially dominated by the free data and collision warning services provided by the U.S. military, commercial companies and foreign governments have increasingly taken a larger role in SSA. As the number of space actors and objects in space continues to increase, so will the demand for better SSA capabilities and a variety of data sources. Government and military agencies have created a valuable base for commercial companies to build upon, and as more countries and private companies build out their SSA capabilities, space is becoming more transparent for all users. While this is a positive development for safety of flight and maintaining the space environment, it also means that governments can no longer control the flow of information about where space objects are and how they operate in orbit. The next 10 years will likely see further improvement in the accuracy and timeliness of SSA services, including in how small an object can be detected and how frequently the location of objects in space can be monitored and updated.

Successful commercial companies that have created catalogues to rival government archives are doing so by triangulating observations from networks of many smaller telescopes and radar sites instead of relying on a handful of powerful telescopes. Commercial companies are able to automate and decrease the costs of operating these broad networks, and they can form partnerships and deploy innovative new technologies at a rapid pace. These fast innovation cycle timelines suggest that commercial SSA operators may be able to understand gaps in SSA capabilities and services and address them at a rate faster than bureaucratic governments can move.

There are also proposals to make SSA easier for commercial satellite operators by requiring satellites to install radio-frequency identification (RFID) tags for easier identification. Optical beacons on satellites can also be used to identify objects in orbit and integrate their orbital data into existing SSA databases. However, the systems that make SSA easier for all are arguably a public good, and private companies may not be willing to bear the additional cost and design complexity (however minor) for something that benefits everyone else - especially if others are not willing to do the same. And the smaller companies that sell these devices may have difficulty getting off the ground without support from large operators or major government organizations.

Accelerating commercial innovation and an increase in international interest into tracking capabilities underscore the vital need for reliable SSA data. With an increase in operators launching more assets into space, governments and private entities rely on SSA data to protect critical infrastructure in the space domain. The investment from an increasing number of nations and private companies involved in SSA has seen a direct impact on the ability to track smaller objects with more accuracy, decrease the size of sensors needed to make observations, and maintain a safe and predictable space domain.