The Cologne Manual on Space Traffic Management

(CM-STM)

Co-operation project between the Institute of Air Law, Space Law and Cyber Law at the University of Cologne and the German Aerospace Center (DLR)

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Content

Abbreviations

ARRA	The Rescue and Return Agreement (1968)
ASA(s)	Air Services Agreement(s)
ATM	Air Traffic Management
CM-STM	Cologne Manual on Space Traffic Management
CONOPS	concept of operations
EASA	European Union Aviation Safety Agency
ESA	European Space Agency
EU	European Union
EU SST	European Union Space Surveillance and Tracking
FAA	Federal Aviation Administration (USA)
GEO	Geostationary-Earth-Orbit
IADC	Inter-Agency Space Debris Coordination Committee
ICAO	International Civil Aviation Organisation
ILA	International Law Association
ILO	International Labour Organisation
IMO	International Maritime Organisation
ISO	International Organization for Standardization
ISS	International Space Station
ITU	International Telecommunications Union
JAXA	Japanese Aerospace Exploration Agency
LEO	Low Earth Orbit
LIAB	The Liability Convention (1972)
LTS Guidelines	Long-term Sustainability Guidelines
MEO	Medium Earth Orbit
MOON	The Moon Agreement (1979)
NASA	National Aeronautics and Space Administration
OST	The Outer Space Treaty (1967)
REG	The Registration Convention (1975)
SDMG	Space Debris Mitigation Guidelines
UNSG	Secretary General of the United Nations
SSA	Space Situational Awareness
STM	Space Traffic Management

UN	United Nations
UNCOPUOS	United Nations Committee for the Peaceful Uses of Outer Space
UNGA	United Nations General Assembly
UNOOSA	United Nations Office for Outer Space Affairs
US SSN	United States Space Surveillance Network

General introduction to the Cologne Manual on Space Traffic Management

The rapid evolution of technology is enabling more actors and more activities in outer space than at any point in human history and is projected to continue to steadily grow in future. Consequently, space traffic has reached unprecedented numbers of active space objects as well as of the accumulation of space debris, which endangers active space objects. Meanwhile, Earth's orbits are a finite resource, and the risk of collision has become a near daily reality of space object operators. The burgeoning activities in outer space – encompassing launches, space exploration and use, and scientific research – therefore necessitate a robust system to manage these endeavours responsibly.

In the ever-evolving landscape of outer space, a significant collaboration has emerged between the Institute of Air Law, Space Law, and Cyber Law at the University of Cologne and the German Aerospace Center (DLR). This partnership has been dedicated to a three-year project which developed a comprehensive study on Space Traffic Management (STM). At the heart of this initiative has been the creation of the "Cologne Manual on Space Traffic Management," which aspires to formulate scientifically grounded yet practical guidelines akin to a "traffic code" for outer space. This endeavour not only builds upon the historical collaborations between the Institute and the DLR but also responds to the growing complexities of space activities, particularly as private entities increasingly participate in space exploration and utilisation.

I. Project Overview and Objectives

The primary objective of this project has been to produce the Cologne Manual as a scientifically and legally sound and practically applicable framework for Space Traffic Management. The urgency of this task is underscored by the mentioned exponential rise in space activities, which necessitates a robust regulatory framework to minimise collision risk and formation of space debris. Presently *ad hoc* measures are being exercised in practice to coordinate and manage space traffic, however, the success of these is credited to still manageable numbers. The space sector is swiftly entering an era of a boom similar to the one experienced in post second world war aviation. This promises to strain present technological tracking and monitoring capabilities, and make numbers of space traffic unmanageable. The existing large constellations such as Starlink are already testing the present ad hoc coordination measures and their continued effectiveness is relying on Starlink self-manoeuvring initiative and low risk thresholds triggering a manoeuvre. With space activity projected to steadily rise and as further large constellations are in the planning by the USA, UK, China and others, such measures and space traffic will in a very short time become untenable. A systematic, scientifically

and legally sound and practically applicable framework for Space Traffic Management is urgently required.

The Institute of Air Law, Space Law and Cyber Law at the University of Cologne has leveraged its considerable legal expertise in aviation, space and cyber domains to produce the Cologne Manual on Space Traffic Management. The DLR, with a wealth of practical experience in both aerospace and aviation sectors, significantly contributed to the project, making this collaboration particularly well-suited to address the intricate dimensions of STM.

Over the course of three years, the project unfolded in several stages, culminating in the formulation of a concrete Manual for regulation of space traffic. To facilitate this, over 40 international experts have been working together, spanning five continents and various professions in the legal as well as technical fields, including experts from space agencies such as the European Space Agency (ESA), the Japanese Aerospace Exploration Agency (JAXA), the Brazilian Space Agency and the Kenya Space Agency (KSA). During the work of the project, four working groups have been established, each focusing on key legal and technical areas essential to the development of a comprehensive STM framework. The first group concentrated on existing space law and its current regulatory landscape, assessing the potential for necessary improvements. The second group explored the intersection of air traffic management and space traffic, investigating whether established concepts from aviation can be adapted for use in outer space and how rising air and space traffic can be safely synchronised. The third group addressed the necessity of facilitating a sustainable space traffic, and, finally, the fourth group focused on cyber security issues in the context of STM.

The collaborative nature of the project was designed to foster continuous dialogue among the working groups, with several interim conferences synthesising findings and sharing insights. Additionally, experts outside the project have been consulted for specific issues and panel discussions have been held to include the different facets space traffic offers. The ultimate goal has been achieved by producing the Cologne Manual, a tangible and actionable document that integrates all relevant legal and practical perspectives on STM.

II. Significance of the Cologne Manual

The Cologne Manual on Space Traffic Management is envisioned as a pivotal contribution to the field of international space regulation.

The project aims to advance the academic and governmental discourse surrounding space regulations and to promote international dialogue on issues of space, air, and cyber law as well as sustainability. By institutionalising the exchange of knowledge among the four working groups, the Cologne Manual encapsulates a forward-thinking approach to STM, addressing the pressing challenges posed by increasing space traffic and the associated risks. It ultimately proposes concrete Guidelines, which can be directly implemented by space object operators as well as by national and international legislators. It thus hopes to provide foundational groundwork for a future comprehensive Space Traffic Management, which builds on existing ad hoc measures and the five United Nations Space Treaties.

III. Research Framework and Methodology

The project adopts a comprehensive legal and technical approach to STM, integrating various perspectives to address the central research questions that underlie the creation of a robust STM framework. Key legal principles from the Outer Space Treaty of 1967, the Registration Convention of 1975, and the Liability Convention of 1972 have served as foundational elements in the development of the Cologne Manual.

Furthermore, the project considered three elements essential to the research; firstly, the necessity of coordination between all stakeholders, including with international organisations, in particular the International Telecommunication Union (ITU) to mitigate harmful interferences; secondly, examination of emerging technologies in space debris remediation and their relevance to STM; thirdly, military uses of outer space, ensuring that the principles of transparency and safety are maintained without compromising security interests.

The project identified research questions, which have then been systematically categorised and assigned to the respective working groups, which have explored the nuances of space traffic regulations, the coordination of air and space traffic, and the implications of sustainability and cyber security in the context of STM. By fostering collaboration among more than 40 international experts in these fields, the project aims to generate a holistic understanding of the challenges and opportunities inherent in managing space traffic.

IV. Key Information regarding the Cologne Manual

Several points should be observed throughout the Cologne Manual.

First, the Guidelines should therefore be interpreted in a manner that ensures and maintains the freedom of access and usability of outer space, thus the “freedom of exploration and use” guaranteed by Article I of the Outer Space Treaty, through facilitating the safe coordination and management of

space traffic for secure and safe space operations, which are the aim of the Cologne Manual. Nothing in the Cologne Manual should consequently be interpreted in a manner that would unduly and legally restrict freedom of access to and use of outer space guaranteed by Article I of the Outer Space Treaty for certain stakeholders or that would injure State sovereignty in space objects protected by Article VIII of the Outer Space Treaty.

Second, all space actors should abide by the Guidelines. The Guideline on Non-Governmental Space Activities and Guideline on Military Space Activities are therefore relevant throughout the Cologne Manual and all Guidelines of the Cologne Manual are applicable to governmental as well as non-governmental actors, while military operators may in all instances deviate from the required level of transparency when required for purposes of State security.

Third, *space object operator* should be understood as both governmental and non-governmental space object operator including both launch operator and operator of space objects in-orbit unless specified otherwise.

V. Conclusion

The Cologne Manual on Space Traffic Management represents a significant step forward in the development of international legal frameworks governing outer space activities. By leveraging the strengths of the Institute of Air Law, Space Law and Cyber Law, the German Aerospace Center and all other participating experts and their institutions, this project produced a comprehensive and practical guide that addresses the complexities of contemporary space traffic management. With the publication of the project, it promises to enhance the scientific discourse surrounding space law and contribute to the establishment of a sustainable and secure regulatory environment for future space endeavours, addressing not just States but also operators.

All the information collated, and the references cited are cross-checked in line with the most recent data, as of May 2025.

The Imperative of Space Traffic Management: A Comprehensive Framework Rooted in the Principles of International Space Law

I. The Concept of Space Traffic Management

Space Traffic Management aims at the development of technical and regulatory guidelines for space traffic. Any use of outer space, be it the launch into outer space, the operation in and travel through outer space or the return from outer space should be undertaken in a manner that takes into account the unique nature of this province of all humankind. This is the expression of the spirit of the international space legislation, which does not explicitly mention Space Traffic Management, but which signals that the unique environment must be preserved for the further use of humankind today and for future generations. In that the concept of Space Traffic Management requests the adoption of measures to minimise collisions in outer space and thus the generation of space debris, it is the background of any sustainable use and thus ultimately a concept for the continues accessibility and usability of outer space.

Presently, STM already exists and is being performed by space object operators, including launch (i.e. rocket) operators as well as in-orbit space object (e.g. payload) operators, on an ad hoc basis. These coordinating and management efforts, however, suffer from lack of transparency, consistency, available instructions for emerging operators, break-downs in communication and a myriad of competing approaches to STM that prolong efficient space traffic coordination.[1] A systematic international STM is required and is already subject of discussions on national, regional and international level by a variety of actors and stakeholders, ranging from academia, to government, to private industry. For instance, STM has been introduced as UNCOPUOS Agenda Item in 2016.[2]

1) These fruitful discussions have proposed various definitions of the concept which elucidate several building blocks of STM concepts as an organisational and operational structure, composed of technical as well as legal or regulatory measures, including notification of dangers and execution of coordination among different actors. These measures are intended to minimise risks of loss of operations, physical collisions or other detrimental effects or interference, e.g. radiofrequency interference, between primarily space operations into, through, in and out of outer space. The latter therefore

[1] See e.g. ESPI, Report 71 (2020).
[2] UN Doc. A/RES/71/90 (2016).

includes preventing physical collision or other detrimental effects and interference with or by non-space operations in airspace, or on and from ground. These should be observed throughout all phases of space activity to assure safety of space operations, thus impacting planning and operation of space activities.

Practice illuminates that STM requires monitoring through appropriate space surveillance capabilities, coordination supported by proper information-sharing, and finally regulation enabling organised process of long-term accessibility and usability of outer space without detrimental interference through systematic, consistent and coordinated approach and synchronisation of space activities to enhance safety, stability and sustainability of space operations, including compliance with best practices and development of international standards. The discourse has illustrated that presently focus is placed on necessity to systematise the process of prevention collisions between physical objects, requiring reliable monitoring and coordinating capacities, which still face several obstacles. Discussions have portrayed that the development of an international synchronised STM adapted to this aim, therefore requires geo-political will, adoption of space "traffic rules" and mechanisms for implementation that will enable the efficient and quick functioning of a systematic collision avoidance process that identifies high probability of collision conjunctions and delivers conjunction data messages (CDMs) to an operator, who then acts in accordance with the space "traffic rules".

It therefore ultimately amounts to a regime idea that would be able of guaranteeing accessibility and usability of outer space in an increasingly congested operational environment through facilitating safe, secure and stable space operations. It is the aim of STM consequently to facilitate and enable the implementation of the freedom of access and use of outer space and should not be misused in a manner that would unduly restrict these freedoms guaranteed by Article I of the Outer Space Treaty or State jurisdiction in space objects guaranteed by Article VIII of the Outer Space Treaty. Development and adherence to an international STM permitting the monitoring, notification, coordination and synchronisation of actionable collision avoidance – passive or active – to assure safety, security and stability of ever-increasing space traffic is consequently in the benefit of all as well as in the self-interest of space-faring nations and space object operators, and other stakeholders.

II. The Outer Space Treaty and Its Relevant Core Principles

As humanity's presence in outer space intensifies, the urgency for an effective framework for Space Traffic Management (STM) becomes increasingly pronounced. This management is inherently linked to the established principles of international space law, particularly as articulated in the Treaty on Principles Governing the Activities of States in the Exploration and Use of Outer Space, including

the Moon and Other Celestial Bodie, known as the Outer Space Treaty (OST) of 1967. This treaty serves as the cornerstone of the building blocks of the Cologne Manual, outlining fundamental norms that regulate the use and exploration of outer space.

The OST posits that outer space is the province of all humankind, encapsulating the dual tenets of freedom of exploration and use and the necessity for responsible stewardship of outer space. As the number of active satellites increases, along with the proliferation of space debris and the rising potential for collisions, the necessity to establish effective management becomes crucial to safeguarding and upholding these freedoms.

The OST has been drafted in general terms as a treaty on principles, in order to allow it to become a living instrument capable of incorporating the newest developments in space technology and activities, and thus not be outdated by the passage of time. In accordance with customary interpretational principles, treaty terms and the law evolve with time and technology, and must be interpreted in accordance with relevant contemporary factors. Therefore, the OST remains a vital foundational bedrock of all space exploration and use.

This section will elucidate the current legal framework (*de lege lata*) and how the fundamental principles of international space law underpin the establishment of a comprehensive STM system. The following will particularly focus on the OST and its innovative interpretations, providing insights into how these principles can inform the development of STM principles, as exemplified in the Cologne Manual. These principles decree that outer space is an area beyond national jurisdiction and shall be free for exploration and use by all States, without any discrimination, that it must be utilised for peaceful purposes, and that States bear responsibility for national space activities, including those conducted by non-governmental entities. The following will delve into these principles, their design and elucidate their significance for STM and their incorporation in the Cologne Manual.

1. Freedom of Exploration and Use

Article I of the OST stipulates that outer space shall be free for exploration and use as well as for scientific investigation to all States without discrimination of any kind, shall be undertaken for the benefit of all States and shall be the province of all humankind. By decreeing that outer space *shall be free for exploration and use by all States*, Article I establishes the right to do so and a duty to maintain conditions that technically enable the enjoyment of the freedoms. This principle thus predicts and necessitates the establishment of an effective and functional STM. The rapid proliferation of space objects such as satellites enabling communication, Earth observation, navigation, scientific

research, provision of internet services and other, often crucial, services has resulted in an increasingly congested orbital environment. The evolution of large constellations of satellites, comprising hundreds and even thousands of active space objects, has furthermore strained the orbital environment, rendering the possibility of collisions in-orbit at an all-time high. While the preceding activities are permitted to States and non-State actors under the freedom of exploration and use, and scientific investigation, it furthermore places obligations on the self-same actors to adopt measures for the preservation of the freedom of exploration and use. The current STC measures are being challenged by the exponential increase in orbital traffic and may no longer suffice to guarantee long-term access and freedom of exploration and use to all. Therefore, it is imperative that the principle of the freedom of exploration and use as well as scientific investigation is prominently represented in the Preamble of the Cologne Manual, highlighting its significance in the context of STM.

2. Non-Appropriation Principle

Article II of the OST, decrees that no State may claim sovereignty over outer space or the celestial bodies, ensuring that outer space remains an area beyond national jurisdiction. Read together with Article I of the OST, this provision therefore delineates outer space as a global common or *res communis*, similar to the High Seas, where freedom of navigation is complimented by duties of States to ensure continued freedom of navigation for all. This principle has been instrumental in preventing conflict in outer space and therefore, as echoed in Article 11 of the Moon Agreement,[3] is fundamental for fostering an environment conducive to collaboration and shared exploration and use. To underscore its importance and support for STM, the Preamble of the Cologne Manual explicitly references this principle, reinforcing the notion that space activities must be conducted in a manner that respects the collective interests of all nations.

3. In Accordance with International Law

Article III of the OST clarifies that all space activities must be conducted in accordance with international law including the United Nations Charter. This not only clarifies that the principles of the OST must be interpreted with regard to all norms of international law, but also means that norms of customary international law as well as general principles of law apply in outer space, such as the principle of "sustainable development". The "no harm rule" as an international custom necessitates that all activities within a State's jurisdiction are undertaken with a degree of due diligence and observe the required standards of care, in order to prevent damage occurring to areas beyond national jurisdiction,

[3] Art.11 Moon Agreement, in: Hobe/Schmidt-Tedd/Schrogl (eds.), Cologne Commentary on Space Law, Vol. II, Carl Heymanns, Cologne 2013, p. 389, mn 175.

such as outer space. As this enables the application of soft-law instruments enshrining or elucidating international standards and best practices, such as the UNCOPUOS Space Debris Mitigation Guidelines, this principle will be underscored in the Cologne Manual as requiring that States and non-State actors comply with STM measures.

4. Military Activities

Following the preamble of the OST, the peaceful exploration and use of space is a vital element of international cooperation in outer space. Additionally, the preamble explicitly references the work done by the Committee on the Peaceful Uses of Outer Space,[4] a Committee that has been "set up by the General Assembly in 1959 to govern the exploration and use of space for the benefit of all humanity".[5] Article IV of the OST adds to this a prohibition of the placement of nuclear weapons or other weapons of mass destruction in outer space. Many activities in outer space use technology supported by the military or utilise military resources. Military activity, like any other, must be in line with the framework of the OST. From an operational and technical aspect there is no difference between military and civil or commercial space traffic, therefore, universal adherence to measures of an effective and functional STM for safe coordination of space traffic is essential. Only through adherence of all actors to a global STM can continued access to and usability of outer space also for military purposes be assured (see Guideline 9).

5. Authorisation and Supervision

Article VI of the OST places the onus of responsibility on States for national activities in outer space and for assuring that these are carried out in conformity with the OST, including activities executed by non-governmental actors e.g. private entities, whose conduct must be authorised and supervised by the appropriate State. This principle has gained heightened relevance in light of the recent surge in commercial space activities, necessitating robust mechanisms for authorisation and supervision, and assuring compliance with the regulatory framework for outer space, normally adopted in national space legislation. In short, through this provision the OST ensures that non-governmental activity complies with its provisions and makes States responsible for ensuring and supervising compliance. Thus, States are accountable for their actions in outer space, including those carried out by private actors and should adopt national legislation to govern such activities via appropriate licencing and

[4] Committee on the Peaceful Uses of Outer Space, Report A/6431 (1966).

[5] UNOOSA, "Committee on the Peaceful Uses of Outer Space", https://www.unoosa.org/oosa/en/ourwork/copuos/index.html (last accessed 09.01.1025).

supervisory procedures. Considering the increasing participation of non-State actors in space activities, the effective implementation of STM Building Blocks as proposed in the Cologne Manual will rely on the incorporation of this principle, particularly regarding the regulation and oversight of non-governmental space activities, in national space legislation (see Guideline 2).

6. Liability

Article VII of the OST, further elaborated on in the Liability Convention of 1972, addresses liability for damage caused by space objects. This international liability is tied to the concept of launching State, i.e. the State that launches, procures the launch or from whose territory or facility an object is launched.[6] International space law determined that absolute liability should be borne for any damage caused on Earth or to aircraft in flight, while fault-based liability should be in place for any damage occurring in outer space as space actors willingly expose themselves to the possibility of damage being caused. While this principle does not occupy a standalone section in the Cologne Manual, it is essential for the overarching framework of STM.

Liability considerations are reflected in the Cologne Manual as it is understood that non-conformity with the due diligence STM requirements can be interpreted as constituting fault under the outer space liability regime. Besides the applicable rules of liability on an international level, liability is also an important concept of national legal systems. It is the recommendation that, in line with existing practice, any national liability of entities providing services relevant and crucial for STC and STM, including SSA activities, that may result in damage should be regulated contractually (see Commentary to Guidelines 8, 9 and 10).

7. Jurisdiction and Control

Article VIII of the OST affirms that a State, which registers an object launched into outer space on its national registry, retains jurisdiction and control over it and any personnel thereof, thus establishing a vital legal foundation for space activities. Under this principle all nationally registered space objects and any personnel thereof are subject to the exclusive legal authority of the registering State and in accordance with international law no other State may therefore interfere with these objects

[6] Art. I Liability Convention.

without consent of the registering State. State jurisdiction, as an instrumental element of State sovereignty, forms a foundational element of international law.[7] Therefore, nothing in the Cologne Manual should be interpreted in a manner inconsistent with this principle.

8. Registration of Space Objects

Article VIII of the OST furthermore mandates registration of space objects, further elaborated in the Registration Convention of 1975 and the United Nations General Assembly Resolution on Enhancing Registration Practices A/RES/62/101 (2007).[8] Registration is essential for a functional STM as it introduces a level of transparency into space activities and as it represents the link between the object and the State's jurisdiction and control. Transparency of this jurisdictional link is an important prerequisite for the sustainable coordination and management of space traffic. Thereafter, the State of Registry retains jurisdiction and control over the object and its personnel. The Registration Convention predicted that the registration should be undertaken by one of the launching States and furthermore added an obligation to forward specified[9] information to the Secretary General of the United Nations, as soon as practicable. This implicit transparency and information sharing requirement will help guide the creation and continued functioning of an efficient STM. Thus, it is crucial to highlight the importance of registration (see Guideline 3) as a starting point for an operational STM.

9. Due Regard, Harmful Interference and Environmental Protection

Article IX of the OST enunciates the principle of "due regard" and the necessity of undertaking consultations to avoid harmful interference with the activities of other States. It was conceived following potentially harmful experiments at the beginning of the space age resulting in the demand of space actors that all activities must be carried out with due regard for the activities of others, employing such international tools as cooperation and consultations. Due regard can most readily be explained as the requirement to observe the required standard of care or due diligence in space activities, by, for example, following the appropriate guidelines and international standards to avoid causing damage to and harmful interference with the activities of other space actors. Article IX of the OST should

[7] Militarv and Puramilitary Activities in und aguinst Nicaragua (Nicaragua v. United States of America). Merits, Judgment. I.C.J. Reports 1986.
[8] Convention on Registration of Objects Launched into Outer Space, 1023 UNTS 15, adopted on 14 January 1975, entered into force on 15 September 1976.
[9] Article IV of the Registration Convention decrees that for each space object the following information should be forwarded to the Secretary General of the United Nations, as soon as practicable: Name of launching State or States; An appropriate designator of the space object or its registration number; date and territory or location of the launch; basic orbital parameters including nodal period, inclination, apogee, perigee and general function of the space object.

therefore be understood as encompassing the prevention of harmful interference and the promotion of safe practices in outer space, such as effective space traffic coordination (see Guideline 5). Ahead of its time, Article IX of the OST furthermore enshrined the agreement of States to conduct activities in a manner that does not cause harmful contamination of outer space or cause adverse changes in the atmosphere of the Earth. Recognising that the safeness of the operational environment for space activities determines the viability of human activity in it, this provision aids in ensuring the freedom of space exploration and use guaranteed by Article I of the OST by keeping the space environment free from obstruction and danger. This principle must therefore be prominently featured in both the Preamble and the commentary sections of the Cologne Manual, signifying the importance of mutual consideration among States engaged in space activities to keep the space environment free of obstacles that could hinder the freedom of exploration and use (see Commentary Guideline 11).

This alignment supports the establishment of norms and guidelines for STM that are consistent with the treaty's objectives. The Cologne Manual, therefore, advocates for best practices that reflect this obligation, underscoring the importance of peaceful coexistence and cooperation in outer space.

10. International Cooperation

Moreover, to ensure the objectives of the OST as enumerated in the illuminated principles of the OST, Article IX of the OST encourages States to engage in international cooperation and mutual understanding underscoring that all space activities should be undertaken in the spirit of cooperation. It thus builds the foundations for respectful cooperation between nations. International cooperation, as enshrined in the OST, is paramount for establishing a comprehensive STM framework and a vital tool guaranteeing its success. Collaborative efforts among States, intergovernmental organisations, and the private sector can facilitate information sharing, the development of best practices, and the establishment of common operational standards crucial to space traffic coordination. STM encompasses the processes and systems governing the movement of space objects to ensure safe and sustainable operations in outer space, including tracking, monitoring, and coordinating of space activities to prevent collisions and effectively manage space debris (see Guidelines 7, 8, 9 and 11) and as such relies on the efficient and comprehensive international cooperation.

11. Information Sharing

Article XI of the OST explains one of the preferred modes of international cooperation as an obligation of information sharing, specifically referencing that State Parties “agree to inform the Secretary-General of the United Nations as well as the public and the international scientific community, to the greatest extent feasible and practicable, of the nature, conduct, locations and results” of their space

activities. Requiring the sharing of relevant information for space traffic coordination and STM will feature prominently in the Cologne Manual (see Guidelines 4 and 5). Article XI of the OST and information exchange are essential for a functional space traffic coordination and STM.

12. The Role of International Organisations

Overall, the OST encourages international cooperation in the peaceful exploration and use of outer space, recognising that the challenges and opportunities in outer space transcend national boundaries. International cooperation therefore also includes the development of international guidance on space activities such as the UNCOPUOS Space Debris Mitigation Guidelines[10], the UNCOPUOS Long-Term Sustainability Guidelines[11], capacity building measures, etc. (see Guidelines 3 and 11). This is not just the overarching theme of the OST, but also the foundation for a practicable STM. For these reasons the role of international organisations, in particular the Organisation of the United Nations with its Office for Outer Space Affairs (UNOOSA) and the United Nations Committee on the Peaceful Uses of Outer Space as sub organ of the UN General Assembly, the International Telecommunication Union (ITU) as well as International Civil Aviation Organization (ICAO), transcend national boundaries, with launches transitioning through national and often international airspace, is vital in facilitating discussions on STM, coordinating efforts, developing and sharing best practices, and promoting compliance with international norms.

III. Conclusion

Having outlined the core principles of the OST, it is essential to understand that these principles interrelate, especially within the context of the Cologne Manual. For instance, while the principle of freedom of exploration and use is paramount, it must be interpreted in accordance with the responsibilities of States to prevent harmful interference with the space activities of others. This duality necessitates innovative regulatory approaches that address the complexities of an increasingly crowded operational environment. The foundational principles of international space law, particularly those enshrined in the OST, provide a solid legal basis for developing an effective framework for STM. To explain, it should be understood that the principles were adopted using broad language in order to be able to encompass any future technologies, development or trend in space activities. By interpreting these principles in accordance with international law and the customary rules of interpretation, thus

[10] Space Debris Mitigation Guidelines of the United Nations Committee on the Peaceful Uses of Outer Space, endorsed by the United Nations General Assembly in its Resolution 62/217 of 22 December 2007.

[11] Guidelines for the Long-term Sustainability of Outer Space Activities (LTS Guidelines), adopted by the United Nation Committee on the Peaceful Uses of Outer Space in 2019.

in light of contemporary challenges, the increasing complexity of contemporary and future space activities can be adequately addressed and these principles are confirmed to require and set the foundations for a functional STM in the conduct of space activities. To ensure the continued freedom of exploration, use and access of outer space for all States, it is imperative that the interpretation of these principles evolves to incorporate the latest *de lege ferenda* considerations. This progression is articulated in the Guidelines of the Cologne Manual, which build upon established principles and State (best) practices while developing necessary guidance to navigate the increasingly congested operational environment for space activities.

Recognising the common interest in managing the space environment is essential for the future of space exploration and use. The sustainability of space activities hinges not only on technological innovations, but also on the collective ability and willingness to cooperate and implement effective governance mechanisms for the benefit of all. The development of a comprehensive STM framework is not merely a legal obligation; it is an ethical imperative to ensure that outer space remains a shared domain for all humanity.

In sum, the complexities of space traffic can only be effectively navigated through concerted efforts that emphasise collaboration and adherence to established international norms. By fostering a culture of responsibility and respect for the shared nature of outer space, the integrity of this vast frontier can be safeguarded for generations to come. Only through unity and shared commitment to responsible stewardship, the heavens as a domain accessible to all can be preserved, ensuring that the exploration and use of outer space will benefit all of humanity.

Guidelines of the Cologne Manual on Space Traffic Management

Space Traffic Management aims at the development of guidelines for the safe use of outer space during all phases of the space travel. During launch, on orbit and end of life phases these guidelines aim to avoid collisions and to enhance efficient space traffic as well as the sustainable access to, transit through and use of outer space.

Preamble

The Cologne Manual on Space Traffic Management has at its core the safety, sustainability and transparency of space traffic. Its overall goal is to assure safety in outer space in times of considerably heavy space traffic. It does not debate, question or contest existing space treaties and is based on the existing international and national space law and practices as well as on other relevant international instruments. The Manual does not restrict access to outer space but instead seeks to support and guarantee access and usability for all actors.

One key theme is ensuring the freedom of space exploration and use, guaranteed by Article I OST whereby the Cologne Manual recognises that the freedom of exploration and use entails responsible exploration and use. Responsible exploration and use mean the enjoyment of the freedoms in a manner that enables the continued exploration and use, taking into account the freedom of other actors and assuming responsibility for preserving the accessibility and usability of outer space.

To this end, access to outer space, the safety and security of on-orbit space operations as well as the safe return from outer space must be guaranteed to ensure space sustainability and use of outer space for future generations. This requires a look at the accompanying obligations, because the freedom of one limits the freedom of others. To respect the rights of others, the increased traffic in Earth orbits (especially in the LEO and GEO regions), necessitates coordinating and managing of space traffic in an international manner. Space objects need to be operated in a way that does not unreasonably impair the freedom of space exploration and use of other space actors. This means, that space object operators must take reasonable steps to be aware of and actively mitigate collision risks. This could be achieved by setting up standard communication and coordinating procedures, including cybersecurity protection measures.

All guidelines of the Cologne Manual consider the immense importance of space technology for the development of humankind and its potential to meet global challenges.

The guidelines are based on existing international space law, according to which outer space is free for exploration and use for the benefit of all and a province of all humankind while space objects remain under the jurisdiction and control of the State that registered them in its national registry as expression of the State's sovereignty over them.

The Cologne Manual is an assembly of guidelines. These guidelines are rooted in international space law but themselves lack the legally binding quality. They are a collection and systematisation of existing best practices grounded in international law and as such offer States and non-State actors a guiding hand in space traffic management. Adherence to them is entirely voluntary and an offer to – through voluntary behaviour – contribute to the future accessibility and usability of outer space.

Space Traffic Management - Definitions

Space Traffic Management encompasses proactive measures to pay due regard for the common interest in the traffic of space objects without harmful interference. These include aspects of safety, security and sustainability.

Safe, secure and sustainable Space Traffic Management should be achieved through responsible management of national space activities, the transparent and timely coordination of all space activities and international cooperation.

States that launch or operate space objects are deemed capable of participating in Space Traffic Management.

States that launch or operate space objects are deemed capable to participate in Space Traffic Management.

The following guidelines are not legally binding. States and non-state actors are encouraged to voluntary consider them.

For an adequate understanding of the Cologne Manual and for the purpose of this Manual the used terms will be defined as follows:

Air Traffic Management (ATM): ATM includes the dynamic, integrated management of air traffic and airspace including air traffic services, airspace management and air traffic flow management — safely, economically and efficiently — through the provision of facilities and seamless services in

collaboration with all parties and involving airborne and ground-based functions. (See ICAO Doc. 4444 PANS-ATM)

Conjunction: Conjunction is a close approach between two space objects that is predicted to occur because the secondary object passes within a chosen geometric or statistical safety volume about the primary (protected) asset. (See NASA Spacecraft and Collision Avoidance Best Practices Handbook)

Mitigation: Mitigation for purposes of the Manual is an act of reducing the danger of collisions in orbit. In space operations these are normally implemented during the planning, manufacturing and design of space objects and operations. Such acts involve e.g. the limit the long-term presence of spacecraft and launch vehicle stages in the Low Earth Orbit region after the end of a mission or to minimise the potential for breakups during operational phases. (See IADC Space Debris Mitigation Guidelines 5 Mitigation Measures)[12]

Operator: Operator for the purpose of this Manual is a natural or legal person carrying out space activities that has effective control over of the space object.

Orbit: Orbit describes the path, relative to a specified frame of reference, described by the centre of mass of a satellite or other object in space subjected primarily to natural forces, mainly the force of gravity. (See ITU definition of 'orbit', ITU (RR Art. 1.184))

Space activity: Space activity includes the launch, operation, guidance, and re-entry of space objects into, in and from outer space and other activities essential for the launch, operation, guidance and re-entry of space objects into, in and from outer space. (See ILA Model Law)

Space debris Are all human made objects including fragments and elements thereof, in Earth orbit or re-entering the atmosphere, that are non-functional. During the operational phases, a spacecraft or orbital stage can be considered as functional. (See IADC Space Debris Mitigation Guidelines 3.1 Space Debris)[13].

Space Situational Awareness (SSA): SSA refers to the knowledge and characterization of space objects and their operational environment to support safe, stable and sustainable space activities.

Space Surveillance and Tracking (SST): SST is the surveillance and tracking of space objects and to predict and alert about risks of collision.

[12] The latest edition: IADC-02-01 Rev. 4 (January 2025).
[13] The latest edition: IADC-02-01 Rev. 4 (January 2025).

Space traffic: The movement of all space objects, including parts thereof and debris, during all phases of flight, including launch, on-orbit and end-of-life, not including frequencies.

Space Traffic Coordination (STC): STC refers to technical means and operative procedures to ensure safe and stable operations in the space environment especially through e.g. the use and exchange of SST information as well as collision avoidance measures.

Space Traffic Management (STM): STM refers to the coordinated international efforts, policies, legal rules, norms, technologies and strategies designed to ensure the safe, sustainable and efficient operation of objects in outer space, and in particular in Earth orbits. It is the safe use of outer space, including launch, on-orbit and end-of-life phases, avoiding collision and enhancing efficient space traffic and aiming at a sustainable access to, transit through and use of outer space. It includes STC, SSA and SST.

Guideline 1 – Pre-launch Activities and Notification

Throughout all operational stages of space activities including the launch, in-orbit and end-of-life phases, operators should issue a notification before every launch, on-orbit manoeuvre or end-of-life activity such as re-entry. It should be notified to all relevant operators, States and other stakeholders. It can be public or directed to specific actors but must inform all relevant players to minimise the risk of collision. Space missions should be designed so that they do not unduly interfere with space traffic, especially human space flight, or endanger life and property on Earth or in the airspace.

1. Pre-launch

Launches should be conducted in a manner that does not interfere with the safe operation of other objects in outer space or airspace, and when relevant on the ground in immediate vicinity of the launch site or directly impacted by the launch. Pre-launch obligations of operators include performing pre-launch activities and issuing a pre-launch notification.

Before launch, a conjunction analysis, an orbit insertion analysis and a space debris modelling should be performed and considered. Before launch, information on on-orbit manoeuvres and end-of-life activities such as re-entry, information about space traffic including space situational awareness, air traffic as well as ground situation immediately surrounding the launch site should be obtained and considered, and measures taken for paying due regard to the safety of air and space traffic and to minimize the risk of collisions.

Pre-launch notification should include information on the launch site, the trajectory, the planned orbit, the launch date as well as time and location of the launch and any other relevant information.

Any changes to the launch date, timeline or planned orbit should be notified immediately.

2. In-orbit

Pre-manoeuvre notification should at the minimum include information about the trajectory of the object, the timeline and the planned orbit.

All planned changes of trajectory, e.g. planned manoeuvres, should be notified beforehand, in the same acceptable and reliable manner as pre-launch notification.

3. Re-entry

All planned re-entry activities should be notified beforehand, in the same acceptable and reliable manner as pre-launch notification. Pre-re-entry notification should include at minimum expected re-entry trajectory, location, date and time, and when relevant landing.

Guideline 2 – Non-governmental Activities and Licensing

States should ensure that any non-governmental space activity complies with space traffic management, thus, are conducted in a manner that ensures that outer space remains free for exploration and use by all countries and with due regard to the corresponding interests of all other States.

Non-governmental space activities are subject to authorisation and supervision of the appropriate State.

Bearing international responsibility for national space activities, whether carried out by governmental or non-governmental actors, and for ensuring compliance with international norms, States should enact national space legislation to regulate authorisation and supervision procedures via appropriate licensing and oversight.

Guideline 3 – Registration

National space object registries should be made publicly available and easily accessible to interested parties and should be regularly updated. National space object registries are essential for the identification of space objects.

In addition to the requirements of the Registration Convention and international guidance as contained in UNGA Resolution 62/101 of 17 December 2007 on Recommendations on enhancing the practice of States and international intergovernmental organisations in registering space objects and the Long Term Sustainability guidelines of the United Nations Committee on the Peaceful Uses of Outer Space of 2021, States should clarify through national regulatory frameworks what kind of information, and through what procedures and communication channels, operators are required to provide necessary information to the competent national authority responsible for space activities for the complete and comprehensive registration of space objects. Operators should provide States the specified information without undue delay. Operators should provide regularly updated information on their space objects and their status to the relevant national authorities.

Registration should be made no later than six months after the launch of the space object with an operational lifetime of more than six months. Space objects with an operational life-time of less than six months should be registered within one month from the time of the launch. Information on the national registry, the objects and any changes in the status of the objects should be communicated to the Secretary-General of the United Nations immediately after their inclusion in the national registry.

Guideline 4 – International Cooperation, Coordination and Consultation

States and operators should communicate, liase, consult and coordinate with each other during all stages of space activity.

This includes coordination and communication with Air Traffic Management systems, the International Telecommunications Union and other relevant international organisations.

Guideline 5 – Space Traffic Coordination

Space traffic coordination on an international level is necessary to ensure the safety of space operations.

1. The operator of a space object
    a. should display the point of contact that must be publicly identifiable and available. The operator must be in a position to take responsibility for decisions regarding the space object.
    b. should establish procedures and proper channels of communication to enable timely responses to a conjunction between two space objects and to consider the necessity of performing a collision avoidance manoeuvre.
    c. should share and discuss their approaches to determining the likelihood of a collision between their space object and an approaching object, as well as the risk determination and risk threshold to trigger a collision avoidance manoeuvre.
2. Providers of SST information should provide information to operators covering collision avoidance, re-entry analysis and fragmentation analysis.
3. Collision avoidance:
    a. Operators of space objects should respond to critical conjunction warnings with appropriate collision avoidance manoeuvres.
    b. In order to ensure effective collision avoidance procedures, States should consider establishing an internationally agreed standard for priorities to minimise the risk of collision. Priorities should include the following:
        i. Conjunctions involving non-manoeuvrable objects: non-manoeuvrable objects should be evaded by manoeuvrable objects to avoid collision.

ii. Conjunctions involving multiple manoeuvrable objects: Objects in distress or otherwise malfunctioning should be given (primary) priority as their manoeuvrability may be impaired. Rescue missions, whether manned or unmanned, should be given priority over all other missions. Human (crewed) space objects should be given priority over non-human (non-crewed) objects.

c. States and operators are encouraged to enter into agreements regarding space traffic priorities and collision avoidance measures.

Guideline 6 – Space Situational Awareness

States and non-state actors should cooperate at all times to acquire, collect, improve, validate and share SSA information to the extent necessary to ensure safe space operations. They are encouraged to cooperate, develop and further improve SSA capabilities and capacities, including monitoring and tracking capabilities. It is in the interest of the international community to make SSA information available and accessible to the maximum extent possible and practicable.

Space actors should aim towards the establishment of a worldwide SSA information base including information about critical conjunctions, orbital traffic, space weather, and the risk of an operation. Until a global information base is established, space actors – including governmental and non-governmental – owners and operators should cooperate and share SSA information, building an international SSA network chain for the quick and efficient exchange of all necessary and vital information, including critical conjunctions alerts and analysis, orbital traffic, space weather, and the risk of an operation.

Guideline 7 – Information Acquisition and Dissemination

Throughout all phases of space activity, operators:

1. should exchange and contribute information.
2. should acquire space situational awareness information before becoming active and should share space situational awareness information.
3. should stay informed of the status of their space objects and should inform the appropriate authority about any relevant changes regarding the space object, its operator or owner, and its status.

All unforeseen events such as catastrophic events, large disposals, satellite transmission issues, and other special events that affect other space flight participants should be reported in a timely manner.

Guideline 8 – Cyber Security

States should ensure the cyber security of infrastructures including ground-based networks and space links and digital data that support Space Traffic Management or the guidance and control of space objects in accordance with current best practices and state of the art.

1. These infrastructures should be considered of high criticality and of international interest and subject to protection, either by international or national legislation.

a. Organisational procedures and technical measures should be implemented against cyber security threats for the protection of infrastructures and digital data.

b. States should obligate the operators of space objects or infrastructures of their responsibility for the implementation of appropriate organisational and technical measures for cyber security.

c. Relevant personnel should be trained to ensure their awareness about potential cyber threats and their knowledge about avoidance and appropriate response.

d. Operators of space objects or infrastructures should respond to incidents promptly and report these without unnecessary delay to established centralised bodies or relevant authorities.

2. International efforts should be undertaken to develop standards for minimum organisational and technical cyber security requirements specific to infrastructures and digital data.

3. Operators of space objects or infrastructure should develop cyber security strategies, perform cyber vulnerability evaluations, and implement best practices for the protection of infrastructures and digital data.

Guideline 9 – Military Activities

1. In all their space activities military operators should follow the space traffic management Guidelines as contained in the Cologne Manual as far as practicable.
2. If, for national security reasons, the desired level of transparency required for the active management of space traffic cannot be ensured, operators
a. may deviate from these requirements as long as they guarantee the same level of space traffic

safety and,

b. must take the necessary manoeuvres at their own expense and bear full liability and responsibility in the event of collision.

Guideline 10 – Communication Systems and International Technical Advisory Body

Operators of space objects should connect and communicate through designated reliable communications systems and interoperable information exchange systems in support of effective space traffic coordination. It should be encouraged to do so by using a single universal and dedicated Communication System and an international technical advisory body to ensure standardised and frictionless operations.

1. Communication System

The Communication System should accommodate information on the operator, its point of contact, and necessary SSA information. Additionally, it should provide information on the following components associated with SSA capabilities engaged with the Communication System: (1) surveillance and tracking capabilities, (2) entities gathering STM relevant information, (3) data centres receiving and analysing information, and (4) third actor using the information for conjunction analysis and collision warnings. Ideally, it should be the aim to centralise this information in a dynamic system.

SSA service providers should be engaged with the Communication System in order to establish the dependable backbone of the Space Traffic Management system including a harmonized space object catalogue, standardized message format, and information sharing parameters. The operators should utilize and collaborate with any of the SSA service providers supporting the Communication System.

Information technology systems in support of Space Traffic Management should be interoperable with machine-to-machine interfaces and be designed and operated to warrant their continuity, availability and integrity.

2. International technical advisory body

Space actors should be encouraged to establish an international technical advisory body to advise operators of space objects, space activities and recommend collision avoidance measures. The objective of the international technical advisory body should be to develop common protocols and standards for effective space traffic coordination.

Guideline 11 – Ensuring long-term accessibility and operational usability of the space environment

Recognising the forward-looking approach of Space Traffic Management, it is necessary to ensure the long-term accessibility and operational usability of outer space by implementing sustainable solutions to space debris and other comparable risks to space traffic.

1. Mitigation of Space Debris

Space actors able to participate in space traffic shall be deemed capable of implementing space debris mitigation measures and should therefore comply with relevant international standards, in particular the Space Mitigation Guidelines set out by the United Nations and the Inter-Agency Space Debris Coordination Committee. Space debris mitigation measures should be implemented during the mission planning, design, manufacturing and operational (launch, mission and disposal) phases of spacecraft and orbital stages. The implementation of mitigation measures should be regularly reviewed and adapted to best legal and technical practices.

2. Remediation of Space Debris

Remediation of space debris should be considered of common interest to be carried out for the benefit of all. All remediation activities should comply with the Guidelines of the Cologne Manual.

3. Environmental Provisions

International environmental standards related to space activities should be respected and observed.

4. Capacity Assessment and Planning

States are encouraged to cooperate in space traffic capacity assessment and planning in critically congested regions of outer space.

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