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Towards a European Approach to Space Traffic Management

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1 Introduction

1.1 Background

The intensification of space activities worldwide and the emergence of new actors (including new space faring nations and commercial companies) and new concepts (e.g. large constellations, CubeSats and miniaturized systems, on-orbit satellite servicing, etc.) are raising new challenges to ensure the security, safety, sustainability and stability of space activities. Among policy responses to these challenges, the development of Space Traffic Management (STM) frameworks was recently brought to the forefront with the adoption of a policy in this domain by the United States.

The U.S. Space Policy Directive-3 (National Space Traffic Management Policy), issued on June 18th 2018, defines the principles, goals, roles and responsibilities as well as guidelines to be followed for the establishment of a new U.S. approach to STM that addresses the current and future operational risks of an increasingly congested and contested space environment.[1] This policy, which is part of an all-round strategy to support U.S. leadership in space, ultimately aims to protect U.S. continued unfettered access to and freedom to operate in space. It outlines, accordingly, a set of goals including, *inter alia*:

- to advance Space Situational Awareness (SSA) technology, improve SSA data interoperability and enable greater SSA data sharing;
- to provide basic SSA data and STM services to the public and encourage U.S. commercial leadership in STM-related technologies, goods, data, and services;
- to develop standards and best practices to encourage safe and responsible behaviour in space and promote them across the international community;
- to improve U.S. domestic space object registry and develop policies and regulations for future U.S. orbital operations.

The policy also provides rather detailed guidelines to be followed in pursuit of these goals and articulates the roles of military and civil branches by clarifying the sharing of responsibility between the U.S. Department of Defense and Department of Commerce.

A comparable STM policy has not yet been developed in Europe.

The question of the relevance of a European approach to STM is however gaining traction among public and private stakeholders, triggered by the adoption of the U.S. policy and stimulated by the ever more prominent place granted to space security in the European space policy agenda. In the proposal for a regulation establishing the space programme of the Union, the European Commission declares, "The increase in space activities may have implication on the international initiatives in the area of the Space Traffic Management. The Union should monitor those developments and may take them into consideration in the context of the mid-term review of the current multiannual financial framework."[2] So far, several public and private stakeholders initiated, separately, different STM-related actions but the overall European effort in this domain remains rather limited and not coordinated.

ESPI briefly elaborated on the implications of the U.S. STM policy for Europe in a previous report on transatlantic relations in space security.[3] The report argues that, although national, this policy could have major direct and indirect consequences for future space activities (e.g. operations, markets, industry,

1 White House (2018). Space Policy Directive-3 National Space Traffic Management Policy. June 18, 2018
2 European Commission (2018) Proposal for a REGULATION OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL establishing the space programme of the Union and the European Union Agency for the Space Programme and repealing Regulations (EU) No 912/2010, (EU) No 1285/2013, (EU) No 377/2014 and Decision 541/2014/EU.
3 ESPI (2018). Security in Outer Space: Perspectives on Transatlantic Relations. ESPI Report 66.

programmes), even beyond U.S. borders. In this context, Europe is faced with new challenges to protect its capacity to autonomously and safely deploy and operate systems in orbit but also to safeguard the competitiveness of its industry on international markets and to maintain a prominent role on the global space scene. The U.S. policy does not necessarily challenge the relevance of multilateral efforts and actually opens the door to the development of multiple national and regional STM frameworks in parallel to international discussions. Considering that the globalization and intensification of space activity will likely make an STM framework necessary in the future, the report suggests that Europe should prepare its own approach to STM, coherent with its own vision, objectives, principles and needs (yet to be defined) and consistent with its contributions to international endeavours.

1.2 Research objectives

As a follow-up of previous ESPI research on space security, this study aims to investigate more thoroughly the whys and wherefores of a European approach to STM and to provide an independent perspective on this matter. More specifically, the study aims to:

- Look into available definitions of Space Traffic Management and contribute to a common understanding among European stakeholders of concepts and issues at stake;
- Examine imperatives for Europe related to STM and assess the relevance and added-value of a European engagement in this domain;
- Provide an overview of the current state of affairs in Europe and identify existing frameworks, activities and initiatives directly or indirectly related to STM;
- Investigate and discuss key elements and principles to be considered for the development of a European approach to STM.

For the purpose of this research, the concept of "European approach" is understood as the set of measures that could be taken by different European stakeholders in the domain of STM including Member States, European institutions (ESA, EUMETSAT…), the European Union and its agencies, private industry and any other relevant European organization. The arrangement of this "European approach" and the level of coordination between its different components is discussed in this report as an element for consideration among others. This study focuses on high-level policy concerns related to STM and does not attempt to address legal and technical aspects related to the provision of STM data or services.

2 What is Space Traffic Management?

2.1 Different actors, different views

The concept of Space Traffic Management, although intensely discussed in multiple instances, has not yet been given a clear, precise and broadly agreed definition. Various stakeholders proposed a definition of STM according to their own approach of issues at stake and understanding of priorities to be set. Therefore, there is still no consensus on the concept and its boundaries. Some authoritative definitions tend, however, to prevail.

The International Academy of Astronautics (IAA), a non-governmental organization bringing together esteemed experts in different space-related domains, proposed a definition for STM as part of the two Cosmic Studies on Space Traffic Management that the Academy published in 2007 and 2018. According to the IAA, Space Traffic Management can be defined as:

"Space Traffic Management means 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."[4]

This definition introduces a relatively wide scope and suggests that STM encompasses a rather broad range of activities addressing an even broader spectrum of concerns in all phases of spaceflight (development, launch, operations, end-of-lie, atmospheric re-entry). The Academy clarifies that the purpose of STM "is to provide appropriate means for conducting space activities without harmful interference [in support of] the universal freedom to use outer space as laid down in the Outer Space Treaty of 1967." and stresses that "for the purpose of achieving a common good, actors have to follow specific rules, which are also in their self-interest."[5]

Another essential definition is the one provided in the preamble of the U.S. National STM Policy:

"Space Traffic Management shall mean the planning, coordination, and on-orbit synchronization of activities to enhance the safety, stability, and sustainability of operations in the space environment."

The U.S. policy definition enlarges the purpose of STM to the enhancement of safety, stability, and sustainability of operations

IAA studies on STM

A group of international experts gathered in the framework of the International Academy of Astronautics to develop a reference document dealing with the concept of STM, first in 2006 and later on in 2018.

The 2006 study titled "Cosmic Study on Space Traffic Management" provides a conceptual approach to the issue and goes in detail to discuss numerous interrelated considerations associated with it. The 2018 study titled "Space Traffic Management - Towards a Roadmap for Implementation" revisits and adjust the concept to the latest developments in space activities to provide an inter-disciplinary context. In line with the title, it discusses the roadmap of implementation of an international regulatory STM framework and looks into both top-down and bottom-up approaches.

The 2018 study concludes that STM could provide for a systematic and coordinated approach and be a powerful tool to safeguard the continued use of outer space free from harmful or unwanted interference, for the benefit of the broader community.

4 International Academy of Astronautics (2018). Space Traffic Management - Towards a Roadmap for Implementation. Editors: Kai-Uwe Schrogl, Corinne Jorgenson, Jana Robinson, Alexander Soucek.
5 Ibid.

in space but narrows down its scope to more operational aspects of space activities. With this definition the U.S. policy also underlines the importance of a better coordination among actors operating in space. By focusing on shared operational issues, this definition also allows to reconcile the concerns of military/civil and public/private actors.

Beyond these two authoritative definitions, many organisations and experts shared their own interpretation of the concept along the years, reflecting a multitude of views on STM.

The former chief of the Space Services Department it the International Telecommunications Union (ITU), Yvon Henri, provided the following definition of Space Traffic Management in 2015:

"Space Traffic Management provides an approach to enter into, operate in and return from space, safe from any interference."[6]

The definition provided by William Ailor, Aerospace Corporation, underlines more specifically the organizational aspect of a process aiming to safeguard the long-term use of space:

"[Space Traffic Management is] an organized process that assures the long-term use of space and space assets without harmful interference."[7]

Recent years have actually been marked by a trend toward more technical, explicit and operation-oriented definitions. For example, Glenn Peterson et al. provided a very specific interpretation of what STM could be about during a presentation at the 69th International Astronautical Congress, focusing on the role of STM to limit the risk of collision between space systems:

"[What is crucial for Space Traffic Management is] a collision avoidance (COLA) process that identifies high probability of collision (Pc) conjunctions and delivers conjunction data messages (CDMs) to a customer."[8]

On the contrary, Ruth Stillwell of the George Washington University Space Policy Institute, describes Space Traffic Management from a more functional perspective stressing the concepts of "control", "authority" and "responsibility":

"[Space Traffic Management is] the control of the orbital environment by an appropriate authority responsible for the prevention of collisions between operational satellites and natural or manmade objects."[9]

Beyond these overarching definitions, experts also share different perspectives (often overlapping) on the various aspects related to STM including constituting elements, building blocks, functions and probably more importantly, objectives and purpose.

With regards to STM core components and functions, Nicolas Johnson from NASA's Johnson Space Center explained, already in 2004, that:

"[Space Traffic Management] shall comprise four areas: the securing of the information needs; a notification system; concrete traffic rules and mechanism for implementation; and lastly control." [10]

6 Henri, Y. (2015). Frequency Management and Space Traffic Management. Technical Presentation at the 2015 UN COPUOS Legal Subcommittee.
7 Ailor, W. (2015). Space Traffic Management. In Schrogl, K.-U. et al. (eds) (2015). Handbook of Space Security. New York : Springer
8 Peterson, G. et al. (2018). Tracking Requirements for Space Traffic Management in the Presence of Proposed Large LEO Constellations. Aerospace Corporation. Presentation at the 69th International Astronautical Congress
9 Stilwell, R. (2019). Decentralized Space Traffic Management.
10 Johnson, N. (2004). Space traffic management concepts and practices. In Acta Astronautica, Vol. 55, Issue. 3-9 [SPECIAL ISSUE], pp. 803-809, DOI 10.1016/j.actaastro.2004.05.055

Along comparable lines, George Kyriakopoulos from the National and Kapodistrian University of Athens, argues that:

"[Space Traffic Management] is grouped into three basic functions: situational awareness, traffic regulation and enforcement, and traffic control. These functions can be performed at launch, on-orbit, and upon re-entry. The main feature, and the basic need for Space Traffic Management at present, is to avoid collisions in orbit [...] Space Traffic Management is the principal tool to achieve this avoidance." [11]

In his remarks at the 2017 AMOS Conference, Uwe Wirt from the German Aerospace Center (DLR) explains that:

"a top-level issue for Space Traffic Management is licensing, allocation, notification, monitoring and coordination of all the services and functions, which are related to maintaining access to space in the future." [12]

Experts also share different perspectives on the specific goals and objectives of STM. William Ailor continues by stating that STM should include policies, regulations, services, and information that:[13]

- Minimize the possibility of short- and long-term collisions, radio frequency, or other interference among orbiting objects, both operating satellites and debris
- Assure compliance with rules and regulations imposed by governments and with best practices adopted by launch and satellite operators
- Minimize interference with and by non-satellite operations such as ground-based telescopes and directed energy sources
- Provide warnings to minimize possibilities of loss of operations or other detrimental effects resulting from space weather and other predictable events.

Other experts define the goal of STM in the following manner:

- Peterson et al.: "The goal for STM system is for dangerous conjunctions to be identified." [14]
- Wirt, U: "[The objective of STM is] to ensure safe and efficient operations of space infrastructure."[15]
- Oltrogge, D: "The primary STM goal is to provide decision-quality results to characterize collision risk and to coordinate and synchronize actionable collision avoidance manoeuvre planning execution."[16]
- Blount: "The goal of STM is to use technical and legal mechanisms to reduce the likelihood of incidents, such as collisions in Earth orbit."[17]

11 Kyriakopoulous, G. (2017). Space Traffic Management as a sine qua non prerequisite for the sustainability of outer space activities: Evaluating Regulatory Patterns Provided by the Airspace Paradigm. Presentation at the 2017 IACO-UNOOSA Workshop.
12 Uwe Wirt speech at the SSA Policy Forum Day 3 of the 2017 AMOS Conference - International Perspectives on the Future of Space Traffic Management, Retrieved from
13 Ailor, W. (2015). Space Traffic Management. In Schrogl, K.-U. et al. (eds) (2015). Handbook of Space Security. New York : Springer
14 Peterson, G. et al. (2018). Tracking Requirements for Space Traffic Management in the Presence of Proposed Large LEO Constellations. Aerospace Corporation. Presentation at the 2018 International Astronautical Congress.
15 Uwe Wirt speech at the SSA Policy Forum Day 3 of the 2017 AMOS Conference - International Perspectives on the Future of Space Traffic Management.
16 Oltrogge, D. and Cooper, J. (2018). Practical considerations and a realistic framework for a space traffic management system. Conference Paper submitted to the AIAC18: 18th Australian International Aerospace Congress
17 Blount, P.J. (2019). Space Traffic Management: Standardizing On-Orbit Behavior. Symposium on the New Space Race.

2.2 Key concepts and proposed models

2.2.1 Commonalities between definitions

There are probably as many definitions of STM as there are organizations and experts addressing the concept. A few of these definitions stand out as more frequently used as academic reference (e.g. IAA definition) or more highly considered because of their official standing (e.g. U.S. SPD-3 definition). Nonetheless, there is no international consensus today on a characterization and delimitation of STM, leaving significant margin to adapt the concept to the various views and needs of different organizations.

This collection of available definitions allows, however, to identify a number of commonalities and points of convergence between them, in particular for what concerns the objective, the scope and key components of STM:

Objectives

- STM aims to enhance the safety of on-orbit operations by reducing the risk of collisions and interferences.
- STM aims to ensure long-term sustainability of space activities by mitigating negative effects on the space environement.
- STM aims to address issues related to the globalisation, intensification and diversification of space activities and to an ever-more congested space environement.

Scope

- STM addresses operational risks of physical (collisions, breakups) and radiofrequency (interferences) nature. *Current STM discussions mostly focus on physical risks since spectrum management issues are addressed in the ITU framework.*
- STM applies to various phases of the space system lifecycle (design, production, launch, deployment, operations, disposal). *Current STM discussions mostly focus on the exploitation phase as the core area of concern.*

Components

- STM encompasses both organisational structures and operational functions.
- STM requires advanced capabilities (systems, data, services, technologies) to support safe and sustainable operations.
- STM implies the definition, enforcement and verification of technical and regulatory provisions (laws, regulations, standards, best practices).
- STM entails an enhanced coordination (decision-making, information-sharing) among different actors (governmental, commercial, international).

Figure 1: Commonalities among existing STM definitions and main STM features

2.2.2 Main points of disagreement

While stakeholders and experts tend to converge on a number of points regarding "WHAT" Space Traffic Management is, they may however disagree on "HOW" Space Traffic Management should be developed and implemented, in particular with regards to the following interrelated elements:

- Regulatory constraints: A key point of discussion and of potential disagreement among stakeholders concerns the nature, scope and strictness of regulatory provisions associated to STM. Today, most stakeholders would agree on the limits of a self-regulation approach. Indeed, it seems unlikely that the safety and sustainability objectives can be achieved without some level of common constraints, or at least incentives. Nevertheless, the definition of additional regulatory provisions is obviously a sensitive part of STM. For instance, the publication of the U.S. STM policy already gave rise to many initiatives from various organisations eager to proactively suggest guidelines for an appropriate approach to the regulatory question.

- Enforcement and verification: Setting up enforcement and verification mechanisms is also highly controversial among stakeholders. Beyond the simple acceptation of the principle, this could be envisioned through the integration of additional provisions to existing regulatory regimes as suggested in the U.S. STM policy (leading to an extension of responsibilities for selected agencies), through the creation of a new regime (possibly dedicated to STM), or through other means.
- International dimension: Most would agree that a fully effective approach to STM can only be envisioned as the outcome of a coherent, coordinated and inclusive effort of all actors. However, stakeholders do not converge on the relevance and role to be played by international frameworks in the development and/or supervision of STM. Views may also diverge on the suitability of multilateral or bilateral setups. A key concern is the capability to converge internationally at the right pace on what has become an urgent and pressing matter.
- Roles and responsibility sharing: The inclusive dimension of STM raises the question of the delineation and distribution of responsibilities among various players including civil/military and public/private organisations. Although these actors share common interests in preserving a safe and sustainable space operational environment, they do not necessarily agree on the requirements, needs and objectives. STM also encompasses a number of sensitive functions such as the collection, processing and distribution of SSA data which makes it obviously difficult to reach consensus on appropriate arrangements.

The above is not meant to be a comprehensive list of potential points of divergence among stakeholders. As the space community is moving forward in the reflection over the establishment of a Space Traffic Management framework, at a different pace and potentially in different directions, any progress made will certainly reveal new issues and critical arbitrations to be made.

2.2.3 Proposed models

Space Traffic Management is therefore an organisational and operational concept that involves a set of complementary means and measures to enhance the safety of on-orbit operations and to safeguard the long-term sustainability of the space operating environment.

Building on identified points of convergence between stakeholders and leaving aside unsettled disputes, it appears that Space Traffic Management entails three core functions:

- Space Traffic Monitoring: Detection, identification, tracking and cataloguing of active and inactive objects constituting space traffic with the objective to provide necessary data and services to ensure the safety of space operations, from launch to re-entry.
- Space Traffic Regulation: Definition, enforcement and verification of technical and regulatory provisions encouraging <u>or</u> compelling actors to conduct their activities in ways that are not detrimental to the safety and long-term sustainability of the space operating environment.
- Space Traffic Coordination: Means and measures to support, promote <u>or</u> constrain actors to conduct their space activities in a coordinated manner with others by sharing information, synchronising their operations or defining and following common procedures for example.

Space Traffic Management can be represented at the crossroad of these three complementary functions.

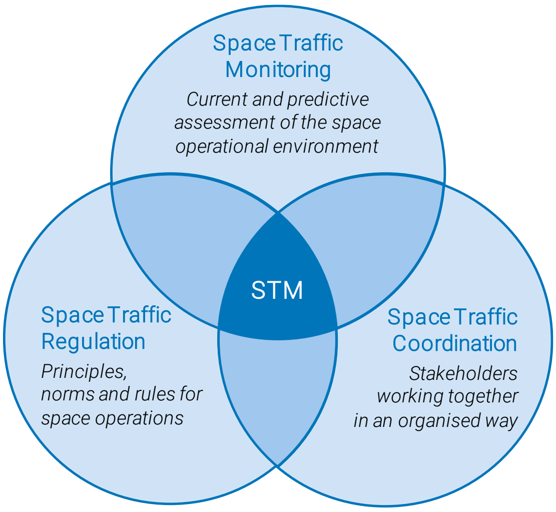


Figure 2: Core functions of Space Traffic Management

To fulfil these functions, any approach to Space Traffic Management must address three main elements:

- STM policy and framework, establishing the objectives, principles and organised distribution of tasks and responsibilities among stakeholders. An STM policy and framework may address, for example:
  - Policy objectives and directives
  - Key principles and guidelines for its implementation
  - Decision-making framework and delineation of roles and responsibilities
  - Cooperation arrangements and agreements
- STM capabilities, including the necessary infrastructure, systems, technologies, data, services, models and expertise. STM capabilities may include, for example:
  - Space Surveillance and Tracking systems and databases
  - Collision Avoidance and Re-entry Analysis services
  - Autonomous Collision Avoidance and Active Debris Removal technologies
  - Systems or platforms supporting space traffic coordination
  - Tracking enhancement devices on-board spacecraft
- STM regime, defining a set of rules, norms, guidelines and other relevant specifications. An STM regime may include, for example:
  - Rules for satellite and mission design
  - Standards for space data messages
  - Legal provisions and licensing regulations
  - International code and guidelines

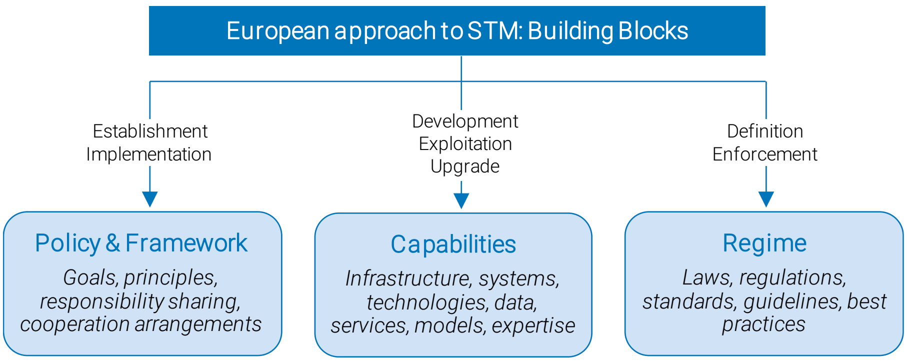


Figure 3: Core components of an approach to Space Traffic Management

2.3 Space Traffic Management already exists

Space Traffic Management is not a new concept. As a matter of fact, space actors already monitor, regulate and coordinate space activities to some extent. With regards to the Space Traffic Monitoring function for example, most governments with advanced space capabilities are already equipped with Space Surveillance and Tracking (SST) or Space Situational Awareness (SSA) programmes. The U.S. Department of Defense operates the most advanced and capable system through its Space Surveillance Network (SSN) of ground and space radars and telescopes. Other states such as Russia, China, Japan, India and European countries also developed space monitoring programmes. SST/SSA are usually addressed as a strategic function, under military control with the support of space agencies and research institutions. Some companies operating private SST/SSA systems and providing commercial data and services on a commercial basis are also emerging.

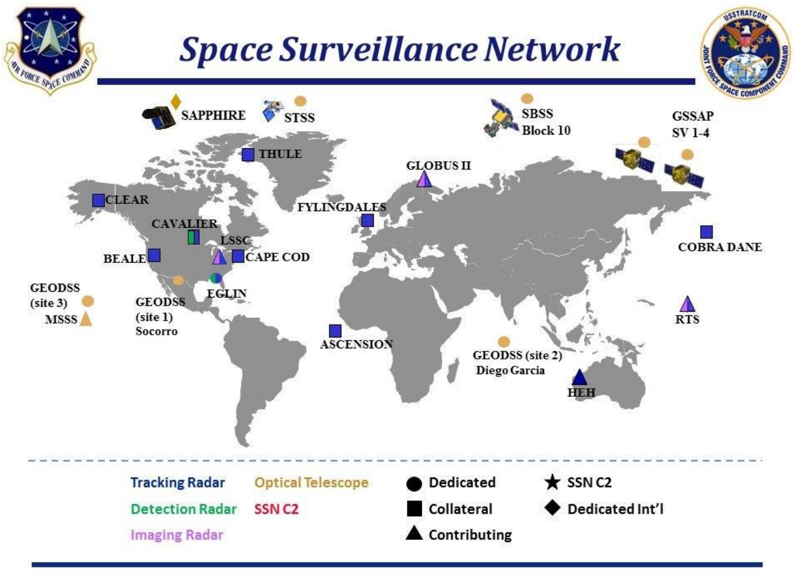


Figure 4: U.S. Space Surveillance Network

There are also multiple activities falling into the Space Traffic Regulation function. Indeed, space operations have long been regulated by states eager to delineate what could be done and how. As a result, space activities are already governed by international treaties, national laws and regulations, industrial standards, commercial licensing and other binding and non-binding provisions. A share of these provisions directly or indirectly addresses space traffic regulation. Some examples include the International Telecommunication Union framework that allocates global radio spectrum and satellite orbits, the ISO 24113 standard on space debris mitigation, the recently approved UN Guidelines or national laws such as the French Space Operations Act that set the conditions and restrictions for licenses authorizing to conduct launch and operate in space.

There are also various endeavours in the domain of Space Traffic Coordination, in particular to promote information sharing. These efforts involve, for example, bilateral and multilateral SSA data sharing agreements, industry-led platforms, such as the one of the Space Data Association for exchange of orbital data and activity, open-source availability of information (e.g. publication of space object ephemerides by some operators) or international registries of space objects within the ITU or UN.

In a way, space traffic management already exists. The U.S. national STM policy actually calls to "develop a new approach to Space Traffic Management that addresses current and future operational risks." The challenge is therefore to develop a BETTER approach to Space Traffic Management, notably by advancing each function to meet new needs and by ensuring consistency across these functions as part of a more integrated and operational approach.

3 A GROWING NEED FOR BETTER SPACE TRAFFIC MANAGEMENT

3.1 Challenges to the security, safety and sustainability of space activities

Although often perceived as slow paced and resistant to change, the space sector is actually fast-changing, both at industry and policy level. Shaped by 60 years of major changes on the geopolitical, technological and commercial scenes, space grew to become, not only a decisive item on governments' agenda, but also a domain of interest for private companies, entrepreneurs and investors. In this sense, "New Space", which is usually presented as a sudden change of paradigm, shaking the foundations of a long-established and rigid industry, can rather be seen as a natural step in the evolution (maturation) of a budding sector.

Notwithstanding, the rise of new actors and innovative ways of conducting space activities that can be witnessed currently is undeniably opening new, sometimes unforeseen, prospects for the sector. These opportunities trigger, in turn, the emergence of new challenges for the sector at large. Challenges that have not always been well anticipated in policies, regimes and frameworks currently in place. A top transverse issue in this new space era is, and will increasingly be, to continue ensuring the security, safety and sustainability of space activities and to safeguard our very capacity to deploy and operate systems in space. Indeed, space systems are exposed to an increasing level of "man-made" threats in addition to a naturally hazardous space environment (e.g. geomagnetic storms, solar radiations…). This includes both unintentional hazards stemming from human activity (e.g. debris, interferences…) and capacities to deliberately disrupt space systems or services (e.g. anti-satellite technologies, signal jamming, cyberattacks…).

In a previous report on the rising stakes for Europe in the field of space security, ESPI investigated these space security threats and described them as:[18]

- Multiple and diverse in nature and origin and, as a consequence, requiring a set of different mitigation and protection measures;
- Interrelated and therefore requiring a coherent and holistic approach adhered to by all space stakeholders;
- Ubiquitous and inclusive, although some systems are less exposed or vulnerable to specific threats;
- Intensifying, driven by endogenous and exogenous trends including:
  - A growing space activity in terms of the number of launches and objects in orbit;
  - An increasing number and diversity of governmental and commercial actors owning and operating space systems;
  - The emergence of new concepts, technologies and capabilities such as miniaturized systems, mega-constellations, on-orbit services or reusable launchers among many others;
  - A space infrastructure that is more and more connected with other ground networks and systems;
  - An ever-more critical space infrastructure, which makes it a key target for a variety of actors pursuing different objectives;
  - The rehabilitation of a 'space warfare' doctrine and development of 'space control' capabilities.

As summarized in the U.S. National Security Space Strategy already in 2011, "space, a domain that no nation owns but on which all rely, is becoming increasingly congested, contested, and competitive."[19]

18 ESPI (2018). Security in Outer Space: Rising Stakes for Europe. ESPI Report 64.
19 U.S. Department of Defence (2011). National Security Space Strategy.

3.2 Increasing space traffic and risks of collision and interference

Summary: The growing need for better Space Traffic Management arises, first and foremost, from hazards related to an increasingly congested space environment, in particular regarding risks of collision and interference. Various trends are at work here, making the space activity more intensive, diversified and globalized than ever before. As a consequence, the space operating environment is changing, marked by a rapidly growing traffic of active satellites and debris and by the emergence of new concepts such as mega-constellations, CubeSats or on-orbit services.

3.2.1 A skyrocketing space activity: outlook and future trends

The global space activity experienced a massive growth since 2013. More than 470 spacecraft were launched in 2017, 2018 and 2019 while only 110 spacecraft were launched in average per year between 2000 and 2013.

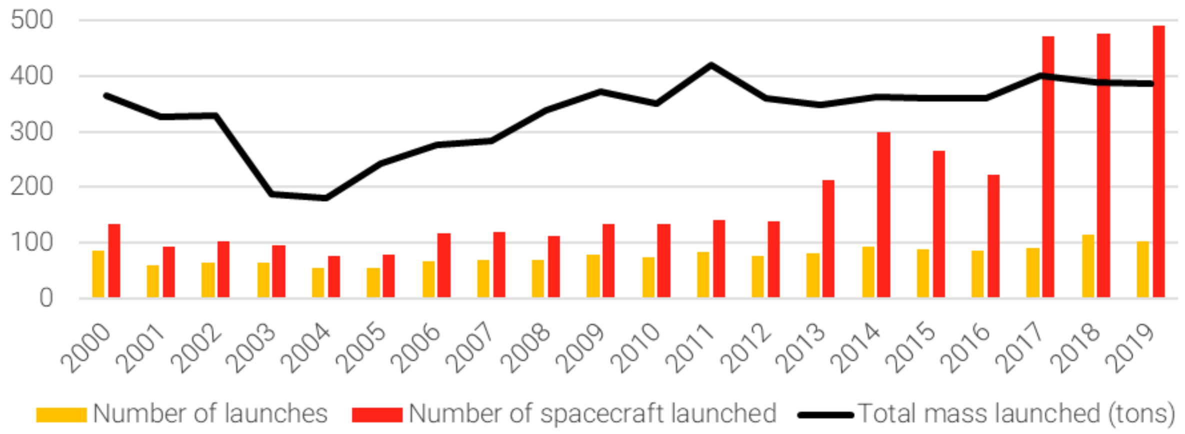


Figure 5: Evolution of the space activity since 2000 (source: ESPI database)

The skyrocketing number of objects launched to space did not necessarily translate into a proportional increase of the number of launches and of the total mass put in orbit. The main reason is that this upsurge concerned mainly very small spacecraft, in particular CubeSats,[20] with a mass below 10kg.

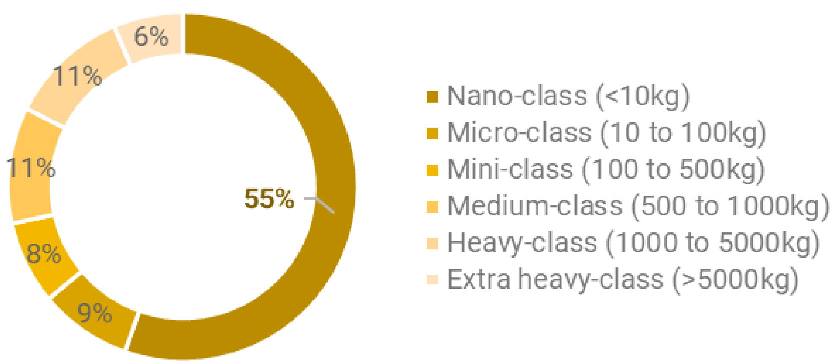


Figure 6: Share of spacecraft launched to orbit in 2017/2018 by mass class (source: ESPI database)

20 Note: Cubesats are a category of spacecraft based on the "cubesat" standard, which has been developed by California Polytechnic State University and Stanford University with the objective to provide an open source architecture to promote and develop the skills necessary for the design, manufacture, and testing of small satellites.

Since the launch of the first CubeSats in 2003, ESPI estimates that more than 1200 of these small spacecrafts were launched for various purposes including mostly educational, commercial and research missions (military and civil).[21] CubeSats correspond to approximately 30% of all objects launched since 2003 but only 0.1% of the total mass put in orbit on the same period. They are more difficult to track because of their small size (10cm per Unit) and generally equipped with a limited capability to manoeuvre in orbit.

A comparable evolution can be observed in Europe where the space activity also experienced a significant growth, this time both in terms of number of launches and spacecraft (i.e. not necessarily launched by European launchers).

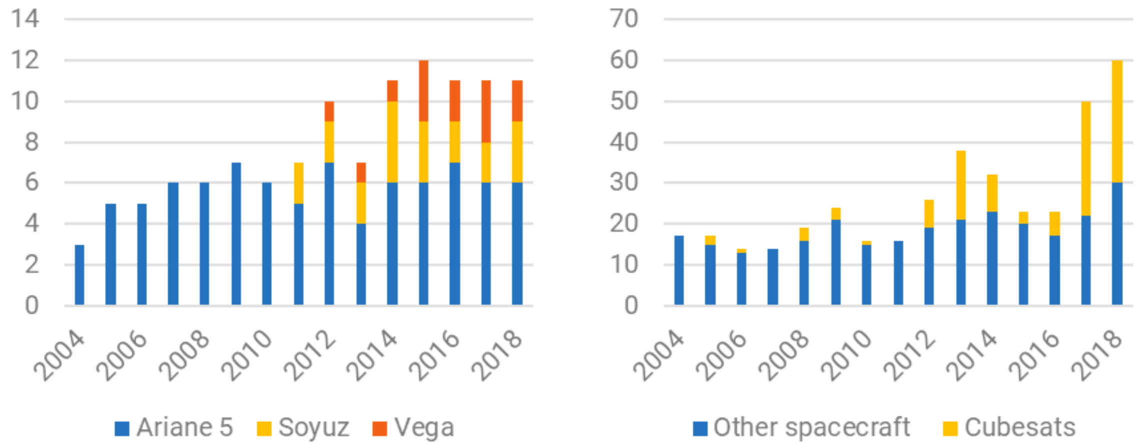


Figure 7: Evolution of the European space activity since 2004 – left, number of launches / right, number of spacecraft (source: ESPI database)

The rise of CubeSats and other miniaturized space systems is obviously not the only trend that has shaped the evolution of the global space activity over the last few years. Other trends such as the entry of new governmental and commercial actors, the noticeable increase of the Chinese space activity and major developments across various space segments (launchers, remote sensing, telecommunication, navigation…), are profoundly impacting the space arena.

The sector is making major steps toward the globalization, diversification and intensification of space activities and this trend is not expected to stop in the near future.

As a matter of fact, the launch of the so-called "mega-constellations", which has been initiated in 2019 with the deployment of 6 satellites of the OneWeb constellation and 120 satellites of the SpaceX's Starlink constellation, is expected to bring the launch activity to another level.

Involving much larger satellites than CubeSat constellations (i.e. Spire, Planet) and unprecedented volumes, the impact of these new commercial endeavours could potentially be enormous, a game-changer if commercially successful.

SpaceX's Starlink planned constellation (4,425 satellites of 260 kg) alone corresponds to the total mass launched to orbit over the last 5 years (Human spaceflight excluded) and to all spacecraft launched since 1992. In 2018, the FCC granted SpaceX with an authorization to launch 7,518 satellites in addition to the initial 4,425 request. OneWeb constellation (648 satellites of 147 kg), although less ambitious, still corresponds roughly to the total mass launched to Low Earth Orbit in 2019 and to twice the number of satellites. Starlink and OneWeb are only two projects among many others.

21 ESPI database, launch data available until 1st January, 2020

Current and planned constellation projects	# of satellites	Satellite mass (kg)	Altitude	Project status
Amazon Kuiper	3,236	unspecified	590-630 km	Development
Astrocast	80	3/6U CubeSats	500-600 km	Demonstration
Boeing V-band	2,956	unspecified	1,200 km	Development
Globalstar 2	24	700 kg	1,410 km	In operation
Hongyan	320	unspecified	1,100 km	Demonstration
Hongyun	156	250 kg	1,000 km	Demonstration
Iceye	18	80 kg	587 km	Deployment
Iridium-NEXT	72	860 kg	780 km	In operation
Kepler	140	3U CubeSats	575 km	Development
LeoSat	108	1.000 kg	1,432 km	Suspended operations
OneWeb	648	147 kg	1,200 km	Deployment
Planet	150	3U CubeSats	370-430 km	In operation
SpaceX Starlink	4,425 (init.) (+7,518)	260 kg	1,100-1,325 km 340 km (add. sats)	Deployment
Spire	175	3U CubeSats	385-650 km	In operation
Swarm	150	0.25U CubeSats	300-550 km	Demonstration
Telesat LEO	117	unspecified	1,000 km	Development
Theia	120	unspecified	800 km	Development

Table 1: Selection of current and planned constellation projects in Low Earth Orbit (source: ESPI compilation)

The jury is still out on the outcome of these projects and on the real impact they will have on the space activity in the short- to long-term future. No one really expects all of the above-mentioned constellation and mega-constellation plans to succeed commercially or even reach full deployment. Experts actually suggest that the next few years will be decisive for most of these projects.[22] This forecast was already illustrated in 2019 when LeoSat, a most serious broadband constellation project backed by Hispasat and Sky Perfect Jsat, ceased operations following difficulties to raise additional investment. Despite

22 Werner, D. (2019). Inflection point within the year for megaconstellations? Retrieved from: https://spacenews.com/megaconstellations-satellite-2019/

uncertainties about the final outcome of these projects, which will now depend on future investment and commercial success, it can reasonably be expected that some of these mega-constellations will be deployed, at least partially.

Forecasts suggest that the deployment of mega-constellations, which actually already started, will contribute to an even bigger increase of the global space activity in the coming years, with 500 to 700 satellites to be launched per year by 2023. In the longer-run, the space activity could reach a plateau and start to stabilise or even decrease.

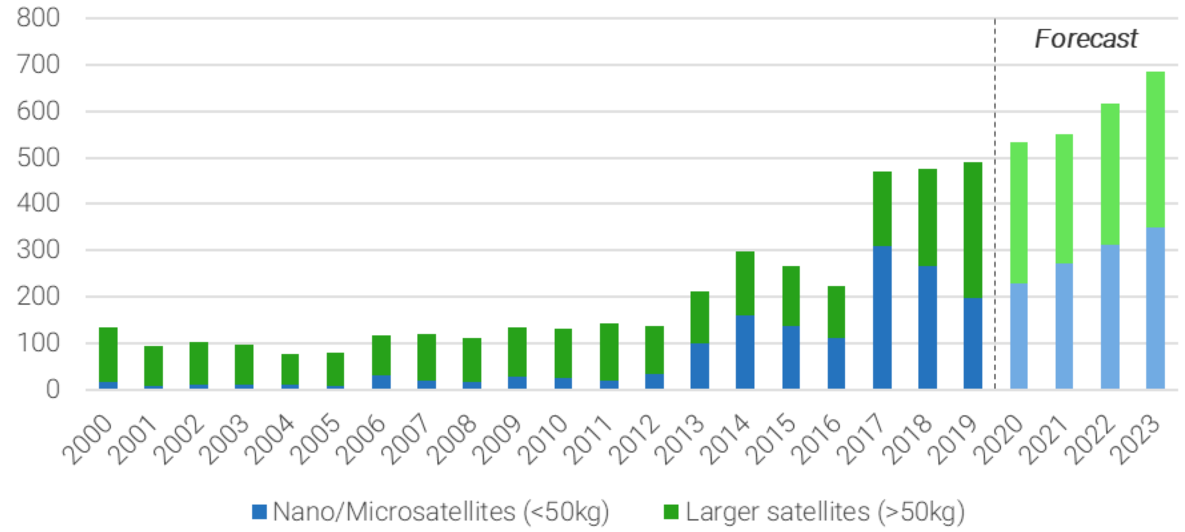


Figure 8: Forecast of satellites to be launched (source: ESPI database, Euroconsult, SpaceWorks)[23]

Constellations of small satellites (<500kg) are expected to be the cornerstone of the massive activity growth projected in the next few years. Euroconsult estimates that up to 8,500 satellites in this category could be launched between 2019 and 2028.

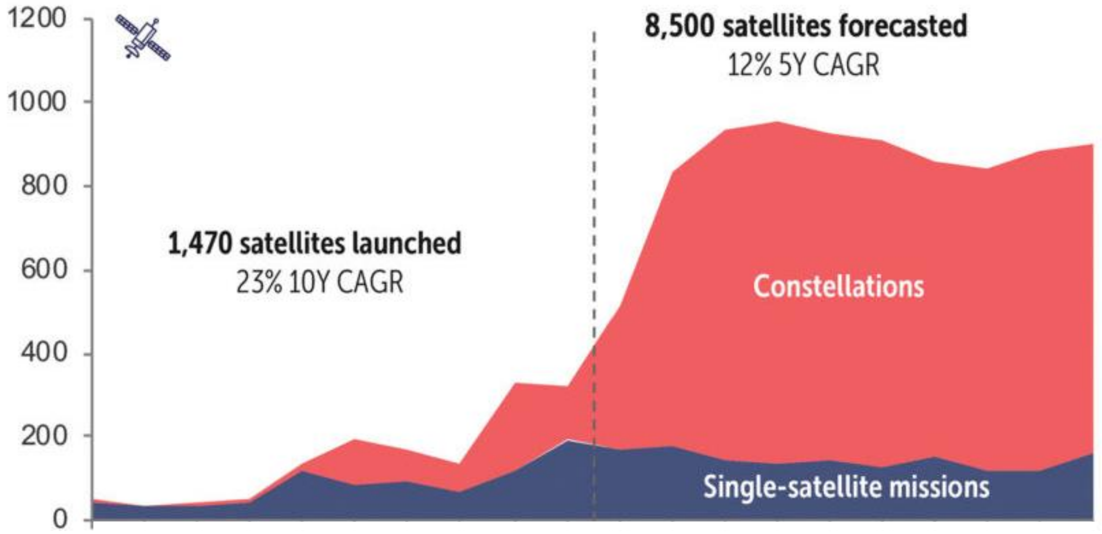


Figure 9: Forecast of small satellites (<500kg) to be launched in 2019-2028 (source: Euroconsult, via SpaceNews)[24]

23 Euroconsult (2019). Satellites to be Built and Launched by 2027. via satnews. Retrieved from: http://www.satnews.com/story.php?number=2091711277, SpaceWorks (2019). Nano/Microsatellite Market Forecast, 9th Edition.
24 Puteaux, M. and Najjar, A.(2019). Are smallsats entering the maturity stage?. Retrieved from: https://spacenews.com/analysis-are-smallsats-entering-the-maturity-stage/

3.2.2 An ever-denser space traffic: operating satellites and space debris

As a direct result of the global space activity upsurge, the number of operating satellites doubled in less than a decade.

According to the Union of Concerned Scientists, there were 923 operating satellites at the beginning of 2010 and there are now more than 2000.

Total number of operating satellites (March 31st, 2019):	2062
By country/region	• United States: 901 • Russia: 153 • China: 299 • Europe: 307 • Others: 402
By orbit	• LEO: 1338 • MEO: 125 • Elliptical: 45 • GEO: 554
By mission:	• Communications: 773 • Earth Observation: 768 • Science: 105 • Navigation: 138 • Technology: 265 • Other missions: 13

Table 2: Operating satellites statistics as of March 31st, 2019 (source: UCS database)

Satellites are mainly located in Low Earth Orbit (LEO) and in the Geostationary belt (GEO) and most of them provide operational capabilities for telecommunication, Earth observation or navigation.

Despite the significant growth of the Chinese activity, the United States are still responsible for most of operating satellites. The last inventory estimated that 43.7% of active satellites are owned and/or operated by U.S. organizations. With 312 active satellites (excl. 16 co-owned satellites), corresponding to 15% of the total, Europe is a major player in space operations.

The globalization of space is also illustrated by the fast-growing number of satellites owned by other countries. In 2018, more than 80 countries had registered a satellite while they were only 50 in 2010 and 40 at the beginning of the century.[25] CubeSats contributed significantly to this growth by making space more accessible but data show that, nano and microsatellites aside, more than 60 countries registered more "sizable" satellites (mass above 50kg).

25 OECD (2019). The Space Economy in Figures.

The number of operating satellites is expected to continue to increase, in line with space activity growth forecasts.

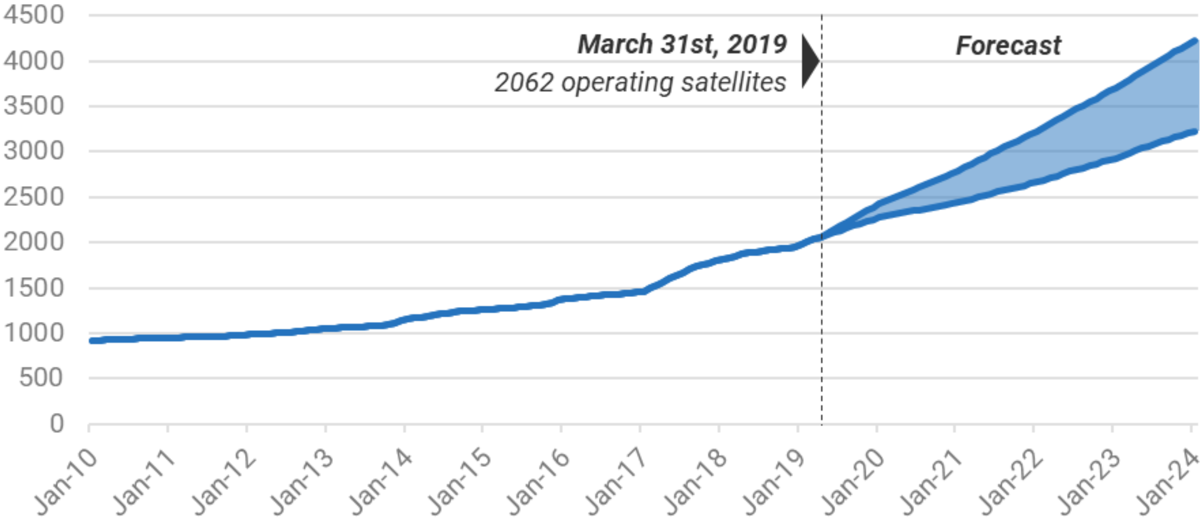


Figure 10: Evolution of the number of operating satellites with forecast (source: UCS database, ESPI database and model)

It can be estimated that the number of operating satellites will grow by 10-16% per year in the next 5 years to reach between 3200 and 4200 active satellites in 2024. This increase will mostly concern the Low Earth Orbit.

Operating satellites actually account for a very small fraction of the total population of objects currently in orbit. In other words, only a very small portion of the space traffic is actually "operationally useful" or "economically valuable". Active satellites have to share space with inactive satellites and rocket bodies as well as countless fragments of various size, nature and origin.

Indeed, the vast majority of objects currently in orbit are "space debris" which, according to the IADC definition encompass "all man-made objects, including fragments and elements thereof, in Earth orbit or re-entering the atmosphere, that are non-functional".[26] Today, it is estimated that 34,000 objects larger than 10 cm are orbiting the Earth along with 900,000 objects from 1 to 10 cm and roughly 128 million from 1 mm to 1 cm.[27] Operating satellites therefore represent only 7% of space objects larger than 10 cm and a negligible portion of the total population. In terms of mass, however, operating satellites still account for more than 35% of the total 8,400 tons of objects in Earth orbit.

26 Inter-Agency Space Debris Coordination Committee (2013). Key Definitions of the Inter-Agency Space Debris Coordination Committee IADC.
27 ESA. Space debris by the numbers. January 2019 data provided by ESA's Space Debris Office at ESOC, Darmstadt. Retrieved from: http://www.esa.int/Our_Activities/Operations/Space_Debris/Space_debris_by_the_numbers

The following figure shows the evolution of the space object population. Only the objects regularly tracked by the Space Surveillance Network in their catalogue (approx. 22.300 objects) are counted here:

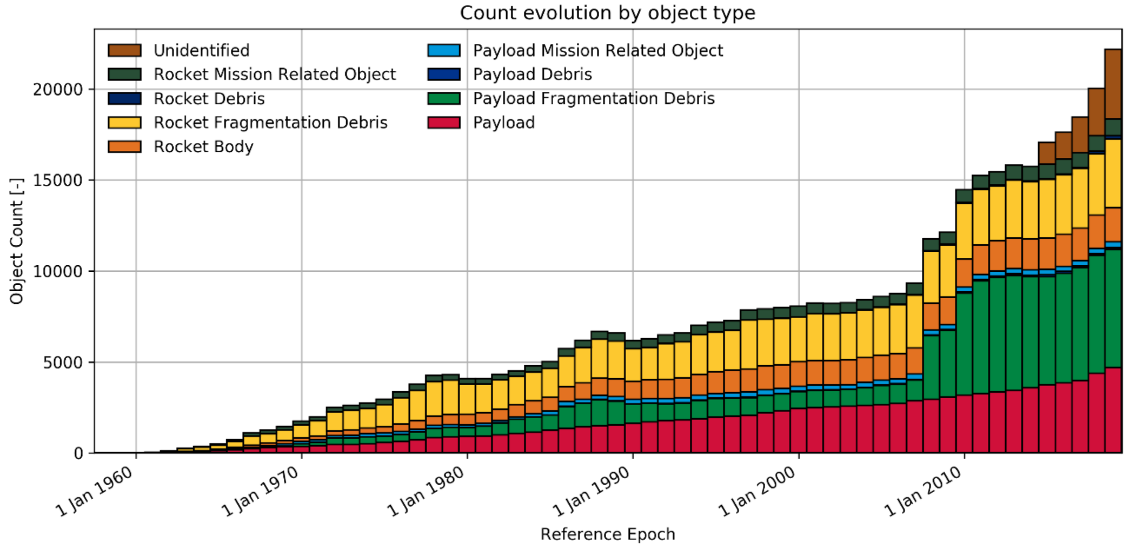


Figure 11: Evolution of the number of objects in orbit (source: ESA Space Environment Report)[28,29]

The number of space debris actually increased even more steeply than the population of operating satellites over the last decade, in particular as an outcome of a few orbital explosions and collisions. These events, that can happen intentionally, for example during anti-satellite technology tests, or unintentionally, when satellites explode or collide, are rare but have dramatic consequences, creating hundreds or thousands of “fragmentation debris”.

Spikes in recent years are the results of two major events in 2007 and 2009 – respectively, a Chinese ASAT kinetic test on the decommissioned weather satellite Feng Yun 1C and a collision between the Russian satellite Cosmos 2251 and the American satellite Iridium 33. Together, these two events increased the space debris population by 40%. The collision between Cosmos 2251 and Iridium 33 created 1,366 pieces larger than 10 cm set to remain in orbit for 20 to 100 years. India’s ASAT test performed in 2019 on a 740kg satellite at an altitude of 300 km generated hundreds of debris including at least 60 larger than 10 cm, some of which will stay in orbit for several years or even decades. Some of these pieces of debris were spotted as high as 2,200 km. The number of space debris eventually reached an all-time high in 2019.

28 ESA (2019). Annual Space Environment Report.
29 ESA definitions of space object categories below:

- Payloads: space object designed to perform a specific function in space excluding launch functionality. This includes operational satellites as well as calibration objects.
- Payload mission related objects: space objects released as space debris which served a purpose for the functioning of a payload. Common examples include covers for optical instruments or astronaut tools.
- Payload fragmentation debris: space objects fragmented or unintentionally released from a payload as space debris for which their genesis can be traced back to a unique event. This class includes objects created when a payload explodes or when it collides with another object.
- Payload debris: space objects fragmented or unintentionally released from a payload as space debris for which the genesis is unclear but orbital or physical properties enable a correlation with a source.
- Rocket body: space object designed to perform launch related functionality; This includes the various orbital stages of launch vehicles, but not payloads which release smaller payloads themselves.
- Rocket mission related objects: space objects intentionally released as space debris which served a purpose for the function of a rocket body. Common examples include shrouds and engines.
- Rocket fragmentation debris: space objects fragmented or unintentionally released from a rocket body as space debris for which their genesis can be traced back to a unique event. This class includes objects created when a launch vehicle explodes.
- Rocket debris: space objects fragmented or unintentionally released from a rocket body as space debris for which the genesis is unclear but orbital or physical properties enable a correlation with a source.

Although the congestion of the space environment is a broad safety and sustainability issue affecting space activities at large, the level of risk is much higher in LEO where most constellations and CubeSats are deployed, or planned to be deployed and were past explosions and collisions took place. LEO is considered, together with the Geostationary belt, as a protected region with regard to the generation of space debris by the IADC space debris mitigation guidelines.[30] This region of space below 2,000 km, counts with close to 60% of space objects regularly tracked. The most densely crowded areas are polar regions (particularly with inclinations of 97° to 100° and altitudes around 800 km) due to the extensive utilization of sun-synchronous orbits for remote sensing missions. The high spatial density (number of objects in a 1 km side cube) in LEO is related to various factors including human activity and orbital dynamics. The congestion of low Earth Orbits does not affect exclusively systems operating in this area but also space systems in transit to higher orbits.[31]

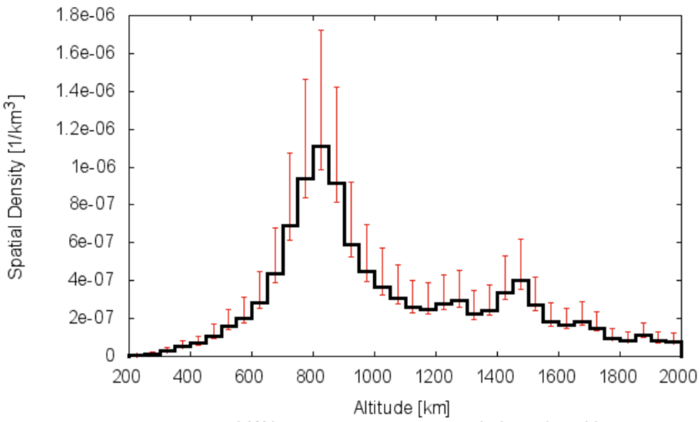


Figure 12: Spatial density of objects (larger than 1cm – with uncertainty bars) in LEO using ESA Master Model – Nov. 2016 (Source: A. Horstmann and S. Hesslbach)[32]

The deployment of large LEO constellations (LLCs) will further contribute an ever-denser traffic in Low Earth Orbit. New space surveillance capabilities will also allow to track even more objects making space traffic monitoring more complex.

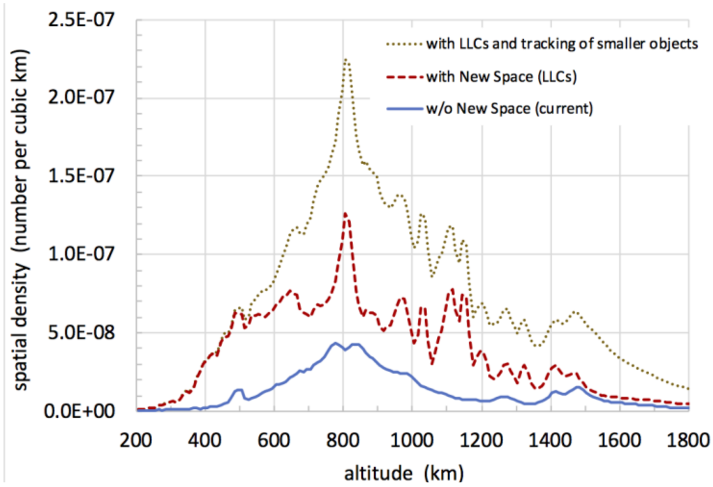


Figure 13: Spatial density of objects in LEO with and without LLCs (Source: The Aerospace Corporation)

30 Inter-Agency Space Debris Coordination Committee (2007). IADC Space Debris Mitigation Guidelines
31 Froeliger, J.L. (2017). Greater Industry Cooperation Needed to Avoid Space Collisions. Intelsat. Retrieved from http://www.intelsat.com/news/blog/greater-industry-cooperation-needed-to-avoid-space-collisions/
32 Horstmann, A. and Hesslbach, C. (2019). ESA-MASTER: Hands-on Enhancement of S/C Fragmentation and Environment Evolution Models. Retrieved from https://conference.sdo.esoc.esa.int/proceedings/ecsl19/paper/16/ECSL19-paper16.pdf

3.2.3 An increasing risk of collisions and interferences

A congested space environment naturally creates a number of risks for space operations - in particular concerning collision and interference hazards. Many stakeholders argue that both issues are strongly intertwined and should be handled together as two sides of the same coin. However, radiofrequency spectrum has long been considered a limited resource requiring proper management and coordination. This role was given to the International Telecommunication Union (ITU). For this reason, this report focuses primarily on the assessment of collision risks, comparably to current STM discussions.

Regardless of the debris size and nature, the consequences of a collision between two objects in space can be dramatic: when orbiting at high velocity, even the smallest piece of debris can have devastating consequences as it can reach a relative speed of 27,000 km/h. An object as small as 5 mm can disrupt or even completely incapacitate a satellite. This means that each debris is a serious hazard to operational systems in orbit, and also to astronauts. A collision with a larger object, be it an operating satellite or a large chunk of debris can be even more disastrous leading to a total fragmentation of the object(s) and to a more or less substantial increase of the debris population. Such catastrophic events have consequences beyond the orbital plane of the two objects and may put at risk other systems in other orbits, for a long time.

Beyond possible damages to operating systems, it is the very capacity of using some orbital planes that is jeopardized by collision risks and the so-called 'Kessler syndrome', the former aggravating the latter. Theorized by NASA scientist Donald Kessler in 1978, the Kessler syndrome predicts a cascading effect on the space debris population. As the number of space debris grows, the risk of collisions also increases. Therefore, as space debris beget space debris, further collisions between debris would create evermore debris, eventually rendering orbital slots impossible to use. The future space operating environment will be impacted by the Kessler syndrome, even if space activities were stopped today and that no more satellites are launched:

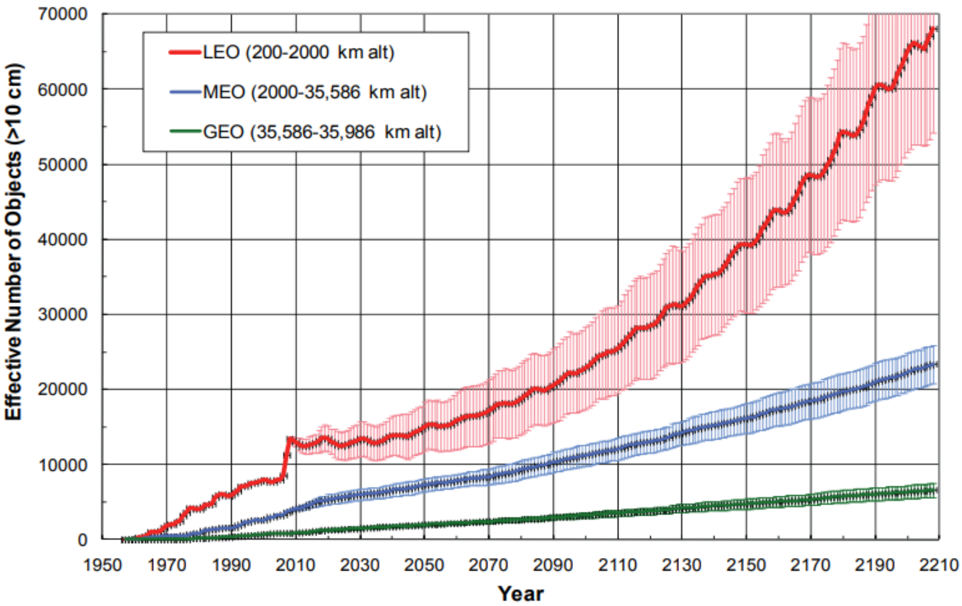


Figure 14: Evolution of the number of objects in orbit if no new satellites were launched – Kessler syndrome (source: NASA)[33]

The risk of collision between two objects in space is complex to calculate and even more to forecast as it is a function of many parameters. Among variables, the orbital spatial density and size of objects are,

33 NASA (2010). Orbital Debris Quarterly News Vol 14 Issue 1, January 2010.

of course, particularly important. The risk of collision increases for large objects in dense areas such as LEO polar orbits, as previously seen. The congestion of some orbits therefore translates into an increasing risk of collision between space objects.

As the result of his "assessment of the orbital debris collision hazard for Low Earth Orbit satellites", [34] D. Steel estimated that, in LEO, the probability for a one-meter cube satellite (i.e. roughly the size of a OneWeb satellite without its solar panels) to collide with a space debris is around 0.005 per year. This implies a lifetime of about 200 years against such collisions with orbital debris. This figure may seem very low, after all there is indeed a lot of "space" for the thousands of objects in orbit, but D. Steel recalls that "there is cause for concern: insert 200 satellites into such orbits and you should expect to lose about one per year initially, then the loss rate would escalate because the debris from the satellites that have been smashed will then pose a much higher collision risk to the remaining satellites occupying the same orbits."[35]

In a second study on "the orbital debris collision hazard for proposed satellite constellations", [36] D. Steel estimated that the OneWeb constellation could lead to one catastrophic collision every 25 years and that the Space X Starlink constellation (based on 4,025 satellites) could lead to as much as one catastrophic collision every 20 months. This estimation is consistent with another study by NASA which attempted to calculate and forecast risks of collisions for different constellation scenarios, taking also into account the level of compliance with existing debris mitigation rules.

- Black scenario: Baseline, large constellations are not launched and 90% of satellites are compliant with Post-Mission Disposal (PMD) rules.
- Other scenarios: Large constellations are launched (8300 satellites) and replenished for 20 years and:
  - Green scenario: 99% of constellation satellites are compliant with PMD rules
  - Blue scenario: 95% of constellation satellites are compliant with PMD rules
  - Red scenario: 90% of constellation satellites are compliant with PMD rules

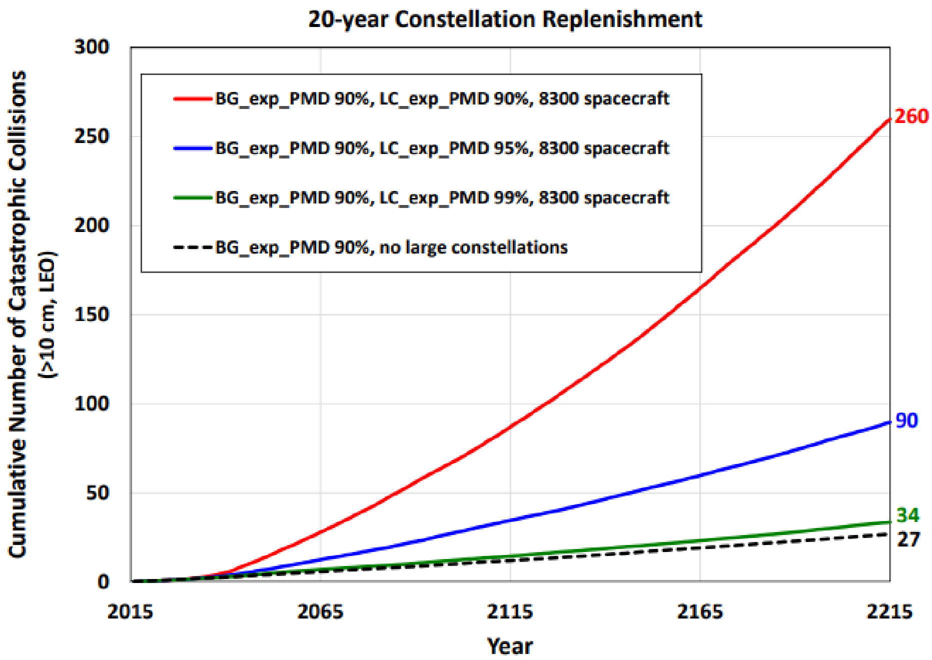


Figure 15: Cumulative number of catastrophic collisions according by scenarios (source: NASA)[37]

34 Steel, D. (2015). Assessment of the orbital debris collision hazard for Low Earth Orbit satellites.
35 Ibid.
36 Steel, D. (2015). The orbital debris collision hazard for proposed satellite constellations.
37 NASA (2018). Orbital Debris Quarterly News Vol 22 Issue 3, September 2018.

This model only shows catastrophic collisions involving objects larger than 10cm and leading to a total fragmentation of the target. Non-catastrophic collisions which result in lower damage to the target and a limited generation of debris, would be much more numerous but are not shown here. These are rather optimistic scenarios based on the assumption of a very high level of compliance with PMD rules.

To conclude, the following key points should be highlighted:

- Any orbital collision can have dramatic consequences for an operating satellite and/or for the space environment if the impact involves the creation of new fragmentation debris.
- The risk of collision is increasing sharply, together with the growing space activity and number of objects in orbit;
- This risk is not evenly distributed and some orbits are more affected than others, in particular in the Low Earth Orbit region;
- The launch of large constellations is expected to increase collision risks substantially, even in case of partial deployment and full compliance with current preventive measures.

Amazon and SpaceX evaluations of collision risks

In its public response to some questions from the U.S. Federal Communications Commission (FCC) about the Kuiper System constellation,[24] Amazon provided an evaluation of collision risks associated to its Kuiper constellation. Amazon estimates that, if 10% of the 3,236 Kuiper satellites lose their capacity to perform collision avoidance maneuvers, there is a 12% chance that one of those satellites could eventually suffer a collision with a piece of space debris measuring 10cm or larger. This probability drops to 6% if only 5% of the satellites fail, and could be as high as 18.3% if 15% of the satellites fail. Multiple causes could lead to such failure. Amazon explains that "failure rate assumptions of 5%, 10%, or 15% of the fully deployed system are well beyond what Amazon would view as expected or acceptable" and that multiple measures will be taken to mitigate any failure risk.

In its response to a similar question in 2017, SpaceX estimated that a 1% failure rate for its 4,425 Starlink satellites would lead to a 1% chance of collision per decade with debris larger than 10 cm. This probability could be linearly extrapolated for more extreme failure rates. SpaceX also explained in this same letter that the company "views satellite failure to deorbit rates of 10 or 5% as unacceptable, and that even a rate of 1% is unlikely."

Recent events suggest, however, that these failure rates could very well be realistic or even optimistic. For example, contact was lost with three of the sixty first Starlink satellites immediately after launch, corresponding to a 5% failure rate, excluding potential future failures during the satellites lifetime.

38 Sources for the infobox:

- Harris, M. (2019). Amazon Reports Collision Risk for Mega-Constellation of Kuiper Internet Satellites. Retrieved from: https://spectrum.ieee.org/tech-talk/aerospace/satellites/amazon-reports-collision-risk-for-its-megaconstellation-of-kuiper-internet-satellites
- Letter from C. Andrew Keisner, Lead Counsel, Kuiper Systems LLC, to Jose P. Albuquerque, Chief, Satellite Division, International Bureau, Federal Communications Commission. September 18, 2019.
- Letter from William M. Wiltshire, Counsel to SpaceX, to Jose P. Albuquerque, Chief, Satellite Division, International Bureau, Federal Communications Commission. April 20, 2017.

3.3 Inadequate regimes and capabilities for future space operational conditions

Summary: Preserving the safety and sustainability of the space environment requires complementary measures and capabilities to prevent, detect, characterize and respond to operational hazards. In the context of growing risks for space operations described previously, the adequacy of current capabilities to monitor space, detect hazards and prevent them as well as the suitability of existing regimes governing space activities are increasingly questioned.

3.3.1 Necessary complementarity between prevention and protection measures

Mitigating space operational hazards requires a set of measures addressing different facets of the safety issue at stake. The necessary diversity and complementarity of these measures is best illustrated when looking closer at the two different types of collision risks:

- Risk of collision between two objects of which at least one has the capacity to perform a collision avoidance manoeuvre. Such situation can involve two operating and manoeuvrable systems or, more often, a manoeuvrable system and a piece of debris.
- Risk of collision between two objects that do not have the capacity to perform a collision avoidance manoeuvre. Non-manoeuvrable objects include of course space debris (inactive satellites, rocket bodies, fragments) but also rudimentary satellites such as CubeSats or satellites having lost this capacity as a result of an accident or flaw.

To achieve safety and sustainability objectives, both risks must be mitigated, in particular when bearing in mind the cascading effect of collisions in orbit (i.e. any collision may create new debris that increase future collision risks). While collisions involving manoeuvrable objects can be avoided if the risk is properly detected, characterized and handled, it is not the case of collisions involving non-manoeuvrable objects. Avoiding such collisions requires to take preventive measures.

Safety and sustainability objectives are strongly intertwined in the space domain. In other words, ensuring the safety of space operations today is a necessary condition to limit the proliferation of debris and preserve a sustainable operating environment in the future, and vice versa. As a consequence, any effective approach to the issue of space safety and sustainability must address both preventive and protective aspects:

- Prevention encompasses all means and measures to mitigate the negative impact of space activities on the space operating environment, in particular in terms of creation of debris throughout the space system lifecycle.
- Protection encompasses all means and measures to safeguard operating satellites from collisions, in particular through capacities to detect and evaluate collision hazards and procedures to respond correctly.

As space activities and operating environment are changing, current prevention and protection measures may reach some limits and need to evolve.

3.3.2 Prevention: low compliance with international guidelines

The principal action to prevent the escalation of collision risks has been the definition and implementation of a set of principles outlining how space systems should be designed, operated and disposed of to mitigate their impact on the space environment, in particular regarding the generation of space debris. In 2002, the Inter-Agency Space Debris Coordination Committee (IADC), which brings together thirteen space agencies,[39] adopted the first set of international space debris mitigation guidelines. Revised in 2007, the document recommends four major mitigation measures:[40]

- Limit debris released during normal operations and avoid any action that would lead to the creation of debris;
- Minimise the potential for on-orbit break-ups by preventing accidental explosions and ruptures at end-of mission or avoiding intentional destructions;
- Dispose of spacecraft away from LEO and GEO protected regions after they have terminated their mission either by manoeuvring to a graveyard orbit (GEO) or to an orbit allowing a re-entry within a maximum of 25 years (LEO), if possible direct and controlled;
- Prevent on-orbit collisions in developing the design and mission profile of a spacecraft and limit the consequences of collisions, in particular on the spacecraft capacity to perform post-mission disposal.

These guidelines were endorsed by the United Nations Committee for Peaceful Use of Outer Space (UN COPUOS) and later by the General Assembly in 2007. There is a strong consensus among experts on the effectiveness of these guidelines if properly followed:

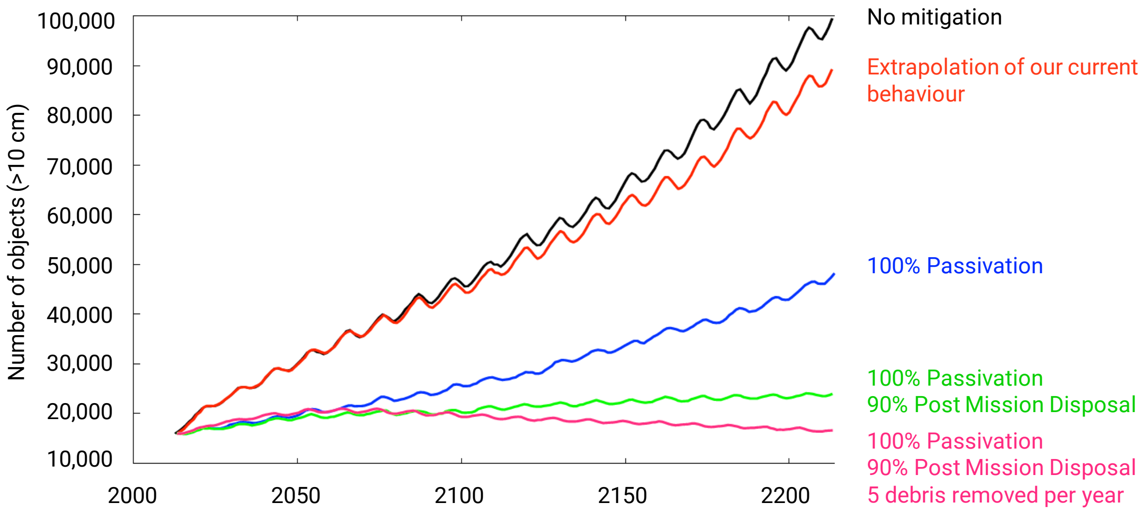


Figure 16: Effectiveness of space debris mitigation measures (source: ESA)[41]

39 IADC members include: Agenzia Spaziale Italiana (ASI), Centre National d'Etudes Spatiales (CNES), China National Space Administration (CNSA), Canadian Space Agency (CSA), German Aerospace Center (DLR), European Space Agency (ESA), Indian Space Research Organisation (ISRO), Japan Aerospace Exploration Agency (JAXA), Korea Aerospace Research Institute (KARI) National Aeronautics and Space Administration (NASA), Russian Federal Space Agency (ROSCOSMOS), State Space Agency of Ukraine (SSAU), United Kingdom Space Agency (UKSA)
40 Inter-Agency Space Debris Coordination Committee (2007). IADC Space Debris Mitigation Guidelines
41 H. Krag (2019). Managing Space Traffic for the Sustainable Use of Space. Presentation at ESPI Evening Event "The Way Ahead Towards Operational Space Traffic Management". Retrieved from: https://espi.or.at/downloads/send/59-2019/410-managing-space-traffic-presentation

- No mitigation: The guidelines are not implemented.
- Extrapolation of our current behaviour: The guidelines are implemented according to the current practices.
- 100% Passivation: All spacecraft comply with passivation guidelines (i.e. depletion of stored energy).
- 100% Passivation + 90% Post Mission Disposal: Previous scenario and 90% of spacecraft comply with PMD guidelines.
- 100% Passivation + 90% Post Mission Disposal + 5 debris removed per year: Previous scenario and five large debris are removed each year (Active Debris Removal)

UN efforts to address space safety and sustainability issues continued with the UN Working Group on the Long-Term Sustainability of Outer Space Activities (WG-LTS). As an outcome of this work, the UN COPUOS adopted a list of 21 Long-Term Sustainability (LTS) guidelines by consensus of its 92 Member States in June 2019. These LTS guidelines are intended to support the development of national and international practices and safety frameworks for conducting space activities. Discussions at UN level regarding space safety and sustainability issues continue.

Space debris mitigation guidelines, and other space safety and sustainability requirements developed along the years by various actors and frameworks, are integrated in legal and regulatory regimes, in norms and standards or in space agencies and industry best practices. For example, France was the first country to integrate the "25-years rule" in its legal regime governing space activities (i.e. the French Space Operations Act). The United States Government Orbital Debris Mitigation Standard Practices (ODMSP) also follow IADC guidelines.[42] These standard practices are applied by U.S. agencies for their space programmes as well as by the FCC for U.S. licensed commercial satellites

Today, the prevention of risks of collision and other space safety and sustainability issues consists in a complex set of laws, regulations, standards and other binding and non-binding rules followed in different ways by international players. Even though some fundamental principles have been consensually adopted in international frameworks, the enforcement of these principles is left to the goodwill of governments, agencies and private companies, raising the inevitable question of the level of compliance.

According to ESA Space Environment Report, "between 30 and 60% of all payload mass estimated as reaching end-of-life during the current decade in the LEO protected region does so in orbits that are estimated to adhere to the space debris mitigation measures [and] between 15 and 25% of payloads reaching end-of-life in a non-compliant orbit attempt to comply with the space debris mitigation measures Between 5% and 15% do so successfully."[43] **The report therefore suggests that the level of compliance with international guidelines for space debris mitigation is still rather low**, far below the 90% considered in NASA study previously cited (see Figure 15). In addition, experts estimate that the overall level of compliance could be negatively affected by the skyrocketing number of CubeSats launched every year and that are rarely compliant with debris mitigation guidelines.[44] The level of compliance of large constellations also remains to be seen. While many large constellation operators repeatedly promised to be exemplary in this respect, their compliance with space safety principles will be decisive for the sustainability of the space operating environment.

3.3.3 Protection: limited capabilities to detect, evaluate and respond to collision risks

The protection of operating satellites from collisions entails the capability to properly detect, evaluate and respond to collision risks. The capability to monitor space objects and to predict and alert about risks of collision is known as Space Surveillance and Tracking (SST) in Europe. It is one of the three pillars of Space Situational Awareness (SSA).[45]

42 U.S. Government Orbital Debris Mitigation Standard Practices.
43 ESA (2019). Annual Space Environment Report.
44 Bonnal, C. (2018). Ensuring future sustainability of space operations: the orbital debris question. Retrieved from: https://www.unoosa.org/res/oosadoc/data/documents/2019/aac_105c_12019crp/aac_105c_12019crp_7_0_html/AC105_C1_2019_CRP07E.pdf
45 Other SSA pillars include
- Space Weather (SW), which concerns the study of natural events in space that can affect space-borne systems or ground infrastructure;
- Near Earth Objects (NEO), which concerns the detection and monitoring of asteroids and comets in order to assess and respond to potential threats to life and property on Earth.

Basically, SST involves:

- The operation of space surveillance sensors (radar, telescopes) to survey, track and catalogue space objects,
- The processing and analysis of orbital data to provide information and services such as:
    - Prediction and evaluation of collision risks (Conjunction Analysis)
    - Analysis of space objects re-entry
    - Analysis of space objects fragmentation

The objective of any SST system is to deliver timely, accurate, and actionable data and services. This obviously depends on the level of performance of the SST system, including in terms of coverage (i.e. share of objects that can be tracked) or precision (i.e. repeatability of measurements).

The growing number of objects in orbit raises new challenges to properly detect, evaluate and respond to collision risks.

A first challenge concerns the capacity to monitor a higher number of objects, at least those that pose a serious threat to safety/sustainability of space operations. Currently, the most advanced SSA capabilities (i.e. U.S. capabilities, shared partially with selected partners) can effectively track objects larger than 5-10cm in LEO and 0.3-1m in GEO. This is still insufficient with respect to the potentially damaging impact of smaller pieces of space debris in case of potential collisions, the lethal not-tracked population. Given the huge kinetic energy released in impact as a result of tremendous relative orbital velocities of resident space objects, even objects much smaller than the current trackability threshold pose significant risks to safety of space operations or even sustainability of the space environment:

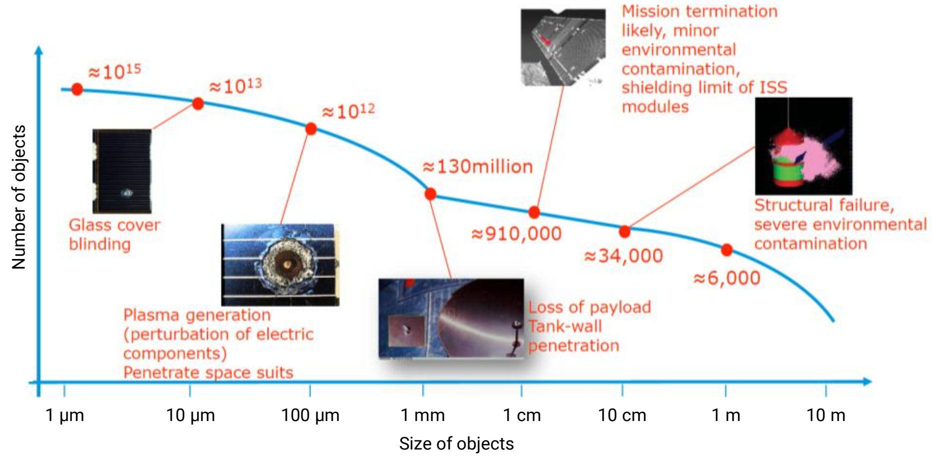


Figure 17: Number of objects and potential damages in case of collision by size (source: ESA)[46]

A second challenge is related to the limited accuracy of current SST data and the resulting uncertainty of conjunction analyses and collision risk evaluations. The issue was well explained in a recent report of the Aerospace Corporation: "there is uncertainty in the predictability of object locations during a conjunction. As a result, there is a predicted location for each object, but in reality, the object could actually be anywhere within an oblong "bubble" surrounding that predicted location. The uncertainties that form this bubble are the result of a combination of inaccuracies in the sensor measurements and errors in predicting how the object will move in its orbit to the point of the conjunction." The level of uncertainty is very high with bubbles 100,000 times bigger than the objects. This leads to many collision risk alerts, difficult to manage:

46 Krag, H. (2019). Managing Space Traffic for the Sustainable Use of Space. Presentation at ESPI Evening Event "The Way Ahead Towards Operational Space Traffic Management". Retrieved from: https://espi.or.at/downloads/send/59-2019/410-managing-space-traffic-presentation

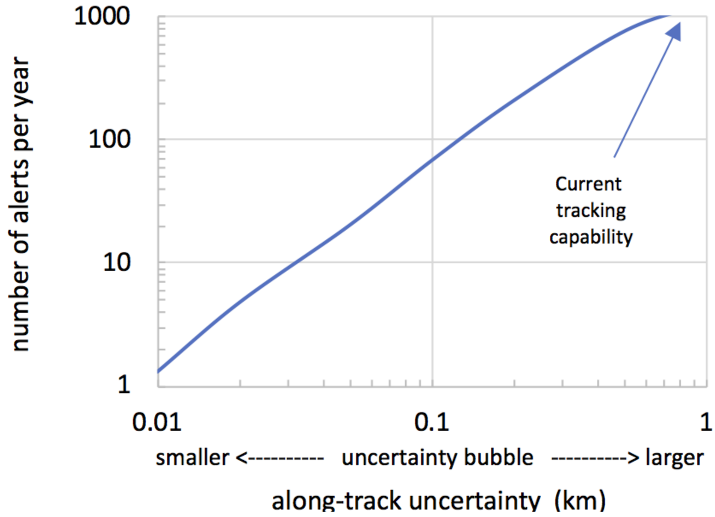


Figure 18: Annual number of expected alerts for Iridium constellation using a threshold probability of 1 in 100,000 (source: The Aerospace Corporation)[47]

Conjunction analyses can be refined, using additional observations and extra analyst time to reduce uncertainties but current SST capabilities eventually reach their limits. As a consequence, satellite operators depend on rather inaccurate data to decide whether to execute a collision avoidance manoeuvre. This would not be a major problem if such manoeuvre did not have a significant cost in terms of disruption to the mission or reduced system lifetime. Evaluating collision risks more precisely and singling out those that justify a manoeuvre is therefore essential. The collision avoidance manoeuvre itself must also be properly planned. Indeed, such manoeuvre impacts all other potential conjunction assessments. In a worst-case scenario, it could lead to an even higher risk of collision with another object.

The example of the catastrophic collision between Iridium-33 and Cosmos 2251 (inactive) on February 9, 2009, which created thousands of debris, provides an excellent illustration. The Aerospace Corporation explains that the collision probability was estimated around 3 in 100,000, a level of risk comparable to 37 other conjunctions during that same week for the constellation. The week of February 9th there were also conjunctions with higher probability of collisions, higher than 2 in 10,000. As a consequence, the conjunction which eventually led to an actual disastrous collision did not stand out of the lot:

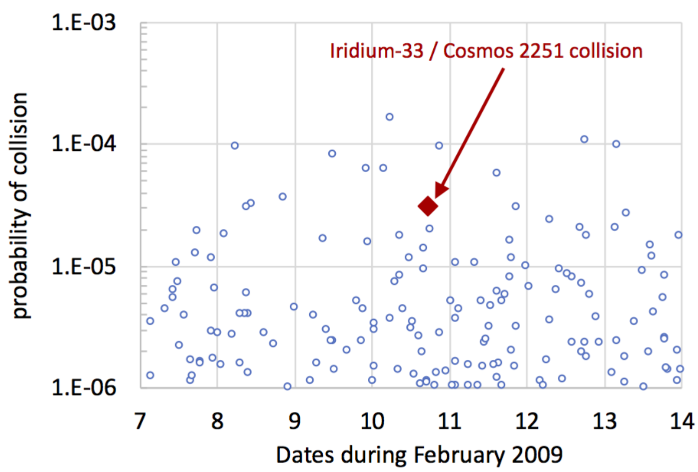


Figure 19: Iridium constellation conjunction probabilities during week of Feb 7, 2009 (source: The Aerospace Corporation)[48]

47 The Aerospace Corporation (2019). Space Traffic Management in the Age of New Space. April 2019.
48 Ibid.

On top of these technical challenges, the effectiveness of SST capabilities is further limited by difficulties to process data into actionable information for all. Standardization of data formats, processing algorithms or models for data fusion from various sources are few of the main outstanding issues in the SST domain on the way ahead towards more advanced, suitable capabilities.

In the case of a collision risk between two operating satellites, the coordination between operators may also be a source of problems, as recently showcased by the Aeolus/Starlink conjunction.

On September 2, 2019, ESA manoeuvred its Aeolus satellite to avoid a potential collision with a SpaceX Starlink satellite. The event provided an excellent illustration of the limits of current best practices for space operations coordination.

The ESA operations team had contacted SpaceX approximately one week ahead of the anticipated close approach between the two objects which had a 1 in 50,000 collision risk probability. On August 28, SpaceX informed ESA via e-mail it did not intend to move the Starlink satellite. As the date of close approach drew closer, the ESA team calculated a significant increase of the collision risk probability (above 1 in 1,000). ESA claimed that subsequent inquiries to SpaceX remained unanswered and that, given the situation, ESA operations team decided to execute a collision avoidance manoeuvre. Later, after the event became public, SpaceX blamed a bug in the company's warning system, which prevented the operator from seeing the follow-on correspondence on this probability increase.

The situation showed the limits of current practices for space traffic coordination based on e-mail distribution of conjunction data messages and ad-hoc e-mails or phone calls between operators in case of high-risk warnings. There are actually no shared protocols for collision avoidance procedures, in particular when two active spacecraft are subject to alert.

Current capabilities to manage collision risks are therefore already limited. These limits will become increasingly problematic with the growth of the number of objects in orbit and resulting collision alerts. The current best practices for space traffic coordination, involving mainly manual work and ad-hoc processes, will no longer be suitable.

4 Strategic, commercial and geopolitical stakes for Europe

4.1 European interests in a safe and sustainable space environment

The deteriorating situation of the space operating environment should be appraised in the context of a growing strategic and socio-economic significance of the sector. In Europe, the importance of operating space systems in a secure, safe and sustainable environment has already been acknowledged by most public and private stakeholders. As a matter of fact, space security became a top policy priority over the years. For example, the Space Strategy for Europe clearly puts forward, "Europe´s autonomy in accessing and using space in a secure and safe environment"[49] as a pillar for Europe.

The strategic significance of space safety and sustainability for Europe arises from its overarching ambition to "promote its position as a leader in space, increase its share on the world space markets, and seize the benefits and opportunities offered by space."[50] Achieving these objectives has a number of security-related implications.

A previous ESPI report suggested that public action in this domain is justified by four key rationales: [51]

- Secure the results of the continuous and substantial investment made by public and private actors;
- Protect the European economy and society against risks related to its pervasive and sizeable dependence on the space infrastructure;
- Contribute to a service-oriented policy by assuring the ability of the infrastructure to deliver a service that can justifiably be trusted, in particular for users in the defence and security domain;
- Guarantee European autonomy and freedom of action in the field of security in outer space, and in the space domain at large.

4.1.1 Protect the value of the European space infrastructure

The value of the European space infrastructure, which is the outcome of a continuous and substantial investment by public and private actors, lies first and foremost in the substantial socio-economic benefits that it enables across a multitude of economic and strategic sectors for Europe. Multiple impact assessments and case studies demonstrated that space applications bring substantial socio-economic benefits across multiple sectors.

There is, however, a consequence that should not be overlooked: as the use of space-based solutions becomes more pervasive and part of business-as-usual, the dependence of governments, businesses and individuals on space infrastructure grows, creating new risks if space assets were to be incapacitated, even partially. A study of the European Commission estimated that more than 10% of the EU GDP depends on space infrastructure and that an incapacitation of space systems - intentional or not - would lead to a significant economic loss of up to EUR 50 billion per year of Gross Added Value and put up to 1 million jobs at risk in Europe.[52] With the intensification of challenges to the security of space systems, the need to protect space assets and to safeguard the benefits that they enable can be considered, alone, as a reasonable argument for Europe to position security at the top of the space policy agenda. This is

49 European Commission (2016). Communication From The Commission To The European Parliament, The Council, The European Economic And Social Committee And The Committee Of The Regions. Space Strategy For Europe. COM (2016) 705 final.
50 Ibid.
51 ESPI (2018). Security in Outer Space: Rising Stakes for Europe. ESPI Report 64
52 European Commission (2017). Dependence of the European Economy on Space Infrastructures: Potential Impacts of Space Assets Loss.

particularly true as European governments and institutions seek to maximize the socio-economic value of the European space infrastructure.

The potential impact of a disruption of the European space infrastructure on economy and society will most probably increase in the future with the uptake of space-based solutions for various sectoral policies and the cross-fertilization of space technologies with ground technologies for promising future concepts in telecommunication networks, precision agriculture, air traffic management, smart energy grids or autonomous vehicles, among others. In short, the more Europe invests in and reaps the benefits from space, the more critical safeguarding the space environment and infrastructure becomes.

4.1.2 Contribute to a “Service-Oriented” Policy

The rising need for enhanced space security in Europe also lies in the considerable development of EU space programmes over the 2014-2020 period (i.e. Galileo, EGNOS, Copernicus) and in the potential introduction of new initiatives such as GOVSATCOM. Entering its exploitation phase, the European GNSS System Galileo will play a pivotal role in the implementation of national and European security policies for localisation and navigation for troops and vehicles, mission planning, delivery of cargos, or search and rescue. GNSS-based services are also key in case of conflict for guidance, strikes, and other related operations. The Copernicus programme already provides critical data for policies related to the atmosphere, marine environment, land, climate change, emergency management, and security. The new GOVSATCOM initiative, which aims to ensure reliable, secure and cost-effective satellite communication services for EU and national public authorities, will also integrate strong security aspects.

These developments are amplifying the importance of a service-driven policy to foster user confidence, encourage the uptake of space services, and consequently maximise the benefits generated by the European space infrastructure. This entails the adoption of a service-oriented approach aiming at 1) a proven or certified level of performance, 2) the long-term availability of services and 3) a service that can justifiably be trusted. This last condition translates into the need to take appropriate measures to protect the infrastructure against faults and threats and to ensure that the space operating environment remains safe. Meeting the most stringent security and safety requirements is imperative for governmental and defence users that the EU seeks to support and to reinforce synergies between civil and defence domains.

It can be legitimately expected that meeting all necessary conditions to deliver high-performance and secure services will further gain in prominence in the European space policy debate over the next MFF period. As a mean of illustration, the recent partial outage of the Galileo system brought back the importance of space infrastructure security back into the spotlight. Consequences of the outage were limited given that the Galileo system is still under initial deployment. The event provided, however, an early warning regarding the potential crisis induced by such a disruption - whether unintentional, indelicate or deliberate - and stressed the criticality importance of preventive measures to mitigate such risks.

4.1.3 Reinforce European Autonomy and Leadership

From a strategic standpoint, Europe also seeks to guarantee the security of its space infrastructure autonomously through independent capabilities (i.e. systems, data, and technologies). The Space Strategy for Europe states that “reinforcing Europe’s autonomy in accessing and using space in a secure and safe environment” is a pillar objective. European stakeholders converge on the assessment that a fully effective approach to space security can only be envisioned as the outcome of a coherent and inclusive global effort and that cooperation with third countries, in particular the United States, is essential for many reasons. Autonomy is therefore not sought at the expense of cooperation with key partners but Europe must ensure its capacity to control its level of reliance on third parties and to maintain it within boundaries that do not compromise its freedom of action.

Regarding Space Situational Awareness for example, a great deal of European players extensively rely on Data Sharing Agreements signed with the United States. This includes national ministries or armies (i.e. Belgium, Denmark, France, Germany, Italy, Netherlands, Norway, Spain, United Kingdom), European intergovernmental organisations (i.e. ESA, EUMETSAT), commercial satellite operators and launch service providers. From a U.S. perspective, SSA Sharing Agreements are powerful leadership instruments that aim to support transparency on operations in outer space, promote cooperation for security and safety, enhance the availability of information among the partners, and improve the quality of U.S. SSA information. From a European perspective, they are a critical input for SSA capabilities at large and, by extension, for potential future STM capabilities to ensure the safety of operations of space systems.

Europe greatly benefits from the open policy of the U.S federal government and the relevance of transatlantic cooperation, in particular in defence and security domains, cannot be challenged. However, the gap between European and American capabilities, expected to increase with the deployment of the U.S. Space Fence, creates a situation of reliance/dependence for European stakeholders and an imbalance in cooperative arrangements. It is clear that Europe has taken advantage of this state of affairs. However, such reliance on U.S. capabilities presents some limitations related to its strategic implications:

- Data and service restrictions: Although SSA Data Sharing Agreements enhance the availability of information among the partners, restrictions exist. Given its intrinsic military nature, a lack of transparency or a delay in availability of information can occur for a variety of motives related to U.S. national security issues.
- Reliability and accountability: Although the most advanced, the U.S. system is not flawless and may provide wrong information due to measurements or processing errors, in particular for smaller objects that Europe cannot track. If Europe has not at least the means to cross-check the data, European operators are left with a "blind" reliance on non-transparent services and processes for making critical decisions.
- Uncertainty on future access: The U.S. Government holds the right to terminate the agreement at any time for any reason, to limit both access duration and data amount, to deny access to SSA data and information, and to change or modify the terms and conditions at any time, and without prior notification.

It is clear that reliance on foreign SSA data and services is a relevant and effective way to augment domestic SSA capabilities. However, the consequences of a potential disruption or restriction of access could be critical and certainly require a strategic reflection. The objective to reach an "appropriate level of European autonomy" is addressed in most, if not all, policy documents setting the route for Europe in this domain. There is, however, no clear definition of a minimum, required, level of capabilities that would be strategically acceptable. On this issue, ensuring convergence of the views of Member States is of paramount importance.

At the moment, and despite various past, current and planned initiatives and measures across the space security spectrum, Europe has not yet established leadership in this field, and instead finds itself increasingly pressured by the proactivity of other players, in particular the United States. As space security holds an increasingly central place in space diplomacy, it can be argued that guaranteeing European autonomy and freedom of action in this field will become a critical factor to establish Europe's credibility and legitimacy in the global space arena. Europe's ambition to promote its position as a leader in space necessarily entails playing a central role (even as initiator) in international dialogues and negotiations as a promoter of a clear, united and consistent "European way". From a more practical standpoint, to be positioned as a key player in the international space scene, Europe must contribute its share to this endeavour and reach a balanced cooperation with other key players including, in particular, the United States.

4.2 The U.S. National Space Traffic Management Policy

4.2.1 Motivations: an integral component of U.S. strategy to assert leadership in space

The United States has long considered space an integral component of its strategic and geopolitical agendas. Successive U.S. administrations consistently embedded space in their respective policies, and vice versa. Although approaches and priorities varied over the years, in line with the political colour of the various administrations, the general orientation remained rather consistent around a central strategic objective to ensure U.S. leadership in space. This objective concerns all aspects of the space domain:

- Space economy and commerce: As an infrastructure supporting U.S. economic prosperity and as a sector with great commercial potential, the United Sates seeks to foster the development of a world leading space industry, in particular through an ambitious technology and innovation policy, a favourable regulatory regime and an assertive commercial diplomacy.
- Space defence and national security: As the "ultimate high-ground", space is a critical asset for U.S. military superiority and a potential vulnerability for national security. With the objective to achieve full-spectrum supremacy, the United States seeks to maintain dominance and control in the space domain. This entails the development of capacities to deter, counter, and defeat hostile threats as well as the mitigation of safety and sustainability issues affecting the space infrastructure and operating environment.
- Space cooperation and foreign policy: Acknowledging the importance of cooperation to promote burden sharing and threat response and the value of conducive international environments for space commerce, the United States seeks to ensure that bilateral and multilateral agreements protect and support U.S. interests.

As part of the "America First" policy, Trump administration further asserted U.S. leadership as a driving force of the U.S. space strategy and policy. The re-established National Space Council, whose role is to "provide a coordinated process for developing and monitoring the implementation of national space policy and strategy"[53] took an active role in developing a comprehensive and coherent set of policies aiming to support U.S. leadership across all domains as part of a "whole-of-government" approach.

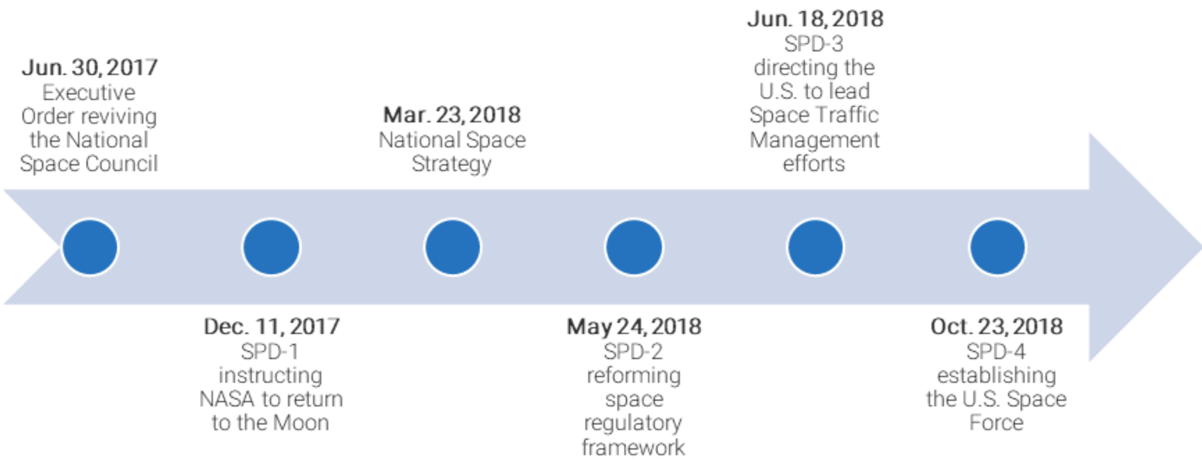


Figure 20: National Space Council Directives

53 White House (2017). Presidential Executive Order on Reviving the National Space Council. June 30, 2017

The U.S. National Space Traffic Management Policy stands at the nexus of U.S. security, commerce and foreign policies and is intended as an instrument to support U.S. leadership in space. The policy clearly states that "through this national policy for STM and other national space strategies and policies, the United States will enhance safety and ensure continued leadership, preeminence, and freedom of action in space."[54] Consistently with the National Space Strategy and other Space Policy Directives, in particular SPD-2 which aims to streamline regulations on commercial use of space, the U.S. STM policy seeks to support U.S. leadership through three complementary objectives.

The first objective is to "protect the U.S. vital interest in space, to ensure unfettered access to, and freedom to operate in space" and to "continue to lead the world in creating the conditions for a safe, stable, and operationally sustainable space environment."[55] In this respect U.S. motivations are clearly detailed in the policy:[56]

- "Today, space is becoming increasingly congested and contested, and that trend presents challenges for the safety, stability, and sustainability of U.S. space operations."
- "[The current] limited traffic management activity and architecture will become inadequate."
- "To maintain U.S. leadership in space, we must develop a new approach to space traffic management (STM) that addresses current and future operational risks."

From this perspective, the primary goal of the policy is to tackle rising challenges to the safety and sustainability of the space operating environment discussed in Chapter 3 of this report.

The second objective is to "encourage and facilitate U.S. commercial leadership in Science and Technology, Space Situational Awareness, and Space Traffic Management."[57] This objective falls into U.S. effort to "prioritize regulatory reforms that will unshackle American industry and ensure [the United States] remain the leading global provider of space services and technology."[58] Beyond U.S. leadership in S&T, SSA and STM, the policy aims to guarantee favourable safety and regulatory conditions for the emergence and growth of new commercial space ventures and activities involving, for example, on-orbit servicing, debris removal, in-space manufacturing, space tourism, small satellites or very large constellations.

The third objective is to "foster conducive international environments [and] ensure that international agreements put the interests of American people, workers, and businesses first." (National Space Strategy)[59] This strategic goal translates, in the STM policy, into the objective to "promote space safety standards and best practices across the international community" and "to encourage safe and responsible behaviour in space while emphasizing the need for international transparency and STM data sharing".[60] Indeed, although national, the U.S. policy does not challenge the relevance and importance of multilateral efforts and actually acknowledges that a fully effective approach can only be envisioned as the outcome of a coherent and inclusive global effort. Notwithstanding, such national-led approach can be seen as a reaction to the limited progress achieved at international level and as an attempt to take leadership in future international efforts. In this respect the policy directs U.S. regulatory agencies to "adopt these standards and best practices in domestic regulatory frameworks and use them to inform and help shape international consensus practices and standards."[61]

54 White House (2018). Space Policy Directive-3 National Space Traffic Management Policy. June 18, 2018
55 White House (2018), President Donald J. Trump is Unveiling an America First National Space Strategy, (March 23, 2018)
56 White House (2018). Space Policy Directive-3 National Space Traffic Management Policy. June 18, 2018
57 Ibid.
58 White House (2018), President Donald J. Trump is Unveiling an America First National Space Strategy, (March 23, 2018)
59 Ibid.
60 White House (2018). Space Policy Directive-3 National Space Traffic Management Policy. June 18, 2018
61 Ibid.

4.2.2 Provisions: national advancement and global outreach

To achieve these objectives the U.S. National Space Traffic Management Policy defines a set of principles and guidelines to be followed for the establishment of a new approach to STM and delineates roles and responsibilities among relevant U.S. stakeholders. According to the policy, the establishment of a new U.S approach will imply:[62]

Advance SSA technology, improve SSA data interoperability and enable greater SSA data sharing

- Complete, timely, accurate, and actionable data are essential to provide necessary insights to safely plan, coordinate, and synchronize in-orbit activities and mitigate collision risks. The United States seeks to significantly improve SSA capabilities through development of national technologies and sensors but also through acquisition of third-party data from allied governments, partner operators and commercial providers. To facilitate greater data sharing, the U.S. will develop the standards and protocols for the creation of an Open Architecture Data Repository. Necessary measures will be taken to safeguard data quality, integrity, availability and confidentiality.

Provide basic SSA data and STM services to the public and encourage U.S. commercial leadership in STM-related technologies, goods, data, and services

- The United States plans to continue to provide basic SSA data and STM services (e.g. Close Approach (CA) emails) to U.S. operators, allies and partners. The United States will also support the development of U.S. commercial solutions competing on international markets for advanced SSA data and value-adding STM services, in particular by investing in commercial R&D as well as streamlining processes and reducing regulatory burdens that could inhibit commercial sector growth and innovation.

Develop a set of norms, best practices, and standards to mitigate the operational effects of orbital debris, to coordinate space traffic, and to encourage a safe and responsible behaviour in space

- A central component of the new U.S. approach to STM will be to update and develop a set of STM-related rules (best practices, technical guidelines, safety standards, behavioural norms) addressing various operational issues (e.g. space traffic coordination, debris mitigation, satellite safety). These rules should address all stages of satellite operation from design through end-of-life and consider in particular maneuverability, tracking, reliability, and disposal. U.S. regulatory agencies should incorporate these rules into Federal law and appropriate domestic regulatory frameworks such as certification and licensing procedures. Rules will be revised periodically.

Promote these norms, best practices, and standards internationally and to explore strategies that will lead to the establishment of common global best practices

- As part of a global engagement strategy for STM, the United States intend to promote a range of norms, best practices, and standards for safe operations in space to minimize the space debris environment and promote data sharing and coordination of space activities. This strategy encompasses bilateral and multilateral discussions and U.S. participation in international organizations such as the IADC, ISO, CCSDS, and UN COPUOS.

Improve policies, processes, and technologies for spectrum use, appropriate to current and future operations, and to prevent unintentional radio frequency interference

- The United States intends to investigate and potentially put into action a more integrated management of space traffic and radiofrequency spectrum issues, which are addressed by independent processes currently. This entails several measures to address traffic and spectrum challenges in a coordinated manner for current and future operations.

62 Ibid.

The U.S: STM policy also articulates a reorganization of roles and responsibilities across U.S. military and civil branches. The rationale behind this move is to:

- Refocus the U.S. Department of Defense on its military and national security mission to protect and defend U.S. space assets and interests.
- Address Space Traffic Management primarily as a civil framework with a public service and commercial-oriented mission

Such approach supposes a clear delineation of the respective roles of the military branch focusing on strategic security-related activities and of the civil branch focusing on monitoring, regulation and coordination for operational safety and commercial-related activities.

The policy calls for a coordinated and coherent effort of U.S. departments and agencies as part of a whole-of-government approach, in close cooperation with industry and academia, whenever appropriate. Concerned U.S. officials include:

- The Secretaries of State, Defense, Commerce, and Transportation (DoS, DoD, DoC, DoT)
- The Administrator of the National Aeronautics and Space Administration (NASA),
- The Director of National Intelligence (DNI),
- The Chairman of the Federal Communications Commission (FCC),
- To a lesser extent, Members of the National Space Council

Noteworthy allocations of responsibilities include:

- With regards to SSA interoperability and data sharing and to the provision of basic SSA data and STM services to the public:
  - The DoD shall maintain the authoritative U.S. catalogue of space objects and ensure that the release of data is consistent with national security interests.
  - The DoC is responsible for the publicly releasable portion of the DoD catalogue and for administering an Open Architecture Data Repository to improve SSA data interoperability and enable greater SSA data sharing. The development of this repository should consider the technical and economic feasibility of options involving partnerships with industry or academia.
  - The DoD and DoC, should cooperatively develop a plan for providing basic SSA data and basic STM services either directly or through a partnership with industry or academia. In particular, the DoC should be the focal point for the delivery of an On-Orbit Collision Avoidance Support Service providing timely warning of potential collisions and basic collision avoidance information free of direct user fees.
- With regards to the development of a set of norms, best practices, and standards to mitigate the operational effects of orbital debris, to coordinate space traffic, and to encourage a safe and responsible behaviour in space:
  - NASA shall lead efforts to update the U.S. Orbital Debris Mitigation Standard Practices (ODMSP) and establish new guidelines for satellite design and operation.
  - The DoD, DoC and DoT shall develop space traffic standards and best practices.
  - The DoC and DoT, in consultation with the FCC, shall assess the suitability of incorporating these updated standards and best practices into their respective licensing processes.

4.2.3 Implementation: political and technical difficulties but steady progress

The U.S. national STM policy, aka Space Policy Directive 3, is part of a broader reform of U.S. administration and regulatory regime governing commercial space activities, already started with the Space Policy Directive 2 on streamlining regulations on commercial use of space. This reform envisions a reorganization of responsibilities across U.S. departments and the allocation of new roles. In particular, the SPD-2 directed the DoC to create a "one-stop-shop" for all commercial spaceflight activities not already handled by other federal entities (i.e. launch and re-entry licensing by the FAA and radio frequency spectrum management by the FCC) with the objective to promote a streamlined and conducive regulatory environment supporting U.S: commercial space activities.

Presidential directives set a clear path for this administrative and regulatory reform but progress has been slowed down by conflicting views on matters at stake across U.S. policy-makers (i.e. both House of Representatives and Senate of the U.S. Congress). Here - and although presidential directives do not entirely require congressional approval, nor can be overturn by the legislators - the U.S. Congress still plays an important part in deciding upon administration mandates and budgets.

With regards to the implementation of the U.S. STM policy more specifically, the Congress shares diverging views on the office/agency best suited to handle responsibilities and tasks related to SSA/STM and to commercial regulation. In June and July 2018, two different bills were introduced in the House of Representatives and Senate - the American Space SAFE Management Act and the Space Frontier Act, which supported different options. Following the legacy of the previous Obama administration, the Space Frontier Act would reinforce the role of the FAA's Office of Commercial Space Transportation (i.e. within the DoT) while the American Space SAFE Management Act would give broader authority over SSA and licensing of commercial space to the DoC, in line with the Trump administration policy. No significant progress has been made on either of these legislative proposals until today, even though the Senate re-introduced the Space Frontier Act in March 2019. Beyond mandate issues, progress has also been stalled by budget allocation. To properly fulfil the functions envisioned by the SPD-2 and 3, the DoC requested a budget of 10 million USD starting in 2020 for a new Bureau of Space Commerce reporting directly to the Secretary of Commerce. The Bureau would merge past and new responsibilities of the current Office of Space Commerce and of the Office of Commercial Remote Sensing Regulatory Affairs. This request has not yet been decided. Specialized press suggests that Congress is unlikely to act soon on the future of the DoC proposed role in handing civil space traffic management.[63]

Despite some administrative and policy blocking points, U.S. departments and agencies already started to work on the concrete implementation of the U.S. STM policy. Some preliminary steps were made to prepare the transfer of civil-oriented SSA/STM responsibilities and competences from the DoD to the DoC:

- Appointment of a senior DoC official to liaise with the DoD (i.e. 18th Space Control Squadron at Vandenberg Air Force base)[64] and prepare the transition.
- Provision of access to the DoC to the USAF's Unified Data Library

Although USAF representatives have voiced out their eagerness to hand over a portion of SSA/STM duties to a civil agency in order to focus more closely on their military unique mission, they also explained that future progress will be conditioned to DoC securing the appropriate resources and mandate. Eventually, the full transfer of civil duties from the DoD to the DoC is not expected to be completed before 2024.

63 Foust, J. (2019). Spending bill highlights ongoing debate on Commerce Department's role in space traffic management. From: https://spacenews.com/spending-bill-highlights-ongoing-debate-on-commerce-departments-role-in-space-traffic-management/

64 Note: The USAF's 18th Space Control Squadron (18SPCS) is tasked with providing 24/7 support to the Space Surveillance Network (SSN), maintaining the space catalog and managing United States Strategic Command's (USSTRATCOM) SSA sharing program. The squadron also conducts advanced analysis, sensor optimization, conjunction assessment, human spaceflight support, reentry/break-up assessment, and launch analysis.

The DoC prepared a workplan and roadmap for the next few years:

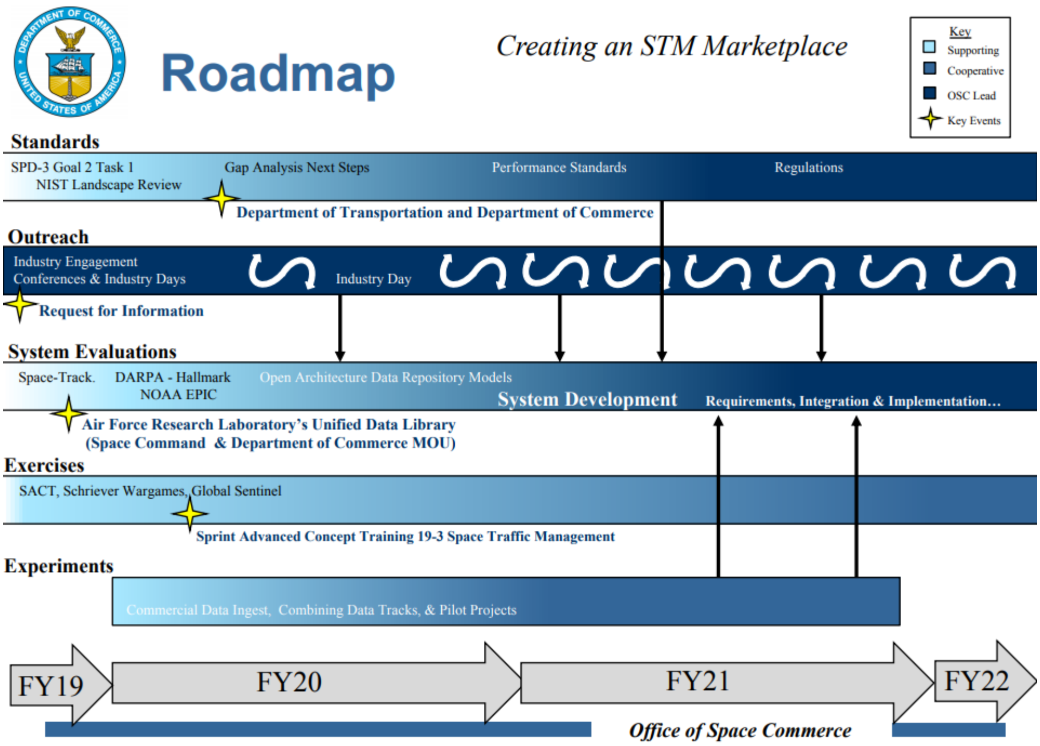


Figure 21: DoC roadmap for their involvement in SPD-3 implementation (source: DoC)[65]

According to the DoC, the principal activity is currently the development of the Open Architecture Data Repository which involves an evaluation of the Unified Data Library and reflection about possible future options. Based on the DoD catalogue, the repository is planned to become the main instrument to provide civil SSA data and STM services. DoC envisions an important contribution from commercial and international partners and is regularly interacting with potential partners. The repository is also envisioned as a "marketplace for innovation" encouraging the development of an SSA/STM value added market.

The DoC as well as other U.S. agencies for space, namely the FAA and FCC, have also launched independent public consultation processes to gather views from industry and experts on future necessary actions related to best practices, standards, regulation and commercial perspectives. There were three consultations in the context of SPD-3 (in chronological order – all consultations are now closed):

- FCC's Notice of Proposed Rulemaking on "Mitigation of Orbital Debris in the New Space Age" (released on 19 February 2019): The consultation aims to prepare the first major overhaul of the FCC's satellite debris mitigation rules since 2004.
- FAA's Notice of Proposed Rulemaking on "Streamlined Launch and Re-entry Licensing Requirements" (released on 14 May 2019): The FAA proposed updating, streamlining and increasing regulation flexibility to establish a single set of licensing and safety regulations across several types of operations and vehicles.
- DoC's Request for Information on "Commercial Capabilities in SSA and STM" (released on 11 April 2019): The consultation involved three primary questions on commercial enhanced SSA/STM capabilities, on orbital debris mitigation best practices, and on appropriate SSA/STM-related regulations to spur U.S. space commerce.

65 Office of Space Commerce (2019). Remarks from AMOS Conference 2019. Retrieved from: https://www.space.commerce.gov/remarks-from-amos-conference-2019/

The launch of a parallel consultation by the FCC in February 2019 actually revealed a lack of coordination/alignment between U.S. agencies in the implementation of SPD-3 provisions related to the update/development of debris mitigation standards. The situation also raised some questions regarding the role of the FCC in the domain of debris mitigation, in particular concerning the capacity of the Commission to address technical issues at stake.[66] The FCC is an independent agency, not legally bound by White House policies, and started requiring space debris mitigation plans as part of its commercial satellite licensing procedure in 2004.

This situation did not prevent an interagency working group led by NASA to progress on the update of U.S. Orbital Debris Mitigation Standard Practices which set rules for all U.S. satellite operators, including the military.[67] Several points of disagreements slowed down the progress of the working group but the federal government eventually issued updated guidelines in November 2019.[68] The updated ODMSP added a 5th objective on "clarification and additional standard practices for certain classes of space operations" including:

- Large constellations, consisting of 100 or more operational spacecraft,
- Small satellites (including CubeSats),
- Rendezvous, proximity operations and satellite servicing,
- Active Debris Removal operations and,
- Tether systems.

The updated ODMSP introduce a new request that "each spacecraft in a large constellation should have a probability of successful postmission disposal at a level greater than 90% with a goal of 99% or better."[69]

Overall, updates to the ODMSP were rather limited and the new version does not require a much more stringent approach to debris mitigation from satellite operators. A major point of discussion within the interagency working group concerned the 25-year rule for disposal deadlines that officials from the DoD sought to reduce, supported by other experts and a part of the industry.[70] It was eventually decided to maintain the 25-year threshold.

66 Hitchens, T. (2019). FCC Debates Space Debris Rules. Retrieved from: https://breakingdefense.com/2019/05/fcc-debates-space-debris-rules/
67 Note: The interagency working group included officials of the U.S. Departments of Defense, State, Commerce and Transportation and of the Office of the Director of National Intelligence. The FCC held a consultation role.
68 U.S. Government Orbital Debris Mitigation Standard Practices, November 2019 Update.
69 Ibid.
70 Hitchens, T. (2019). New Space Debris Rules Stalled By Year-Long Interagency Spat. Retrieved from: https://breakingdefense.com/2019/09/new-space-debris-rules-stalled-by-year-long-interagency-spat/.

4.2.4 Implications: opportunities and risks for Europe

The U.S. National STM Policy has implications for Europe that should not be overlooked. The implementation of some provisions could offer interesting opportunities to revisit and reinforce transatlantic cooperation in STM-related fields but could also, on the contrary, challenge European strategic autonomy and industrial competitiveness. Sooner or later, European interests will be put at stake by:

- U.S. plans to improve SSA capabilities through greater SSA data sharing
- U.S. plans to encourage U.S. commercial leadership in STM solutions
- U.S. plans to develop, update and promote STM-related standards and best practices

Opportunities and risks associated with greater SSA data sharing

A central objective of the U.S. policy is to provide timely, accurate and actionable SSA data to ensure the safety of operations. To do so, the policy recalls that "the United States should seek to minimize deficiencies in SSA capability, particularly coverage in regions with limited sensor availability and sensitivity in detection of small debris, through SSA data sharing, the purchase of SSA data, or the provision of new sensors."[71] Enhancing SSA data precision and accuracy necessarily implies to rely on multiple data sources including:

- National SSA data (based on domestic systems);
- SSA data from third parties (based on foreign/commercial SSA systems)
- Satellite operators' data (incl. satellite orbital parameters and manoeuvres).

In short, the United States seeks to enhance domestic SSA capabilities through the advancement of SSA technologies and development of new sensors, the improvement of SSA data sharing and through partnerships with industry (i.e. satellite operators and commercial SSA providers) and academia. Relying on multiple data sources, as planned for the open architecture data repository, will raise new interoperability challenges to ensure data quality, integrity, availability and confidentiality.

There is an undeniable opportunity for Europe to augment its SSA capabilities through a greater SSA data sharing policy provided it is based on mutual benefits.

SSA data sharing agreements are already a backbone of transatlantic cooperation. Even though the U.S. already have far better capabilities today, Europe has much to offer to an open architecture data repository. For example, European sensors provide complementary and redundant capabilities that contribute to a worldwide distribution of sensors and to enhanced tracking accuracy based on multiple measurement points.

There is also a risk of greater dependence on U.S. capabilities and reduced strategic autonomy.

U.S. SSA Sharing Agreements are powerful leadership instruments that can provide a great political and commercial lever, in particular if used in combination with regulation (e.g. standards). From this standpoint, and although transatlantic cooperation is essential and should be encouraged and reinforced, Europe must guarantee a capacity to control its level of reliance and to maintain it within acceptable boundaries. Europe certainly benefits from the U.S. "openness" but the current capability gap and imbalance in cooperative arrangements, poised to increase in the future, has strategic implications that should not be overlooked (see 4.1.3.Reinforce European Autonomy and Leadership, page 29). Europe is

71 White House (2018). Space Policy Directive-3 National Space Traffic Management Policy. June 18, 2018

therefore increasingly pressured to cope with the proactivity and efforts of the United States to reach an "appropriate level of European autonomy", yet to be defined.

Seizing the opportunity offered by U.S. plans to develop SSA data sharing and mitigating risks associated to a greater dependence on U.S. capabilities will likely be conditioned by:

- an improvement of European SSA capabilities supporting a more balanced burden sharing,
- an enhancement of SSA data interoperability, complementarity and redundancy to provide timely, accurate and actionable data while ensuring data quality, integrity, availability and confidentiality,
- a necessary prioritization of European strategic autonomy.

Opportunities and risks associated with the development of commercial solutions

The United States also intends to support and leverage private contributions to augment public SSA/STM capabilities and to ensure U.S. commercial leadership on an SSA/STM marketplace. To do so, the United States plans to better integrate private data and solutions, to finance R&D and innovation, and to optimize regulation to support commercial sector growth. The objective is twofold:

- enhance public capabilities and take advantage of competitive and innovative private solutions,
- allow public actors to focus on their strategic mission and on the delivery of basic public services while enabling the private sector to provide value-adding services.

The private sector already engaged proactively in the development of STM-related initiatives. The Space Data Association (SDA), for example, which was founded in 2009 as a response to the limitations of U.S. public SSA data, brings together satellite operators to share STM-related information. The association eventually established its own Space Data Centre (SDC) to provide conjunction assessment and warning services on the basis of member companies data as well as other available sources. The platform is designed and operated by the private U.S. company Analytical Graphics, Inc. (AGI). However, AGI is not the only private player and commercial SSA capabilities are actually developing quickly. For example, LeoLabs, another U.S.-based company, unveiled in 2019 its new Kiwi Space Radar (New Zealand), designed to track an estimated 250,000 additional objects down to 2 centimetres in size in LEO.[72] Other private companies, including a few European ones, are developing commercial STM-related solutions in particular for SSA data provision, processing and analytics.

Europe could also take advantage of a commercial SSA/STM marketplace and support the emergence of competitive and innovative European private solutions.

The commercial benefits and added-value sought by the U.S. government (e.g. cost savings, innovation, business development) would also be applicable to Europe. For this reason, supporting the emergence of European champions, offering competitive and innovative solutions to European and foreign users, could be considered a component of a European approach to STM. A prerequisite to explore such opportunity would be to engage more actively with the private sector, with the objective to:

- map European private capabilities,
- evaluate business opportunities and challenges,
- assess R&D needs.

Beyond the risk to miss an occasion to better leverage private contributions and give way to potentially promising markets, there are also risks associated with a U.S. commercial monopoly in STM.

72 LeoLabs (2019). LeoLabs Unveils Kiwi Space Radar. Retrieved from: https://www.leolabs.space/LeoLabs-KSR-Announcement.pdf.

Opportunities and risks associated with the development of standards and best practices

The United States clearly intends to support the development of operational standards and best practices to promote safe and responsible behaviour in space. In this respect, the policy states that "a critical first step […] is to develop U.S.-led minimum safety standards and best practices to coordinate space traffic […] and to use them to inform and help shape international consensus, practices, and standards."[73] The work already started with industry and experts' consultations launched by the DoC, FAA and FCC. Ultimately, these standards will be integrated in the U.S. regulatory framework including in particular certification and licensing procedures and will be promoted internationally.

Although Europe shares U.S. willingness to promote safe and responsible behaviour in space, the unilateral development of U.S.-led standards poses an obvious risk of competitive disadvantage for the European industry.

These standards will include specifications applicable at all stages of launcher and satellite operation. Compliance with these specifications will be a condition to get necessary certifications and licenses, for example by the FAA and FCC, and will inevitably create a disadvantage for European companies seeking to serve U.S. customers in the telecom domain, to compete on open U.S. satellite and launch markets but also to participate in U.S. space programmes.

The promotion of such U.S.-led standards as a basis for the establishment of common global best practices could extend their influence to other markets. The impact on commercial markets would be particularly severe if insurance companies decided to consider compliance with these safety standards in the calculation of insurance premiums for satellites and/or launch services.

The risk could be even greater if compliance with these standards requires or implies the use of SSA/STM capabilities that only the U.S. government or U.S. private sector can provide.

Such situation would dramatically increase the power of SSA data sharing agreements as political and commercial levers and assert a U.S. commercial dominance on SSA/STM markets.

For this reason, Europe must play a role in the development of STM standards and best practices to protect European industry interests and safeguard European strategic autonomy and freedom of action.

There could, however, be an opportunity to promote common standards and best practices provided that Europe plays an active role in their development.

As a matter of fact, the development of a set of common (or at least compatible) safety standards and best practices could form a second backbone for transatlantic cooperation. European and international standardization bodies (e.g. ECSS, ISO) could play an essential role to promote a coherent European contribution to the definition of common practices favourable to future programmatic cooperation, industry-to-industry collaboration and fair competition on international markets.

73 White House (2018). Space Policy Directive-3 National Space Traffic Management Policy. June 18, 2018

4.3 Views on Space Traffic Management in other countries

STM is not a new topic for other countries either. Even though no national STM policy framework comparable to the one of the United States has been formally enacted in any other country, it should be recalled that most spacefaring countries have, in fact, already embarked upon various activities that fall within the concept of STM.

Among these, 3 main areas of activity should be mentioned:

- The building-up and operation of space traffic monitoring functions through the setting-up of indigenous SSA capabilities or SSA data exchanges in order to gain more precise and timely information and enhance one's own otherwise insufficient capabilities. While the United States continues to maintain the most robust SSA system globally, other states such as Russia, China, Japan and India are also developing space monitoring programmes.
- Development, implementation and verification of regulations relevant to STM at both
    - international level: e.g. contribution to the definition of international guidelines for debris mitigation measures and long-term sustainability of outer space activities, contribution to international standards in ISO or CCSDS bodies, etc.
    - national level: e.g. development of a domestic regime of laws, regulations, standards, licensing procedures etc. The number of countries equipped with a specific regulatory framework or a dedicated national space legislation providing for safe and responsible behaviour in space is sensibly growing.
- Reinforcement of efforts in the domain of space traffic coordination including in particular transparency measures building on bilateral and multilateral information-sharing.

While these activities are generally not yet approached under a so-called STM umbrella, such inclusive concept is currently drawing a lot of attention. In 2015, Member States of the UN COPUOS agreed to make of STM a single agenda item in the annual deliberations of the Legal Subcommittee. During the first three years of discussions, 11 countries actively participated in deliberations on legal aspects of STM (Austria, Germany, Indonesia, Japan, Morocco, Netherlands, Pakistan, Russia, UAE, USA).[74] Incidentally, deliberations concluded that many elements of STM are already in place, that existing international space law already contains relevant provisions for STM, and that LTS guidelines include important recommendations in this respect. For example, Guideline B.1 recommends to "provide updated contact information and share information on space objects and orbital events" and Guideline B.2 recommends to "improve accuracy of orbital data on space objects and enhance the practice and utility of sharing orbital information on space objects".[75, 76]

Some actors have started discussing national approaches to STM, even though with a lower level of priority, maturity or transparency as compared to the United States. Recent developments in Japan highlight the possible taking up of an approach closely resembling the U.S. process. Some bottom-up initiatives such as, most notably, the Keio-JAXA study group on STM with participation of a broad range of stakeholders, are evidence of this progressive consolidation of a national approach to STM.[77]

74 Betmann, M. and Stube, P. (2018). Space Traffic Management: An analysis of three years of discussions at the Legal Subcommittee of UNCOPUOS. Conference Paper at the 2018 International Astronautical Congress (Paper ID IAC-18,E3,4,9,x44235)
75 UN Doc. A/AC.105/C.2/L.309/Add.1 Status and application of the five United Nations treaties on outer space (2019).
76 UAE Space Agency (2019). Space Traffic Management. Retrieved from: https://www.unoosa.org/documents/pdf/copuos/lsc/2019/tech-03E.pdf.
77 Takeuchi, Y. (2019). Space Traffic Management (STM) in the Nature of International Space Law. 5th Space Traffic Management Conference. Retrieved from https://commons.erau.edu/cgi/viewcontent.cgi?filename=2&article=1254&context=stm&type=additional

The Chinese government has also recognized the importance of setting up an STM regime. While STM has not yet been specifically mentioned in any national legal or policy documents, Yang Kuan, of the Beijing Institute of Technology, argues that "[Chinese] regulations and policies have undoubtedly laid the foundation for building a STM regime"[78] taking as an example the recently issued Interim Measures on Space Debris Mitigation and Protective Management. At the same time, Chinese officials have made it clear that since space activities are inherently international, the establishment and implementation of an STM system should build on the international legal regime and that national approaches should not be privileged.

On a similar stance, Russia has formally recognized the importance of setting-up an STM system, but also stressed that the establishment and management of such system should be based on an internationally agreed-upon mechanism rather than distinct national approaches. The statement made by the Russian delegation at the 4th Committee of the UN General Assembly in October 2018 illustrates Russian views and concerns[79]:

"We have to state that the current phase of discussions on STM in various formats is to an ever greater and dangerous degree being characterized by an outright politicization and preconception [...] Complete concept of STM should cover all issues related to: ensuring the safe operation of large constellations, pre-launch conjunction assessments, performing close proximity operations, active space debris removal, warning on potentially hazardous events. STM implementation largely depends on the degree of success of States in the mutual provision of information on space objects and events and in their joint efforts to increase the accuracy of such information [...] The politically motivated speeding up of decisions on STM we are witnessing is fraught with serious danger [...] As of today no one has provided a distinct concept of a truly international mechanism of modelling STM."

Irrespective of these specific national stances on STM issues, it is important to highlight that several other countries have already started to reflect upon their own approach to STM. There are major points of divergence across these countries, due to their understandably divergent interests, priorities and concerns. This situation might slow down or even deter the implementation of effective international efforts in this domain.

78 Kuan, Y. (2019). Chinese perspective on an international regime of space traffic management. In The Journal of Space Safety Engineering. Vol 6. Issue 2, pp. 156 – 160.
79 Statement of the Russian Federation at the UN General Assembly 4th Committee on October 24 2018.

5 CURRENT APPROACH TO SPACE SAFETY AND SUSTAINABILITY IN EUROPE

Summary: As a major space player, eager to protect its space infrastructure from harm and to promote the preservation of a safe and secure space environment, Europe is already actively involved in the monitoring, regulation and coordination of space traffic. As a matter of fact, it can be argued that Europe already set some principles and developed some building blocks that could constitute the foundations of a more integrated and operational approach to Space Traffic Management.

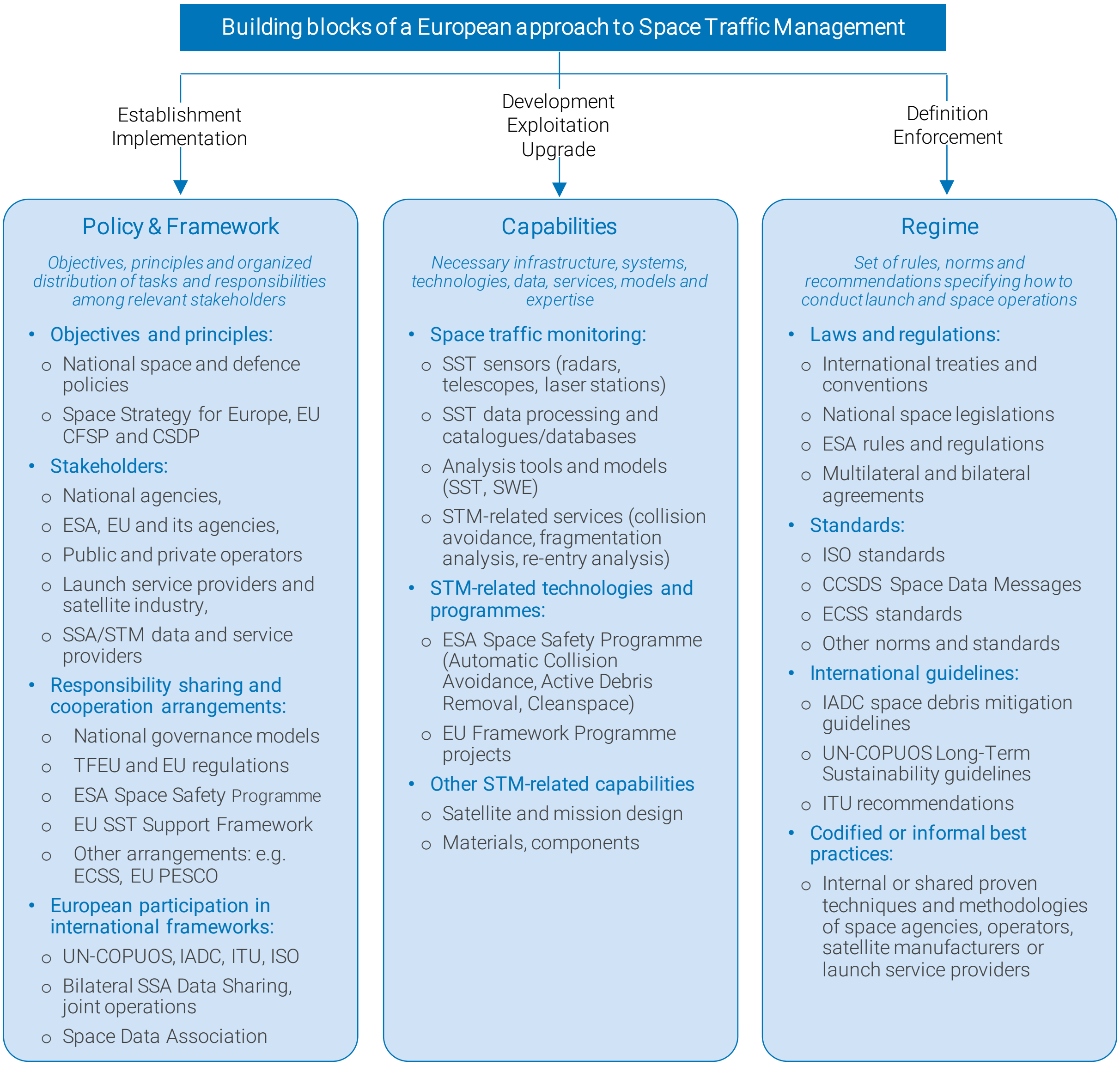


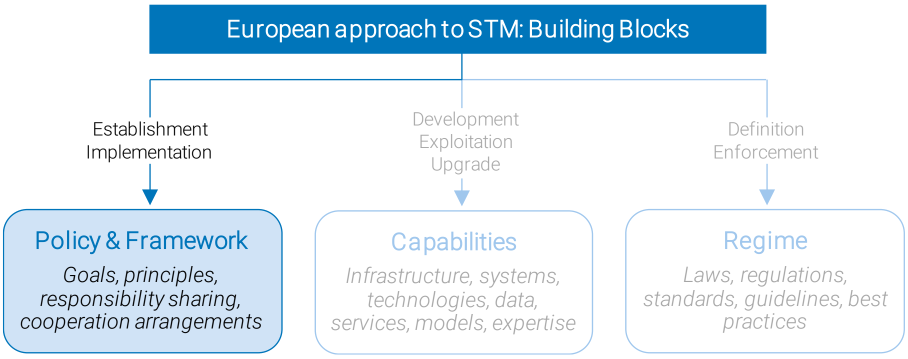
Figure 22: Building blocks of a European approach to Space Traffic Management

Main observations:

- *Europe already addresses a share of STM functions through various parallel domestic activities as well as an active participation in multilateral and bilateral frameworks.*
- *The European approach to STM-related issues is multilayered, centred around the sovereign competence of national governments over policy, regulation and capabilities in space security domains.*
- *A more integrated and operational approach to STM in Europe will require some update/upgrade and harmonisation of European frameworks, capabilities and regime along a common policy.*

5.1 European policy and framework to address STM-related issues

European actors already developed several policies and activity frameworks that are directly or indirectly related to Space Traffic Management and usually addressed within the scope of space security.



Together, they establish some principles and goals relevant to STM and outline the roles and responsibilities of the various European stakeholders with regards to space traffic monitoring, regulation and coordination.

Main observations:

- The European approach to STM-related issues is multilayered and encompasses various national, intergovernmental, supranational and international engagements that are not always coordinated. Authority, responsibility, competence, expertise and resources are scattered across multiple national and European stakeholders which brings an additional layer of complexity.
- A vast majority of STM functions fall within Member States competence and national governments remain central players of most STM-related engagements. The level of involvement and effort remains uneven among European countries and most activities are led by a handful of more motivated Member States. There is, however, a growing appetite in Europe to promote a responsible behaviour in outer space and STM-related issues are raising interest in an increasing number of European Members States.
- European cooperation is progressing. The role of the EU is so far limited to supporting and facilitating cooperation between Member States. ESA plays an important role in capacity-building and development of standards and best practices. The role that European institutions shall play in the future will need to be further refined, in particular in light of the substantial progress made by the EU space programme and the rising importance of its security dimension.
- The role granted to the private sector is so far limited and does not seem to be perceived as a priority in Europe for the moment, contrasting with the commercial-oriented approach sought in the United States. Some private companies are, however, seeking a more proactive role in various STM-related areas.
- The publication of the U.S. national STM policy contributed to raising awareness about the criticality and urgency of issues at stake and triggered initial reflections about a potential European approach to Space Traffic Management. Preliminary discussions revealed a multiplicity of viewpoints about this issue among Member States, European institutions and experts.

5.1.1 A multilayered framework structured around national competence

In Europe, the current approach to STM-related functions (i.e. monitoring, regulation, coordination) builds upon a multilayered structure of diverse frameworks and activities. Organized at national, intergovernmental and European levels, institutional efforts span across the spectrum of capacity-building programmes, legal and regulatory measures, cooperation arrangements and diplomatic initiatives.

In Europe, STM-related activities are primarily led and organized at national level:

- National governments are the owners and operators of the main systems monitoring space traffic that are managed as assets of strategic significance for national security and sovereignty.
- National space laws and regulations govern activities in space by setting the requirements for licenses authorizing organisations to conduct launch and space operations.
- National delegations hold voting rights in international frameworks such as the UN COPUOS or ITU.

Despite a convergence of interests between different policy domains in the field of space security, the military and national security dimension remains prevalent at national level. Consequently, the most active countries in military space programmes (i.e. France, Germany, Italy, United Kingdom, Spain) are also the most active in space traffic monitoring. These countries may have different objectives, although overall convergent, that are set by national policy documents (space policy, defence policy). Different concerns and approaches gave rise to different national governance models involving several ministries and organisations concerned by space security matters among which, of course, national space agencies. Efforts also remain uneven among the most proactive countries, in particular in the field of space traffic monitoring capabilities and regulation.

Although national sovereignty remains, so far, a structural component of space security in Europe, national action in this field has for long been flanked by the development of bi- and multi-lateral agreements for data sharing, resources pooling, operational coordination or diplomatic collaboration among European countries. Dispositions to cooperate stem from a programmatic and geopolitical environment facilitating and promoting cooperation between European countries (i.e. European Union, ESA…) but also from practical considerations concerning the difficulty for these countries to achieve, on their own, objectives that require considerable resources. From this standpoint, national strategies underline a growing readiness and willingness to build on European cooperation in the field of space security. The involvement of European institutions in space security, namely the European Union and the European Space Agency, obviously contributed to give raise to a new dimension in European cooperation. Building on bilateral and pan-European cooperation, the French Stratégie Spatiale de Défense, published in July 2019, declares in this respect that "beyond existing projects, a Europe of space must emerge to contribute directly to the construction of European security and defence on the continent. To do so the Franco-German motor must federate energies, in particular in the frame of a European SSA project."[80]

5.1.2 European cooperation, the structuring roles of the EU and ESA

In this context, the role of the European Union in space security has grown within a broader and more political framework and at the nexus between developments of the EU mandate and ambitions in the space domain on one hand, and in the security and defence domain on the other. In this regard, the Lisbon Treaty (2009) was a stepping stone for both domains, establishing shared competences between Member States and the European Union, but it is the significant progress of EU space programmes together with Jean-Claude Juncker's Security Union ambitions that contributed more recently to make

80 Ministère des Armées (2019). Stratégie Spatiale de Défence.

the European Union an increasingly relevant actor in the space security field. Notwithstanding a noticeable progress of its perimeter and involvement, the role of the Union in this field remains, so far, limited to support actions and diplomatic initiatives:

- Support to R&D projects, funded under Framework Programmes for Research and Technological Development (FP7, H2020) for a total contribution estimated around €68 million between 2007 and 2017. EU grants supported a wide range of R&D projects from SSA-related technologies to active debris removal solutions or autonomous collision avoidance.
- Support to European SST cooperation, with the establishment of a Space Surveillance and Tracking Support Framework in 2014 (EU SST Support Framework) with the objective to network national SST assets and provide STM-like services to European users.
- Diplomacy and international cooperation, with the establishment of Space Policy Dialogues with key partners, active participation in international organisations and committees such as the UN COPUOS or ITU, and the promotion of international initiatives such as the ill-fated proposal for an International Code of Conduct for Outer Space Activities (ICoC) and more recently the 3SOS initiative aiming at encouraging efforts towards safety, security and sustainability of outer space activities.

ESA also plays an important role in the field of space safety, in particular for capacity-building, R&D and standardisation. Despite a convention that did not envision (but did not forbid either) activities in the field of space security and safety, ESA developed a recognized competence and expertise in the scientific and research dimension, with somewhat limited connection to national defence and security strategies. Eventually, the Agency "has evolved to conduct security related projects and programmes and to address the threats to its own activities".[81] ESA now has the capacity to receive, store, and produce classified information as well as to exchange classified information with third parties such as the EU Council, marking a step forward in the role that the Agency could play in the field of space security in the future. Beyond security-related responsibilities in the management of space programmes and the safe operation of its own space systems, activities of the Agency in the field of space security include noticeably:

- An SSA programme funded by 19 ESA Member States through 2020 at approximately €200 million for the period 2009-2020 and dedicated to a variety of capacity-building projects and systems procurement across Space Surveillance & Tracking, Space Weather and Near-Earth Objects pillars.
- The CleanSpace Initiative, which promotes an eco-friendly and sustainable approach to space activity through different projects addressing the entire lifecycle of space systems from conceptual design to end of life, up to removal of debris.
- The development of standards through the European Cooperation for Space Standardisation (ECSS) and liaison/participation in ISO or CCSDS frameworks.
- Participation in international fora that work in different ways on space security including the IADC or the UN COPUOS of which ESA became an observer in 1972.

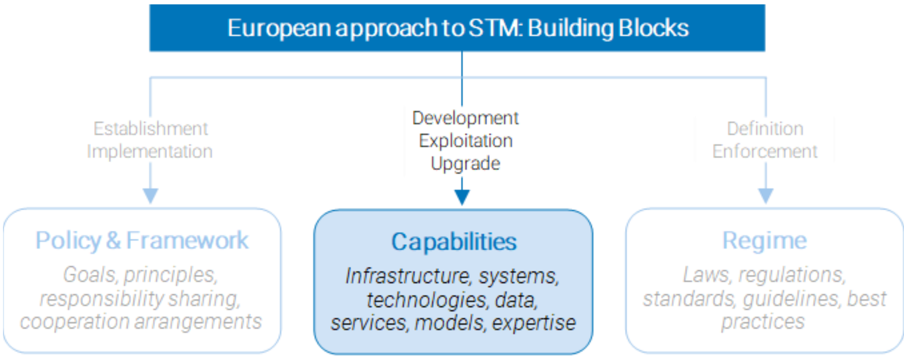
In addition to these central institutional actors and activities, the European space security landscape also encompasses other minor public activities as well as some industry-led endeavours to which European companies actively participate or even lead such as the Space Data Association, a non-profit association of satellite operators that supports the controlled, reliable and efficient sharing of data that is critical to the safety and integrity of satellite operations. Today, the involvement of the European private sector in space traffic monitoring for the provision of STM-related data and services is rather limited but industry actively contributes to STM-related R&D programmes as well as standardization efforts.

81 Giannopapa. C, Adriaensen. M, Antoni. N, & Schrogl. K-U. (2018). Elements of ESA's policy on space and security. In: Acta Astronautica 147, pp. 346–349.

5.2 Space traffic monitoring capabilities and other STM-related technologies

A first outcome of European activities in the space security domain has been the development of domestic STM-related capabilities including in particular:

- Space traffic monitoring capabilities, up to the provision of STM-like services
- STM-related technologies such as automatic collision avoidance or active debris removal



Together, these capabilities could constitute the main technical building blocks of an operational approach to Space Traffic Management in Europe.

Main observations:

- Member States are the primary owners and operators of space surveillance systems. The operation of these systems involves both military and civil actors and they are managed as assets of strategic significance for national security and sovereignty.
- The EU SST consortium substantially reinforced European cooperation by supporting capabilities pooling & sharing (sensors networking, data sharing, common database, precursor catalogue, data policy) to deliver operational STM-like services to registered European users (collision avoidance, re-entry analysis, fragmentation analysis).
- Space traffic monitoring capabilities currently available in Europe are not fully adapted to deliver the level of performance (coverage, accuracy, timeliness) required by a fully operational monitoring of space traffic. Limitations mostly stem from sensor performance, availability and geographical distribution. A sound gap-analysis between current capabilities and future user needs in the context of STM would be a prerequisite to devise an operational approach in Europe.
- Europe considerably relies on U.S. data sharing agreements for the monitoring of traffic in space and the provision of STM-like services to European operators. Mitigating this dependence is a matter of enhancing European capabilities to autonomously detect and track a higher number of objects with a suitable level of precision. A meaningful reduction of this dependence in the foreseeable future would require a determined plan and involve considerable investments.
- At the Space19+ conference, Member States confirmed the key role of ESA in space safety both in the promotion of a safe and sustainable approach to space activities and in the development of pioneering STM-related technologies (e.g. Automatic Collision Avoidance, Active Debris Removal) which could give Europe a technological edge in the domain.

5.2.1 National sensors, strategic assets

In Europe, capabilities to monitor objects in space are referred to as Space Surveillance and Tracking or SST. It is a component of the wider Space Situational Awareness domain that also encompasses the monitoring of space weather (SWE) and near-Earth objects (NEO). In short, SST capabilities include:

- A sensor function involving ground-based and/or space-based systems (i.e. sensors) using optical or radar techniques to detect and track objects in space. These sensors, that can be networked, provide raw data on the object geometry and/or orbital dynamics.
- A processing function consisting in models, algorithms and other analysis tools and methods to process raw data into actionable information that can be stored in databases and catalogues of space objects.
- A service function based on SST data and value-adding analysis, processing, measurements to provide users with useful information supporting space operations such as Conjunction Data Messages (detection and information on potential conjunctions), support to collision avoidance (analysis, recommendations) or reports on specific events such as object re-entry or fragmentation.

European SST sensors include radars, telescopes as well as laser stations located principally in continental Europe but also in other parts of the World (telescopes only) in North and South America, Africa, Oceania, Asia and islands in the Atlantic and Pacific Ocean. Many of these sensors are not fully dedicated to the surveillance and tracking of objects in space.

12 Radars

Mode	Name	MS
Surveillance	BIRALES	IT
	Fylingdales [1]	UK
	GRAVES	FR
	GESTRA [1, 2]	DE
	S3TSR	ES
Tracking	BIRALET	IT
	CASTR	UK
	MFDR	IT
	SATAM (3)	FR
	TIRA	DE

4 Lasers

Mode	Name	MS
Tracking	SLR Graz	DE
	ROA SLR	ES
	MLRO	IT
	Borówiec SLR	PL

35 Telescopes

Mode	Name	MS
Surveillance	Anjin-San [2]	PL
	Beata [2]	PL
	CENTU	ES
	MoonBase [1]	PL
	NEEMO-35	RO
	OASA	PT
	PANOPTES (3) [1, 2]	PL
	Polonia [1]	PL
	Rantiga [1]	PL
	Solaris [1]	PL
	SPADE	IT
	TAROT (3) [1]	FR
	TFRM	ES
	T04-Berthelot [1,2]	RO
	Starbrook	UK
Tracking	Bootes (2)	ES
	CAS	IT
	Cassini	IT
	GEOF	UK
	IAC-80	ES
	NEEMO-50 [2]	RO
	PANOPTES	PL
	PdM-MiTe	IT
	PST-2	PL
	Solaris (2)	PL
	TJO	ES
	Tracker	ES
	T030-AROAC [2]	RO
	T030-BitNET [2]	RO

[1] Sensors perform both surveillance and tracking

[2] Sensors will enter into operations later than 1st April 2019, as declared in the 1SST2018-20 Grant

Figure 23: Non-exhaustive list of European SST sensors (source: EU SST Consortium)

As suggested in the figure above, European states are the primary owners and operators of SST sensors in Europe. ESA also funded the development of complementary systems as part of its SSA programme such as a space debris test radar located in Spain, designed to test new methods for finding orbital debris.[82] These systems are operated in different ways according to the nature of ownership (civil/military) and to their initial purpose (scientific/operational). Different protocols and data policies are also implemented for the handling and processing of sensor data. Although the management of SST systems and data involves both military and civil actors, the national security dimension outweighs other concerns overall. As a consequence, Member States are particularly eager to preserve their national sovereignty in the SST domain and to retain control over the operation and ownership of SST sensors.

82 ESA. (2012). ESA deploys first orbital debris test radar in Spain. Retrieved from: https://www.esa.int/Safety_Security/Space_Debris/ESA_deploys_first_orbital_debris_test_radar_in_Spain.

5.2.2 EU SST Support Framework: delivering STM services since 2016

Although national sovereignty remains an important component of European countries' approach to space traffic monitoring, this objective is not pursued at the expense of cooperation, in particular with other European countries. From this standpoint, European countries engaged in a number of bi- and multi-lateral agreements for data sharing, resources pooling, technology transfer, and other cooperation arrangements.

A major step forward was made with the introduction of the SST Support Framework by the European Union in April 2014, on request of some Member States, especially France and Germany, who sought to cooperate through a specific governance scheme allowing them to maintain control over their assets while pooling and sharing SST data. The objective was then to promote a framework that would foster European cooperation and improve cost-efficiency (e.g. by avoiding unnecessary duplication of efforts) to deliver services to registered users while complying with national concerns resulting from the specific nature of SST systems and data. In compliance with the principle of shared competences between the European Union and Member States in the field of security and space, the framework would also enable to transfer a share of the financial burden to the European Union. Eventually, the European Parliament and the Council adopted Decision No 541/2014/EU which established the EU SST Support Framework.[83]

The purpose of the framework is very well aligned with STM objectives with the specific goals to 1) assess and reduce the risks of collision to enable operators to carry out and plan mitigation measures, 2) reduce risks related to launches, 3) survey uncontrolled re-entries of space objects to Earth atmosphere and 4) prevent the proliferation of space debris. To do so, the support framework aims to pool and network national and European assets to provide services. The following diagram provides a simplified representation of how the EU SST Consortium mobilizes European capabilities to provide STM-like services for collision avoidance (CA), re-entry analysis (RE) and fragmentation analysis (FG):

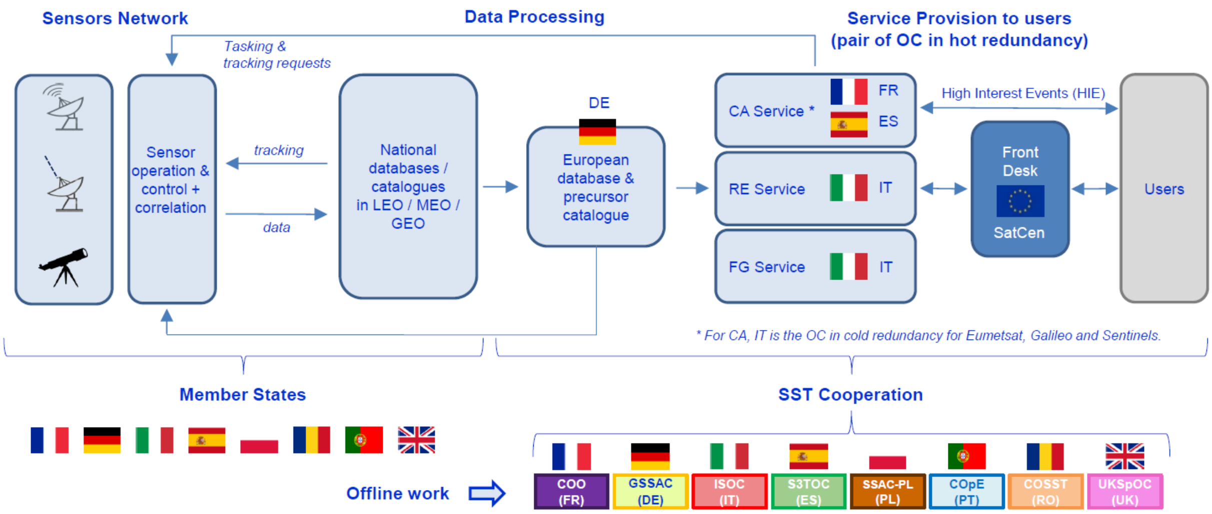


Figure 24: SST service provision model in Europe (source: EU SST Consortium)

Specific activities include:

- The establishment and operation of a sensor function consisting of a network of Member States and European sensors to survey and track space objects, creating then a database;
- The establishment and operation of a processing function to process and analyse SST data (at national level) in order to produce SST information;

83 European Commission (2014). DECISION No 541/2014/EU OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 16 April 2014 establishing a Framework for Space Surveillance and Tracking Support.

- The provision of public civil services to registered users including all Member States, the European Commission and Council, the European External Action Service, public and private spacecraft operators and public authorities concerned with civil protection.

According to a report from the European Commission on the implementation of the framework (covering 2014-2017) published in May 2018, "a total of EUR 167.5 million has been allocated for 2015-2020 through various grants".[84]

Member States are directly responsible for the operation of their national sensors and the processing of data in compliance with agreed upon data and information policies. The role of the Commission is to manage the SST Support Framework, as well as monitor and ensure its implementation. The Commission also defines the general guidelines for the governance of the framework and facilitates the broadest participation of Member States. The EU SatCen cooperates with the consortium and acts as the EU SST Front Desk, providing SST services to SST Users. The consortium started in March 2015 with five Member States (i.e. France, Germany, Italy, Spain and the United Kingdom) represented by a national entity (i.e. respectively CNES, DLR, ASI, CDTI and UKSA). In line with the ambition to develop a broader European SST capability benefiting all Member States, Poland, Portugal and Romania joined the consortium in 2019.[85] Other countries have also expressed their interest.

In 2018, the European Commission reported the following key achievements from the framework:[86]

- availability of the EU SST services (i.e. collision avoidance, in-orbit fragmentation and re-entry services) to all European institutional users and spacecraft owners and operators free of charge and on a 24/7 basis through the EU SST portal, since July 1st 2016;
- outreach to users including identification of potential users, documentation of their needs and awareness raising of space risks and the need to protect space infrastructure. As of April 1st 2019, there were a total of 103 users, representing 56 organisations and 18 EU Member States;
- cooperation and collection of shared know-how with the establishment of regular communication between national operations centres and increased cooperation between national experts through working groups;
- mapping and pooling of European assets with 33 sensors (now 51) contributing to the initial EU SST operations, a complete mapping of national and European sensors and be-ginning of national sensors upgrades;
- outreach to other Member States to collaborate with or to join the SST Consortium.

A European database to share and store measurement data from sensors of the network is operational since April 1st 2019. It is a first important step in the development of a European precursor catalogue of objects with orbital data based on a pre-processing, analysis and correlation of measurement data from the database. As an increasing volume of data will be shared through the European database and processed into a European precursor catalogue, a data policy revision is planned to ensure an efficient sharing and use of the data while considering national security constraints. All Member States have general security agreements for the protection of classified material with each other but Germany and France are the only European countries to have formalized a bilateral SSA data sharing agreement covering the exchange of classified SSA data.

84 European Commission (2018). REPORT FROM THE COMMISSION TO THE EUROPEAN PARLIAMENT AND THE COUNCIL on the implementation of the Space Surveillance and Tracking (SST) support framework (2014-2017).
85 Note: Applying states must own or have access to adequate SST sensors, already available or under development, as well as to the human resources to operate them and must establish and present an action plan including the modalities of cooperation with other Member States.
86 European Commission (2018). REPORT FROM THE COMMISSION TO THE EUROPEAN PARLIAMENT AND THE COUNCIL on the implementation of the Space Surveillance and Tracking (SST) support framework (2014-2017).

5.2.3 European monitoring capabilities and reliance on U.S. data sharing agreements

The following table provides a simplified overview of European capabilities in terms of share of objects observed and planned to be observed according to different architecture simulations.[87]

	Reference population	2017	2021	2028
LEO (>7cm)	25.313 objects	19%	23%	37-45%
MEO (>35cm)	271 objects	18%	-	80%
GEO (>35cm)	2.210 objects	-	93%	100%
GEO (>50cm)	2.024 objects	40%	99%	100%

Table 3: Share of the reference population of objects observed by European sensors – evaluation in 2017 and latest simulations for 2021 and 2028 (source: European Commission, EU SST Consortium)

Results of the feasibility study conducted by the EU SST Consortium show that:

- In GEO, a complete autonomous survey capability is feasible by 2028 for objects larger than 35cm,
- In MEO, Europe could be able to catalogue 80% of objects larger than 35cm by 2028,
- In LEO, Europe could be able to catalogue 37 to 45% of objects larger than 7 cm and up to 60% of objects larger than 10 cm by 2028.

The limitations of European capabilities stem from sensor performance, availability and geographical distribution. For MEO for example, limitations come mainly from a non-optimized surveillance strategy rather than network capabilities.

Public information on European capabilities are limited. A sound gap analysis between European capabilities and user needs in light of STM objectives would be a prerequisite for any European approach to STM.

European capabilities are still highly reliant on U.S. SSA data sharing agreements for the provision of services. In 2018, the European Commission estimated that 97% of Conjunction Data Messages uploaded to the EU SST portal included information received from the United States for the second object. This percentage drops to 78% for conjunctions in MEO and GEO orbits. U.S. data are used directly by Member States as part of the processing function:

- 7 Member States (Germany, Spain, France, Italy, Poland, Romania, UK) concluded specific bilateral SSA data sharing agreements with the United States, covering the exchange of unclassified SSA data.
- Germany, France and the United Kingdom also have bilateral SSA data sharing agreements with the United States that cover the exchange of classified SSA data as well as liaison officers.

Overall, the USSTRATCOM signed SSA data sharing agreements with 14 governmental European entities (2 IGOs – ESA and EUMETSAT, 12 national governments).[88] Mitigating Europe's reliance on the United States and closing the capability gap would require considerable investments, in particular in light of the $1.6 billion invested in the U.S. Space Fence programme that will further increase U.S. monitoring capabilities. This situation implies that Europe will have to ensure a balance between the need for European strategic autonomy and the necessary reliance on U.S. data to achieve operational objectives.

87 Note: the table brings together two sources with different scopes and does not consider differences between "observed" and "well observed" objects as well as differences between cataloguing and coverage simulations.
88 The USSTRATCOM signed SSA sharing agreements with Belgium, Denmark, Finland, France, Germany, Italy, Netherlands, Norway, Poland, Romania, Spain, UK. In addition, the USSTRATCOM signed 8 other agreements – Brazil, Canada, Israel, Japan, New Zealand, South Korea, Thailand and UAE and established 80+ partnerships with private operators.

5.2.4 Space19+, confirmation of ESA key role in R&D for STM-related technologies

ESA already plays an essential role and has developed a well-established expertise in a number of STM-related activities in particular through the European Space Operations Centre (ESOC), the CleanSpace Initiative and the ESA SSA programme. The optional programme has been funded by 19 ESA Member States through 2020 at approximately €200 million for the period 2009-2020. A total budget of €95 million was allocated on the period 2017-2020 alone. This budget has been dedicated to a variety of capacity-building projects including research and technology, set-up and operation of data and coordination centres, and systems development and procurement. The programme involved, among other things, the development of two new radars, respectively, in Spain (monostatic test radar) and France (bistatic test radar) to support future SST capabilities for civilian purposes.

Following the Space 19+ Ministerial Conference, ESA activities were substantially reorganized. The SSA programme was integrated with other activities in a broader Space Safety & Security Programme covering activities in the field of space weather,[89] near-Earth objects,[90] cybersecurity, security applications and, in STM-related domains:

- Space debris: ESA contributes to ensure the safety and sustainability of the space operating environment. Planned activities include:[91]
  - ESA will enable the safe operation of individual satellites and large constellations by developing and demonstrating an Automated Collision Avoidance System, free from causing damage.
  - ESA will support the monitoring and safe management of space traffic and the application and verification of the necessary debris mitigation measures according to internationally agreed upon guidelines, standards and best practices
  - ESA's Space Debris Office will continue to assessing, model and mitigate the risks caused by debris and re-entries through development of new sensor and monitoring technology for radars, laser ranging and optical space surveillance, based in orbit and on ground, to include 'piggyback' hosted payload and smallsat options.
- CleanSpace: Established in 2012, the main objective of the ESA CleanSpace Initiative is to promote an eco-friendly and sustainable approach to space activity through the development of industrial materials, processes and technologies that are both Earth and space environment-friendly. The initiative addresses the entire lifecycle of space systems from conceptual design to end of life, and up to removal of debris. With the objective of covering all aspects of the environmental footprint of space activities, CleanSpace comprises three branches:
  - CleanSat: development of techniques and technologies to reduce the production of space debris
  - EcoDesign: designing to address environmental impacts and foster green technologies through the establishment of a common eco-design framework for the European space sector.
  - Active Debris Removal/In-Orbit Servicing (previously known as eDeorbit): development of a multi-purpose In-Orbit Servicing Vehicle (IOSV) able to perform a variety of operations in orbit including in the field of active debris removal.

At the Space19+ Conference, ESA Space Safety Programme received an envelope of 412 M€ for activities through 2022, including 90M€ for core activities. Some of these pioneering activities could give Europe a technological edge, in particular to automate collision avoidance or remove most hazardous debris.

89 Note: ESA plans to develop a European space weather monitoring system based on multiple space- and ground-based sensors, establish a European Space Weather Service Network to process data and provide analysis on space weather events, enhance ESA's Space Weather Coordination Centre's ability to provide warnings and alerts and other activities to bring Europe closer to the delivery of full-fledged space weather services.
90 Note: ESA will conduct several missions and complementary activities to improve knowledge about asteroids and contribute of a global planetary defence system, capable of providing early warning and deflection capabilities for potential geo-cruisers.
91 ESA. Plans for the future. Retrieved from: https://www.esa.int/Safety_Security/Plans_for_the_future

ClearSpace-1 will be the first space mission to remove an item of debris from orbit, planned for launch in 2025.

ESA also developed and provides its member states with various software and analysis tools, which have great benefit to process raw SSA data and thus also have significance in STM considerations:

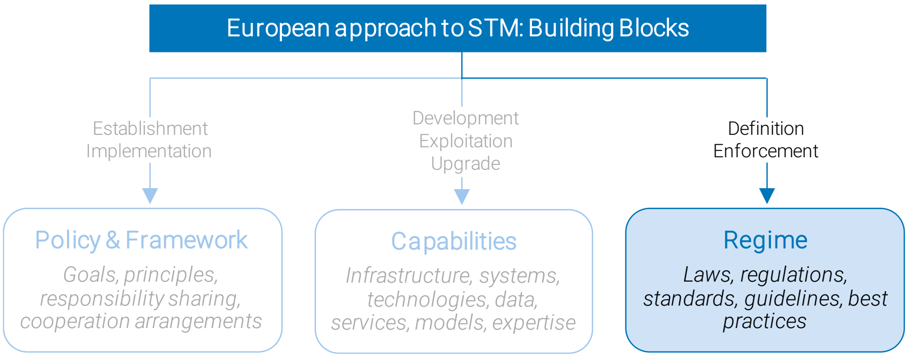
- DRAMA (Debris Risk Assessment and Mitigation Analysis), a tool for the verification of space mission compliance with mitigation guidelines;
- MASTER (Meteoroid and Space Debris Terrestrial Environment), a model for the prediction of debris and meteoroid particle fluxes;
- DELTA (Debris Environment Long--Term Analysis), a tool for investigation of the evolution of the space debris environment in different orbits and over a number of years.
- Spacecraft Conjunction Assessment and Risk Front-end (SCARF) supporting close approach analysis and communication with the flight control, flight dynamics and mission management
- DISCOS (Database and Information System Characterising Objects in Space), a reference database for all trackable, unclassified objects (totalling over 40 000 objects, but mostly from U.S. data).

Additional software tools as well as provision of services are also developed at national levels (French JAC software, German BACARDI software…). These software tools are predominantly used for internal purposes within the broader national SST system.

In the frame of its engagement in the promotion of a safe and sustainable space operating environment, ESA works closely with European and international partners. ESA coordinates its efforts with European Member States, interacting with ministries of defence, space agencies and other national institutions, as well as with foreign institutions. At the international level, ESA is particularly proactive in international forums that work in different ways on security in outer space including the IADC, IAA, and UNCOPUOS of which ESA became an observer in 1972.

5.3 European regime and STM-related provisions

A second outcome of the European approach to space security has been the development of a "regime" governing space activities in Europe and which includes various provisions encouraging, or even compelling, European actors to conduct these activities in ways that are not detrimental to the safety and long-term sustainability of the space operating environment.



Comparably, the laws, rules and standards comprising this regime could constitute the main building blocks of a European approach to space traffic regulation.

Main observations:

- International space law makes States responsible and liable for space activities, which motivated the most active ones, in particular launching states such as France, to adopt domestic legislations for licensing and authorization of space activities reflecting their international commitments.
- The regime governing space activities in Europe is comprised of multiple laws, regulations, and standards setting requirements to conduct launch and space operations. These requirements can be legally binding or not. Some of these requirements are directly or indirectly related to STM issues (e.g. regarding space objects registration, space debris mitigation measures, post-mission lifetime limitation). Many provisions are derived from international treaties, guidelines or best practices, in particular those related to space safety and sustainability or to space objects registration.
- Standardization bodies play a central role to capture best practices of a variety of stakeholders and to translate them into common requirements. Europe has developed a particularly well-organized structure for the production and update of space standards, such as the ECSS, providing for a coherent system of norms. ISO has been the most active standardization body to address space operations and to promote a global approach to safety and sustainability. ISO is contemplating ways to improve the adequacy, coherence and added-value of standardization in the context of STM.
- There is a strong bottom-up harmonisation of European best practices and contributions to international norm-setting, either through well-established cooperation setups or through a proactive coordination among European actors in international frameworks. There is however no formal mechanism to ensure the suitability and consistency of the overall regime at European level.
- Europe is a major advocate of the preservation of a safe and sustainable space operating environment. The European regime, among the most stringent in this respect, as well as European contributions and initiatives on the international scene, demonstrated Europe's willingness to take a constructive role in this domain.

5.3.1 European regime and provisions related to Space Traffic Management

The regime governing space activities in Europe is comprised of a mix of binding and non-binding instruments such as laws, regulations, standards, guidelines and best practices that provide rules, norms and recommendations on how space activities shall, or should, be conducted:

	Examples
Laws and regulations System of rules developed by an authority to govern activities in the space sector and which may be legally enforced.	**International treaties and conventions** • Outer Space Treaty • Liability Convention, Registration Convention • ITU Convention and regulations **National legislations** • Netherlands' Space Activities Act (2007) • French Space Operation Act (2008) • Austria's Outer Space Act (2011) • Danish Outer Space Act (2016) **ESA rules and regulations** • ESA Procurement Regulations • ESA Security Regulations • ESA Rules on Information, Data and Intellectual Property **Multilateral and bilateral agreements** • Data sharing agreements • Cooperation agreements
Standards Established norms based on codified documentation describing measurable and verifiable requirements, specifications or characteristics of a process or system.	**International and European standards** • ISO standards • CCSDS Space Data Messages • ECSS standards • Other norms and standards
Guidelines and best practices Set of recommendations on how something should be done including techniques or methodologies with proven results and accepted as superior to alternative practices.	**International guidelines** • IADC space debris mitigation guidelines • UN COPUOS space debris mitigation and Long-term sustainability guidelines • ITU recommendations **Codified or informal best practices** • Internal and informally shared best practises • Procedures for data management, archiving and sharing.

Table 4: Overview of rule-based mechanisms applicable to space activities (non-comprehensive)

Space Traffic Management is not mentioned in these documents but some of them provide directives, specifications or recommendations that apply to activities, directly or indirectly, associated with Space Traffic Management functions.

This includes, in particular, the definition, enforcement and verification of technical and regulatory provisions encouraging or compelling actors to conduct their activities in ways that are not detrimental to the safety and long-term sustainability of the space operating environment. It also includes provisions promoting transparency and coordination among international actors. In general, STM-related provisions can be grouped in three main areas:

- Information sharing, addressing for example:
  - Space object registration and launch notification
  - Information sharing on space objects and orbital events
  - SSA data management, archiving and sharing
- Spacecraft and mission design, addressing for example:
  - Safety aspects of spacecraft and mission design
  - Post-mission depletion and disposal
  - Radiofrequency spectrum management
- Launcher and spacecraft operation, addressing for example:
  - Launch safety verifications
  - Conjunction assessment
  - Collision risk mitigation and avoidance

Compliance with STM-related requirements may be left to voluntary implementation or enforced by legislative acts, authorizations, licenses, agreements or contracts.

5.3.2 International treaties and guidelines

The first layer of legally-binding acts applicable to European space activities are international treaties to which European states are parties, including:

- The Outer Space Treaty - 1967: Principles governing the activities of states in the exploration and use of outer space, including the Moon and other celestial bodies.
- The Rescue Agreement - 1968: Agreement on the rescue of astronauts, the return of astronauts and the return of objects launched into outer space
- The Liability Convention 1972: Convention on liability for damage caused by space objects
- The Registration Convention - 1976: Convention on registration of objects launched into outer space
- The Moon Agreement - 1984: Agreement governing the activities of states on the Moon and other celestial bodies

Not all European countries have signed these international treaties, usually depending on their level of involvement in space activities. For example, Portugal and Slovenia only recently signed the Registration Convention, in 2018 and 2019 respectively. These treaties include STM-related principles:

- The Outer Space Treaty establishes that States shall be responsible for national space activities carried out by governmental and non-governmental entities, shall be liable for damage caused by their space objects and shall avoid harmful contamination of space;
- The Registration Convention requires states to provide information about their space objects to the United Nations with details about the launching state, date and location of launch, basic orbital parameters and general function of the space object;

- The Liability Convention provides that a launching state shall be absolutely liable to pay compensation for damage caused by its space objects. The convention also provides for procedures for the settlement of claims for damages.

European space activities are also governed by the Constitution and Convention of the ITU, and subsequent amendments by the plenipotentiary conferences. This treaty and other ITU regulations constitute the international regime for utilization of radio frequencies in space activities and for conducting operations in and in the proximity of the geostationary orbit. Compliance with this international regime is ensured by national agencies such as the French Agence nationale des fréquences or the German Bundesnetzagentur who also usually process authorizations and licenses for telecommunication satellites.

The international regime of legally-binding treaties is complemented by voluntary-based instruments approved as the outcome of multilateral discussions and negotiations. European stakeholders are heavily involved in various international platforms that develop guidelines and recommendations for safe and sustainable space activities. The most prominent international documents are:

- IADC Space Debris Mitigation Guidelines: In 2002, the Inter-Agency Space Debris Coordination Committee (IADC), which brings together thirteen space agencies, adopted a first set of international space debris mitigation guidelines. Revised in 2007, the document recommends four major mitigation measures:[92]
  - Limit debris released during normal operations and avoid any action that would lead to the creation of debris;
  - Minimise the potential for on-orbit break-ups by preventing accidental explosions and ruptures at end-of mission or avoiding intentional destructions;
  - Dispose of spacecraft away from LEO and GEO protected regions after they have terminated their mission either by manoeuvring to a graveyard orbit (GEO) or to an orbit allowing a re-entry within a maximum of 25 years (LEO), if possible direct and controlled;
  - Prevent collisions in developing the design and mission profile of a spacecraft and limit the consequences of collisions, through spacecraft capacity to perform post-mission disposal.

  These guidelines were endorsed by the UN-COPUOS and later by the UN General Assembly in 2007.
- UN-COPUOS Guidelines for the long-term sustainability of outer space activities: After 8 years of negotiations, the UN COPUOS adopted a list of 21 guidelines by consensus of its 92 Member States in June 2019. These LTS guidelines are intended to support the development of national and international practices and safety frameworks for conducting space activities. They address four aspects of issues at stake:
  - Policy and regulatory framework for space activities
  - Safety of space operations
  - International cooperation, capacity-building, and awareness
  - Scientific and technical research and development

In the past the European Union and its member states attempted to contribute to the development of a voluntary-based international framework with the promotion of an International Code of Conduct for Outer Space Activities (ICoC). The purpose of the Code was "to enhance the safety, security, and sustainability of all outer space activities" and to "establish transparency and confidence-building measures, with the aim of enhancing mutual understanding and trust and helping both to prevent confrontation and foster national, regional and global security and stability".[93] With these overarching objectives, the Code

92 Inter-Agency Space Debris Coordination Committee (2007). IADC Space Debris Mitigation Guidelines
93 Code of Conduct Working Document 21 (2014). Draft International Code of Conduct for Outer Space Activities. Retrieved from https://eeas.europa.eu/sites/eeas/files/space_code_conduct_draft_vers_31-march-2014_en.pdf

provided a set of rules and measures to be followed by subscribing states in the field of Outer Space Operations and Space Debris Mitigation, Notification of Outer Space Activities, Information on Outer Space Activities and a Consultation Mechanism. The initiative eventually failed to get a consensual support from the international community. Recently the European External Action Service announced a new diplomacy initiative for safety, security and sustainability of outer space activities (3SOS), demonstrating Europe's willingness to work with the international community on these issues.

International discussions over an appropriate approach to space safety and sustainability, including options involving a more ambitious Space Traffic Management framework continue. However, stakeholders do not converge yet on the relevance and role to be played by international frameworks in the development of STM. As a voluntary-based instrument, the implementation of international guidelines is left to governments' and operators' decision. From this perspective, European stakeholders demonstrated at multiple occasions a strong willingness to reflect international agreements and commitments in their management of space activities.

5.3.3 National space laws and other legally-binding regulations and agreements

The second layer of the European regime is comprised of laws and regulations adopted by European Member States as part of their national legislation. International space law makes states responsible and liable for space activities, which motivated the most active ones, in particular launching states such as France, to adopt domestic legal regimes for licensing and authorization of space activities. This provides the government with mechanisms to oversee the adherence to safety, responsibility and transparency of space activities. It also provides for the implementation of international treaty provisions into national law, such as obligations related to space object registration. Over the years, various European Member States developed such national space legislation including:[94]

- Austria: Outer Space Act (2011), Outer Space Regulation (2015)
- Belgium: Law on the Activities of Launching, Flight Operations or Guidance of Space Objects (2005)
- Denmark: Outer Space Act (2016)
- Finland: Act on Space Activities (2018)
- France: French Space Operation Act (2008)
- Germany: Law Governing the Transfer of Responsibilities for Space Activities (1990), Satellite Data Security Act (2007)
- Italy: Law for the implementation for the Convention on International Liability for damages caused by space objects (1983), Law on Registration of space objects (2005)
- Netherlands: Space Activities Act (2006) and successive amendments (last in 2015)
- Norway: Act on Launching Objects from Norwegian Territory in Outer Space (1969)
- Portugal: National Space Law (2019)
- Spain: Royal Decree on the Establishment of a National Registry in Compliance with the Registration Convention (1995)
- Sweden: Act on Space Activities (1982), Ordinance with Instructions for the Space Board (1996)
- United Kingdom: Outer Space Act (1986), Space Industry Act (2018)

As presented in a schematic overview elaborated by of the UN-COPUOS,[95] national legal and regulatory frameworks for space activities may include provisions addressing the authorization, supervision,

94 UNOOSA, National Space Law Collection. Retrieved from: https://www.unoosa.org/oosa/en/ourwork/spacelaw/nationalspacelaw/index.html
95 UNOOSA . Schematic overview of national regulatory frameworks for space activities. Retrieved from: https://www.unoosa.org/oosa/en/ourwork/spacelaw/nationalspacelaw/schematic-overview.html

registration, liability, insurance and safety of space activities, including launch and space operations. Many of these legal provisions relate directly or indirectly to Space Traffic Management by laying down operators' obligations in the domain of launch and/or satellite operations, in particular to share relevant information and ensure the safety and long-term sustainability of the space operating environment.

The purpose of national space legislations is to establish a regime to regulate space activities for which the government bears liability in accordance with international treaties and to reflect the government's international agreements and commitments.

For example, Austria's Outer Space Act stipulates that space activities (i.e. launch, operation or control of a space object, as well as the operation of a launch facility) require an authorisation by the Minister for Transport, Innovation and Technology. To be granted this authorisation, "the operator has to make provision for the mitigation of space debris in accordance with the state of the art and in due consideration of the internationally recognised guidelines for the mitigation of space debris." With regards to space object registration, the Act also instructs space operators to submit information required by the International Convention on Registration to the Minister for Transport, Innovation and Technology who shall communicate it to the Secretary General of the United Nations after the launch of the space object without delay.[96]

As a launching state, France has developed the most comprehensive legislation for space activities in Europe, see Annex D – Details on the French Space Operation Act (FSOA). The Act establishes a complete authorization and control regime including penalties in case of non-compliance. Authorization requirements are specified by a detailed technical regulation which includes quantified objectives to mitigate debris generation and collision risks throughout space activities from pre-launch risk assessment to object re-entry.[97] One of the obligations most often cited is the so-called "25-year rule" which, in line with international guidelines, requires space objects to re-enter the atmosphere within 25 years after the end of their mission (Articles 21 and 40).

International agreements play a central role in the elaboration of national space legislations in Europe: most authorization requirements are derived from international treaties, guidelines or best practices, in particular those related to space safety and sustainability or to space objects registration.

Space law is left to Member States discretion and there is no formal mechanism to ensure consistency at European level. The Lisbon Treaty recognizes space an area of shared competence, meaning that both the European Union and its Member States may adopt legally binding acts. However, EU legislative acts in the space domain deal primarily with the establishment of space programmes, statutes of Union agencies and cooperation agreements with other European and international bodies. As Schmidt-Tedd argues, the practice suggests that space is rather addressed as a parallel competence with emphasis put on the role of Member States than as a traditional shared competence.[98] Other national legal and regulatory acts may address directly or indirectly space activities such as regimes governing the allocation of radio frequencies. At European level, some EU directives on telecoms include provisions relative to satellite broadcasting.

A third layer of legally-binding provisions should also be considered. ESA regulatory framework such as procurement regulations for example, also play an essential role, in particular to make space safety standards applicable to European space programmes (e.g. Space Debris Mitigation Policy for Agency Projects). Lately, the Agency set up a framework (Security Agreement, Security Regulations and

96 Austrian Federal Law on the Authorisation of Space Activities and the Establishment of a National Space Registry (Austrian Outer Space Act, adopted by the National Council on 6 December 2011, entered into force on 28 December 2011)
97 Arrêté du 31 mars 2011 relatif à la réglementation technique en application du décret n° 2009-643 du 9 juin 2009 relatif aux autorisations délivrées en application de la loi n° 2008-518 du 3 juin 2008 relative aux opérations spatiales
98 Schmidt-Tedd, B. (2011). Authorisation of Space Activities after the Entry into Force of the EU Reform Treaty. In Von Der Dunk, F. (ed) (2011). National Space Legislation in Europe, Martinus Nijhoff Publishers.

Implementing Procedures and Facilities) to establish a capability to receive, store, and produce classified information and exchange classified information with third parties. Last but not least. multilateral and bilateral agreements such as SSA data sharing agreements between European countries (so far, only France and Germany) and with the United States, also establish legal foundations of the STM-related legal and regulatory regime applicable to European activities.

5.3.4 Standardization bodies and systems

Standards are another important pillar of the European framework for space activities. The goal of standardization is to harmonize the activity of a sector and to improve, with independence of single suppliers (commoditization), compatibility, interoperability, safety, repeatability, or quality. Standards provide requirements, specifications, guidelines or characteristics that can be used consistently to ensure that materials, products, processes and services are fit for their purpose. Standards can be made applicable through a legal document such as a business agreement (e.g. contract) and/or internal directives. Eventually, they may be integrated or used as a basis for the development of generic procurement practices (customer side) or quality management systems (supplier side). Today, the European space sector uses standards developed by various Standard Development Organizations (SDO):

- European Cooperation for Space Standardization (ECSS): Established in 1993 with the objective to provide a single and coherent system, ECSS is recognised as the central structure for development of space standards in Europe. ECSS standards cover space project management (M-branch), space engineering (E-branch), space product assurance (Q-branch) and space sustainability (U-branch).
- International Standardisation Organisation (ISO): ISO is the main International standard-setting body. It is an independent, non-governmental organisation composed of representatives from various national standards organizations. Within ISO, two subcommittees of Technical Committee 20 deal specifically with space topics:
    - TC20/SC13 deals with Space Data and Information Transfer
    - TC20/SC14 deals with Space Systems and Operations
- Consultative Committee for Space Data Systems (CCSDS): CCSDS was founded in 1982 by the major space agencies of the world. It is a multinational forum for the development of communication and data systems standards for spaceflight. CCSDS entered into an arrangement with ISO which allows CCSDS standards to be processed and approved as ISO standards.
- European Committees for Standardisation (CEN-CENELEC-ETSI): CEN, CENELEC and ETSI are the three official standardisation bodies recognised by the European Union. In 2011, the European Commission mandated these bodies to work on space standards.[99] The work is carried out by CEN/CLC/JTC-5 in close collaboration with the ECSS. The transfer of ECSS standards to EN standards is now automatically proposed to CEN/CENELEC who, in return, recognizes ECSS as the single European body for Space systems standardization.[100]
- Other standardization systems such as ITU, NASA, MIL, ASD-STAN or national standards.

European stakeholders are represented in different ways in these organizations, either through space agencies or national standardization bodies (see Annex E – European membership/representation in ECSS, ISO and CCSDS). The European space industry association, Eurospace, coordinates industry

99 European Commission (2011). Mandate M/496 addressed to CEN, CENELEC and ETSI to develop standardisation regarding space industry.
100 Note: When approved, ECSS documents become, without modification, EN standards and thus become available for entities committed to use the official European SDO set of documents such as the European Commission. Adoption of ECSS standards by CEN-CENELEC also gives a legal frame to the set of standards. Indeed, ECSS is not a legal entity and the European Space Agency, on behalf of the participating members, holds copyright for all ECSS documents. Adoption of ECSS documents by the European SDO officialises their status of European space standards.

positions through its standardization working group. Eurospace is directly represented in the ECSS and contributes through various channels to the work of other standardization bodies.

There is an active coordination between standardization bodies either through formal cooperation agreements or through informal liaison. Standards may also be adopted (with or without modification) by other standardization bodies. This is for example the case of the ECSS standard for space debris mitigation which consists in an adoption notice of ISO 24113.

There is a strong top-down and bottom-up coordination among standardization systems. Europe has developed a particularly well-organized structure for the production and update of space standards providing for a coherent system of requirements.

With regards to STM-related functions specifically, ISO has been the most active standardization body to address space operations and to promote a global approach to safety and sustainability.

TC20/SC13 works closely with the CCSDS to facilitate data exchange and interoperability.[101] Noticeably, CCSDS and ISO have produced standards for space data messages facilitating exchange of information about orbit, tracking, conjunction, fragmentation or re-entry, among others.

TC20/SC14 includes various working groups:

- WG 1 - Design engineering and production
- WG 2 - System requirements, verification and validation, interfaces, integration, and test
- WG 3 - Operations and support systems
- WG 4 - Space environment (natural and artificial)
- WG 5 - Space System Program Management and Quality
- WG 6 - Materials and processes
- WG 7 - Orbital Debris

Multiple ISO standards such as standard 24113 on space debris mitigation, standard 16158 on collision avoidance or standards 16164 and 26872 on spacecraft disposal, directly or indirectly address STM concepts. They provide requirements and specifications to model the space environment, improve and harmonize space operations, minimize the creation of space debris, dispose of space systems, share data on satellite manoeuvres or avoid collisions. ISO is contemplating ways to improve the adequacy, coherence and added-value of standardization to space safety and sustainability. In the current context and from a standardization standpoint, progress on space traffic management will imply to update and consolidate existing standards into a coherent framework but also to develop new standards in areas where norms have not yet been formalized. The spectrum of options regarding the best approach to issues at stake is wide-ranging and standard organizations, in particular ISO, are already examining the matter.

Standardization bodies could play a central role to capture best practices of a variety of stakeholders and to translate them into shared specifications for Space Traffic Management. The use of these standards will however be left to agencies and operators' decision. Additional coordination efforts among international stakeholders would be necessary to maximize their implementation.

101 Note: in 1990, CCSDS entered into a cooperative arrangement with ISO TC20/SC13. CCSDS documents are submitted to ISO for adoption as international standards. They are processed via the normal ISO procedures of review and voting. They retain the CCSDS format but are appended with an ISO cover sheet and control number.

5.3.5 Codified best practises

Space safety and sustainability matters, including Space Traffic Management, are increasingly looked into by the private sector (including European).

Various industry-led initiatives concentrating around commitments to safe and sustainable space operations have recently taken shape and proceed to attract new members and signatories. The first significant private endeavour in this domain has been the foundation of the Space Data Association in 2009, a first of its kind operators alliance created with the goal to foster information exchange among its members and operational collision avoidance. More recent initiatives revolve mostly around the proactive definition of space safety and sustainability principles by various industry groupings concerned about future developments in this domain.

In 2019 only, three independent space industry groupings (memberships overlapping) published dedicated formal documents or press releases containing codified sets of best practices and commitments from their members (e.g. concerning spacecraft and mission design, information sharing, space operations):

- The Consortium for Execution of Rendezvous and Servicing Operations (CONFERS), an industry-led initiative with initial seed funding provided by the U.S. Defense Advanced Research Projects Agency (DARPA), issued a "CONFERS Recommended Design and Operational Practices" addressing commercial rendezvous and proximity operations and in-orbit servicing.
- Building up on the initial work laid down through the Global VSAT Forum, The Space Safety Coalition (SSC), a global ad hoc coalition dedicated to developing and maintaining a set of "living" space-safety best practices, published a rather detailed document titled "Best Practices for Sustainability of Space Operations." intended to improve space safety, including measures to minimize the risk of orbital collisions.
- The Satellite Industry Association (SIA), a U.S.-based trade association, released a set of Principles of Space Safety, drafted to help protect freedom of use and long-term access to space by ensuring safe flight operations for satellites, human spacecraft and other space missions.

The European space industry participates actively to some of these endeavours, even though they are mostly led by U.S. organizations.

The multiplicity of proactive endeavours led by industry shows that the perception and approach of the private sector to space safety and sustainability issues is changing.

Although there is still a multiplicity of viewpoints and approaches to space safety and sustainability issues in the private industry, recent years have been marked by a growing importance given to "corporate responsibility" in space. This trend is best illustrated by a recent public/private initiative to develop a Space Sustainability Rating (SSR) system, a metric defining adherence to guidelines to ensure the long-term sustainability of space. The development of such rating also includes a visible European footprint, through a significant ESA involvement in the ongoing work.

6 Towards a European approach to Space Traffic Management

Summary: Although multiple building blocks already exist and provide a solid groundwork to develop a more integrated and operational approach to Space Traffic Management in Europe, moving forward in this domain will present serious political and technical challenges, in particular to:

- *Reinforce European cooperation and reach a necessary political consensus on the goals and principles of a European STM policy and on a suitable governance (i.e. leadership, responsibility-sharing and cooperation arrangements);*
- *Advance European capabilities and best practices to address current and future operational risks and find an acceptable compromise between the desire for strategic autonomy and the need to achieve demanding technical objectives at effective economic conditions.*
- *Contribute to the progress of international endeavours in the field of Space Traffic Management while consistently promoting European positions and protecting European interests.*

6.1 Setting up a joint European STM policy and framework

Any effective approach to STM shall entail an enhanced coordination and cooperation among various players because of the interdependent nature of operational risks at stake and collaborative dimension of mitigation solutions. A global framework would be ideal to best achieve space safety and sustainability objectives and multilateral efforts in the domain of STM should be encouraged. However, recent developments raise legitimate concerns about the capability to converge internationally at the right pace on what has become an urgent and pressing matter.

As far as Europe is concerned, the development of a "regional" approach, building on already well-established cooperation arrangements between governmental and industrial players would be highly desirable, with the objective to:

- Develop a joint policy and framework for the safe and sustainable management of European space traffic and operations,
- Leverage the capabilities, expertise and added-value of all relevant European stakeholders, public and private,
- Share the financial burden among relevant parties and maximise cost-effectiveness by avoiding duplication of efforts,
- Harmonise and upgrade best practices and safety standards applicable to space activities in Europe,
- Strengthen European contribution to multilateral efforts by promoting clear, common and consistent European positions on the international scene.

The publication and implementation of the U.S. national STM policy demonstrated the importance of a top-down policy to promote a coherent and consistent approach and avoid, as far as possible, divergence among stakeholders. In Europe, various frameworks have been instrumental to reinforce cooperation and harmonize best practices among stakeholders but a comparable top-down policy, empowered to define the principles of a European action in the STM domain, is still missing.

The development of such joint European STM policy and framework, implies to reach a broad political consensus among Member States, on:

- Shared goals and principles to be set for European efforts in the field of STM,
- Mechanisms to ensure a productive and efficient coordination among stakeholders,
- An appropriate delineation of roles, sharing of responsibilities and distribution of activities.

Reaching consensus on a framework meeting the needs, interests and constrains of multiple stakeholders will likely prove difficult and will probably require to reconsider some current arrangements.

While the current European setup - designed to accommodate the interests of various stakeholders - allowed to progress substantially on many technical and cooperation challenges, questions arise on its capacity, in its current form, to address future operational risks. Several issues arise from the unresolved question of the relative weight of national interests and European cooperation. From a purely practical perspective, two immediate risks come to mind:

- A risk of divergence of interests among stakeholders, hindering the capacity to implement a coordinated policy. This risk is growing as stakeholders' concerns and positions on STM-related issues tend to progress faster than European integration and leadership.
- A risk of duplication of efforts and reduced cost-effectiveness, if motives to develop specific national capabilities surpasses the willingness (and readiness) to focus on distribution and complementarity across Europe. This risk is also growing as the need to optimize resource utilization increases with the overall cost of required capabilities to provide necessary coverage and precision.

To engage in a more integrated and operational approach to STM in Europe, further progress shall be made in terms of balancing national interests against the merits of a European cooperation. The role that European institutions shall play in the future will need to be further refined, in particular in light of the progress made by the EU space programme and the growing importance of its security dimension.

Accommodating an enhanced European cooperation while preserving core national concerns will become an increasingly pressing issue. A major blocking point remains Member States willingness to preserve their sovereignty over a share of STM-related functions, in particular over space surveillance because of the dual nature and strategic significance of this domain. Comparable concerns across the Atlantic led to a separation between military and civil functions to ensure that each actor can focus on its core mission. This option was selected on the basis of a comparative analysis between different possible frameworks which suggested that "a framework that best balances the needs for safety, national security, and economic interest is a framework led by a civil agency":[102]

Red: Fails to meet most or nearly all objectives Yellow: Meets some objectives and fails to meet others Green: Meets all or nearly all objectives	Ensure Safety of the Space Domain	Protect and Enhance National Security Space (NSS) Interests	Ensure the Economic Vitality of the Space Domain and Space Industrial Base
Private Space Traffic Monitoring and Coordination	Red	Red	Red
DoD-Based Space Traffic Safety Monitoring and Data Sharing (status quo)	Yellow	Yellow	Yellow
Civil-Based Space Traffic Safety Monitoring and Facilitation	Green	Green	Green
Civil-Based Space Traffic Safety Monitoring and Coordination	Green	Green	Yellow
Civil-Based Space Traffic Management	Yellow	Yellow	Red

Figure 25: Comparative analysis of the relevance of different space traffic safety governance options with regards to the achievement U.S. government objectives (source: SAIC)

The European STM policy should address civil needs and be applicable to civil programmes, including national and commercial as well as EU and ESA programmes.

102 Science Applications International Corporation (SAIC) (2016). Orbital Traffic Management Study. Retrieved from: https://www.spacepolicyonline.com/pages/images/stories/Orbital%20Traffic%20Mgmt%20report%20from%20SAIC.pdf.

With the objective to ensure a productive and efficient coordination among stakeholders, the delineation of roles, sharing of responsibilities and distribution of activities should be based on thorough preparatory consultations and investigations, including:

- An evaluation of the relevance and feasibility of a clearer delineation between military and civil domains for space safety,
- A comparative analysis between different governance scenarios with regards to their capacity to achieve joint European objectives,
- An assessment of necessary evolutions to pre-existing mandates and institutional constrains.

6.2 Advancing European capabilities and best practices

With the ultimate goal to protect the European space infrastructure from harm, a central objective of a European STM policy and framework should be to advance European capabilities and best practices as part of a coherent and effective Risk Management Strategy.[103]

FIRST, this will require a sound risk analysis based on a collaboration between relevant experts from public institutions (ESA, national agencies, European institutions) and private industry (satellite operators, launch service providers, manufacturers) to characterise precisely current and future operational risks and user needs and to evaluate the feasibility and effectiveness of different technical solutions to reduce these risks, including:

- Space traffic monitoring architectures,
- Safety standards and best practices for space operations and systems,
- Technology developments (e.g. tracking beacons, active debris removal, artificial intelligence).

A suitable technical approach to space safety and sustainability issues will certainly involve a coherent mix of different solutions. It should provide realistic options that take into account impacts in terms of economic feasibility and competitiveness as well.

SECOND, this will also require to devise technical roadmaps to organize and plan necessary activities and developments in a coordinated manner. These roadmaps should be based on:

- a mapping of public and private capabilities and best practices,
- a gap-analysis to identify operational and R&D needs,
- the identification of programmatic options and associated budgets.

Special consideration should be given to achieve a sufficient level of coordination to avoid unnecessary duplication of efforts and optimize the distribution of activities among various stakeholders. To this end, these roadmaps should be validated and executed under the supervision by a joint governance.

THIRD, this will require to mobilize appropriate funding through various complementary sources such as the EU Space Programme, Horizon Europe, the European Defence Fund, national and ESA programmes as well as private funding.

Providing actionable STM data and services supporting safe and sustainable space operations represents a considerable technical challenge that will likely require to mobilize substantial resources. Consequently, Europe will have to find an acceptable compromise between its desire for strategic autonomy and the

103 Note: A Risk Management Strategy encompasses all means and measures to avoid, transfer, eliminate, share and reduce operational risks to an acceptable level.

need to achieve demanding technical objectives at effective economic conditions, at least in the foreseeable future.

In the context of global STM developments, the European political and technical approach to space traffic management should prepare for an evolution of the strategic value of SSA data which will be impacted by a greater data sharing policy and emergence of advanced commercial solutions.[104] To this end Europe should consider the possibility to:

- Enhance and formalize data sharing with third parties (i.e. foreign governments, satellite operators) through greater cooperation arrangements building on SSA data interoperability, complementarity and redundancy to provide timely, accurate and actionable data while ensuring data quality, integrity, availability and confidentiality.
- Further integrate commercial data and services to leverage cost-effective and innovative solutions whenever relevant and support the emergence of European companies able to compete on international STM data and service markets.

6.3 Promoting European positions on the international scene

Even though stakeholders do not converge today on the relevance and role to be played by international frameworks for STM, the interdependence between global players in space will require to converge on some international arrangement(s) or agreement(s) at some point in time. This process will likely be incremental and involve various multilateral frameworks such as the UN-COPUOS, ITU, IADC, ISO or CCSDS as well as bilateral dialogues for data sharing for example.

Europe must play a key role in international discussions related to STM and promote clear, common and consistent European positions in the various relevant multilateral and bilateral frameworks. Ultimately, it is the place of Europe as a competitor on commercial markets, as a partner in international programmes and as an actor in outer space that is at stake.

European governments have already demonstrated their willingness to work with the international community on space security, safety and sustainability issues but the recent acceleration of policy developments in these domains, in particular in the United States, is pressing Europe to step up its effort around a more determined and assertive approach to weigh in upcoming international frameworks and ensure a balanced cooperation with other actors. The ill-fated International Code of Conduct for Outer Space Activities has revealed the need for Europe to reinforce bilateral and multilateral relations with international partners, including both established space powers and emerging spacefaring nations.

The international dimension of STM should be fully integrated in the European STM policy and framework which should address:

- Relevant external actions to promote European positions and protect European interests,
- Appropriate mechanisms to promote a coherent diplomatic engagement by:
  - enhancing the coordination between European stakeholders
  - ensuring consistency between internal and external actions
- Mandates to ensure an appropriate representation in relevant fora,

A more immediate need will be to ensure a suitable participation and contribution of European stakeholders to the development of international safety standards and best practices.

104 Note: Several experts anticipate a trend toward more transparency between space players, including military ones. In this respect the development of new capabilities, commercial in particular, may lead to a paradigm shift in the value of SSA data confidentiality versus availability.

Annexes

Annex A – Overview of the European space traffic

The European space infrastructure accounts for around 15% of all operating satellites. It includes approximately 312 satellites owned/operated by European public and private organizations (excluding satellites co-owned/co-operated with non-European organizations). Together, Europe is the second space player, far behind the United States who owns/operates 901 satellites but still above China and Russia who own/operate 299 and 153 satellites respectively.

European satellites provide a wide range of capabilities but the vast majority are telecommunication and Earth Observation satellites. They are mostly located in LEO and in particular Sun-Synchronous Orbit (80% or European LEO satellites) and in GEO. Approximately 57% of these satellites are used for a commercial purpose. The main European satellite operators include private companies (e.g. Eutelsat, SES, Inmarsat, Telenor, Avanti, RapidEye), national space agencies, ESA, EUMETSAT, defense ministries and armed forces and industry, either directly or on behalf of public institutions.

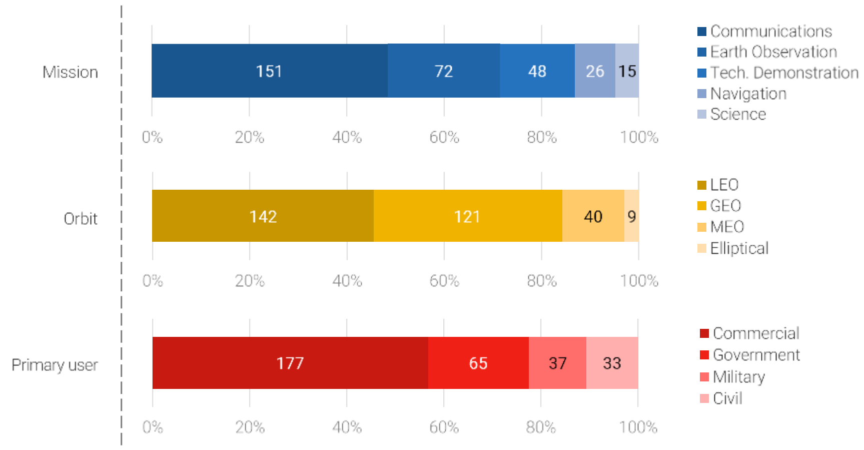


Figure 26: Overview of the European space infrastructure (source: UCS database, ESPI)

European space traffic also includes a regular launch activity from French Guiana:

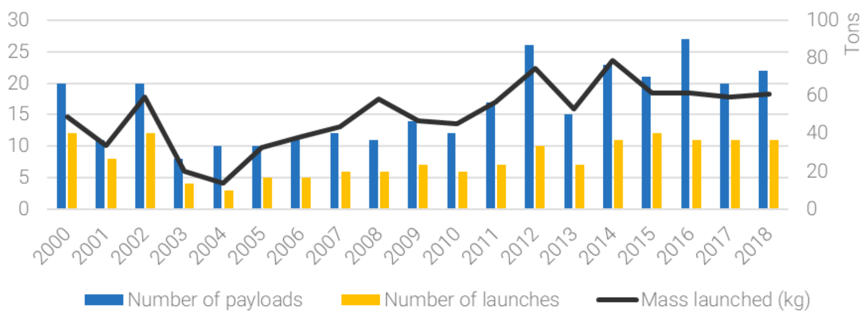


Figure 27: Overview of the launch activity from Guiana Space Center (source: ESPI database)

Last but not least, European space traffic also includes orbital debris generated by the European space activity including inactive satellites, rocket bodies as well as mission-related and fragmentation debris. The public space-track catalogue, which registers approximately 20,000 objects,[105] counts 1,250 European objects (6.2% of all objects).

105 SATCAT data retrieved on December 10, 2019

Annex B – Member States involvement in STM-related frameworks and activities

The following table provides an overview of European countries involvement (EU and ESA Member States) in 22 STM-related frameworks and activities.

EU and ESA Member States (30)	International and multilateral frameworks									
	Outer Space Treaty (1967) Ratification or Signature	Liability Convention (1972) Ratification or Signature	Registration Convention (1975) Ratification or Signature	UN COPUOS membership	Participation in one or both UN GGEs on space (TCBMs or PAROS)	Experience with ITU filings for RF coordination	Space Frequency Coordination Group (SFCG) membership	Involvement in standardi-zation (ECSS or ISO/TC 20/SC 13 or ISO/TC 20/SC 14)	Involvement in the ISS Programme	IADC membership
Austria	•	•	•	•		•	•			
Belgium	•	•	•	•		•		•	•	
Bulgaria	•	•	•	•		•				
Croatia		•								
Cyprus	•	•	•	•		•				
Czechia	•	•	•	•		•		•		
Denmark	•	•	•	•		•			•	
Estonia	•					•				
Finland	•	•	•	•		•		•		
France	•	•	•	•	•	•	•	•	•	•
Germany	•	•	•	•	•	•	•	•	•	•
Greece	•	•	•	•		•				
Hungary	•	•	•	•		•				
Ireland	•	•				•				
Italy	•	•	•	•	•	•	•	•	•	•
Latvia						•				
Lithuania	•	•	•			•				
Luxembourg	•	•		•		•				
Malta	•	•	•							
Netherlands	•	•	•	•		•	•	•	•	
Poland	•	•	•	•		•		•		
Portugal	•	•		•		•				
Romania	•	•		•	•	•		•		
Slovakia	•	•	•	•		•		•		
Slovenia		•				•				
Spain	•	•	•	•		•	•		•	
Sweden	•	•	•	•		•	•	•	•	
United Kingdom	•	•	•	•	•	•	•	•	•	•
Norway	•	•	•	•		•		•	•	
Switzerland	•	•	•	•		•			•	

EU and ESA Member States (30)	European, national and bilateral frameworks											
	Declared Space Debris mitigation measures in national practice (per UN Compendium)	National space law or regulatory act	Formal Space Strategy or Official Space Policy	Signed SSA Data sharing agreement with the USA	Participation in ESA's SSA Programme (2017 - 2020)	EU SST Consortium states	Military satellites in operation	Experienced commercial operators operating primarily from the state	GovSatCom demonstra-tor project participating states	PESCO participating states	EISC Full Members	Current or potential future launch sites	First adoption of national space legislation and last revision
Austria	•	•	•		•				•	•			2011 / 2015
Belgium	•	•	A	•	•				•	•	•		2005
Bulgaria										•			
Croatia										•			
Cyprus								•		•			
Czechia	•		•		•					•	•		
Denmark	•	•	•	•	•		•						2016
Estonia			•						•	•	•		
Finland	•	•	•		•					•			2018
France	•	•	•	•	•	•	•	•	•	•	•	•	1962 / 2008
Germany	•	•	•	•	•	•	•		•	•	•		1998 / 2007
Greece	•	•			•				•	•			2017
Hungary			•							•			
Ireland			•							•			
Italy	•	•	•	•	•	•	•	•	•	•	•	•	1983 / 2005
Latvia									•	•			
Lithuania									•	•			
Luxembourg		•			•		•	•	•	•	•		2017
Malta			•										
Netherlands	•	•	•	•	•					•			2006 / 2015
Poland	•		•		•	•			•	•	•		
Portugal		•	•		•	•			•	•		•	2019
Romania					•	•		•		•	•		
Slovakia	•									•			
Slovenia										•			
Spain	•	•		•	•	•	•	•	•	•	•		1995
Sweden		•	•		•				•	•		•	1982
United Kingdom	•	•	•	•	•	•	•	•	•		•	•	1986 / 2018
Norway		•	•	•	•			•	•		•	•	1969
Switzerland	•		•		•								

Annex C – About STM and other Traffic Management frameworks

Any kind of discussion on space traffic management may naturally lead towards references to other existing traffic management regimes. Regimes governing air traffic or sea traffic certainly introduced some management principles and best practices that could be relevant to consider for Space Traffic Management. However, although the air, sea and space domains share some commonalities, there are also fundamental differences related to spaceflight (e.g. launch phase, orbital dynamics, space environment) but also to geopolitical and industrial dimensions (e.g. dual nature of space activities, lopsided involvement of States) that make space a distinctively unique domain that required independent traffic management considerations.

	Air Traffic Management	Sea Traffic Management	Space Traffic Management
Domain	Single authority over designated volume of airspace	Multiple authorities operating in shared domain	Multiple authorities operating in shared domain
Collision Avoidance	• Separation (vertical, lateral, longitudinal), rules put in place) • Utilisation of dedicated systems (e.g. TCAS) used to recognize conjunction, • Air Traffic Coordination authority for navigation	• International Regulations for Preventing Collisions at Sea set up principles. • Operational handling based on judgement of operators of vessels.	• No protocols handling close conjunctions • Arbitrary best-practises for collision alerts • Ad-hoc coordination procedures between operators

Table 5: Selected commonalities and differences between selected Traffic Management Regimes with regards to collision avoidance

Best practises from decades of handling of increasing volumes of traffic in the air or on the sea can serve as an inspiration when devising legal or operational measures of space traffic management. Some of the measures that come into play, are:

- collision avoidance systems and separation rules in air traffic,
- boating right-of-way rules, or even
- train signalling in rail traffic management.

Some likeminded suggestions, to explore the applicability of air / maritime traffic management have emerged, interestingly, also in the private sector. Greg Wyler, founder of OneWeb was quoted in 2018 recommending to "look to aviation air traffic control and the spacing between aircraft as a great model for how to deal with constellation collisions."[106]

Future of spaceflight will also require deeper integration of space with air traffic management regimes. Space activities naturally interfere with air traffic in national and international airspace, particularly during the launch phase, which often leads to closures of airspace surrounding the spaceport due to safety concerns. Future space activities (namely due to increased and diversified launch traffic) will further amplify impact of spaceflight on air transportation.

106 Reals, K. (2018). OneWeb founder Greg Wyler calls for ATC-style space rules. Retrieved from https://runwaygirlnetwork.com/2018/04/23/oneweb-founder-greg-wyler-calls-for-atc-style-space-rules/

Annex D – Details on the French Space Operation Act (FSOA)

The French Space Operations Act (FSOA), adopted in 2008 and supplemented by the Technical Regulation, establishes the legal framework for space activities in France. With the goal to set up a national regime to authorize and monitor space operations under French jurisdiction or for which the French Government bears international liability, the FSOA sets up an authorization and continuous supervision process of the space activities of the French operators, in accordance with the international treaties (such as the Outer space Treaty). The scope of the FSOA covers:[107]

- Launch and return operations carried out from the French territory
- Launch and return operations carried out by a French operator from a foreign country
- Procurement of a launch by a French entity
- Control of space objects in outer space by a French operator

The FSOA came into force two years after the initial adoption. The French space agency (CNES) holds the responsibility of assessing conformity with legal and technical requirements and regulations of space operations. The authorisation to perform a space operation (launch or on-orbit control) is given only after evaluation of compliance with the Technical Regulation.

The Technical Regulation issued in 2011 pursuant to the FSOA contains the technical requirements that operator shall comply with in order to be granted appropriate authorisations and licenses. The Technical Regulation is composed of a first part dedicated to launch systems and of a second part dedicated to orbital systems.

With regards to space safety and sustainability, the Technical Regulation comprises requirements specifying that space operators shall:[108]

- limit the number of fragments and performs end of life operations respecting the protected regions,
- limit ground risks to populations and properties during the launch and re-entry of space objects,
- limit risks to public health and the environment associated with the elements coming back to Earth,

Measures laid down in the Technical Regulation, which are related to space debris mitigation (notably the collision risk plan, post-mission disposal requirements and mission and spacecraft design details) are closely linked to space traffic management functions. They reflect IADC guidelines.

A critical design review of the space system and procedures shall be carried out by applicant space operators. The authorization process and the assessment of compliance with the technical regulations provides assurance that the operators have the means, resources, necessary skills and are appropriately organized to perform the operation in compliance with the Space Act.

The systems and procedures carried out by the operator must also comply with Guiana Space Center (GSC) Safety Regulation if the space system is operated from the GSC. Overall, The FSOA remains applicable with regards to European spaceport in French Guiana (CSG), as the CSG is located at French territory and an operator of a spaceport is therefore also subject to this law. The French Act on Space Operations and the Decrees adopted for its application do not provide for a general regime for the operation of spaceports. Instead, the legislator only set certain conditions applicable for the exploitation of the Guiana Space Centre, especially through entrusting special missions to CNES and its President.

107 Clerc, P. (2016). French Space Operations Act: Lessons Learned from Implementation. France/Japan Seminar – Cross-cutting perspectives in space law. Retrieved from http://www.unoosa.org/documents/pdf/copuos/lsc/2016/sem2-201.pdf
108) UN document A/AC.105/C.1/2017/CRP.26 (2007). General presentation of French activities and views for the long-term sustainability of outer space, in relation with the implementation of the first set of guidelines. Retrieved from: http://www.unoosa.org/res/oosadoc/data/documents/2017/aac_105c_12017crp/aac_105c_12017crp_

Annex E – European membership/representation in ECSS, ISO and CCSDS

	Membership/Representation
ECSS	• Full members, participating in ECSS document production and update: ○ Agenzia Spaziale Italiana (ASI) ○ Centre National d'Etudes Spatiales (CNES) ○ Deutsches Zentrum für Luft- und Raumfahrt e.V (DLR) ○ European Space Agency (ESA) ○ Eurospace (European Space Industry representation) ○ Netherlands Space Office ○ Norwegian Space Centre ○ UK Space Agency ○ As associate member, Canadian Space Agency • Observers, participating in the development process: ○ EUMETSAT ○ European Commission ○ European Defence Agency ○ CEN/CENELEC
CCSDS	• European member agencies (out of 11 member agencies) ○ Agenzia Spaziale Italiana (ASI) ○ Centre National d'Etudes Spatiales (CNES) ○ Deutsches Zentrum für Luft- und Raumfahrt e.V (DLR) ○ European Space Agency (ESA) ○ UK Space Agency • European observing agencies (out of 32 observing agencies) ○ Austrian Space Agency (ASA) ○ Belgian Federal Science Policy Office (BESPO) ○ Danish National Space Center (DNSC) ○ Hellenic National Space Committee (HNSC) ○ Netherlands Space Office (NSO) ○ Hungary Research Institute for Particle & Nuclear Physics (KFKI) ○ Swedish Space Corporation (SSC) ○ Swiss Space Office (SSO) ○ EUTELSAT ○ EUMETSAT
ISO TC 20 / SC 13	• European participating members (out of 12 participating members) ○ France - Association française de normalization (AFNOR) ○ Germany - Deutsches Institut für Normung (DIN) ○ Italy - Ente Nazionale Italiano di Unificazione (UNI) ○ United Kingdom - British Standards Institution (BSI) • European observing members (out of 10 observing members) ○ Belgium - Bureau de Normalisation (NBN) ○ Czech Republic - Office for Standards, Metrology and Testing (UNMZ) ○ Finland - Finnish Standards Association (SFS)

	○ Netherlands - Royal Netherlands Standardization Institute (NEN) ○ Poland - Polish Committee for Standardization (PKN) ○ Romania - Asociatia de Standardizare din România (ASRO) ○ Sweden - Swedish Institute for Standards (SIS)
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Inzerillo, Gianni	Arianespace
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Klock, Erich	Austrocontrol
Krag, Holger	European Space Agency (ESA)
Leurquin, Christine	SES
Monham, Andrew	EUMETSAT
Munoz, Rodolphe	European Commission (EC)
Oltrogge, Dan	AGI

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Schrögl, Kai-Uwe	German Federal Ministry for Economic Affairs and Energy
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