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Executive Summary

Towards a European Approach to Space Traffic Management

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A GROWING NEED FOR BETTER SPACE TRAFFIC MANAGEMENT

Space Traffic Management already exists

The intensification of space activities worldwide and the emergence of new actors (including new space-faring nations and commercial companies) as well as 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 in June 2018.

Space Traffic Management has not yet been given a broadly accepted definition, but experts and officials tend to converge on a number of points regarding the objectives, 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.
- STM applies to various phases of the space system lifecycle (design, production, launch, deployment, operations, disposal).

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).

Commonalities among existing STM definitions and main STM features

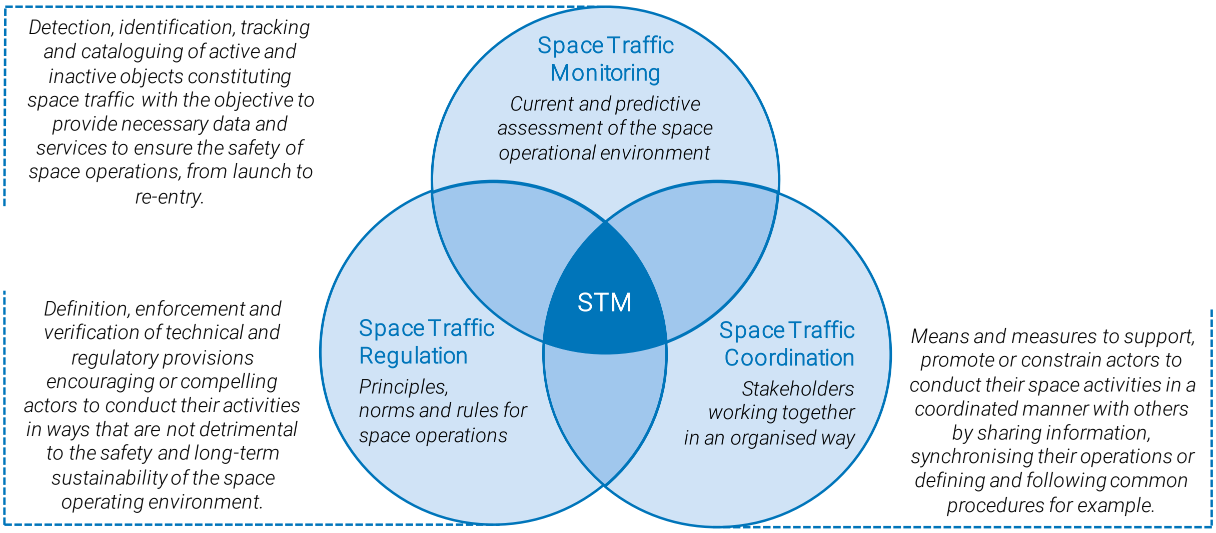
While stakeholders and experts tend to agree on a number of points regarding "WHAT" Space Traffic Management is, they may however disagree on "HOW" Space Traffic Management should be developed and implemented, in particular with regards to the following aspects:

- Regulatory constraints: Today, most stakeholders would agree on the limits of a self-regulation approach and on the necessity of some level of common constraints, or at least incentives, to achieve space safety and sustainability objectives. Nevertheless, the nature, scope and strictness of these constrains is obviously a sensitive part of Space Traffic Management. Setting up enforcement and verification mechanisms is also highly controversial among stakeholders.
- International dimension: Most stakeholders would also agree that a fully effective approach to Space Traffic Management requires a coordinated and inclusive effort of all spacefaring nations. However,

stakeholders do not converge on the relevance and role to be played by international frameworks in the development and/or supervision of Space Traffic Management. 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 Space Traffic Management 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 environment, their needs, concerns and priorities do not necessarily converge. Space Traffic Management also encompasses sensitive functions such as the collection, processing and distribution of space surveillance data which makes it obviously difficult to reach consensus on appropriate arrangements.

Space Traffic Management is therefore an organizational and operational concept that stands at the crossroad of three complementary functions:



Core functions of Space Traffic Management

Space Traffic Management is not a new concept and space actors already monitor, regulate and coordinate space activities to some extent.

Most governments with advanced space capabilities have already developed Space Surveillance and Tracking (SST) or Space Situational Awareness (SSA) programmes, usually addressed as a strategic mission, under military control and with the support of space agencies and research institutions. Space activities are also already somewhat regulated by international treaties, national legislations and regulations, safety standards and other binding and non-binding provisions. A share of these provisions directly or indirectly addresses space traffic regulation. There are also various multilateral and bilateral efforts to enhance coordination and information-sharing among governmental, commercial, international actors.

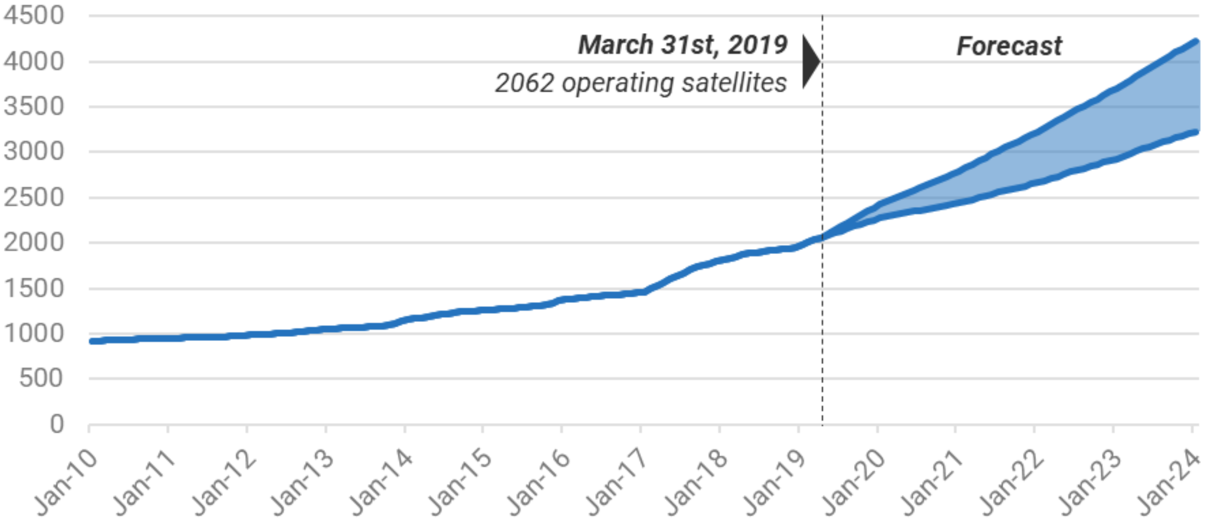
As underlined by the U.S. national Space Traffic Management policy the challenge is to develop a new approach to Space Traffic Management that addresses current and future operational risks.

Increasing space traffic and risks of collision and interference

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.

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. This growth, which concerned mainly very small spacecraft with a mass below 10kg like CubeSats so far is not expected to stop and the launch of "mega-constellations" is actually expected to bring the space activity to an entirely new level. Involving much larger satellites and unprecedented volumes, the impact of this new concept could potentially be enormous, a game-changer if commercially successful and called to become a sustainable activity. Forecasts suggest that the deployment of mega-constellations 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.

As a direct result, the number of operating satellites doubled in less than a decade and is expected to continue to increase sharply. 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 (mostly in Low Earth Orbit).



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

Operating satellites will also have to share their orbits with an even larger population of "space debris". 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. Operating satellites therefore represent only 7% of space objects larger than 10 cm and a negligible portion of the total population. More than half of these space debris are the results of a few "catastrophic events" including orbital explosions and collisions.

A congested space environment naturally creates a number of risks for space operations in particular concerning collision and interference hazards.

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. 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 due to the extensive utilization of sun-synchronous orbits for remote sensing missions. The congestion of Low Earth Orbits does not affect exclusively systems operating in this area but also space systems in transit to higher orbits.

Space is vast and the probability of a collision between two objects is statistically low, even in the most congested orbits. The risk is, however, poised to grow considerably with the intensification, diversification and globalisation of the space activity and in particular with the launch of large constellations, even in case of partial deployment.

The risk of collision must be fully mitigated as the consequences of such event are dramatic. An object as small as 5 mm can disrupt or even completely incapacitate a satellite and a collision with a larger object can lead to a total fragmentation and to a 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. As space debris beget space debris, it is the very capacity of using some orbital planes that is at stake.

To mitigate collision risks and ensure that the space operating environment remains safe, a mix of preventive and protective measures are necessary:

- Prevention to limit the impact of space activities on the space operating environment, in particular in terms of creation of debris throughout the space system lifecycle from launch to re-entry.
- Protection to safeguard operating satellites from collisions, in particular through capabilities 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.

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, 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

Inadequate regimes and capabilities for future space operational conditions

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.

Prevention: low compliance with international guidelines

Today, space activities are governed by a set of international agreements, national legislations, technical standards and other binding and non-binding rules, some of which provide directives, specifications or recommendations addressing, directly or indirectly, space safety and sustainability issues.

At the international level, the principal actions have been the promotion of transparency and coordination among actors and the definition of a set of standards and best practices 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 (e.g. IADC and UN guidelines, ISO standards). The implementation of these guidelines and standards is left to governments' and operators' decision.

There is a strong consensus among experts on the effectiveness of international standards and best practices but ESA Space Environment Report suggests that the level of compliance with is still rather low, far below what would be necessary to achieve space safety and sustainability objectives.

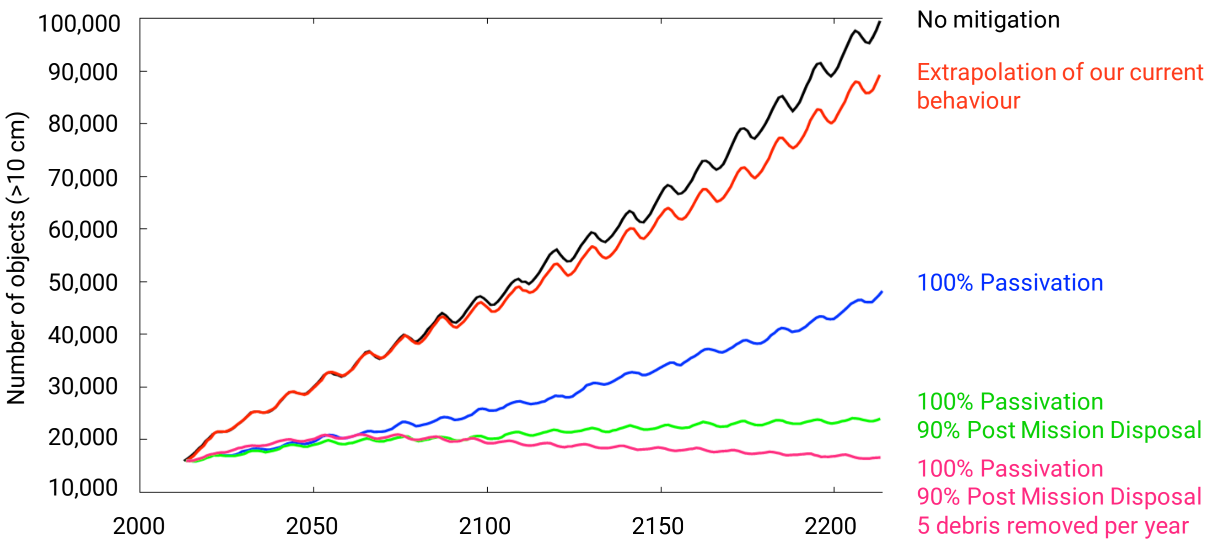


Figure 1: Effectiveness of space debris mitigation measures (source: ESA)[1]

The compliance of future spacecraft with international best practices, in particular mega-constellations, will be decisive to prevent an escalation of collision risks and other safety and sustainability issues.

[1] H. Krag (2019). Managing Space Traffic for the Sustainable Use of Space.
- 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)

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

The protection of operating satellites from collisions requires adapted capabilities to detect, evaluate and respond to collision risks. The capability to monitor space traffic and to predict and alert about collision risks is known as Space Surveillance & Tracking (SST) or Space Situational Awareness (SSA). It entails:

- The development and operation of ground-based and/or space-based systems (i.e. sensors) using optical or radar techniques to detect and track objects in space, providing raw data on the object geometry and orbital dynamics that can be stored into databases and catalogues.
- The processing of raw data into actionable information and value-adding analysis to deliver services to satellite operators such as Conjunction Data Messages providing information on a risk of collision.

The growing number of objects in orbit raises new technical and operational challenges to properly monitor space traffic and provide SST/SSA data and services adapted to a more congested environment.

With an increasingly dense space traffic and the development of new sensors able to monitor a higher share of orbital objects, satellite operators will have to manage a considerable number of collision alerts. Given the cost of collision avoidance manoeuvres in terms of disruption to the mission or reduced system lifetime, it will become essential to better detect and evaluate collision risks to single out those that justify such manoeuvre.

The collision avoidance manoeuvre itself must also be properly planned and coordinated since it impacts other conjunction assessments and, in a worst-case scenario, could lead to an even higher risk of collision with another object. In the case of a collision risk between two operating satellites, current best practices for coordination between operators will also reach their limits. Involving mainly manual work and ad-hoc processes, even in case of high-risk warnings, the future space operating environment will raise the need for shared protocols, in particular for collision avoidance procedures.

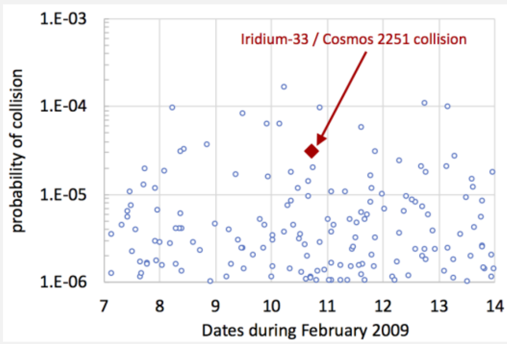
Providing timely, accurate and actionable data and services supporting safe operations in a congested space environment is a serious technical challenge that will require greater transparency and information sharing among operators and space surveillance systems which will, in turn, raise new interoperability issues to ensure data quality, integrity, availability and confidentiality.

Adapting capabilities and best practices to changing space environment conditions is becoming an increasingly pressing issue.

Detection of the collision Iridium-33 / Cosmos 2251

The example of the catastrophic collision between Iridium-33 (active) and Cosmos 2251 (inactive) on February 9, 2009, which created thousands of debris, provides an excellent illustration of the need for timely, accurate and actionable data.

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 Iridium constellation. The week of February 9th there were even conjunctions with higher probability of collisions, in the order of 2 in 10,000. As a consequence, the conjunction which eventually led to an actual disastrous collision did not stand out:



Iridium constellation conjunction probabilities during week of Feb 7, 2009 (source: The Aerospace Corporation)

Strategic, commercial and geopolitical stakes for Europe

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. The Space Strategy for Europe already puts forward, "Europe´s autonomy in accessing and using space in a secure and safe environment" as a strategic pillar for Europe. Public action in this domain is justified by three key rationales:

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. 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.[2] The need to protect space assets and to safeguard the benefits that they enable will 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.

Contribute to a service-oriented policy

Europe interests in a safe and sustainable space environment also lie in the considerable development of the EU space programme over the 2014-2020 period and in the introduction of new initiatives such as GOVSATCOM. Encouraging the uptake of space services and maximising their benefits will require to assure the ability of the infrastructure to deliver a service that can justifiably be trusted, in particular for users in the defence and security domain. This 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 to reinforce synergies between civil and defence domains.

Reinforce European autonomy and leadership

From a strategic standpoint, Europe seeks to guarantee the security of its space infrastructure independently. Autonomy is 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. Today, a great deal Europe extensively relies on U.S. SSA Data Sharing Agreements. Although Europe greatly benefits from the open policy of the U.S federal government and that the importance of transatlantic cooperation cannot be challenged, this creates a situation of reliance/dependence and an imbalance in cooperative arrangements that have strategic implications.

As space security holds an increasingly central place in space diplomacy, Europe is increasingly pressured by the proactivity of other players in this domain. Europe's ambition to promote its position as a leader in space necessarily entails to play a central role in international dialogues and negotiations.

[2] 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 (European Commission. Dependence of the European Economy on Space Infrastructures: Potential Impacts of Space Assets Loss. March 2017.)

U.S. National Space Traffic Management Policy

The United States has long considered space an integral component of its strategic and geopolitical agendas. 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 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.

The U.S. National Space Traffic Management Policy stands at the crossroad of U.S. security, commerce and foreign policies and is intended as an instrument to support U.S. leadership in space. The policy defines a set of objectives, principles and guidelines to be followed for the establishment of a new approach to Space Traffic Management:

- Advance SSA technology, improve SSA data interoperability and enable greater SSA data sharing
- Provide basic SSA data and STM services to the public and encourage U.S. commercial leadership in STM-related technologies, goods, data, and services
- 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
- Promote these norms, best practices, and standards internationally and to explore strategies that will lead to the establishment of common global best practices
- Improve policies, processes, and technologies for spectrum use, appropriate to current and future operations, and to prevent unintentional radio frequency interference

The U.S: policy also articulates a reorganization of roles and responsibilities across U.S. military and civil branches to refocus the U.S. Department of Defense (DoD) on its military and national security mission and to address Space Traffic Management as a civil framework with a public service and commercial-oriented mission under responsibility of a civil agency. The policy envisioned this agency to be the Department of Commerce (DoC), as part of a broader reform of U.S. administration and regulatory regime governing commercial space activities, but progress on this matter has been slowed down by conflicting views among U.S. policy-makers.

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 with:

- The preparation of the transfer of civil-oriented SSA/STM responsibilities and competences from the DoD to the DoC (expected to be completed in 2024).
- The development of an Open Architecture Data Repository which will become the main tool to provide civil SSA/STM data and services and to encourage the development of a value-adding marketplace.
- The launch of independent consultations by various U.S. agencies in 2019 (i.e. DoC, FAA, FCC) to gather views from industry and experts on STM capabilities and regulations.
- The update of U.S. Orbital Debris Mitigation Standard Practices by an interagency working group led by NASA in November 2019.

Implications for Europe

U.S. plans to improve SSA capabilities through greater SSA data sharing

Enhancing SSA data precision and accuracy necessarily implies to rely on multiple data sources including from third parties (foreign/commercial). There is an undeniable opportunity for Europe to take advantage of a greater SSA data sharing policy provided it is based on mutual benefits. SSA data sharing agreements are already a backbone of transatlantic cooperation and Europe has much to offer to an open architecture data repository to support complementary and redundant capabilities and contribute to a worldwide distribution of sensors.

There is also a risk of greater dependence on U.S. capabilities and reduced strategic autonomy. Data sharing agreements are powerful leadership instruments for the United States that can provide a great political and commercial lever. 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.

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.

U.S. plans to encourage U.S. commercial leadership in STM 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. 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.

U.S. plans to develop, update and promote STM-related standards and best practices

The United States 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>U.S.-led</u> minimum safety standards and best practices to coordinate space traffic […] and to use them to inform and <u>help shape international consensus</u>, practices, and standards."[3]

Although Europe shares U.S. willingness to promote a safe and responsible behaviour in space, the unilateral development of standards poses a risk of competitive disadvantage for the European industry seeking to serve U.S. customers in the telecom domain, to compete on open U.S. satellite and launch markets or 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 also extend their influence to other markets.

Europe must play an active role in the development of STM standards and best practices. The development of a set of common safety standards and best practices could form a second backbone for transatlantic cooperation.

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

Current approach to space safety and sustainability in Europe

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 comprehensive and operational approach to Space Traffic Management.

Building blocks of a European approach to Space Traffic Management

Establishment
Implementation

Policy & Framework

Objectives, principles and organized distribution of tasks and responsibilities among relevant stakeholders

- **Objectives and principles:**
  - National space and defence policies
  - Space Strategy for Europe, EU CFSP and CSDP
- **Stakeholders:**
  - National agencies,
  - ESA, EU and its agencies,
  - Public and private operators
  - Launch service providers and satellite industry,
  - SSA/STM data and service providers
- **Responsibility sharing and cooperation arrangements:**
  - National governance models
  - TFEU and EU regulations
  - ESA Space Safety Programme
  - EU SST Support Framework
  - Other arrangements: e.g. ECSS, EU PESCO
- **European participation in international frameworks:**
  - UN-COPUOS, IADC, ITU, ISO
  - Bilateral SSA Data Sharing, joint operations
  - Space Data Association

Development
Exploitation
Upgrade

Capabilities

Necessary infrastructure, systems, technologies, data, services, models and expertise

- **Space traffic monitoring:**
  - SST sensors (radars, telescopes, laser stations)
  - SST data processing and catalogues/databases
  - Analysis tools and models (SST, SWE)
  - STM-related services (collision avoidance, fragmentation analysis, re-entry analysis)
- **STM-related technologies and programmes:**
  - ESA Space Safety Programme (Automatic Collision Avoidance, Active Debris Removal, Cleanspace)
  - EU Framework Programme projects
- **Other STM-related capabilities**
  - Satellite and mission design
  - Materials, components

Definition
Enforcement

Regime

Set of rules, norms and recommendations specifying how to conduct launch and space operations

- **Laws and regulations:**
  - International treaties and conventions
  - National space legislations
  - ESA rules and regulations
  - Multilateral and bilateral agreements
- **Standards:**
  - ISO standards
  - CCSDS Space Data Messages
  - ECSS standards
  - Other norms and standards
- **International guidelines:**
  - IADC space debris mitigation guidelines
  - UN-COPUOS Long-Term Sustainability guidelines
  - ITU recommendations
- **Codified or informal best practices:**
  - Internal or shared proven techniques and methodologies of space agencies, operators, satellite manufacturers or launch service providers

Building blocks of a European approach to Space Traffic Management

Main observations

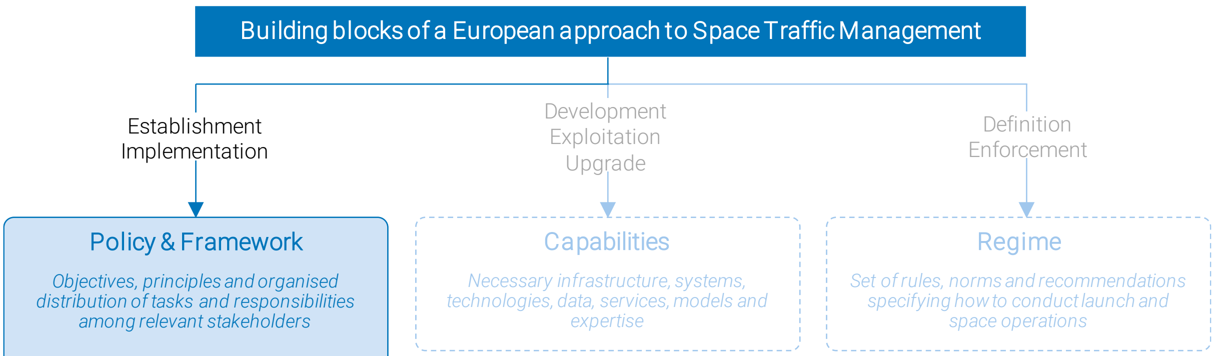
- *Europe already addresses a share of STM functions through various parallel domestic activities as well as an active participation in multilateral and bilateral frameworks.*
- *The European approach to STM-related issues is multilayered, centred around the sovereign competence of national governments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

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.

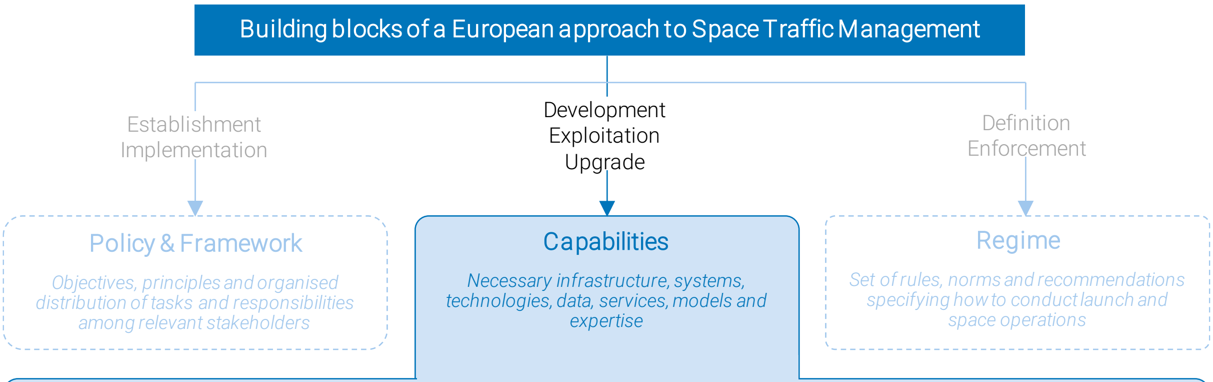
Space traffic monitoring capabilities and other STM-related technologies

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, from development and operation of SST/SSA sensors 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



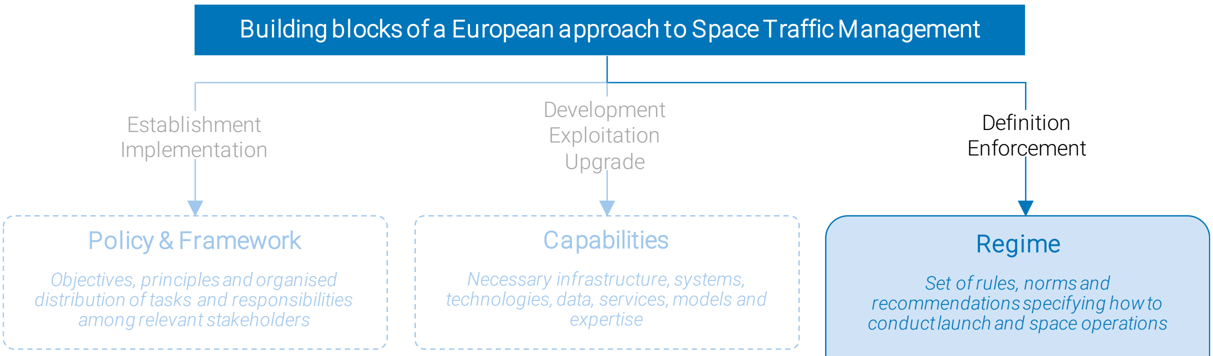
- Member States are the primary owners and operators of space surveillance systems. The operation of these systems involves both military and civil actors and they are managed as assets of strategic significance for national security and sovereignty.
- The EU SST consortium substantially reinforced European 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.

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.

Towards a European approach to Space Traffic Management

Although multiple building blocks already exist and provide a solid groundwork to develop a more comprehensive 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.*

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 relevant European players, 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 comprehensive 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":[4]

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

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.

[4] Science Applications International Corporation (SAIC). Orbital Traffic Management Study. November 2016

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.

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 comprehensive and coherent Risk Management Strategy.

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,
- Technologies development (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 committee.

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 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.[5] 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.

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.

[5] 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.

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