# Space Traffic Management

## *Top Priority for Safety Operations*

*Claudiu Mihai Taiatu**

*"Space Traffic Management is a safety issue that requires international coordination and uniform rules"*[1]

### Abstract

The Outer Space Treaty, as the Magna Charta of Outer Space, should remain untouched and rather than seeking to amend it, new instruments could be introduced that correspondingly address the present legal uncertainties.

The absence of an international Space Traffic Management system and the ever-growing need for international cooperation in the conduct of space activities, together with the unprecedented growth of non-governmental entities in the space industry, has brought to light the actual gaps in Space Law and the need for a set of 'rules of the road' without which an incident will more probably than not happen. The absence of norms or any standards for the behaviour of launching and operation of space objects makes it difficult to assure the safety of air space for both national and foreign users. Generally, Space Traffic Management has been defined as the set of technical and regulatory provisions for promoting (i) safe access to outer space, (ii) the conduction of operations in outer space, and (iii) the return of space objects from outer space free from interference of any form.

This paper shall consequently address selected issues of Space Traffic Management, namely issues that relate to the launching phase and to orbital traffic including collision avoidance and the concept of fault in case of damage caused in outer space. Furthermore, this paper shall strive to present the views on space traffic management in different parts of the world, namely the European Space Agency Study White Paper on the *"Implementation of a European Space Traffic Management System"* conducted in its behalf by the German Aerospace Center and partner institutions on *"Implementation of a European Space Traffic Management System"*, the United States "Orbital Traffic Management Study– Final Report prepared for NASA" on 21 November 2016 and the much expected 2nd edition of the International Academy of

* Adv. LL.M. in Air and Space Law, Leiden University.

1 Rongier I., Sgobba T., *"Space Safety and Space Traffic Management"*, International Institute of Space Law/European Centre for Space Law Space Law Symposium, United Nations Committee on the Peaceful Uses of Outer Space (UN COPUOS), Space Law Symposium 2015, Online: www.unoosa.org/pdf/pres/lsc2015/symp-03.pdf, (accessed 06.09.2017).

Astronautics Study, "*Space Traffic Management: Towards a Roadmap for Implementation*".

**Keywords**: Space Traffic Management, Space Situational Awareness, Fault, IAA Study.

## 1. Introduction

It could be soundly affirmed that the space sector is witnessing a period of steep changes in the perception of the States and the industry. From a relatively discrete sector serving mainly security applications, science and space exploration, the space sector is becoming more and more commercial and the participation of diverse actors such as non-governmental entities evidenced a shift of activities from public to private commercial. In this context, access to space is not anymore just a tool for pioneering but a demand to support economic growth, mitigate risks and ensure innovations on Earth.

For this reason, the space sector is facing a period of regulatory challenges, seeking policy and regulatory solutions for the recurrent questions of the industry. The most debated issues are: (i) Small satellite business such as the surge of Megaconstellations; (ii) Reusable rockets; (iii) Space Mining; (iv) Commercial human space flight and (v) Space Debris and mitigation measures. The regulatory concern linking all these activities could be covered under the concept of Space Traffic Management (STM) which could be regarded as a concept addressing mainly safety operations to, in and from outer space.

Over the last decade, the Space Traffic Management (STM) concept has slowly but steadily evolved and gained relevance for outer space activities especially due to the strong development of the New Space Industry. However, the problem is that Space Traffic Management (STM) has been neither regulated nationally nor internationally which *lato sensu* means that currently there are no self-standing "rules of the road"[2] in outer space. The regulatory aspects pose particular problems and various studies have addressed them, attracting lots of interest and legal debates. Thus, the importance of such a system remains to be further analyzed answering the following research questions:

a) How is the implementation of an international Space Traffic Management (STM) regime being addressed taking account of different approaches of the United States (U.S.), European Space Agency (ESA) and the International Academy of Astronautics (IAA)?

2 Van Fanema P., "Legal aspects of launch services and space transportation", in F. von der Dunk, F. Tronchetti, "Handbook of Space Law", Research Handbooks in International Law Series. Cheltenham: Edward Elgar Pub., 2015, pp. 382-455.

b) What is the role of Space Situational Awareness (SSA) regime in the regulatory framework of an international Space Traffic Management (STM)?
c) Is it helpful to address the notion of fault in case of a collision in outer space from the Space Traffic Management (STM) regime point of view?

## 2. The Concept of Space Traffic Management

The United Nations (UN) treaties among which the Outer Space Treaty (1967), the Liability Convention (1972) and the Registration Convention (1975) do not restrict a legal regulation of a Space Traffic Management (STM) regime but neither provide solutions for its implementation. Thus, it could be concluded that the *Corpus Iuris Spatialis* allows the space sector to come with solutions for implementing the Space Traffic Management (STM) regime in order to address the concerns of the New Space Industry.

Traditionally, it was acknowledged that space traffic already happens "however minuscule with regard to the dimension of near-Earth outer space" questioning thus the relevance of such a regime.[3] More than 10 years ago, the STM concept was introduced to the international community and was not considered a priority from the regulatory point of view. Due to the steady growth in the space sector, the situation could be regarded as different in 2017. Up to this moment, several efforts were made to bring more attention to this topic, for instance, the UNCOPUOS Legal subcommittee approval in 2015 to add STM as an agenda item in 2016.[4] The concept of Space Traffic Management (STM) could be described by making reference to several studies which proposed introducing and researching this concept, representing the views in different parts of the world.

3 Contant C., Lala P., Schrogl K.U., "Statuts of the IAA study group on traffic management rules for space operations", Acta Astronautica 61, 2007, pp. 644-647. See also: Schrogl K.U., "Space Traffic Management: The new comprehensive approach for regulating the use of outer space – Results from the 2006 IAA cosmic study", Acta Astronautica 62, 2008, pp. 272-276.

4 UN General Assembly resolution A/RES/70/82, "International cooperation in the peaceful uses of outer space", 21 December 2015, Online: www.unoosa.org/oosa/oosadoc/data/resolutions/2015/general_assembly_70th_session/ares7082.html, (accessed 06.09.2017). See also: UNCOPUOS General Assembly A/AC.105/C.2/L.298/Add., Online: www.unoosa.org/res/oosadoc/data/documents/2016/aac_105c_2l/aac_105c_2l_298add_1_0_html/AC105_C2_L298Add01E.pdf, (accessed 01.09.2017).

### 2.1 Cosmic Study on Space Traffic Management

The 2006 Cosmic Study on Space Traffic Management conducted by the International Academy of Astronautics (IAA) defines Space Traffic Management (STM) as:

> "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."

The 2006 IAA "Cosmic Study on Space Traffic Management" is a multi-disciplinary approach representing the first comprehensive study about STM.[5] The aim of the Study was to provide a conceptual view and to identify the areas where further research related to STM was needed. The main idea of the Study was that the Space activities have to be regarded as a space traffic system and not as disconnected activities. However, STM was described to require "a roadmap for a research program, identifying areas where further research is necessary" in the context that States where at a point where it was premature to accept discussions about a regulation that would limit their freedom. This Study has been regarded as very useful but currently, could be considered that adjustments would be necessary to address the recent challenges.

The 2006 Study represents the basis for the IAA Study "STM: Towards a Roadmap for Implementation" which was expected to be published ten years after the first study but finally approved in April 2017 and delayed its publication for later this year.[6]

### 2.2 Orbital Traffic Management Study – Final Report

The 2016 "Orbital Traffic Management Study – Final Report" prepared for National Aeronautics and Space Administration (NASA) Headquarters, by Science Applications International Corporation (SAIC) does not contain a definition of Space Traffic Management (STM). A definition is provided neither for *orbital traffic management* nor for *space traffic management,* but only for Space Traffic Safety, described as:

> "(…) freedom from those conditions in orbital space that may lead to incidents resulting in harm (death or injury to astronauts and spaceflight participants,

5 Schrogl K.U., "Space Traffic Management: The new comprehensive approach for regulating the use of outer space – Results from the 2006 IAA cosmic study", Acta Astronautica 62, 2008, pp. 272-276.

6 Soucek A., "Space Traffic Management", International Civil Aviation Organization/United Nations Office Outer Space Affairs Symposium, 15-17 March 2016, Abu Dhabi, United Arab Emirates, Online: https://www.icao.int/Meetings/SPACE2016/Presentations/7%20-%20A.%20Soucek%20-%20ESA.pdf, (accessed 06.09.2017).

> damage to public welfare, damage or loss of spacecraft, interference to spacecraft). Incidents of specific concern are collisions or orbital breakups."[7]

As the Study focuses on developing a national system than an international regime, it seems that is has been preferred the word *safety* than *management,* which could be interpreted as a concern of the authors as regards the implications of such a regime. The Study argues that: "use of the phrase "space traffic management" is problematic, in that it implies centralized command and control (...) also creates a direct analog to "air traffic management". It can be concluded that through the above mentioned definition, the U.S. system proposes at this point to support a strong national system, questioning the efforts to implement a future international system where a possible international institution, whether one which already exists such as the International Civil Aviation Organization (ICAO) or one to be established, such as an International Space Organization could manage the outer space traffic at international level.

The 2016 Orbital Traffic Management Study – Final Report to NASA, supports the idea of a national framework for space traffic management applicable for the US Governmental and non-Governmental entities. This framework proposes to introduce STM as part of a future civil agency that will "best balance the needs for safety, national security and economic interest".[8] In this context, it proposes to maintain the military information to be administrated by the U.S. Department of Defense (DoD) and other entities, and the civil public or private to be provided under the rules of the civil agency. The future civil agency is considered to be "the quickest and most affordable way"[9] to implement a framework allowing multilateral gathering and sharing of data. Additionally, the civil agency will be provided with liability indemnification and will develop interagency coordination procedures.

Overall, the Study presents five Frameworks as alternatives to implement a STM regime through a civil-agency, each of them addressing three categories: (i) Policy Domain – related to data sharing, best practices, guidelines, standards, rules and regulations; (ii) Technology Domain – related to products and services to private and foreign space operators; (iii) Operations Domain – related to SSA operators and developing operational processes and procedures:[10] (i) Private Space Traffic Safety Monitoring and Coordination; (ii) DOD-Based Space traffic Safety Monitoring and Data Sharing; (iii) Civil-Based Space Traffic Safety Monitoring and Facilitation; (iv) Civil-Based Space

7 Brown O. et al.: "Orbital Traffic Management Study – Final Report", prepared for National Aeronautics and Space Administration (NASA) Headquarters, prepared by Science applications InternationalCorporation(SAIC), 21November 2016.

8 *Ibid.*, *supra* note 7.

9 *Ibid.*, *supra* note 7.

10 *Ibid.*, *supra* note 7.

Traffic Monitoring and Coordination; (v) Civil-Based Space Traffic Management. From the five framework alternatives, the third "Civil-Based Space Traffic Safety Monitoring and Facilitation" and the forth "Civil-Based Space Traffic Monitoring and Coordination" have received the most positive assessment criteria. Firstly, regarding the ability to ensure safety of operations in outer space, these two options would enable informed decision-making due to a regulatory framework which allows a rapid development and implementation of diversified SSA sensors. Secondly, it was mentioned that these frameworks would provide more certainty to startups of Space Traffic Safety related to licensing requirements.

The aim of the proposed civil agency has been described to: (i) "facilitate (...) development of codified best practices"; (ii)"become a trusted open source of SSA data"; (iii) "develop data-sharing relationships with international owner-operators and partners"; (iv) "promote (...) commerce in orbital space"; (v) "use a business approach for providing SSA products"; (vi) "interface appropriately with all interagency partners". Aiming to offer codified best practices would mean that a number of domestic private owner-operators should adhere to such a system and make us of the data. But the system would be also open for foreign operators which could help disseminate internationally the procedures which were nationally developed. It would be expected that in this context, other spacefaring nations to prefer legislate their own procedures but make use of the data provided by the U.S. From another point of view, by promoting a national STM regime and not adhering to the collision avoidance maneuver system by other foreign actors in space will give rise to lots of uncertainties in case of a Court case. In such a case, it would be possible for the judge to advantage the State that has put in place such a system. A court would have the elements to reason on the due diligence taken by the U.S. in avoiding the risk of collision while others participants in traffic will have to explain why did not adhere to such a system. A precedent of such national regulation could put under question the legality of the operations on the other actors in space traffic.

It could be concluded that through the future civil agency, the U.S. aims to keep the command and control at national level but allow others to participate with data and develop a cost-effective model for civil operations. However, the products and services would remain free of charge, in an advisory role. The Study states that the ability of a Framework to mitigate incidents is limited and that the "the Outer Space Treaty provides no authority for a State Party to regulate the outer space activities of any entities not affiliated with that State Party". Overall, this could put under question the ability of a national system, even civil regulated, to become internationally accepted and feasible in promoting an international STM regime. However, promoting a standard of care that could be discussed internationally will represent an option for the States to voluntarily adhere to such a system and make use of it in case of a collision avoidance procedure.

### 2.3 Implementation of a European Space Traffic Management System

The 2017 German Aerospace Center (DLR) White paper on the "Implementation of a European Space Traffic Management System" defines Space Traffic Management (STM) as:

> "Execution of all necessary Managing and Monitoring & Control Operations (including routine and contingency scenarios) to ensure safe ballistic travel of manned and unmanned Suborbital Space Vehicles (SSVs) and spaceplanes through Near-Earth space and airspace under consideration of the existing European Air Traffic Management System and Infrastructure."

Mentioning the 2017 DLR White Paper "On the implementation of a European Space Traffic Management System",[11] the Study consists of 3 volumes and apprehends the imminent development of a global commercial space travel market and the need for a STM regime to address safety and support "integration of space vehicles into the daily air traffic flow". This Study desires to be regarded as a roadmap for the implementation of a European STM, focusing its attention on suborbital point-to-point transportation. In the first volume, the research has identified the top 10 pressing issues regarding the implementation of a European STM regime, mentioned in Table 5 of the Study. The second Volume researches upon the Safety and Reliability strategy while the third volume contains the technical Requirements.

This study conducted by DLR and partner institutes in behalf of the European Space Agency (ESA) could be regarded as the most complex study on STM addressing solely the European level.

### 2.4 Space Traffic Management: Towards a Roadmap for Implementation

Finally, it is expected that the 2017 IAA Study would offer more details on how to overcome the regulatory barriers by proposing a "Roadmap for implementation". The study is expected to contain more details of a future instrument to support elements of the STM regime.[12] While approaching international cooperation is considered as a *"conditio sine qua non"* for management of space[13] and also as a sustainable development of space activities, the Study proposes to adjust the concept of STM in order to tackle

11 Tüllmann R. et al.: *"On the Implementation of a European Space Traffic Management System – Volume I. A White Paper; Volume II. The Safety and Reliability Strategy; Volume III. Technical Requirements"*, conducted on behalf of European Space Agency (ESA) by German Aerospace Center (DLR) and partner Institutes and Companies, 27 April 2017.

12 Schrogl K.U., Jorgenson C., Robinson J., Soucek A., "*The IAA Cosmic Study on Space Traffic Management*, United Nations Committee on the Peaceful Uses of Outer Space (UN COPUOS), 6 April 2017, Online: www.unoosa.org/documents/pdf/copuos/lsc/2017/tech-10.pdf, (accessed 06.09.2017).

13 *Ibid.*, *supra* note 12.

the current advancements in space activities, the diversification and growth of actors and how would such a regime contribute to the regulatory framework of space law.

In comparison with the 2006 Study which addressed the STM up to 2020, the new Study will cover the activities until 2030. Following the objective to cover this period and given the fact that it was said that implementation could take an estimated 15 years from the political acceptance of a comprehensive STM regime, it could be reasonably assessed that the new Study would propose a regime to enter in force in 2035.

It was also mentioned that a STM regime could be established through (i) a bottom-up approach or a (ii) top-down approach.[14] Regarding the first option, it was mentioned that elements of the bottom-up approach are already in place today, meaning that STM elements exist and are divided into different categories, such as: (i) development of SSA capabilities; (ii) Space Debris mitigation guidelines developed by UN and the Inter-Agency Space Debris coordination Committee (IADC); (iii) cooperation with the ITU for spectrum allocation in GEO and with ICAO regarding rules for Air Traffic Management, etc. It could result that a bottom-up approach necessarily implies coordination between the various stages of the existing regimes.

The top-down approach was mentioned to represent an opportunity to achieve "a coherent end-to-end framework". It means that the new Study may propose a new international instrument to address STM, addressing a model of international cooperation in the form of an Outer Space Convention (OSC). It should be remembered that the 2006 Cosmic Study mentioned already as a first step an agreement taking account of the existing space treaties towards a STM regime – which would be the bottom-up approach mentioned earlier, and then the implementation of a comprehensive Outer Space Convention, which will supersede the previous agreements.

### 2.5 Other Legal Opinions about Space Traffic Management Concept

Various publications have addressed Space Traffic Management (STM) and analyzed the objectives of such system. For instance, the STM concept was described as "to provide appropriate means so that space activities can be conducted without harmful interference"[15] and that "Mainly space traffic consists of the motion and the interaction of space debris, space vehicles and the use of the radio frequency spectrum in outer space"[16] putting into discussion the role of the International Civil Aviation Organization (ICAO) and the International Telecommunication Union (ITU). Both views support

14 *Ibid.*, *supra* note 12.

15 Contant C., Lala P., Schrogl K.U., *"Statuts of the IAA study group on traffic management rules for space operations"*, Acta Astronautica 61, 2007, pp. 644-647.

16 Cukurtepe H., Akgun I., *"Towards Space Traffic Management System"*, Acta Astronautica 65, no. 5, 2009, pp. 870-78.

the idea that a Space Traffic Management (STM) should be necessary in relation to space objects and space debris, but also in addition to the frequency spectrum allocation regarding orbital slots and orbital planes approved by the International Telecommunication Union (ITU).
In his visionary contribution to the STM concept, Professor Dr. Kai-Uwe Schrogl considered in 2007 that STM will be more than only the sum of existing regimes for specific areas "like the ITU regulations on using the orbit/frequency spectrum of the GSO or the emerging space debris mitigation regime developed in IADC or even the rocket launch notification regime of the HCOC".[17] This is the reason why, Dr. Schrogl concluded that the "STM will develop all provisions in one coherent way from the overarching principle of guaranteeing safe operations in the space traffic system" envisioning the need for a single international instrument to address STM, with reference to the "Outer Space Convention" mentioned in the 2006 Study.[18] In addition, Space Traffic Management (STM) has been considered an:

> "(…) evolutionary step away from the <fragmented> system of space law towards a more comprehensive system of traffic rules (...) The main purpose of STM is to conduct space activities without suffering any harmful interference."[19]

This view shares the direction implemented by the IAA Study in 2006 and adds to the idea that a sustainable development of the New Space needs a Space Traffic Management (STM) system.

In conclusion, the approach of the definitions proves that the Space Traffic Management (STM) concept has not yet matured and debates are still on-going about the need of understanding such a regime. However, common for all the above mentioned legal views is that a STM regime focus on the *safety* of operations of space traffic but also on space debris and preservation of the space environment. In other words, the core of the STM is to provide a standard of care for launching, in-orbit services and re-entry phase. The concept was very well summarized as to "provide an approach to enter into, operate in and return from space, safe from any interference".[20] To do so, Space Traffic Management (STM) should address a number of elements such

17 *Ibid.*, *supra* note 5.
18 *Ibid.*, *supra* note 5.
19 Moro-Aguilar R., Mirmina S., *"Space traffic management and space situational awareness",* in Jakhu R. S., Dempsey P.S., *"Routledge Handbook of Space Law"*, 2016.
20 Henri Y., "Frequency Management and Space Traffic Management", International Institute of Space Law United Nations Committee on the Peaceful Uses of Outer Space (UN COPUOS), Space Law Symposium, April 2015, Online: www.unoosa.org/pdf/pres/lsc2015/symp-04.pdf, (accessed 06.09.2017).

as: (i) SSA; (ii) a Notification system; (iii) Concrete traffic rules and (iv) Mechanism for implementation.[21] Reference to the elements of STM includes a standard of care and addresses space debris and harmful interference as well.

## 3. Space Situational Awareness

### 3.1 Overview

The Space Situational Awareness (SSA) is the system which includes "the ability to detect, track and identify potential hazards in space" determining "the movement and motives of objects in space" which "is critical to protecting (...) space assets".[22] The SSA was also referred interchangeably as Space Surveillance Capability and described to "providing around-the-clock visibility to detect distant space objects without interference from weather, atmosphere or time of day".[23]

A definition of SSA is provided by the Orbital Traffic Management Study – Final Report for NASA in Chapter 1.1 named "Definition of terms". SSA is defined as:

> "(...) the requisite decision-making knowledge to deter, predict, avoid, operate through, recover from, or attribute cause to the loss, disruption, or degradation of space services, capabilities, or activities, including space traffic safety hazards."

This definition support the legal base of a STM regime implemented by the 2006 Cosmic Study for safe activities to, in and from outer space, free from any interference.

The 2006 Cosmic Study does not contain any reference to Space Situational Awareness (SSA) and the lack of a definition could be interpreted that such notion was not ready at that point to address the Space Traffic Management regime. However, in Chapter 2 of the Study, point 2.1.7 entitled "Monitoring of Artificial Space Objects", reference was made to the methods of tracking a satellite and was summary mentioned the US Space Surveillance Network (SSN) and the Russian Space Surveillance System (SSS) together with the catalogues developed by each of them. Reference is also made to the database developed by the European Space Agency (ESA), however, without

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21 *Ibid.*, *supra* note 5; See also: Weeden B., Oprong A., Baseley-Walker B., "Space Traffic Management", United Nations Committee on the Peaceful Uses of Outer Space (UN COPUOS), 2008, Online: www.unoosa.org/pdf/pres/stsc2008/tech-05.pdf, (accessed 06.09.2017).

22 Sheridan T.J, Cooning C., Taylor D.L., "Space Based Space Surveillance – Revolutionizing Space Awareness", 2010, Online: www.boeing.com/assets/pdf/defense-space/space/satellite/MissionBook.pdf, (accessed 15.08.2017).

23 *Ibid.*, *supra* note 22.

mentioning other details. The lack of SSA concept from this Study should be solved by the new IAA Study "Towards a Roadmap for implementation" and extensively addressed to present the relevance of the notion for an international STM regime.

The German Aerospace Center (DLR) White Paper makes reference to the European Space Agency`s (ESA) Space Situational Awareness (SSA) Programme and proposes to "investigate how to integrate ESA's Space Situational Awareness (SSA) monitoring efforts into a holistic European Space Traffic Management concept and develop a roadmap for its implementation". However, the Study does not define the concept of SSA and do not allocate any chapter for explaining its importance for a European Space Traffic Management (STM) regime. Reference to SSA is only made at the beginning of the first Volume of the Study without making any further reference. In such conditions, even if the relevance of such notion for this Study is without doubt, it could be put under question the progress at the European level in providing this kind of information. It would have been necessary for the Study to show the progress of such a system and relevance in regard to the STM regime in order to create a solid base to adhere and support a future international STM regime.

The European Space Agency (ESA) has developed a Space Situational Awareness Programme which was formally launched in 2009. On this basis, ESA has established to carry out SSA activities in domains such as Space Debris, Space Weather and Near Earth Objects.[24] As part of the three main areas, the "Space Surveillance and Tracking" (SST) segment refers to Space Debris and was defined as "The ability to detect and predict the movement of space debris in orbit around the Earth". The current SSA Programme was established until 2020 and it is expected that ESA would manage the SSA capabilities in behalf of the Member States.

In conclusion, from the variety of Space Situational Awareness (SSA) definitions it could result that such a system was only recently proposed to the international community. The fact that SSA was initially developed as a defense military system for monitoring the near earth space and predict orbital events could explain the lack of harmonization but as the purpose of space activities has changed, SSA has currently been identified as to "fill the gap between space risks and information".[25] It would be desirable to harmonize this concept and implement it internationally.

In addition, the current problem of SSA is that having data is not enough. It is very important how data is used, to whom data is shared and if data is multilaterally accepted. Transparency was identified as the biggest challenge

24 Ferrazzani M., "Preliminary considerations on the European Preparatory Programme on Space Situational Awareness", 2010, Online: http://download.esa.int/docs/ECSL/20100930-FINAL_paper_on_SSA_IISL_2010.pdf, (accessed 01.09.2017).

25 *Ibid.*, *supra* note 24.

of a SSA system regarding an international STM regime.[26] Currently, the information could be challenged by countries that did not adhere to such a system and thus, the lack of an international SSA regime puts in difficulty operations that relate to the registration of satellites and frequency assignments. For instance, it could be regarded as challenging for the ITU to maintain the Master International Frequency Register (MIFR) and detect "paper satellites" in absence of an international recognized SSA system.
Only a multilateral access to an international SSA system could address the factor of diversification and the increased risk of harmful interference and collision in the congested corridors of outer space.[27] It was already assessed that access and sharing of SSA data may be perceived as a precondition to any international STM. Prof. Dr. Kai –Uwe Schrogl stated that:

> "In order to manage traffic, a sound information basis regarding space situational awareness has to be established. (..) Only on such a basis, a shared knowledge about what is going on in the Earth orbits, traffic rules can become meaningful."[28]

To implement an effective system, challenges have to be overpassed such as access to, gathering of and sharing of the information through a multilateral SSA system. Such information needs to be made available without posing the risk of revealing military intelligence information but to support the objective of a STM which is to improve the safety and sustainability of space activities.[29]

### 3.2 How Should the Space Situational Awareness Capabilities Be Integrated into an International Space Traffic Management System?

Space Traffic Management (STM) has been divided into three phases: (i) the launching phase; (ii) the in-orbit operation phase and (iii) the re-entry phase.[30] Such a partition gives the view that different rules should apply, at least for the operations that involve Air on the one hand and Space on the other hand and operations that involve only space and which could request

26 Samson V., "SSA and STM: Current Status and Possible Improvements", Secure World Foundation, 13 November 2015, Online: https://swfound.org/media/205317/victoria-samson_the-evolving-landscape-of-stm_erau_nov-13-2015.pdf, (accessed: 06.09.2017).
27 *Ibid*.. *supra* note 7.
28 *Ibid*., *supra* note 5.
29 Federal Aviation Administration (FAA), "AST Commercial Space Transportation – Towards a Civil Space Traffic Management System", 2016, Online: https://www.faa.gov/about/office_org/headquarters_offices/ast/media/6_space_traffic_management_plans.pdf, (accessed 03.09.2017).
30 International Academy of Astronautics (IAA), "Cosmic Study on Space Traffic Management", Paris 2006, C. Contant-Jorgensen (Secretary of the Study Group), P. Lala, K.U. Schrogl (Coordinators of the Study Group).

specific rules for GEO, MEO and LEO.[31] The STM system needs SSA especially for in orbit services and avoidance maneuvers but also for the launching and re-entry phases.

However, space objects are more often than desired involved in collisions while in orbit. To give just a few examples, the ISS is the only operational man crewed space object in space with a planned mission till 2024 and the avoidance maneuvers are necessary to avoid danger to human life. In perspective, other objects are expected to contain man crew in space, such as the China plans to construct a permanent space station by 2022 or even the suborbital flights. According to NASA, a maneuver for the ISS can take up to 7 minutes in order to avoid a predetermined risk of collision while the collision warning and avoidance process begins about 4 to 7 days before a possible close approach might take place. It could be reminded here the incident in 2015 that forced the ISS crew to evacuate into the escape Soyuz spacecraft attached to the station, which was the 4th time that the ISS crew had to prepare to escape due to the danger of collision with debris. Damage to the ISS has been registered in 2016 when small debris caused a small crack to the Cupola observation module. According to NASA, in 2014 were needed 21 collision avoidance maneuvers by robotic spacecraft.

Another example is the European Space Agency satellite Sentinel-1A which suffered an impact from debris to one of its solar panels. Such an incident made the Head of the Space Debris Office at ESA Darmstadt Germany, Holger Krag, to note that

> "Such hits, caused by particles of millimeter size, are not unexpected. These very small objects are not trackable from the ground because only objects greater than about 5 cm can usually be tracked and thus, avoided by maneuvering the satellites".[32]

Lastly, conjunction assessment and collision avoidance which are part of the extended concept of SSA have been regarded as a subset of orbital debris mitigation, involving the track of space objects and conducting maneuvers when necessary and if possible.[33] Space debris is one of the problems that need to be addressed by the STM under SSA and Avoidance collision. Problems were raised in the most recent European conference on Space

31 Hobe S., "The legal regime for private space tourism activities – An overview", Acta Astronautica, Vol. 66, Issues11-12, 2010, pp. 1593-596.

32 European Space Agency (ESA), "Copernicus Sentinel-1A Satellite Hit By Space Particle, 31 August 2016, Online: http://m.esa.int/Our_Activities/Observing_the_Earth/Copernicus/Sentinel-1/Copernicus_Sentinel-1A_satellite_hit_by_space_particle, (accessed 01.09.2017).

33 Harris L. Jr., LL.M. Thesis, "Space Traffic Safety: Is Global Space Traffic Control the Answer", 2016, Online http://digitalcommons.apus.edu/cgi/viewcontent.cgi?article=1139&context=theses, (accessed 01.09.2017).

Debris in ESA Darmstadt on "Microsatellites, Megaconstellations and strategies for combating increasing volumes of space debris".[34] Overall, a recent study on impacts of the satellites with debris concluded that 10% of functional satellites suffer debris impacts and for this reason the latest concern is to deploy in-orbit Space debris Sensors above 600 km in altitude to track the smaller objects than 10 cm. The Space Debris Sensor (SDS) of the Debris Resistive/Acoustic Grid Orbital NASA-Navy Sensor (DRAGONS) represent a project development by NASA to collect information about "the size, speed, direction and density of small impacting objects".[35]

For the re-entry phase, SSA also plays a very important role, to help the operators to avoid any interference in the descending track at the end-of-life of a maneuverable or non-maneuverable satellite. To give some numbers "More than 600 satellites, launch vehicle upper stages and other debris were recorded by U.S. Space surveillance Network in 2014, from which 86 satellites, 49 upper stages, 467 debris".[36] There are two expected major re-entries, the ESA Envisat satellite and the Chinese Tiangong-1 Space Lab. The risk of collision could be prevented by an increased cooperation between participants to space traffic, on the basis on a multilateral SSA system.

In conclusion, the increasing population of in-orbit satellites and predictions of growth of space debris poses new challenges that could be attempted to be overcome by a comprehensive STM, putting both the space debris mitigation measures and space situational awareness on the forefront of developing an international space traffic management system. To avoid collisions, protect the safe operations of the space assets but also support the outer space environment and sustainability of the Earth`s orbits, the SSA and multilateral access and contribution to it should be regarded as an essential criterion of any future STM. In addition, SSA capabilities should focus on the near-Earth space and especially in LEO where the traffic growth is expected to grow even more. Because only few states pose capabilities of SSA, it would become innovative to negotiate a solution by which states could jointly adhere to international rules of the road, make use of the data available and abide by

34 German Aerospace Center (DLR), 7th European Conference on Space Debris in Darmstadt 18-21 April 2017 "Microsatellites, megaconstelations and strategies for combatting increasing volumes of space debris", 13 April 2017, Online: www.dlr.de/dlr/en/desktopdefault.aspx/tabid-10080/150_read-22092/year-all/#/gallery/9464, (accessed 01.09.2017).

35 Hamilton J.,.Liou J.C, Anz-Meador P.D., Corsaro B., Giovane F., Matney M., Christiansen E., "Development of the Space Debris Sensor", ESA proceeding 7th European Conference on Space Debris, Darmstadt Germany, 18-21 April 2017, Online https://conference.sdo.esoc.esa.int/proceedings/sdc7/paper/965/SDC7-paper 965.pdf, (accessed 01.09.2017).

36 Wittig M., "Space Debris and De-Orbiting", slide 13, 2015, Online: https://www.itu.int/en/ITU-R/space/workshops/2015-prague-small-sat/Presentations/MEW-Prague.pdf, (accessed 01.09.2017).

the traffic rules, thus contributing to the safety and sustainability of the activities in outer space.

## 4. Liability

To begin with, the provisions of Article VI Outer Space Treaty (OST) provide that States bear international responsibility for any activity in Outer Space in accordance with relevant rules of international law: "From the very inception an international obligation is created, a duty to respond as between States".[37] As it was further expressed, States have the obligation to put in place appropriate provisions to ensure that persons engaged in outer space activity conduct it in accordance with international law.[38] In general international law, only an illicit act gives rise to international responsibility. According to Judge Manfred Lacks citing a former decision, if there is no omission of duty, then there is no fault and there is nothing to justify a complaint.[39] Referring to the LIAB and the rules governing liability for damage was also stated that "This is clearly a very modest beginning and, before long, it is to be expected that law will have to respond to the need for further elaboration".[40]

According to the provisions of Article III of the Liability Convention (LIAB), in the event of a damage caused in outer space, a state shall be liable only if the damage was caused due to its fault or the fault of persons for whom is responsible.[41] The problem with the fault-based liability for damage caused in outer space is the fact that although the treaty requires proof of fault, does not offer a definition of fault nor refers to a standard of care for determining fault.[42]

The concept of fault necessarily implies a code of conduct or a standard of care by which the reasonableness of the State actions can be judged.[43] Related to the STM, in order to establish that the launching state was in fault and is liable for the damage resulted from the collision with another object in outer space, it must be proved that has breached the standard of care traduced in

37 Lachs M., Masson-Zwaan T. L., Hobe S., "The Law of Outer Space: An Experience in Contemporary Law-Making", Reissued on the occasion of the 50th Anniversary of the International Institute of Space Law, 2010, Chapter XI, pp. 113-124.

38 Hobe, Schmidt-Tedd, Schrogl, "Cologne Commentary on Space Law", Vol. II, Carl Heymanns Verlag 2014, pp. 115-118.

39 *Ibid.*, *supra* note 38.

40 *Ibid.*, *supra* note 38.

41 Smith, Kerrest, "Article III – Fault Liability", in Hobe, Schmidt, Todd, Schrogl, "Cologne Commentary on Space Law", Vol. II, Carl Heymanns Verlag 2014, pp. 132.

42 Tammandon S., "State Liability for Damage Caused by Space Activities under the 1972 Liability Convention and the Italian Implementation", Space Law and Policy, Leiden University, LL.M. Air and Space Law, 2017.

43 *Ibid.*, *supra* note 42.

traffic rules or the rules of the road. These rules have to be accepted by the operators engaged in space traffic. The current status of the LIAB challenges as regards the STM was very well described by the following:

> "While liability remains a key issue, there is some criticism that the requirement of fault for damage in outer space is ineffective. Not only is fault difficult to prove; there are no accepted international standards on which to measure the standard of care in the individual case. This negatively impacts on the operation of Art. III LIAB and gives rise to concern as to its longer-term feasibility."[44]

The consequences of fault make the state responsible for the damage. But how would a state be responsible without a legal definition of fault? Fault has been described as ambiguous in the context of space law and also very difficult to prove.[45] It results that in a case of collision, fault will be difficult to prove. In other words, the provisions of Article III LIAB impose liability in outer space for the State breaching the objective conduct imposed by the international law of outer space. However, without international binding instruments that would impose obligations for instance for collision avoidance, it would be difficult to prove in practice who was at fault at the moment when the damage occurred.

In conclusion, there are two reasons for the urgent need of regulation of traffic rules: (i) as long as procedures will not be put in place to take multilateral, fast and well informed decisions on the basis of a right-of-way passage, any risk of conjunction could degenerate into disorganized measures leading to collisions that could otherwise be prevented and (ii) without a standard of care, liability is hard to be proven in practice in case of a collision in outer space.[46] The Studies developed by the IAA, DLR and NASA are extremely important for raising awareness on the concept of STM as part of the safe access and operations in outer space, to study the actual developments and current challenges and support future cooperation. Even if barrier towards developing an international system are yet to be surpassed, it is very important that discussions are taking place and significant workload is given to the regulatory and technical challenges to enable the procedures and standards of conduct for in orbit activities. The significance of this studies and the close relation with the Inter-Agency Space Debris Coordination (IADC) guidelines is to promote standards from which it could be measured the fault in case of collisions.

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44 *Ibid.*, *supra* note 38.

45 Cheng B., "Studies in International Space Law", Oxford [etc.]: Clarendon, 1997. See also: Chatterjee J., "Legal Issues Relating to Unauthorized Space Debris Remediation" McGill University, Institute of Air and Space Law, 65th International AstronauticalCongress,Toronto, 2014.

46 *Ibid.*, *supra* note 38.

## 5. Conclusions and Recommendations

The legal and political implications of a Space Traffic Management (STM) regime plays an important role towards addressing the dilemma of when and under which circumstances would States might be ready to negotiate a completely new instrument for space activities.[47] It is not desirable to modify the well-established Outer Space Treaty. Addressing the current challenges seems more realistic to be made in two phases, firstly by developing, coordinating and harmonizing the existing elements of a STM regime and secondly, by proposing a new instrument that would supersede the existing UN treaties. In other words, a STM regime has to be discussed and become internationally regulated in a harmonized manner, before an Outer Space Convention to be implemented. The IAA Study "Space Traffic Management – Towards a roadmap for implementation" will represent a milestone for the implementation of a STM regime on an international level. It results that national regulations come before international agreements.

Implementing a comprehensive STM regime is not that easy and many challenges have to be overpassed in the attempt to cater the needs of the new industry. It could be concluded that such a regime implies a new level of international cooperation and focus on a number of selected priorities that are likely to improve the current regulatory landscape and support the sustainability of space activities such as the Space Situational Awareness (SSA), a standard of care translated into traffic rules, but also to allow coordination with the International Telecommunication Union (ITU) and International Civil Aviation Organization (ICAO). Thus, the urgency is both to develop a multilateral and open information system, namely a Space Situational Awareness (SSA) but also a standard of care, namely traffic rules to address access to, in and from outer space. For the above mentioned arguments, Space Traffic Management represents a top priority for safety operations in outer space, representing the reason to convince decision makers of the need to establish an international STM regime.

A STM regime should first and foremost apply internationally. If analyzing the past contributions to space law such as UNIDROIT Space Protocol, the Moon Agreement and the IADC Guidelines, it could be concluded that the procedure to implement a binding instrument is slow and is usually reactive than proactive. For this reason, a recommendation could address the following two options: Firstly, the implementation of a future STM should promote proactive measures in addition to the current principles. Respecting

47 Wang G., "Space Traffic Management and Governance of Space Activities", International Institute of Space Law/European Centre for Space Law Space Law Symposium, United Nations Committee on the Peaceful Uses of Outer Space ( UN COPUOS), 13 April 2015. Online: www.unoosa.org/pdf/pres/lsc2015/symp-05.pdf, (accessed: 06.09.2017).

the direction imposed by the 2006 Cosmic Study, the final goal should be implementing of an Outer Space Convention. To reach such a result, preliminary steps should be taken such as harmonizing, coordinating and developing the current efforts that could be regarded as elements of a STM regime. An Agreement for STM should propose a dual purpose normative system composed of (i) primary legal principles that should not be altered, based on the current principles and (ii) secondary provisions, which are more flexible and which would allow a mechanism to update the regime in regard of the technological advancements.

Secondly, data collection and sharing of information through a SSA system is quintessential for developing a truly international STM regime. Collecting the data from multilateral sources and sharing it openly across the interested operators while accepting it as a trustworthy source is one of the current challenges that have to be overpassed and only the international consensus will reach this goal. SSA exists today but the level of cooperation and acceptance is not sufficient for a STM regime and work has to be done to achieve impartial access and acceptance of data gathering and sharing. However, it would not be an easy task to attempt implementing STM changing the UN treaties but it is rather recommended to supplement them with additional binding instruments to be negotiated separately on the international level.

Overall, the lack of a STM regime up to this moment could have been treated as superfluous due to the fact that man-made missions in outer space were regarded as exceptional. However, if the humanity ambition is to conquer space by sending people to an asteroid or Mars, develop regular crewed missions in outer space to lunar orbit or surface, then the consequences of unregulated space traffic are much more complex and could endanger life of astronauts. In addition to the *Corpus Juris Spatialis,* Article 3 of the Universal Declaration of Human Rights (UDHR) guarantees the right to life of every human being stating that "Everyone has the right to life, liberty and security of person". From UDHR point of view, to implement a STM regime could be considered as an international commitment based on the right to life.

*How is the implementation of an international Space Traffic Management (STM) regime being addressed taking account of different approaches of the United States (U.S.), European Space Agency (ESA) and the International Academy of Astronautics (IAA)?*

Comparing the three studies analyzed above, it could be concluded that the IAA "Towards a roadmap for implementation" will represent the most important achievement for an international STM regime. Similar to Space Mining regulatory framework developed by the US and Luxembourg, it seems that the US has the most developed project until now to develop a national regime for STM. Despite the reality that a national system will be most probably implemented before an international regime, this game has to be played together and the national regulation could represent only the starting point for further international negotiations. The stage of the projects for implementing a STM regime at national level represents a solid argument for the international community to create the premises for a new comprehensive international STM regime.

*What is the role of the Space Situational Awareness regime in the regulatory framework of an international STM?*
The primary scope of any system of Traffic Management is to promote the safety of the operations. In this scenario, the most relevant issues for STM is to find solutions for guaranteeing the sharing of and access to SSA data and services. A strong synergy exists between SSA and STM,[48] which determines the recommendation to allow a multilateral and open system of data gathering and data sharing among international actors. Based on the safety concerns in outer space, the SSA is considered a priority for an international STM regime. Efforts should be made to allow the governmental organizations to work together with nongovernmental entities and contribute in developing an international civil system. Without overcoming these challenges, regulatory barriers will continue to exist towards an international STM regulatory framework.

*Is it helpful to address the notion of fault in case of a collision in outer space from the Space Traffic Management (STM) regime point of view?*
The central concern for a future STM regime is to implement a standard of care comprised in a set of traffic rules to be internationally recognized. Such rules would regulate the traffic (i) to, (ii) in and (iii) from outer space, regarded as the launching phase; in-orbit operations and re-entry phase. It would be helpful to address the notion of fault from the STM regime point of view in order to clarify the notion of fault in case of damage caused in outer space, which was preconized since 2006 IAA Study. The convenience of an international STM regime will both address the safety operations in space traffic and will also benefit the application of space law in case of any collision in outer space.

48 Stelmakh-Drescher O., Space Situational Awareness and Space Traffic Management: Towards Their Comprehensive Paradigm, 17 November 2016, Online: https://webcache.googleusercontent.com/search?q=cache:cl0pVFvoaGkJ:https://www.researchgate.net/profile/Olga_Stelmakh-Drescher/publication/310946251_Space_Situational_Awareness_and_Space_Traffic_Management_Towards_Their_Comprehensive_Paradigm/links/583afec008ae3d9172412480+&cd=4&hl=ro&ct=clnk&gl=ro, (accessed: 06.09.2017).