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► **To cite this version:**

Alberto Águeda Maté, Carla Filotico, João Alves, David Zamora, Tomas Hrozensky, et al.. EUSTM: European Steps towards Space Traffic Management. IAC 2021, Oct 2021, Dubai, United Arab Emirates. hal-03465134

HAL Id: hal-03465134

<https://hal.science/hal-03465134v1>

Submitted on 3 Dec 2021

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EUSTM: European Steps towards Space Traffic Management

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Abstract

The rapid increase of space activities raises concerns about the safety, security and sustainability of future space operations. The EU has started working on an independent space surveillance and tracking (SST) capability, demonstrating leadership in space traffic management (STM). In this context, supported by the EU's H2020 research and innovation programme (GA 101004319), EUSTM (“Space Traffic Management for XXI Century Space Operations”) is a comprehensive project that analyses the current STM support competences in Europe and defines the related needs for an autonomous European STM capability. It covers technology, governance, legal, regulatory, standardization, strategy and policy aspects and it will recommend STM guidelines and best practices. In addition, it

aims to further develop and fortify the European network of space traffic management experts and increase the awareness of space traffic management and related topics amongst wider audiences.

Keywords: *space traffic management – STM, space surveillance & tracking – SST, Space Situational Awareness – SSA, space sustainability, STM guidelines, STM policy.*

Acronyms/Abbreviations

- active debris removal (ADR)
- air traffic management (ATM)
- artificial intelligence (AI)
- collision avoidance (CA)
- collision avoidance manoeuvre (CAM)
- end-of-life (EOL)
- European Union (EU)
- Space Traffic Management for XXI Century Space Operations (EUSTM)
- geosynchronous orbit (GEO)
- European Health and Digital Executive Agency (HaDEA)
- Inter-Agency Space Debris Coordination Committee (IADC)
- International Organization for Standardization (ISO)
- low Earth orbit (LEO)
- medium Earth orbit (MEO)
- radio frequency (RF)
- Space Based Space Surveillance (SBSS)
- space situational awareness (SSA)
- space surveillance and tracking (SST)
- space traffic management (STM)
- United States (US)
- work package (WP)

1. Introduction

EUSTM relies on 19 European partners with in-depth expertise in all aspects of space traffic management (STM), including conventional and NewSpace-related activities, and it benefits from consultations with relevant worldwide industrial and institutional stakeholders in all STM-related fields.

After its start in January 2021, this 20-month activity has already launched its first analyses and tasks and successfully held its first workshop, which benefitted from a remarkable level of involvement between the project's team of experts and the European members of its Advisory Board. Aside from achieving a granular specification of project activities, the partners have begun work on generic concepts applicable to STM, such as its requirements and needs, policy considerations, guidelines and the technologies that support it, obtaining an overview of the most important STM-related topics and imminent next steps.

This contribution summarises the initial results and considerations reached within the EUSTM project — an end-to-end activity towards the definition of a future European STM capability.

2. General and Policy Analysis

While reaching a full consensus on a common definition of STM will require dedicated time and effort, it proves to be more productive to proceed step-by-step with a series of mutually-agreed-upon points that will gradually lead to the implementation of changes as understanding deepens.

Regarding commonly-agreed-upon aspects, there is a clear understanding that STM should address all Earth-bound orbital regimes and that it should apply to both passive and active objects. As the precise definition of the spatial domain of STM is still a work in progress, other orbital regions could be discussed (e.g. Lagrangian points or orbital regimes around other celestial bodies) and the need may arise to define various levels of regulation and/or management.

In Europe, many STM-related functions (SST/SSA and other capabilities, rules of behaviour, coordination of activities, etc.) are already being conducted in parallel at different levels (private, national, European, etc.). What has been missing so far is an overarching common policy. The current approach to STM-related issues in Europe can thus be assessed as multi-layered. The definition of geopolitical groupings or levels (i.e. national, European and international) will be critical in the future approach to a European STM system. A core part of the EUSTM policy analysis activities is to identify and investigate the limits of the current policy framework for STM in Europe and the specific risks that stem from these limitations. These will represent important considerations for the identification of options and recommendations on the way ahead.

STM policies are lacking globally and there are no powerful incentives currently to follow a tentative set of rules. The first STM regulation to be launched will have the potential of a driving effect. The first countries to enforce a strong STM policy may condition the rest to follow and/or cooperate to some extent.

As there is currently no international STM regulation with legally binding rules, political negotiation could take decades, considering the international diplomatic and political context required for negotiation. This opens a window for the development of norms, requirements, guidelines and rules for responsible behaviour in space, as well as for data sharing and exchange, leadership in different capabilities (e.g. SST/SSA, materials, CAMs, ADR), or for support to the commercial perspectives of European industry within and outside of Europe.

3. Data Governance and Security Issues

A common paradigm in the STM domain lies in ensuring a fair balance between not disclosing sensitive information versus the need to ensure the safety of all through information sharing. A significant effort is required on behalf of so many different stakeholders to successfully reach an agreement on all the necessary regulations, policies and principles.

Classification, and in some cases timely declassification, are the key elements for STM civilian operations, as civilian application radars may detect or generate measurements related to classified or sensitive space objects. Additional restrictions will arise with the increased involvement of new and varied actors (the private sector, operators, governments, etc.). It is obvious that the military is not the only user managing sensitive information — satellite operators also need their manoeuvring plans to be managed securely.

The US model sheds light on the boundaries within which the system shares data; there is a clear border between internal sharing and external sharing. It is critical to strike a balance on whether the information is shared in the interests of security, transparency and safety and it is up to nations themselves to define their policies on these matters. Beyond declassification, there is a need to innovate in finding ways for efficiently addressing STM critical situations without disclosing anything about the involved object, except what is strictly required (e.g. position, speed, expected behaviour, etc.). For instance, information about the owner, mission purpose or intent is very likely to be off-topic for the actual scope of STM.

4. Legal Aspects and Regulation

Despite the fact that the objective of the various involved actors has been to safeguard the space environment while ensuring the proper development and innovation within the space sector, the strict regulation of the space sector — as opposed to its unrestricted development — are perceived as two opposing sides in the debate.

Regulation is necessary for space sector development as commercial operators of today need to know the exact limits of the risks they take. However, the introduction of a data exchange regulatory framework can be expected to change the involved risk and possible liabilities, which may need to be mapped and understood in advance. These require agreement on standards, interoperability and accompanying legal definitions of concepts such as fault.

While the concept of fault and substandard behaviour is known in law, the measure of what is substandard activity or fault for orbital activity has not yet been adjudicated or determined. This can and in fact may well still occur. However, with the majority of low Earth orbit (LEO) satellites not necessarily covered by

third-party liability insurance, direct damage to satellites is generally managed by own insurance cover. The damaging effect of debris on the orbital environment has not been taken into account in the fault debate, since the environment has no legal personality to support its protection. This is a great lacuna, as the current orbital state shows. It has resulted in the community being placed in a situation in which there has been no incentive to reduce the volumes of debris, beyond making it a pre-mission licensing requirement.

STM requires the community to clarify the pre-and post-mission debris mitigation requirements for each phase of activity and end-of-life (EOL), whilst developing appropriate STM rules for collision avoidance (CA). This latter part – CA – is effectively the new STM component, with the other elements, stemming in part from international standardisation agreement, designed to reduce the effect of debris. STM is therefore an additional layer of traffic rules that goes beyond technical requirements for minimising or reducing the effect of debris for the operational phases. Some national statutes have very precise requirements for the reduction and minimisation of debris based on the Inter-Agency Space Debris Coordination Committee (IADC) Guidelines; while these provisions themselves relate to technical standards, they do not yet contain full provisions for authorisation of the next level of performing STM. This, together with an appropriate architecture, is where the recent studies on STM can contribute greatly to the discussion.

The body of authority that would best manage an STM system is the subject of debate, as it is unclear whether it should be an already established entity or whether a new one should be designed and created. Given the level of dependency between the different actors, this should be the result of an international shared effort. Nevertheless, while some actions reflect a clear need for international cooperation, others may be sufficiently or more appropriately addressed at the European, regional or national levels.

The most appropriate manner of exerting pressure on space actors is also a matter of deliberation. There is a real possibility of a fear of sanctions, but in the absence of an internationally binding agreement, could suffer from divergent and even absent national rules. A penalties–incentive approach could offer Europe an opportunity for leadership in the space sector, as previously showcased in the case of environmental regulations.

With the knowledge that there is an ocean of interests and differing views on what a global STM system should look like, convergence will not be easy from legal, diplomatic, political and strategic points of view. However, what needs to be determined are the elements of STM that we are willing to discuss at the

international level in order to achieve the sustainability we need to ensure.

5. High-Level Needs

STM-related standardisation can be expected to create barriers to technological development and stall its current momentum. A large number of new satellites and satellite operators must agree on several common, minimal measures that should be put in place. The gradual but relentless increase in the number of satellites in orbit means that operators progressively have less time to react to potential issues. Although collision avoidance analysis and management are almost fully automatic, new constellations generate an increased number of close approach alerts. To understand the spectrum of required actions, it is important to understand what kind of manoeuvres may be applied.

There is an existing need to standardise the methodology for CA and steer towards more automation, which would lead to an increase in its efficiency. Although there are some discussions in ISO on this issue, each key actor has its particular way of performing CA and no consensus has been reached on it yet. In terms of technical challenges, there is a need to perform a sensitivity analysis on the covariances to avoid missing risky conjunctions and to better understand the attitude and geometry of the conjunction when using a fully automated process.

In addition to the risk of space debris remaining in orbit, another point of interest is the risks caused by space debris and uncontrolled re-entries on surface or airborne assets. Similar to SST providers, STM services should also monitor these re-entries and provide calculations on potential re-entry landing point determinations, assessing also the risk of falling on a populated area, sensitive facilities or similar critical infrastructure.

6. Validation of the Understanding of STM Needs per User Category

To minimise the risk of debris generation, an STM system should also address EOL operations, including de-orbiting, graveyarding or passivation. This represents a controversial issue for large constellations, as some regulations require them to be compliant as a package, and not per individual satellite.

Mega-constellations carry a very high overall collision risk, as the cumulative risk over thousands of satellites adds up. The enforcement of orbit separation can be addressed by an STM system, which could establish non-overlapping corridors and coordinate them. It may also be of interest to impose some level of agility and controllability of the manoeuvring system. In-depth knowledge of manoeuvring capabilities would

require enormous transparency and a lot of information provided by all operators, which may not be feasible.

With regards to potential overlaps with air traffic management (ATM), although some options may allow to avoid having to define an altitude boundary, it might be still necessary to define which system is going to deal with what and to define an altitude above which STM will take priority and responsibility. It would be interesting to also have an incorporated solution that vertically integrates down to the surface level for STM, as well.

7. Technological Challenges

Doubtlessly, the main challenge of STM lies in the detection of increasingly smaller objects and in the setting of a critical limit to how far they must be trackable and catalogued. Radar, while effective for LEO, has limitations in that it is very expensive, consumes a lot of power, operates in a saturated radio frequency spectrum and suffers from environmental limits to its power. Once smaller objects need to be detected, its frequency bandwidth and possibly its emission power need to be increased.

Telescopes, traditionally used for medium Earth orbits (MEO) and geosynchronous orbits (GEO) and now for LEO as well, present an interesting solution, as they are cheaper in comparison to radars, but a larger number of them is needed for the same function as a radar and, if robotic, their cost skyrockets. Space Based Space Surveillance (SBSS) sensors, on the other hand, add redundancy to ground sensors and can be used to provide statistical information on the lethal population of small-sized debris that is undetectable by ground-based radar. However, telescopes have several significant constraints that need to be taken into consideration.

When it comes to active payload satellites, passive radio frequency sensor networks are an interesting topic, as they can pick up any RF emission (from telecom payload signals down to beacon telemetry or even noise signals) and perform orbit determination by differentiation. In current discussions, there is potential for satellite positioning operations that would extend this to LEO constellations, with several studies and companies trying to realise passive RF using only satellite telemetry, the technology being already validated for MEO/GEO.

Since solar activity has a strong impact on the drag and propagation of catalogues in LEO, mathematical modelling is necessary to estimate the uncertainty of ephemeris and for propagation consistency. It is crucial to use suitable and precise models, further develop technologies such as parallelisation or cloud processing, as well as to timely manage vast amounts of data and maintain catalogues with low latencies. Additional processing capabilities that build on artificial

intelligence (AI) for data pre-processing, identification of objects in images, deep learning and communication security will also be required. Such AI capabilities-based decision support systems can assist ground operators by implementing machine learning techniques on the CA manoeuvres datasets to predict collisions and plan such manoeuvres accordingly. Although the significance of human-in-the-loop intervention systems is subject to debate, the increase in the number of satellites in orbit suggests an even more acute need to expand the reach of automatisisation and data processing capabilities.

European STM capabilities have been increasing rapidly in recent years and are releasing autonomous data (as within EU SST services). As the EUSTM

project develops, we aim to identify and analyse all these challenges and come up with proposals towards defining a state-of-the-art STM capability for Europe in the dynamic space environment of the 21st century.

Acknowledgement and Disclaimer

The EUSTM project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 101004319.

This abstract reflects the authors' view and does not necessarily represent or reflect the views of the European Commission or the European Health and Digital Executive Agency (HaDEA).