European Space Policy Institute

Full Report

Space Environment Capacity

Policy, regulatory and diplomatic perspectives on threshold-based models for space safety & sustainability

Prepared for esa

Report:
Title: "ESPI Report 82 - Space Environment Capacity - Full Report"
Published: April 2022
ISSN: 2218-0931 (print) • 2076-6688 (online)

Editor and publisher:
European Space Policy Institute (ESPI)
Schwarzenbergplatz 6 • 1030 Vienna • Austria
Phone: +43 1 718 11 18 -0
E-Mail: office@espi.or.at
Website: www.espi.or.at

Design: copylot.at

Cover page picture credit: Shutterstock

Table of Content

1 Background

The intensification of space activities and the emergence of new actors along with new technologies and business concepts (e.g. large constellations, miniaturized systems, etc.) have raised, and continue raising, new challenges to ensure the safety of operations in space and the long-term sustainability of the space environment.

Among existing responses, the UN COPUOS Guidelines for the Long-term Sustainability of Outer Space Activities and the IADC Space Debris Mitigation Guidelines were developed, but the low degree of compliance with these rules has not sufficiently remediated the longstanding safety and sustainability concerns. ESA's 2021 Space Environment Report concluded that our current behaviour in space is unsustainable, in particular, because of the limited compliance of space activities with international guidelines for space debris mitigation.[1] As a result, the rapidly growing number of objects in orbit will make it increasingly difficult to operate safely in outer space.

The current operational reality in the Earth orbital environment leads a number of scientists, industry leaders, public-sector executives, and policymakers to voice concern over increasing risks and the inefficient implementation and enforcement of existing rules. This recognized challenge, therefore, calls for new approaches, philosophies, and concepts that could efficiently mitigate and decrease risks related to increasing congestion and debris generation.

In this context, there is a growing need for innovative measures to improve compliance with existing guidelines and to ensure the long-term sustainability of the space environment.

Models leaning on threshold-based mechanisms have and continue to be extensively used (with varying degrees of success) at both local and international levels for managing limited natural resources and the commons, as they address the risk of surpassing levels of exploitation that could lead to the depletion or the destruction of the resource.

Before discussing targets, the prerequisite for defining thresholds is to develop a commonly agreed metric among those benefitting from the resource - noting that *you cannot manage what you cannot measure* and *you cannot measure what you cannot define*.

The Space Environment Capacity Concept developed by the ESA Space Debris Office is an attempt to ideate, develop and implement a threshold-based approach relevant to the Earth orbital environment. Conceived as a tool that can measure the impact of space missions on the sustainability of the space environment, it can additionally also provide an innovative approach and provide new impetus for discussions on the international coordination and management of the Earth orbital environment.

This report builds on this concept and examines, more generally, the relevance of a threshold-based approach to the Earth orbital environment through an assessment of policy, regulatory and diplomatic implications. The analysis involved a consultation campaign consisting of a set of interviews with high-level experts and an interactive online workshop.

The report recognizes the value of the threshold-based approach in addressing safety and sustainability concerns in outer space. Moreover, it identifies the need to further mature and elaborate the approach by identifying sustained activities through both scientific & technical dimensions and policy & diplomatic dimensions.

[1] *ESA's Space Environment Report 2021*, by ESA Space Debris Office (Darmstadt, Germany: European Space Agency, 2021).

2 Scope, Objectives and Methodology

2.1 Scope of the Report

This report follows a request by the European Space Agency's Space Debris Office to independently assess the policy, regulatory and diplomatic relevance of threshold-based models in the Earth orbital environment, taking into account the ESA-developed Space Environment Capacity Concept, which pursues the underlying aim of serving as a tool that enables measuring the sustainability of the use of orbital environments.

Moreover, the development of a threshold-based approach to the Earth orbital environment could potentially provide impetus to discussions related to an international coordination framework based on transparent, objective, and flexible metrics. Therefore, policy, regulatory and diplomatic perspectives and implications related to such ambitions were also explored.

2.2 Objectives of the Report

The objective of this report is to assess policy, regulatory and diplomatic relevance, perspectives, and implications of threshold-based models in the Earth orbital environment. The report builds on top of the Space Environment Capacity Concept developed by the ESA Space Debris Office, but also addresses a broader spectrum of questions related to safety and sustainability of the Earth orbital environment.

As a foundation, defining the limits of the existing regulatory framework related to operations in the Earth orbital environment, and understanding whether objective threshold-based models can incentivize actors towards safer and more sustainable exploitation of the environment are explored in the report. This is further reinforced by analysing failures, lessons, and achievements within a set of international efforts to manage or coordinate the use, exploitation, or conservation of limited natural resources and the commons.

Furthermore, the report explores the role of threshold-based models in supporting the development of regulatory environments related to space safety and sustainability as well as the inherent drivers, blocking points, and implications that one can expect when pursuing such efforts.

The report also raises awareness of policy options to address the question of the safety and sustainability of outer space through the prism of threshold-based approaches by informing and involving various stakeholders in its elaboration. Moreover, it provides a platform to spur further discussions on the topic in line with the report's conclusions, exploring desirability and feasibility and offering preliminary insights into how future efforts can be interwoven with international ambition.

Finally, the report hopes to offer a layer of informed contributions to discussions and efforts aiming to minimize risks related to the proliferation of objects in the Earth orbital environment and prevent or halt behaviour that could lead to an onset of collisional cascading, thus ensuring the long-term viability and conservation of the Earth orbital environment.

2.3 Methodology used in the Study

The methodology that provides the foundation for this report follows a four-pronged assessment model, which combines research of primary and secondary sources, concept deconstruction & policy interpretation, private consultations with relevant actors as well as an interactive participatory workshop, hosting a panel of experts. Each of the assessment activities is further described below.

Activities leveraging external expertise, knowledge, and perception were prepared based on preliminary research, concept deconstruction, and policy interpretation activities, which in the first instance informed the consultation campaign, itself then feeding into the topics and questions addressed during the workshop.

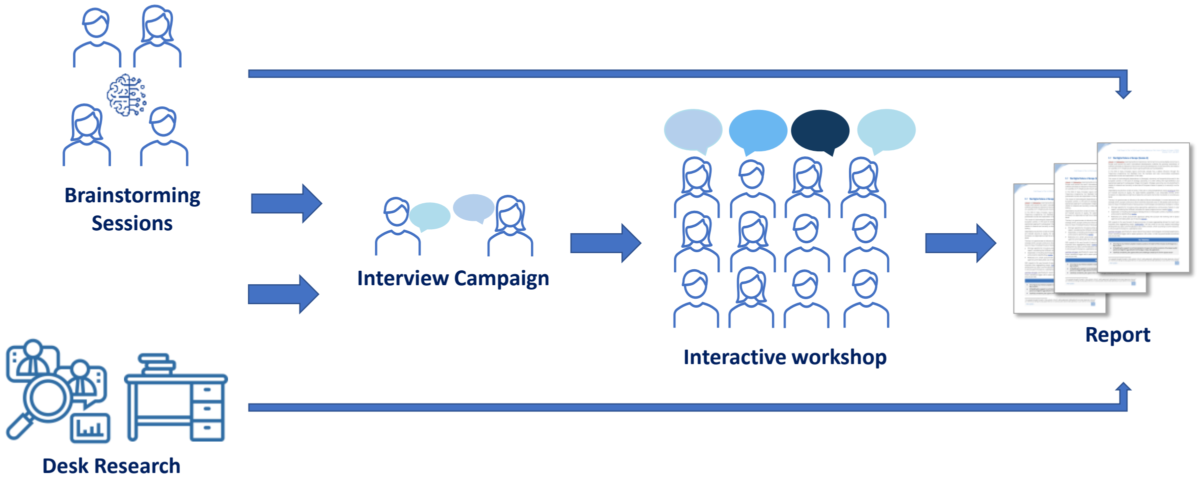

Figure 1: Methodology workflow

2.3.1 Research of Primary and Secondary Sources

The assessment initially focused on the research of primary and secondary sources with regard to existing coordination and target-setting mechanisms at international level. As orbits comprising the Earth orbital environment were recognized as common pool resources, the management of similar resources was taken into account and the level of international coordination, as well as the underlying implementation and enforcement modalities, were compared.

This initial desktop research led the research team to identify three areas of particular interest, namely:

- International frequency coordination through the International Telecommunication Union
- International efforts for setting greenhouse gases emission targets and mitigating climate change
- International and regional management and conservation of fisheries

The underlying frameworks, mechanisms, and efforts related to these three areas of interest were further analysed, from the perspective of the challenges, solutions, and benefits they entail, and helped identify relevant components and discussion points for ensuing assessment activities, while also informing on the relevance and perspective of threshold-based approaches for managing commons at face-value.

2.3.2 Concept Deconstruction & Policy Interpretation

In parallel, the Space Environment Capacity Concept, initially devised as a mathematical & technically applied concept was deconstructed based on a set of parameters, and the technical language translated into a policy-focused narrative while also identifying:

- A set of policy-oriented definitions;
- Objectives of the concept;

- Principles & Guidelines for its implementation.

This activity was crucial in identifying the underlying research question of the relevance and feasibility of threshold-based models in the Earth orbital environment. Moreover, the activity provided a solid basis for the next step of the assessment – the stakeholder consultation campaign whereby the stakeholders were provided a 2-page policy summary (based on an internally developed policy paper) that translated technical concepts and terminology into a policy-friendly narrative.

2.3.3 Stakeholder Consultations

The above activities were followed by a series of online consultations taking place in November and December 2021, which explored a set of pre-defined questions and topics based on the assessed opportunities, challenges, and solutions enabled or implied by the prospects of a threshold-based model in the Earth orbital environment.

The Consultation campaign included 18 individuals, representing 11 different international stakeholders including satellite operators, the manufacturing industry, academia, national ministries, international organizations, and national space agencies. The full list of all interviewees can be found in the Acknowledgment section of this report.

The opportunities, issues, potential blocking points, and perceptions of stakeholders were analysed, consolidated, and elaborated as topics for the individual interactive sessions during the online workshop.

2.3.4 Interactive Workshop

The workshop was organized as the last building block before the final analysis leading to this report. The workshop was organized across five interactive sessions, which tested various perceptions, identified challenges, and potential ways forward, which were pre-identified by the ESPI research team based on the stakeholder interviews. Namely, the five sessions addressed:

- The Adequacy of the Existing Framework
- The Relevance & Effectiveness of Threshold-based models
- The Feasibility of Threshold-based Models
- The Role of Public actors at Large
- The Future Evolution and Next Steps

Moreover, an in-depth technical presentation of the Space Environment Capacity concept was provided by ESA between the first and second interactive sessions.

A real-time online survey tool was used to anonymously collect perceptions and opinions of the participants, which further informed and fostered a moderated discussion revolving around the five pre-identified topics.

The workshop was attended by almost 30 participants joining from Europe, North America, and the Asia Pacific region, representing satellite operators, the manufacturing industry, consultants, academia, think tanks, diplomats, international organizations, national space agencies, and EU institutions.

The outcomes of the workshop were consolidated, analysed, and contextualized and provide the backbone for the final chapters of this report, and decisively inform the identification of the proposed next steps and actions related to the concept.

3 Existing Regulatory Overview For Operations in Orbital Environments

Operations in outer space are internationally regulated through the body of international space law, which sets international obligations for states, however not being prescriptive in the implementation of these obligations nationally. This leads to a diverging level of national regulations related to space operations with some countries upholding a highly detailed and prescriptive regulatory environment related to all aspects of space operations, while others rely on very limited or in some cases non-existent frameworks.[2]

International space law, with the treaties developed in the 1960s and the 1970s, continues to be relevant but developments over the past decades, compel us to look at operational realities through the prism of higher on-orbit risk on one end and better domain awareness on the other. This led to a number of efforts to ensure a safe and sustainable operational environment through soft law mechanisms, complementing and interpreting the treaties.

Despite these efforts, contemporary developments in legal doctrine at large, especially related to environmental damage, environmental preservation, state responsibility, and transboundary harm, taking place since the 1980s, urge policymakers and regulators to take these developments into account when discussing the outer space environment. This is especially relevant in light of the fact that international environmental law as we know it today has only developed after the 1967 Outer Space Treaty came into force.

3.1 International Space Law

Traditionally, international space law consists of five international treaties, which carry core provisions that regulate the activities of humankind in outer space (namely the 1967 Outer Space Treaty, the 1968 Rescue Agreement, the 1971 Liability Convention, the 1976 Registration Convention, and the 1979 Moon Agreement). It is further complemented by relevant UNGA resolutions and regional or bilateral treaties. While the Treaties hold abstract provisions and do not always explicitly address the challenges related to space safety or space debris in today's context, the general nature of the provisions allows the treaties to remain relevant today, even when addressing these issues and emerging challenges.

Outer Space Treaty

The 1967 Outer Space Treaty (OST) represents the cornerstone of international space law and is especially relevant when addressing questions related to the sustainability and safety of operations in space.

- Article I provides that the exploration and use of outer space "shall be carried out for the benefit and in the interests of all countries, … and shall be the province of all [humankind]". As space debris can potentially tamper with the right of states to explore and use outer space in the long term, an obligation to mitigate the risks associated with space debris, and ensure a safe operational environment, might be considered implied.
- Article VI provides that States are internationally responsible for national activities in outer space, including those of nongovernmental entities and international organisations. Thus, in case of any

[2] The French legal framework (LOI n° 2008-518 du 3 juin 2008 relative aux opérations spatiales) related to operations in outer space is often cited as an example of a highly prescriptive but efficient and responsible regulatory regime.

space safety obligations, it is the responsibility of the relevant state to ensure that private entities will adhere to such rules.

- Article VI establishes the liability of the State having a genuine connection to the entity whose activity has caused damage to other states. Liability matters are further covered by the Liability Convention.
- Article VIII provides that a State exercises jurisdiction over a space object carried on its national registry. As neither the Outer Space Treaty, the Liability Convention nor the Registration Convention recognize salvage rights in space, legal implications of (re)moving debris objects without permission from the relevant State are contentious.
- Article IX, building upon the principle of due regard to the corresponding interests of other parties, develops the concepts of harmful interference and harmful contamination and aims to preclude operations that could lead to them:
  - Primarily, activities that could potentially cause harmful interference should lead to "*appropriate international consultations before proceeding with any such activity*" or to the possibility "*to request consultation concerning the activity*", clearly aiming to avoid and prevent harmful interference.
  - Secondly, the article provides that activities in outer space, including the Moon and other celestial bodies, and their exploration shall be conducted "*so as to avoid their harmful contamination*". In addition, States Parties "*shall adopt appropriate measures for this purpose*". The treaty does not define "harmful contamination" or "appropriate measures" and does not establish any mechanism to hold States responsible for its violation. The article has mostly been interpreted in reference to planetary protection, but a contextual interpretation of the article can enlarge its scope to the outer space environment in general, and thus also to any single orbit.

Liability Convention

Building on Articles VI and VII of the OST, the legal regime dealing with liability for damage caused by space objects is further specified in the 1972 Liability Convention, and can be considered relevant for damage caused by operational satellites as well as space debris:

- Article 1(d) defines the *term "space object"* as *"including component parts of a space object as well as its launch vehicle and parts thereof"* and can, therefore, *a maiore ad minus*, be considered relevant for space debris.

This interpretation is affirmed by a draft set of "high-level qualitative guidelines" developed by the UN COPUOS Space Debris Working Group and endorsed by the UNGA through Resolution 62/217. It defines space debris as "all man-made objects including fragments and elements thereof, in Earth orbit or re-entering the atmosphere, that are non-functional".

- Article II and Article III provide the basis of liability of a launching state for damage caused by a space object to another state or its natural or juridical persons.

Two types of liability are defined:

- Regime of absolute liability if the damage caused by a space object occurs on the surface of the Earth or to aircraft in flight (no need for proof of fault).
- Regime of fault-based liability if the damage is caused in outer space (fault must be proven by the victim of the incident in outer space).

With the latter being relevant in the case of space debris, issues concerning the control and assignability of debris fragments, and the subsequent enforcement, lead to open questions.

Registration Convention

Furthermore, the 1976 Registration Convention expressed that a "*mandatory system of registering the launched objects would assist in their identification and would contribute to the application and development of international space law*"

- Article II requires States and international intergovernmental organizations that agree to abide by the Convention to establish their own national registries of space objects and provide information to the Secretary-General for inclusion in the United Nations Register.
- Article III provides that "*the UN Secretary-General maintains a Register in which the information furnished in accordance with article IV shall be recorded" In addition, the article provides for* full and open access to the information in this Register.
- Under Article IV, the State of registry shall furnish to the UN Secretary-General information concerning each space object carried on its registry. Information to be provided includes:
  - The name of the launching State(s);
  - An appropriate designator of the space object or its registration number;
  - Date and territory or location of launch; as well as
  - Basic orbital parameters.

As a general international practice pursuant to the Registration Convention, States have indeed frequently registered their space objects and shared related information, but a number of space objects nevertheless remain unregistered.

Cooperation and transparency at the international level represent a required feature for ensuring the continued responsible and sustainable activities in outer space, and one could argue that increased on-orbit risk could be partially managed through higher levels of information sharing among relevant states and operators.

3.2 International Environmental Law

Principles of international environmental law may also be considered relevant in the contemporary context, are used to overcome uncertainties concerning international legal instruments, and provide guidance to behaviour in outer space.[3]

It is worth noting general principles of international environmental law such as sustainable development, equity, due diligence, precaution, common but differentiated responsibilities, polluter pays, and abuse of rights.[4] The vast majority of these principles have been developed from obligations set up on a domestic or transboundary level and emerged from the application of international law to environmental issues.[5] They are the result of different sources, such as treaties, juridical decisions, declarations, resolutions, and opinions, embedding customary international law, as well as new and emerging principles (*de lege ferenda*).

The most relevant treaties in this context are the 1972 Declaration of the UN Conference on the Human Environment (Stockholm Declaration), the first document on recognized principles of environmental law, and the later 1992 Rio Declaration on Environment and Development (Rio Declaration) as well as the UN

[3] Sands P., *Principles of International Environmental Law*, (Cambridge: University Press, 2003).

[4] J. Verschuuren, *Principle of Environment Law* (Nomos Verlagsges, 2003), at 77.

[5] Jutta Brunnée, "Sources of International Environmental Law", (26 October 2017), online: *The Oxford Handbook of the Sources of International Law*.

Environment Programme Principles, and the 1995 UN CSD Principles of International Law of Sustainable Development.

3.3 Soft Law Mechanisms and Other Relevant Guidelines & Initiatives

UN COPUOS Guidelines for the Long-term Sustainability of Outer Space Activities

The Working Group on the Long-term Sustainability of Outer Space Activities of the Scientific and Technical Subcommittee of UNCOPUOS has developed a set of guidelines, aimed at promoting the long-term sustainability of outer space activities. The 21 agreed-upon LTS-Guidelines are voluntary and not legally binding under international law, but any action taken towards their implementation should be in line with the applicable principles and norms of international law.[6]

The IADC guidelines (described below) served as the basis for the work of the Scientific and Technical Subcommittee (STSC) of UN COPUOS. [7]

The long-term sustainability of outer space activities is defined as *"the ability to maintain the conduct of space activities indefinitely into the future in a manner that realizes the objectives of equitable access to the benefits of the exploration and use of outer space for peaceful purposes, in order to meet the needs of the present generations while preserving the outer space environment for future generations"* and recognizes that *"the Earth's orbital space environment constitutes a finite resource"*.

The guidelines comprise internationally recognized measures for ensuring the long-term sustainability of space activities and for enhancing the safety of operations. They are grouped into four categories:

- Policy and regulatory framework for space activities,
- Safety of space operations,
- International cooperation, capacity-building, and awareness,
- Scientific and technical research and development.

Recent developments related to the launch of large constellations have made space sustainability a priority topic within UNCOPUOS, increasingly gaining prominence in political debates.

However, it is worth noting that the aforementioned initiatives took a long time to be developed and adopted. In addition, as they are voluntary and not legally binding, which may lead operators and States to be free riders benefiting from the good behaviour of others while not contributing to the cause themselves.

The Committee is continuing to be (one of) the main fora for a continued institutionalized dialogue on issues related to the implementation and review of the guidelines, and a five-year working plan has been established for its further work.[8]

IADC Space Debris Mitigation Guidelines

The IADC Space Debris Mitigation Guidelines were published in 2002 by the Inter-Agency Space Debris Coordination Committee, an international governmental forum for the worldwide coordination of activities related to the issues of human-made and natural debris in space. The IADC Guidelines are a result of a multi-year effort of several national space agencies, including ESA, to build consensus and adopt a set of

[6] UN COPUOS, *Guidelines for the long-term sustainability of outer space activities* (2019) (Link).
[7] UN COPUOS, *Space Debris Mitigation Guidelines of the Committee on the Peaceful Uses of Outer Space* (2010) (Link)
[8] UN COPUOS, *Terms of reference, methods of work and workplan of the Working Group on the Long-Term Sustainability of Outer Space Activities of the Scientific and Technical Subcommittee* (2021) (Link).

guidelines that provide practices for limiting the generation of space debris in the environment. They have been subject to minor revisions, the latest of which occurred in June 2021.[9]

Space debris mitigation measures can be divided into two categories:

- Those that curtail the generation of potentially harmful space debris in the near (short) term, and
- Those that limit their generation over the longer term.

The former involves the reduction of the production of mission-related space debris and the avoidance of break-ups. The latter concerns end-of-life procedures that remove decommissioned spacecraft and launch vehicle orbital stages from regions populated by operational spacecraft.

The IADC Guidelines cover the overall environmental impact of the missions with a focus on four aspects:

- Limitation of debris released during normal operations,
- Minimization of the potential for on-orbit break-ups,
- Post-mission disposal,
- Prevention of on-orbit collisions.

Like the LTS Guidelines, the IADC Guidelines are non-binding, and non-compliance cannot be reviewed or sanctioned. However, several countries have reflected them in their respective national legislation.

At its 33rd meeting in Houston in March 2015, the IADC noted the emerging plans for large constellations of spacecraft in LEO and recognised the potential for such systems to have an important influence on the evolution of the space debris environment and the consequent impact on the population of human-made spacecraft orbiting Earth.

More recently, in September 2017, IADC has released the latest revision of the IADC Statement on Large Constellations of Satellites in Low Earth Orbit, which was significantly expanded, providing more technical depth in July 2021.[10] The Statement does not represent an expansion of the IADC guidelines, but technical guidance on how to reinforce the relevance of its existing space debris mitigation measures to constellation architectures. The document is divided into three sections, providing tailored guidelines for each of them, namely:

- Constellation Design (Altitude Separation, Operational orbits, number of spacecraft, configuration),
- Spacecraft Design (Reliability of the Post Mission Disposal Function, Design measures to minimize consequences of break-ups, On-ground Risk, Structural Integrity, Trackability),
- Launch Vehicle Orbital Stage Design, and Operations (Collision Avoidance, Disposal Strategy, Launch, and Early Operations).

ISO 24113: Space systems – Space debris mitigation requirements

Since 2010, the International Organization for Standardization (ISO) has been publishing a comprehensive set of international (voluntary) standards on space debris mitigation, notably the ISO 24113 "Space systems – Space debris mitigation requirements", which can be considered a normative interpretation of guidelines and best practices from the IADC, COPUOS and other bodies.[11] The standards have been reviewed every 5 years, and a third edition was published in July 2019.

Even though the ISO Standards on space debris are generally not explicitly referred to in national space legislation, they can be considered implied where national legislation calls for reliance on "internationally

[9] Inter-Agency Space Debris Coordination Committee, *IADC Space Debris Mitigation Guidelines* (2021
[10] IADC, *IADC Statement on Large Constellations of Satellites in Low Earth Orbit* (2021).
[11] International Organization for Standardization, "ISO 24113:2019", online: *ISO*

recognised guidelines for the mitigation of space debris" while their normative nature allows for easier monitoring and potential sanctioning if so envisaged by the relevant public authority.[12]

The standards define the primary space debris mitigation requirements applicable to all elements of uncrewed systems launched into or passing through, near-Earth space, including launch vehicle orbital stages, operating spacecraft, and any objects released as part of normal operations.

International Telecommunications Union Constitution, Convention, and Radio Regulations

The ITU legal framework is mainly based on the ITU Constitution and Convention (CC) and the Radio Regulations. ITU Article 44 CC, called "Use of the Radio-Frequency Spectrum and of the Geostationary-Satellite and Other Satellite Orbits", paragraph 2 provides that *"in using frequency bands for radio services, Member States shall bear in mind that radio frequencies and any associated orbits, including the geostationary-satellite orbit, are limited natural resources and that they must be used rationally, efficiently and economically, in conformity with the provisions of the Radio Regulations, so that countries or groups of countries may have equitable access to those orbits and frequencies, taking into account the special needs of the developing countries and the geographical situation of particular countries."*

In addition, due to the increasing number of satellites and associated launches and, consequently, the growing creation of debris in GSO, the ITU has provided guidance about disposal orbits for satellites through the Recommendation ITU-R S.1003.2 (12/2010) on the Environmental protection of the GSO,[13] which is not legally binding. The recommendations embodied in ITU-R S.1003.2 are:

- Recommendation 1: As little debris as possible should be released into the GSO region during the placement of a satellite in orbit.
- Recommendation 2: Every reasonable effort should be made to shorten the lifetime of debris in elliptical transfer orbits with the apogees at or near GSO altitude.
- Recommendation 3: Before complete exhaustion of its propellant, a geostationary satellite at the end of its life should be removed from the GSO region such that under the influence of perturbing forces on its trajectory, it would subsequently remain in an orbit with a perigee no less than 200 km above the geostationary altitude.
- Recommendation 4: The transfer to the graveyard orbit should be carried out with particular caution in order to avoid radio frequency interference with active satellites.

3.4 (In)Adequacy of the Existing Framework and Identified Shortcomings

Contemporary developments of the operational reality in the Earth orbital environment, notably in parts of Low Earth Orbit, compel industry leaders, engineers, policymakers, and the civil society at large to take note of increased risks related to the proliferation of activities in this domain.

In 2021 the UN Secretary General published the *"Our Common Agenda"* report, whereby better management of global commons, represents one of its core pillars.[14] Peaceful, secure, and sustainable use of outer space represents one of the 8 high-level tracks, positioning space dialogue side-by-side with climate action, sustainable development, the new agenda for peace, and the global digital compact (among others). The agenda calls for the protection of our global commons, including the atmosphere,

[12] United Nations - Office for Outer Space Affairs, *Compendium: Space Debris Mitigation Standards adopted by states and international organizations* (UNOOSA, 2018).
[13] ITU, Recommendation ITU-R S.1003.2 (12/2010), online: ITU (Link)
[14] United Nations, "Secretary-General's report on 'Our Common Agenda'", online: UN (Link).

the high seas, Antarctica, and outer space "*all of which are now in crisis*", singling out the increased density of objects in orbit as a risk to the degradation of the global commons.[15]

The UN Secretary General is not alone in manifesting concerns; a number of high-level stakeholders are raising awareness regarding the risks of unprecedented proliferation of space activities in Earth orbits.

- "*The space sector risks of becoming part of the problem because of crowding in low Earth orbit*" (Philippe Baptiste, Chairman & CEO, CNES)[16]
- "*There is a need for global engagement because if LEO is ruined, it's ruined for everybody, genuinely everybody*" (Steve Collar, CEO, SES)[17]
- "*Nobody anticipated an environment where there would be so many satellites that the physical congestion of orbits would be a dominant issue*" (Mark D, Dankberg, Chairman, Viasat Inc.)[18]
- "*There is a risk that the current trend will become unsustainable and harm operations both in and from space – not just in the low-Earth orbit (LEO), but in all orbits*" (David Bertolotti, Director of Institutional and International Affairs, EUTELSAT)[19]
- "*There is an urgent need to stabilise global space operations*." "*We must future-proof activities now to deliver a safe, secure and sustainable space environment for tomorrow*." (Simonetta Di Pippo, Director of the UN Office for Outer Space Affairs)[20]
- "*Space will be much more restrictive [in terms of] frequencies and orbital slots*" (Josef Aschbacher, Director General, ESA)[21]
- "*An increasingly congested space is threatening the viability and security of space infrastructures and operations*" (Thierry Breton, European Commissioner for the Internal Market)[22]
- "*The situation in LEO is getting bad enough that it could render the entire orbit unusable at some point*" (Philippe Pham, Airbus Defence and Space Senior Vice President for Earth observation and science)[23]
- "*Although there are no titles or deeds for orbital space, there is a finite carrying capacity to any given orbital highway and, thus, whoever takes this capacity first, wins*" (Moriba K. Jah, Associate Professor, University of Texas at Austin)[24]
- "*Collective, concrete steps must be taken to prevent a rapid degradation of Earth's orbital environment*" (Net Zero Space Declaration)[25]
- "*We're running the risk of having a totally congested space*" (Michel Azibert, Deputy CEO, EUTELSAT)
- "*I see hundreds of drones and thousands of satellites and we need checks and balances to make sure we are not crowding the skies*" (Sunil Bharti Mittal, Chairman, OneWeb)[26]

This view was also confirmed by the participants of the interactive workshop organised by ESPI (see Section 2.3.4). When asked whether they believe the existing international framework for ensuring the

[15] *Ibid* at 49.
[16] "With LEO orbit crowding, absent regulators may not be industry's best friend", (27 October 2021), online: *Space Intel Report (Link)*.
[17] "SES's Collar: You want LEO operators to improve their behavior? Deny them market access", (25 October 2021), online: *Space Intel Report* (Link).
[18] "Satellite operators criticize 'extreme' megaconstellation filings", (14 December 2021), online: *SpaceNews (Link)*.
[19] "Preserving a sustainable space environment: Eutelsat", (17 June 2021), online: *ITU Hub (Link)*.
[20] "G7 nations commit to the safe and sustainable use of space", online: (Link)
[21] Peggy Hollinger & Clive Cookson, "Elon Musk being allowed to 'make the rules' in space, ESA chief warns", *Financial Times* (5 December 2021),
[22] "Speech by Commissioner Thierry Breton at the 13th European Space Conference", (12 January 2021), online: *European Commission (Link)*.
[23] note 16.
[24] Moriba Kemessia Jah, "Crowded outer space: Can a global Space Traffic Management (STM) be a reality?", online: *ORF (Link)*.
[25] "Net Zero Space", online: *Paris Peace Forum (Link)*.
[26] Peter B de Selding, "OneWeb chairman: Securing landing rights in ~ 30 nations, starting with India, is going to be especially tough", (23 November 2021), online: *Space Intel Report (Link)*.

sustainability in outer space is adequate, 65% of them responded it is either only partially adequate or not adequate at all. Several participants however noted that the implementation of the existing regulatory framework is most likely the deciding factor that defines the current environment as (partially) inadequate.

None of the participants considered the existing framework as absolutely adequate and only 20% considered it largely adequate.

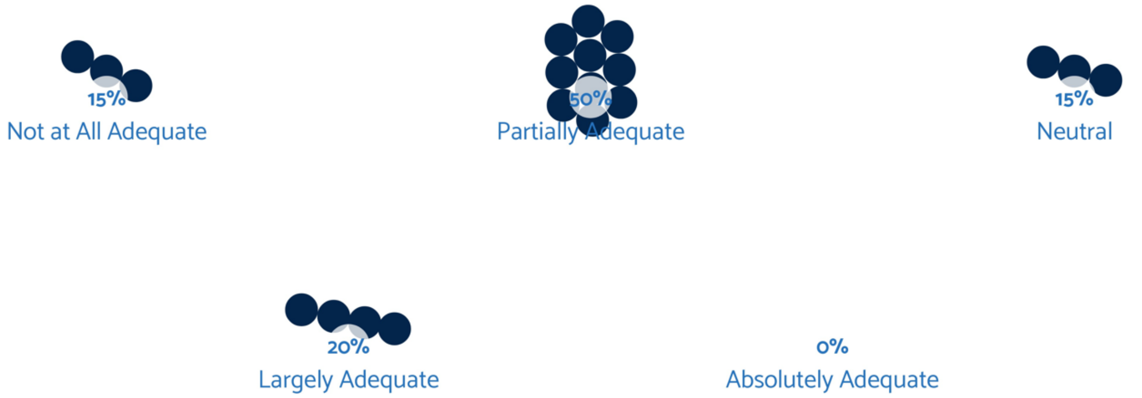

Figure 2: Adequacy of the existing international framework for ensuring sustainability in outer space (Aggregated score of 20 votes)

In addition, many of the cited (and other) stakeholders have also called for an update to existing regulations with regard to the saturation of orbital environments, both from the perspective of space debris generation as well as from the perspective of authorization processes for large constellations as the current regime catalyses actors to occupy space rather than prioritize (long-term) environmental sustainability.

- "*There's a lot more to be done on the regulatory side.*" "*The pace of regulation is at a certain pace. The pace of industry innovation is much faster*." (Peter Marquez, Head, Space policy, Amazon Web Services)[27]
- "*The challenge with regulators is that we have gone from a world where the ITU governs, to a world where national regulators govern*." "*That's really unfortunate, because you've basically got no global body looking out for the industry and organizing how things happen*." (Steve Collar, CEO, SES)[28]
- "*Establishing a space traffic management system is also necessary. There are different elements… from the regulatory point of view who is allowed, and under what conditions, to put spacecraft in orbit and the management at the end of their lives*." (Josef Aschbacher, Director General, ESA)[29]
- "*There is a race to be first among all the countries to occupy space and to dominate space*." (Brian Weimer, Partner, Sheppard Mullin)[30]
- "*There needs to be an agency with unambiguous authority that can compel somebody to manoeuvre*." (Jim Bridenstine, former Administrator, NASA)[31]
- "*The single biggest problem isn't that the ITU doesn't have enforcement powers. It's that the ITU has zero regulations around orbital congestion*." (Mark D. Dankberg, Chairman, Viasat Inc)[32]

[27] note 16.
[28] note 17.
[29] House of Commons - Science and Technology Committee, *Formal meeting (oral evidence session): UK space strategy and UK satellite infrastructure*, (12 January 2022).
[30] note 16.
[31] Bill Beyer & Nicholas Nelson, "Viewpoint: Space Congestion Threatens to 'Darken Skies'" *National Defense Magazine* (28 June 2018).
[32] note 18.

- *"We are entering a new era where space monitoring, space traffic management and spectrum-orbit management are indispensable to assuring a secure, safe, and sustainable space sector"* (Jorge Ciccorossi, Chairman, 22nd International Space Radio Monitoring Meeting).[33]

Finally, the G7 endorsed a joint statement whereby it recognizes "*the growing hazard of space debris and increasing congestion in earth's orbit*" and considers that "*As the orbit of our planet is a fragile and valuable environment that is becoming increasingly crowded, which all nations must act together to safeguard*, …." indicating that the question of orbital congestion and sustainability is now becoming a topic of political relevance at the highest political level.[34]

These sets of statements are just a glimpse of a wider set of cross-sectorial discussions on orbital saturation, space debris, space traffic management, and appropriate regulatory frameworks. The vast majority of these views recognize the increased risk for operations in outer space and overwhelmingly conclude that new initiatives, efforts, and concepts are indeed necessary to efficiently safeguard the Earth's orbital space environment.

[33] "Managing radio frequency spectrum amid a new space race", (12 November 2021), online: *ITU Hub (Link)*.
[34] note 20.

4 International Management and Coordination of Commons

Analysing statements cited in the previous section, one must conclude that the Earth orbital environment currently lacks an adequate framework for its exploitation and use. The implications identified by these voices share an underlying understanding that the Earth orbital environment is at risk and that all relevant stakeholders must act together to safeguard this shared environment. This leads to a conclusion that the Earth orbital environments can indeed be identified as a global common and that orbits within that environment are common-pool resources (CPR), i.e. limited natural resources that are universally accessible, and where users are difficult to exclude.

Any ambitions to develop and implement an adequate framework must therefore take stock of existing mechanisms and instruments supporting the implementation of international efforts in domains where similar implications as in the Earth orbital environment are at stake.

Managing and coordinating the exploitation of common-pool resources is often a challenge as the open access to these natural resources can lead to over-exploitation. Various mechanisms have historically been developed in different forms, encompassing both (hyper)local and international regimes. However, the risks of a tragedy of the commons in many CPR led the UN Secretary General to call for "*better management of critical global commons, and global public goods that deliver equitably and sustainably for all*".[35]

Despite obvious shortcomings and needs for revision, existing coordination mechanisms related to the global commons or limited natural resources can serve as relevant examples and comparison tools for the Earth orbital environment. This section will first address the status of space as a common pool resource and then analyse three coordination mechanisms that comprise thresholds and target-based regimes that each provide valuable elements and lessons, namely:

- International Telecommunication Union (ITU) for radio frequency spectrum management
- Climate Change Mitigation and GHG emission reduction targets management
- Fisheries stock management

4.1 Orbital Environments as Common Pool Resources

It was in 1987 that the World Commission on Environment and Development warned that "*without agreed, equitable, and enforceable rules governing the rights and duties of states in respect of the global commons,* the pressure of demands on finite resources will destroy their ecological integrity over time."[36]

Building upon the recognition of the UN Guidelines for the Long-term Sustainability of Outer Space Activities that "*The Earth's orbital space environment constitutes a finite resource*", this report considers orbits within the Earth orbital environment as a common-pool resource (CPR).[37] Economic literature defines common pool resources as natural resources that are:

- Universally accessible and not excludable, which means that the exclusion of users is difficult by nature, whereby in light of the Earth orbital environment this aspect is embedded in Article I of the OST.

[35] note 14.
[36] World Commission on Environment & Development, *Our Common Future* (Oxford University Press, 1987).
[37] Elinor Ostrom, "Institutions and Common-Pool Resources" (1992) 4:3 Journal of Theoretical Politics 243–245 at 1; Barney Warf, "Common Pool Resources" in *Encyclopedia of Geography* (Thousand Oaks: SAGE Publications, Inc., 2010) 526; Johnson-Freese & Weeden, "Application of Ostrom's Principles for Sustainable Governance of Common-Pool Resources to Near-Earth Orbit" (2012) 3:1 Global Policy 72–81.

- Rival, meaning that the use of an orbit by one user decreases resource benefits for other users. In terms of the Earth orbital environment, the number of satellites that can operate safely in the same orbit is physically limited.

As the Earth orbital environment is becoming increasingly saturated, certain regions are already at the risk of oversaturation, whereby the European Space Agency notes that "*our current behaviour in space is unsustainable. If we continue as we are, the number of objects in orbit will make it hard to safely operate in space at all.*"[38] In economic theory, "*when individuals exploit CPRs, each is driven by an inexorable logic to withdraw more of the resource units (or invest less in the maintenance of the resource) than is Pareto optimal.*"[39]

The main challenge regarding common pool resources is managing their exploitation. As they are not owned by anyone and used by all, CPRs tend to be over-exploited, causing (international) environmental problems, lack of equity and resource depletion.

The table below depicts the differences and similarities between limited natural resources such as radio spectrum, land, water, air, and capacity of Earth orbits.[40]

Parameter	Radio Spectrum	Land	Water	Airspace	Earth Orbit Capacity
Is it potentially universally accessible?	YES	YES	YES	YES	YES
A finite resource in terms of instant capacity?	YES	YES	YES	YES	YES
Is it inexhaustible when used over time?[41]	YES	Partially	Partially	YES	Partially
Is it subject to rival exploitation?	YES	YES	Partially	Partially	YES
Can it be made more productive?[42]	YES	YES	Partially	YES	YES
Is it reusable?[43]	YES	Partially	Partially	YES	Partially
Is the resource varied?[44]	YES	YES	YES	Partially	Partially
Can it be stored for later use?	NO	Partially	YES	NO	NO
Can it be traded?[45]	YES	YES	Partially	NO	YES

Table 1: Comparison between natural limited resources (Credit: ITU, ESPI)

[38] ESA Space Debris Office, *supra* note 1.
[39] James M Walker & Roy Gardner, "Probabilistic Destruction of Common-pool Resources: Experimental Evidence" (1992) 102:414 The Economic Journal 1149–1161.
[40] Arturas Medeisis, *Spectrum Management fundamentals, policy and regulatory aspects for different services* (ITU, 2011).
[41] Based on existing exploitation modalities.
[42] Can a resource unit be used more efficiently or rationally (notably through innovation and R&D)?
[43] Is a resource unit eternally unavailable once consumed?
[44] Does the resource unit come in various states and modalities?
[45] See Annex B.

When focusing on common-pool resources, other examples include fisheries, forests, and underwater basins.[46] Common-pool resources should not be confused with collective goods, which can be defined as not excludable and non-rival (e.g., public lighting, air).

The UN Secretary General, in Our Common Agenda notes that as global commons, including outer space, are in crisis, "*One of the strongest calls emanating from the consultations on the seventy-fifth anniversary and Our Common Agenda was to* strengthen the governance of our global commons *and global public goods*".[47] Moreover, the report cautions that "*Increasing congestion and competition in outer space could imperil access and use by succeeding generations*."[48]

Despite governance through threshold-based models currently perhaps only relevant for operations in regions of LEO (due to the urgency in terms of the environment's long-term sustainability and congestion), the idea can be applied universally to other orbital regions and the Space Environment Capacity Concept, an example of such a model, embeds this quality in its design.

Our Common Agenda further identifies a need for an update to the governance of the global commons "*through networked, inclusive and effective multilateralism*".[49]

Multilateral efforts can of course not be conceived without challenges – with perhaps the main one identified by Elinor Ostrom, 2009 Nobel laureate in Economic sciences, in her seminal work on governing commons, as "*how a group of principals who are in an interdependent situation can organize and govern themselves to obtain continuing joint benefits when all face temptations to free-ride, shirk, or otherwise act opportunistically*."[50]

While the economic inefficiency is definitely at stake when (mis)managing common-pool resources, the real risk is "*the problem of the destruction of the resource*" and the long-term inability to use it.[51]

Various attempts, arguably with different levels of success, were and continue to be developed to internationally manage or coordinate commons and/or limited natural resources, with three notable examples presented in the following sections.

4.2 International Frequency Coordination through the ITU

The international regulation of telecommunications by satellites comprises an extensive and complex international regulatory regime, which has been established through the International Telecommunication Union (ITU), the oldest specialized agency of the UN.

The ITU first addressed the question of satellite communications through the Extraordinary Administrative Radio Conference to allocate frequency bands for space radiocommunication purposes, which was held in Geneva in 1963, also called the Space Conference. Moreover, in 1985 and 1988, the World Administrative Radio Conference on the use of the geostationary-satellite orbit and the planning of the space services utilizing it convened in Geneva had the task "*to reconcile the principle of guaranteed and equitable access with that of the efficient and economic use of two limited natural resources: the geosynchronous orbit (GSO) and the radio frequency spectrum*".[52]

---

[46] A. Héritier,, International Encyclopedia of the Social & Behavioral Sciences, 2001
[47] note 14 at 48.
[48] *Ibid* at 62.
[49] *Ibid* at 77.
[50] Elinor Ostrom, *Governing the Commons: The Evolution of Institutions for Collective Action* (Cambridge University Press, 1990) at 29.
[51] Walker & Gardner, "Probabilistic Destruction of Common-pool Resources", *supra* note 39.
[52] ITU, "World Administrative Radio Conference on the use of the geostationary-satellite orbit and the planning of the space services utilizing it (1st session) (Geneva, 1985)", online: *History Portal of the ITU* (Link).

4.2.1 Overview of ITU approach

ITU has two types of memberships: Member States and Sector Members, in addition to the participation of Associates, and Academia (Article 2, ITU CS).

The Plenipotentiary Conference (PP) is the supreme body of the ITU and generally convenes every four years to determine the general policies of the ITU and adopt the Financial Plan (Article 8 CS). In the interval between PPs, the Council meets annually to act as the governing body of the ITU, on behalf of the PP. In particular, the Council adopts the agendas for administrative radio conferences (WRC and RRC).

Conferences have led to the adoption of several international treaties, which represent the key legal framework on which coordination mechanisms are based. They include:

- Constitution of the International Telecommunication Union, (CS)
- Convention of the International Telecommunication Union, (CV)
- Administrative Regulations (AR):
  - International Telecommunication Regulations (TR)
  - International Radio Regulations (RR)

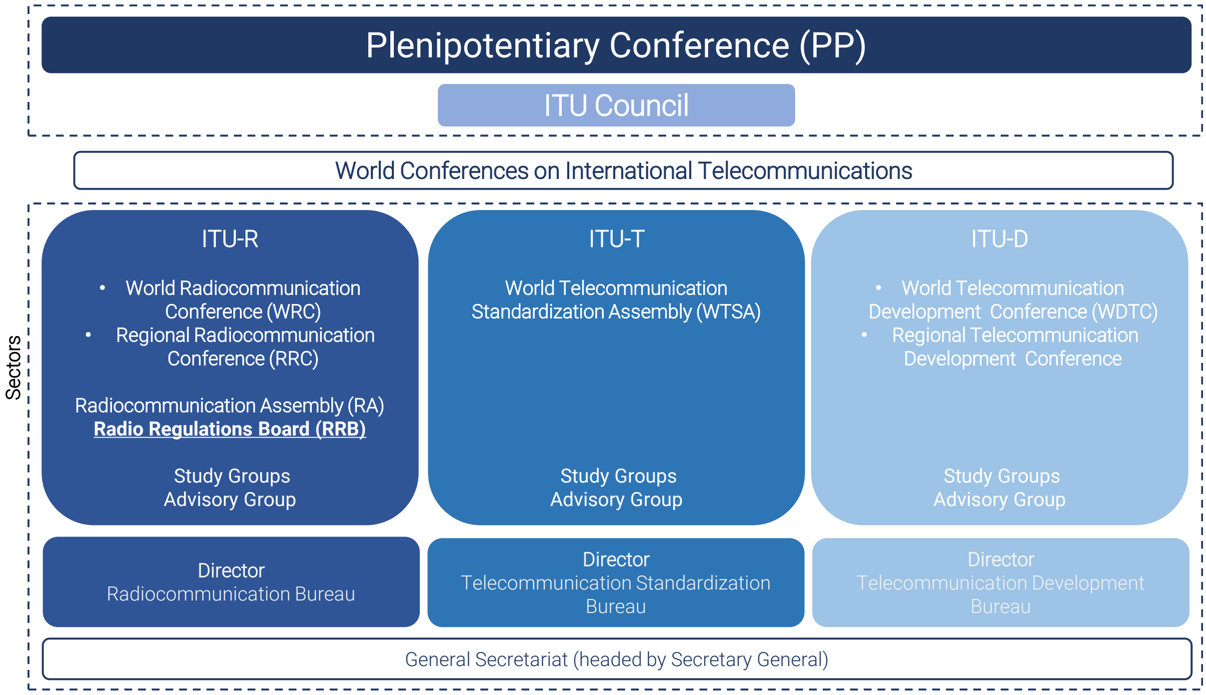

Figure 3: ITU Organigramme (Article 7 CS) (Source: ITU, ESPI)

Each of the three ITU Sectors has its own unique characteristics and activities:

- ITU Radiocommunication sector (ITU-R) oversees the global radio-frequencies spectrum and satellite orbit management and coordination and develops and updates international regulations in the use of orbit/spectrum at WRC and RRC.
- ITU Telecommunication Standardization Sector (ITU-T) studies technical, operating, and tariff matters and adopts global standards for international telecommunications (recommendations).
- ITU Telecommunication Development Sector (ITU-D) facilitates and enhances telecommunications development by offering, organizing, and coordinating technical cooperation and assistance activities in developing countries.

4.2.2 Radiocommunications sector (ITU-R)

Radio frequencies and any associated orbits, including the geostationary-satellite orbit (orbital positions) are valuable assets and indispensable resources for satellite communications. As they are limited natural resources, they must be used rationally, efficiently, and economically, in conformity with provisions of the Radio Regulations (RR).

Within the Radiocommunications sector (ITU-R), ITU activities are distributed among several actors and fora:

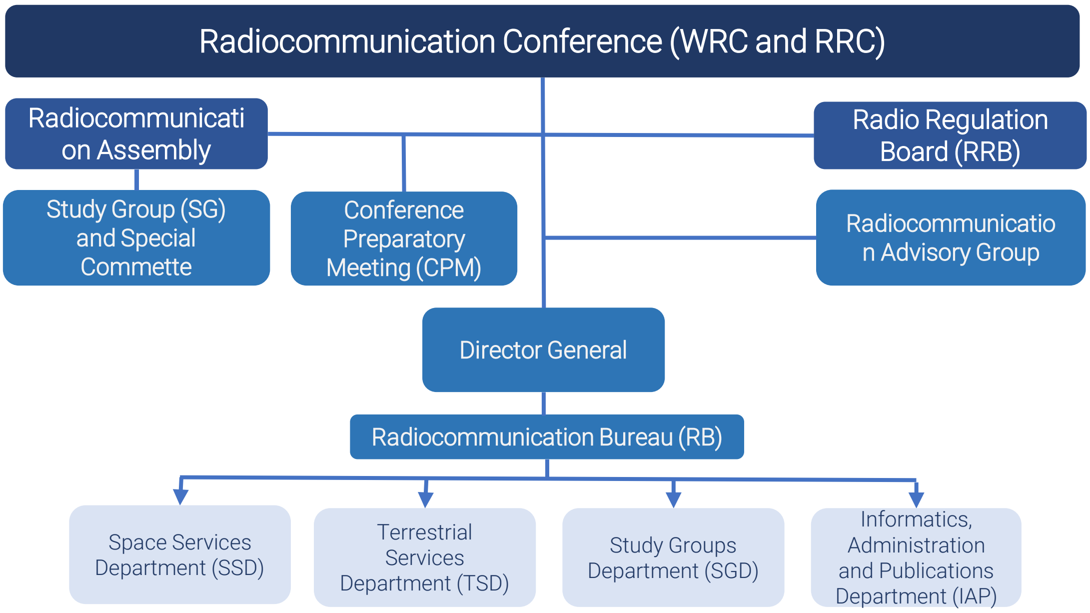

Figure 4: ITU-R organigramme (Source: ITU, ESPI)

RR are a binding international treaty providing a framework for the use of radio-frequency spectrum and satellite orbit resources through a system of international coordination. It contains allocations, plans, and procedures (table of frequency allocation to the services, regulatory provisions for spectrum utilization, and are supplemented by rules of procedures). Because of their binding nature, states have to domestically apply their provisions, adopting adequate national legislation, in addition to special bilateral or multilateral arrangements. Radio frequencies and any associated orbits are regulated with the intent:

- To avoid harmful interference, which might reduce the quality of telecommunications (interference-free radio frequencies and appropriate satellite path or orbit in outer space) (Art. 45, ITU CS).
- To Guarantee they are equitably shared among several services and among all countries (limited natural international resources) (Article 44, ITU CS).

The coordination mechanism is built upon the concept of allocation, allotment, and assignment:

- Allocation: The ITU Conferences (in particular, the WRC) have been responsible for the frequency spectrum allocation of given frequency bands to different categories of terrestrial or space radiocommunication services or the radio astronomy services under specified conditions, and their respective entry in the Table of Frequency Allocations. Radio services are divided between primary and secondary category tiers, with further specifications on how the frequencies are to be assigned or used (block allocation methodology).
- Allotment: Member Administrations have access to a predetermined share of the frequency spectrum and GSO positions, allocated under a frequency/orbital position plan ensuring equitable access. The

agreed allotment plans are adopted by the competent conference, for use by one or more administrations for a terrestrial or space radiocommunication service in one or more identified countries or geographical areas and under specified conditions.

- Assignment: National Frequency spectrum management authorities are in charge of designating the frequencies/orbital resources required (both for planned & non-planned services) to public & private space networks and applying the relevant ITU procedures.

The assignment of a radio station to a radio frequency or RF channel and orbital positions is carried out by national administrations in line with national licensing systems. The satellite operator must therefore meet the mandatory requirements for a national radio license under national regulatory procedures.

The allocation and allotment activities are pursued at the ITU World Radiocommunication Conference (WRC) and Regional Radiocommunication Conference (RRC) level. The WRC is a treaty-making conference, which convenes every 3 to 4 years, based on the Agenda recommended by the previous WRC and approved by Council. It plays a key role in shaping the technical and regulatory framework for the provision of radiocommunication services in all countries. Among other tasks, it revises the Radio Regulations (including Appendices), adopts technical studies and work plans for a 6–10-year cycle, adopts spectrum allocations, adopts satellite regulatory procedures, adopts allotment Plans of the radio frequency spectrum, and reviews Rules of Procedure and appeals from the RRB. The WRC Cycle is represented below:[53]

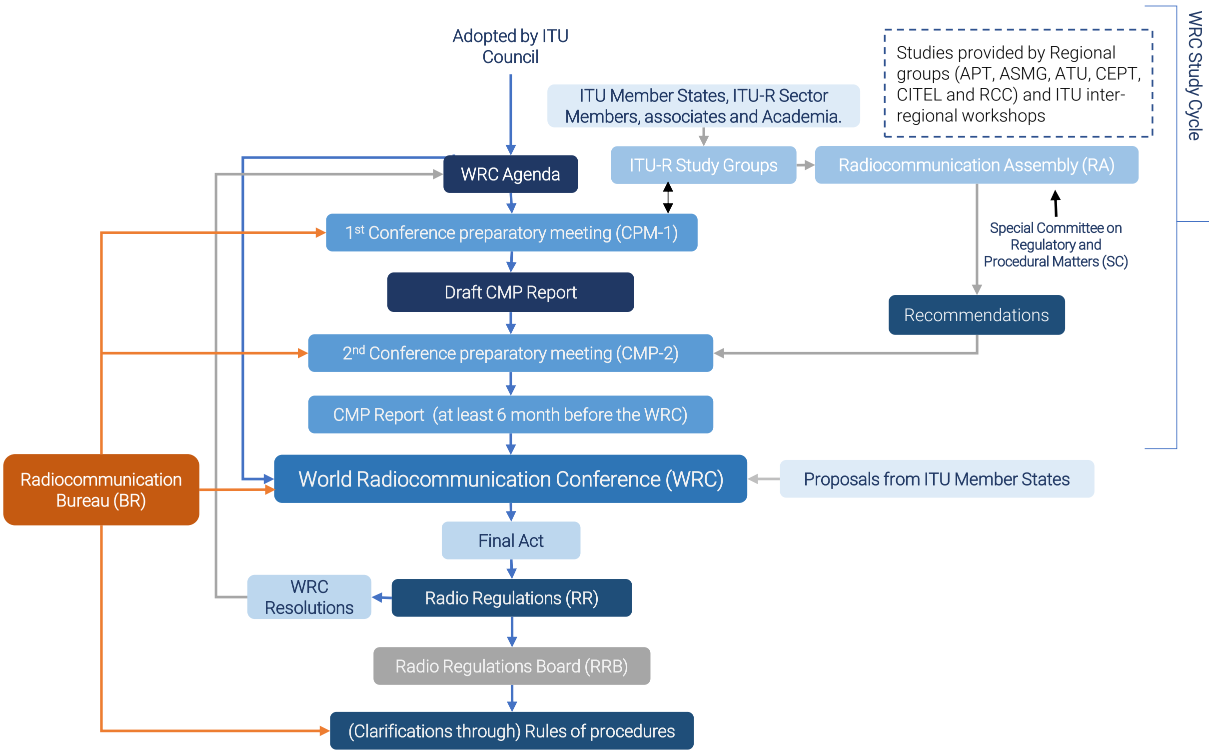

Figure 5: WRC Cycle (Source: ESPI, ITU)

The preparations for the conference include discussions at the level of ITU-R Study groups, the Conference Preparatory Meeting, as well as the ITU inter-regional workshops, and within regional groups. Industry contributes to the Conference Preparatory Meeting Report and participates in the WRC either as being part of Member State formal delegations or as an observer, whereby in the latter role industry may

[53] The ITU Radiocommunication Bureau acts as the executive arm of the RRB.

only submit information documents and provide advice, but cannot submit proposals or participate in debates.

Subsequently to the ITU allocation and allotment activities, spectrum management procedures for the assignment of frequencies and orbits to a network have been laid down by the WRC.

Two main mechanisms of sharing spectrum/orbits are envisaged under the framework and used in parallel :

- A priori allotment planning approach (principle of equitable access) (Appendix 30, 30A, and 30B)
- "Coordination before use" approach for non-planned services (principle of First Come First Served/ principle of efficiency), which includes two procedures:
    - Advance Publication Information (API) procedure, with publication in the Radiocommunication Bureau's International Frequency Information Circular (BR IFIC) for some non-GSO networks.
    - Coordination procedures (CR), with ITU technical examination and coordination with relevant administrators for GSO and some non-GSO networks.

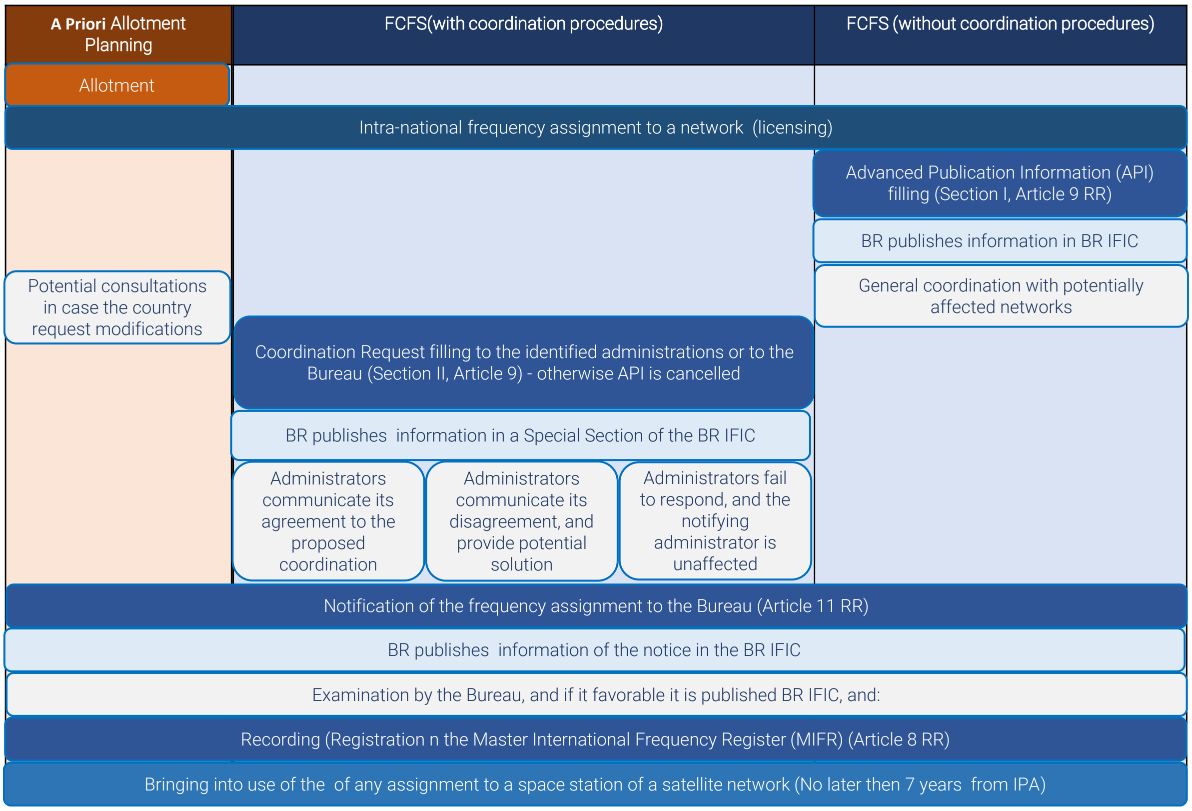

Figure 6: Spectrum management procedures (Source: ESPI)

Member States have sovereign authority over the use of spectrum within their territory. They are in charge of managing national frequency allocations tables, issuing spectrum licenses, enforcing regulations at the national level, and updating national regulations to take account of modified ITU RR. Even though it offers support to industry in the process, the ITU only receives files from the national administrations.

Recording frequency assignment, and as appropriate, orbital information in the Master International Frequency Registration (MIFR) guarantees international recognition of the rights to use frequencies by these networks/stations and coordination and protection from harmful interference. After the registration, Member States assume continuing responsibility for the networks. However, the FCFS principle is based on good faith, and no sanctions can be imposed on those violating the system.

4.2.3 Relevance of the Mechanism for the Earth Orbital Environment

The process of establishing ITU's space-related regulations has initially been based on the First Come, First Served (FCFS) (and coordination before use) procedure in line with the principle of efficient, rational, and cost-effective spectrum/orbit management/utilization. Criticisms of several developing countries concerned by the progressive exploitation and congestion of GSO frequencies/orbital position have led Member States to implement a parallel equitable access procedure with dedicated frequency/orbital position plans for each country.

Even continuous attempts to implement requirements of efficiency and equity, the introduction of non-GSO satellite systems for commercial communications, the liberalisation of commercial communications markets, and the globalization of communication systems are posing new challenges to the approach. The ITU FCFS approach is also facing criticism in other international fora, most prominently within the framework of UN COPUOS (STSC, LSC). In particular, criticisms with regard to the FCFS model as a key factor in restricting long-term access to space.

An overview of the evolution of the FFS approach within the ITU framework and its interplay with equitable access can be found in Annex A.

Although the ITU coordination mechanism has been tailored and regulated based on the necessity of frequencies and orbital positions pairs in GSO and frequencies in non-GSO environments, some of its features can lead to considerations of its applicability in other contexts. Indeed, similarly to the frequencies and orbital positions management mechanism embedded in the ITU system, attempts to coordinate the space environment through a threshold-based model would be based on a risk metric that determines the technical and operational constraints of a space mission. Conceptually, both deal with a risk of interference caused respectively by operations and the presence of other space objects.

On the other hand, a clear difference exists, as the ITU system focuses on the operational period of a satellite (or a transmitting device), while the capacity concept is focused on the long-term behaviour of space objects, notably after the mission is operationally concluded or when control over spacecraft is lost.

The dynamic stemming from the FCFS approach toward more equitable planning would most likely need to be embedded in threshold-based models concerning the Earth orbital environment at large. Similarly, to the radio frequency spectrum framework, the implementation of a threshold-based model for the space environment would indeed require a balance between "efficient and economic use" with the question of "equitable access" under the spotlight. Furthermore, implications related to tradability in light of spectrum management are presented in Annex B.

This very balance between guaranteeing efficiency and equity, therefore, raises several questions on the applicability of the model implemented by the ITU. Moreover, the identification of the appropriate forum or fora was identified as a potential blocking point as well as the identification of efficient tools for its implementation and enforceability as identifying frequency interference can be pre-identified or at least identified in real-time, whereas future collision or debris-generating risk is harder to determine. On the other hand, through the prism of space capacity, the risk is easier to avoid in the first place, if missions are systematically designed in line with sustainability-focused design principles (e.g. deployment of less reliable systems in lower orbits).

4.3 Climate Change and GHG Emissions

4.3.1 International Efforts for Reaching GHG Reduction Targets

In 1990, IPCC's First Assessment Report (FAR) pioneered "*thoughts in economic and social issues of climate change, valuing impacts and consequences as major and considerable*".[54] It notably concluded "*that carbon dioxide (CO_2) is responsible for over half of the greenhouse gas effect in the past, and "that continued "Business as Usual" emissions would commit us to increased concentrations for centuries*".[55]

It was following the publication of the FAR in 1990 that political processes and negotiations leading to the United Nations Framework Convention on Climate Change (UNFCCC) were given impetus that led to the adoption of the Convention in 1992.

United Nations Framework Convention on Climate Change (UNFCCC)

The United Nations Framework Convention on Climate Change (UNFCCC) is an international treaty, which entered into force in 1994, and has been ratified by 197 countries with the ultimate goal to stabilise "*greenhouse gas concentrations in the atmosphere at the level that would prevent dangerous anthropogenic interference with the climate system*".[56] Negotiations on the tools, mechanisms, benchmarks and targets take place during multiple 'rounds', including governing bodies of developing and developed countries. In the course of negotiations, additional bodies have been added to the UNFCCC organisational structure. The supreme governing and decision-making body of the UNFCCC is the Conference of the Parties (COP). Its primary task is to promote and review the implementation of the Convention and related legal instruments (e.g. Kyoto Protocol). Indeed, COP serves as the meeting of the Parties to the Kyoto Protocol (CMP), and as the meeting of the Parties to the Paris Agreement (CMA). The work of the governing bodies is supported by the Bureau of the COP, CMP, and CMA.

Two UNFCCC permanent subsidiary bodies (which also serve other Agreements) are:

- The Subsidiary Body for Scientific and Technological Advice (SBSTA), which provides the governing bodies with information and advice on scientific and technological concerns (as they relate to the Convention, the Kyoto Protocol, and the Paris Agreement);
- The Subsidiary Body for Implementation (SBI), assists the governing bodies in the assessment and review of the implementation of the Convention, the Kyoto Protocol, and the Paris Agreement.

Figure 7: UNFCC´s bodies

[54] IPCC, "Statement on the 30th anniversary of the IPCC First Assessment Report", online: IPCC (Link).
[55] *Ibid.*
[56] United Nations Conference on Environment and Development (UNCED), *United Nations Framework Convention on Climate Change* (1992).

In addition, negotiations are supported by external processes, such as G7, regional meetings and other forums (e.g., Major Economies Forum on Energy and Climate).

Signatories to the UNFCCC are split into three groups (UNFCCC structure):

- UNFCCC Annex I: List of Developed Nations (industrialized economies) and Nations with Economies in Transition (EIT).
- UNFCCC Annex II: List of Annex I countries without countries with Economies in Transition (EIT). Those are the richest Annex I countries (members of the Organisation for Economic Co-operation and Development (OECD) in 1992).
- Non-annex I: List of developing countries, which are only required to report emissions.

Annex I countries, are under the general commitment to take measures to reduce GHG emissions. Annex II countries have the additional obligations to provide financial resources to "enable developing countries to undertake emissions reduction activities under the Convention and to help them adapt to adverse effects of climate change. In addition, they have to "take all practicable steps" to promote the development and transfer of environmentally friendly technologies to EIT Parties and developing countries, to enable them to implement the provisions of the Convention.[57]

Following the UNFCCC in 1994, a few agreements have been negotiated at intergovernmental level aiming at a reduction in emissions, together with establishing the institutional arrangements for the climate change intergovernmental process. Those include:

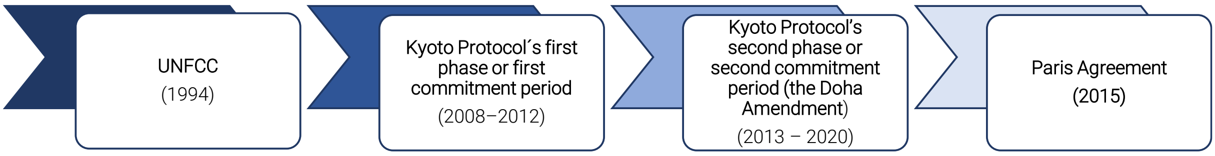

Figure 8: Timeline

Kyoto-Protocol to the UNFCCC

With the view to operationalizing the UNFCCC, the first agreement, named the Kyoto Protocol, was adopted at the COP 3 in 1997.

For the Protocol to become legally binding, the Protocol had to be signed and ratified by 55 countries, which had to represent at least 55% of the world's total carbon dioxide emission for 1990. The Protocol entered into force in 2005 to supplement and strengthen the UNFCCC.

The Protocol is based on the UNFCCC principles and provisions and follows its annex-based structure:

- Annex A: List of seven greenhouse gases (GHG)
- Annex B: Countries/Parties signatories to the Kyoto Protocol that are subject to caps on their GHG emissions and committed to reduction targets

Scientific Assessments and Target Setting

There were increased warnings of the negative impacts of rising emissions on the Earth environment throughout the 1970s and 1980s, along with calls to use temperature as a guide for society's response to climate change. The Stockholm Environment Institute is widely credited with scientifically linking global warming as a guide for where to set an overarching limit (while also considering sea-level rise and the

[57] UNFCCC, "Parties & Observers", online: UNFCCC (Link).

concentration of carbon dioxide in the atmosphere), noting that *"temperature increases beyond 1.0°C may elicit rapid, unpredictable, and non-linear responses that could lead to extensive ecosystem damage"*, suggesting there is *"nothing necessarily 'safe' about a two-degree limit"*.[58]

Today, the most credible and influential scientific reference is the International Panel on Climate Change (IPCC), an intergovernmental UN body for assessing interdisciplinary science related to (human-induced) climate change. The IPCC is an internationally accepted authority on climate change that has a double function as a scientific committee and at the same time an intergovernmental committee, comprised of 195 member states, and 173 institutions (30 UN institutions and 143 international and civil organizations) that are accredited as observers.[59] The objective of IPCC is to provide policymakers with regular scientific assessments on climate change, its implications, and future and present natural, political, and economic impacts and risks as well as to push forward adaption and mitigation options.

IPCC reports, especially the Assessment Reports, provide key input and a basis for policymakers and have a great weight for international fora and negotiations. One of the most important indicators of its policy relevance is the use of IPCC reports in international climate negotiations in view of the Conference of the Parties (COP) of the UNFCCC: "*COP uses the information in IPCC reports as a baseline on the state of knowledge on climate change when making science-based decisions*".[60]

Over the years, "*the focus of IPCC reports has expanded from establishing the nature of the climate problem to zooming into regional characteristics of climate risks of impacts and exploring possible solutions to the challenge of climate change and impacts from the response options*."[61]

At the international level, IPCC assessment reports were highly influential for important target-setting decisions and milestones in international climate negotiations:

- The Second Assessment Report (AR2) was influential in defining the provisions of the Kyoto Protocol.
- The Third Assessment Report (AR3) was influential in defining the rules for meeting targets set out in the Kyoto Protocol and strong grounds for starting processes towards developing a global climate goal.
- The Fourth Assessment Report (AR4) informed the decision on the ultimate objective (2°C) and created a strong basis for a post-Kyoto Protocol agreement and long-term cooperative action.
- The Fifth Assessment Report (AR5) informed the review of the 2°C objective (preferably to 1.5°C) prior to the adoption of the Paris Agreement in 2015.

Over the years, the role and relevance of various IPCC reports for COPs and policymaking, in general, has been increasing. The IPCC's function to provide information that delivers a basis for policy decisions on climate change is increasingly extended to a more policy-prescriptive function, providing concrete solutions, noting that science was markedly better acknowledged in the final Glasgow Climate Pact of COP26, compared to outcomes from previous COP summits.[62] Nevertheless, it needs to be recognized that, the targets are a compromise between a scientifically reasonable and politically agreed-upon benchmark.[63]

Further to target setting, estimating remaining carbon budgets is an exercise whereby an upper limit of total GHG emissions, associated with the statistical chance to remain below a specific global average

[58] Carbon Brief Staff, "Two degrees: The history of climate change's speed limit", (8 December 2014), online: *Carbon Brief* (Link)
[59] IPCC, "About", online: (Link).
[60] Jonathan Lynn & Werani Zabula, "Outcomes of COP21 and the IPCC", (1 November 2016), online: *WMO* (Link).
[61] IPCC, *supra* note 54.
[62] Sonia Seneviratne et al, "Guest post: How COP26 finally recognised the latest IPCC climate science", (2021), online: *Carbon Brief* (Link)
[63] "What does the 2 degree target mean for climate change and climate policy? | Munich Re Topics Online", online: *munichre (Link)* "What is the 1.5C target? And how does it affect the climate crisis?", (9 August 2021), online: *The Independent* (Link)

temperature, is calculated and set.[64] Behind these simplified metrics, one finds layers of complexity and uncertainties. This is becoming increasingly relevant as scientists try agreeing on a carbon budget for the set temperature limits. As our planet is well on its way towards the 1.5C target, the remaining budget is relatively small and, therefore, the approach used is very sensitive.[65]

Commitment and Implementation

While the Convention encouraged industrialized countries to stabilize GHG emissions, the Protocol moved to binding commitments. It committed industrialised and EIT countries to limit and reduce GHG emissions in accordance with agreed individual targets. The Protocol set a heavier burden on developed countries under the principle of "common but differentiated responsibility and respective capabilities", recognizing their large responsibility for the current high levels of GHG emissions in the atmosphere, in addition to the recognition that the share of emissions in developing countries will grow to meet their social and development needs. In particular, it sets binding emission reduction targets for 37 developed countries (Annex B), [66] while developing countries were not subject to emission reductions commitments in the first Kyoto commitment period. Limit emissions in developing countries were envisaged through Clean Development Mechanism (CDM), with some sectors falling beyond the scope of national emission targets.

During negotiations, countries (including the U.S.) collectively agreed to set an average reduction target of 5.2% compared to 1990 levels for the first commitment period (2008-2012).[67] Since the U.S. did not ratify the treaty (even though it has not withdrawn from it), the average target fell to 4.2% below the base year.

Under the Protocol, committed countries had to primarily adopt national mitigation policies and measures in order to meet their targets, and to report periodically. However, the Protocol also offers additional means to meet the targets (facilitating compliance with commitments) and lowering the overall cost to do so, through flexible market-based mechanisms:

- Joint implementation (JI) (Article 6 KP), is a mechanism by which a party to the Protocol can invest in a project that reduces emissions in another country, and consequently receives credit based on the result of the project (Emission Reduction Units - ERU).
- Clean Development Mechanism (CDM) (Article 12 KP), is a mechanism that generates credits for investing in projects in countries not parties to the Protocol (Certified Emission Reduction - CER). The credit assigned through this mechanism are units that increase the total assigned amount available for parties to the Protocol collectively and can be counted towards meeting Kyoto targets
- International Emissions Trading (IET) (Article 17 KP), under which parties of the Protocol can transfer units or acquire Assigned Amount Units (AAU) between each other without affecting the total collective assigned target. While the units acquirable are unlimited, the over-transfer of units is limited to the country's Commitment Period Reserve (CPR), which is a minimum national level of units that a country should hold in its national registry.

[64] Malte Meinshausen et al, "Greenhouse-gas emission targets for limiting global warming to 2 °C" (2009) 458:7242 Nature 1158–1162 Bandiera_abtest: aCg_type: Nature Research Journalsnumber: 7242Primary_atype: Researchpublisher: Nature Publishing Group; Josep Candela & David Carlson, "The Annual Global Carbon Budget", (21 March 2017), online: *WMO* (Link)
[65] Zeke Hausfather, "Analysis: Why the IPCC 1.5C report expanded the carbon budget", (8 October 2018), online: *Carbon Brief* (Link)
[66] The Protocol's targets cover four greenhouse gases and two group of gases. Namely, carbon dioxide (CO2), methane (CH4), nitrous oxide (N2O), hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), and sulphur hexafluoride (SF6).
[67] UNFCCC, "Kyoto Protocol - Targets for the first commitment period", online: UNFCCC (Link).

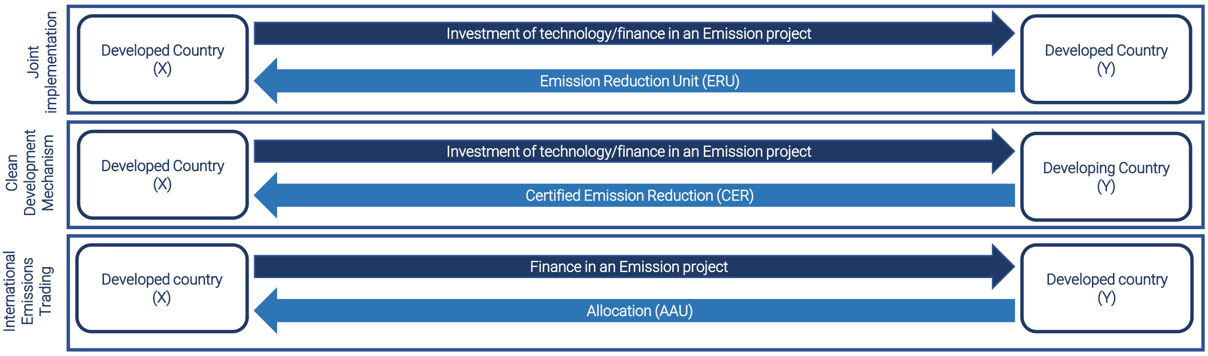

Figure 9: Flexible market-based mechanisms

Compliance and Adaptation

As additional mechanisms, the Kyoto Protocol also established monitoring, review, verification, and compliance system, as well as adaptation mechanisms:

- Registry systems track and record transactions by Parties under the mechanisms to verify that transactions/trades are consistent with the rules of the Protocol.[68]
- Reporting is done by Parties by submitting annual emission inventories and national reports under the Protocol at regular intervals.
- A Compliance system to ensure transparency and that Parties meet their commitments and support them to meet their commitments in case difficulties arise.[69]

The Kyoto protocol is also designated to assist countries in adapting to the effects of climate change. For instance, an Adaptation Fund financed by developed countries was created to assist countries in adapting to the adverse effects of climate change (especially developing countries that are Parties to the Kyoto Protocol). In the 1st commitment period, the Fund was financed mainly with a share of proceeds from CDM project activities. Focusing on enforcement, it has been established that non-compliance with national limits would result in two types of penalties:

- Compensation in the 2nd commitment period with an added 30% burden;
- Suspension of transfers under emission trading mechanisms.

Countries over-achieving in their 1st commitment period were allowed to bank their unused allowances for use in the subsequent period.

Doha Amendment to the Kyoto Protocol

In 2012, the Doha Amendment to the Kyoto Protocol was adopted for a 2nd commitment period for 37 countries, starting in 2013 and lasting until 2020.[70] For entry into force of the Amendment to be initiated in 2020, 144 Parties to the Kyoto Protocol had to deposit their instrument of acceptance with the Depositary. However, the Doha Amendment has not yet entered into force, especially under the criticism of a too rigid bifurcation between developed and developing States' obligations.

The amendment includes new commitments for Annex I Parties to the Kyoto Protocol who agreed to the 2nd commitment period, and amendments to several articles of the Kyoto Protocol.[71]

[68] UNFCCC, "Registry Systems under the Kyoto Protocol", online: UNFCCC (Link)
[69] UNFCCC, "Adaptation Fund", online: UNFCCC (Link).
[70] Negotiation for the following commitments started with the Bali Action Plan (2012). (Link)
[71] During this time, the emissions of the 37 developed countries and economies in transition that had reduction targets declined by more than 22% compared to 1990, far exceeding the initial target of 5% compared to 1990.

Paris Climate Agreement (2015)

In 2015, 196 Parties at COP21 adopted the Paris Agreement. The international treaty on climate change entered into force in 2016 (following domestic ratification processes). The Agreement aims to keep global warming below 2°C compared to preindustrial levels, and pursue efforts to limit it to 1.5°C.

The Agreement contains mandatory and non-mandatory key provisions relating to:

- Mitigation (Article 3-6) National climate protection goals are self-defined by the states, under non-binding Intended Nationally Determined Contributions (INDC). Each country is responsible to prepare and update its National Climate Action Plan known as Nationally Determined Contributions (NDCs), which includes activities that will take to meet the temperature targets agreed upon under the Paris Agreement.[72]
- Adaptation (Article 7): All countries should submit adaptation communications, detailing adaptation priorities, support needs, plans, and actions, which should be updated periodically. Through NDC's countries communicate defined actions to build resilience to the impacts of rising temperatures.

To better frame the efforts towards the long-term goal, all countries are encouraged (voluntary) to formulate and submit a Long-Term Low-Emission Development Strategy (LT-LEDS), which provides the long-term horizon to the NDCs. The mechanism is based on a steady cycle of systematic increase of ambition (5-year NDC cycles).

The Global Stocktake is an essential element of the Paris Agreement, which is used to monitor its implementation and evaluate the collective progress of parties. A global stocktake will take place every five years to assess collective/aggregate progress towards achieving the purpose of the Agreement and its long-term goals, and to inform the next set of NDCs.

2015: Paris Agreement is adopted. Article 14 of the Paris Agreement established the Global Stocktake. The first comprehensive Global Stocktake will be undertaken in 2023 and every five years thereafter.

2018: Facilitative Dialogue to jointly take stock of global efforts to reduce emissions, discuss how these efforts are effective, identify avenues for increasing collective ambition.
Countries agreed on the process for the Global Stocktake at COP24. It should be conducted in three phases: information collection and preparation; technical assessment; consideration of outputs.

2020: Parties submit new of updated Nationally Determined Contributions (NDCs).

2021-2022. Phase I: Information collection and preparation.
The UNFCCC is gathering country reports, NDCs, IPCC and UN reports, etc. to write synthesis reports and establish a technical assessment.

2022 Phase II: Technical Assessment.
Technical dialogues to be held over two or three consecutive UN climate conferences to assess progress on mitigation, adaptation, and means of implementation and support. Summary reports for each area and cross-cutting issues will be released.

2023: Phase III: Consideration of outputs.
Findings of the technical assessment will be discussed and presented at the COP in 2023. Opportunities for enhancing climate action will be identified.

Figure 10: The Global Stocktake Timeline

[72] Aims to reach global peaking of emissions as soon as possible, to achieve a balance between anthropogenic emissions by sources and removals by sinks of greenhouse gases in the second half of this century.

Moreover, the Agreement establishes a Compliance Committee, a committee of experts, to facilitate implementation in a transparent and non-punitive manner, and promote compliance with the Paris Agreement.

Countries can cooperate in delivering their NDCs (Article 6 of the Paris Agreement), but the rules for international transfers and for the mechanism have yet to be finalized by the Parties and have been a subject of discussion during COP26 in 2021.

Developed countries will provide financial support to developing countries to assist them with their mitigation and adaptation efforts, will address technology development and transfer, and will report their public protection (incentive setting, picking up and supporting less-wealthy states).

Types of carbon pricing have been implemented in response to commitments under the UNFCC:

- Pollution taxes, which is a market mechanism and price instruments that directly sets a price on carbon by defining a tax rate on GHG emissions or the carbon content of fossil fuels.
- Cap-and-trade system, is a market-based approach that sets a cap on the total level of GHG emissions for countries or companies and creates allowances for those with low emissions to sell their extra allowances to a larger emitter. Many countries have designed their own schemes (e.g., EU Emissions Trading System - ETS).

To achieve the target set in the Paris Agreement, the UNFCCC secretariat launched the "Climate Neutral Now initiative in 2015.

4.3.2 Other initiatives relevant to GHG emissions and climate change mitigation

In addition to the set of traditional rule-making international fora, the climate change and GHG emission mitigation efforts are supported by a number of non-traditional organizations from both the public and the private sphere, described below.

This shows that wider policy domains, especially those related to the commons (in the widest possible meaning of the word) require a multi-layered, participative approach with a set of non-traditional quasi-regulatory, implementation, and monitoring actors that bolster public policy efforts.

Greenhouse Gas Protocol

The Greenhouse Gas (GHG) Protocol is a global comprehensive standardized framework to measure and manage GHG emissions from private and public sector operations, combined with associated reporting for companies and increasingly for the public sector. In particular, the standard series includes greenhouse gas accounting standards (carbon accounting), as well as Corporate Standard, GHG Protocol for Cities, Mitigation Goals Standards, Project Protocol. GHG Protocol also offers several additional resources such as Calculation Tools, Online Training, and "Built on GHG Protocol" Review Service.

The development of the GHG Protocol is coordinated by:

- The World Resources Institute (WRI), a global non-profit organization that works with leaders in government, business, and civil society that focus its activities on 7 urgent challenges (Food, Forests, Water, Ocean, Cities, Energy, and Climate).
- The World Business Council for Sustainable Development (WBCSD), a global organization of over 200 companies working together to accelerate the transition to a sustainable world.

Building on a 20-year partnership between WRI and WBCSD, GHG Protocol works with governments, industry associations, NGOs, businesses, and other organizations.

The GHG Protocol are the world's most widely used gas accounting standards. They are mostly in compliance with standards recognized by the international climate policy regime, while also focusing on regulatory gaps that have not yet been filled by states. Numerous other standards are based on it, including ISO 14064 (GHG) and many state-adopted standards.

ISO 14064

The norm series ISO 14064, consisting of three norms, aims to support companies and organisations to monitor and evaluate their GHG emissions and purposefully target their carbon footprint – delivering the framework for GHG-balancing and its verification as well as a basis for reporting. ISO 14064 is an instrument for industry and agencies for the realisation and development of programmes/projects to reduce emissions and supports companies in the administration of emissions trading. Companies can therefore contribute to emissions reduction and are attracted by incentives in order to increase trust, transparency, and credibility.

- ISO 14064-1 (inspired by the GHG Protocol) is the basis for the balancing of the companies' GHG emissions, creating/developing the Corporate Carbon Footprint (CCF), and provides information on the principles and demands/requirements for the planning, development, and reporting of GHG-stocks in companies.
- ISO 14064-2 provides a guideline/instruction to measure the reduction of emissions at project-level.
- ISO 14064-3 forms the basis for the verification of CO2 balance.

On the basis of this norm – and after a successful verification – DQS (one of the leading certification bodies for management systems worldwide) certifies compliance with the specifications for CO2 balance.

Science-based Targets initiative (SBTi)

Science-based Targets is a joint initiative by the Carbon Disclosure Project, the UN Global Compact (UNGC), the World Resources Institute (WRI), and World Wide Fund for Nature. It shows companies how much and how quickly they need to reduce their GHG emissions to prevent the worst effects of climate change.[73] Organizations are setting increasingly aggressive targets, based on scientific research. As of the end of 2020, more than 500 companies have set targets based on guidance and resources provided by the Science-based Targets initiative (SBTi). The SBTi defines and promotes best practices in science-based target setting. Offering a range of target-setting resources and guidance, the SBTi independently assesses and approves tailored companies' targets in line with its strict criteria.

4.3.3 European Framework for GHG reduction targets and carbon trading

The EU Emission Trading Scheme (EU ETS)

At the EU level, the first European Climate Change Programme (ECCP, 2000) led to the introduction of the EU Emission Trading Scheme (ETS) to facilitate compliance of the EU and its Member States with the Kyoto Protocol.[74] It is a cap-and-trade system, meaning that the EU ETS establishes a 'cap' on the number of emission allowances. It is a cap for the total volume of GHG emissions that can be emitted by installations in the power sector (power plants) and manufacturing industry (covered by the system), as well as airlines operating in the EEA (until 2023).[75]

[73] CDP, *Target-setting pitfalls and lessons learned* (Webinar, 2017) (Link).
[74] Climate Policy Info Hub, "European Climate Policy - History and State of Play", online: (Link).
[75] European Commission, "EU Emissions Trading System (EU ETS)", online: EC (Link).

Within the cap, the system allows trading of emission allowances so that the total emissions of the installations and aircraft operators stay within the cap and the least-cost measures can be taken up to reduce emissions. The cap decreases annually at an increased annual linear reduction factor, ensuring that total emissions fall in the long-term.[76]

The caps were defined in the below-described trading phases:

- Phase 1 NAPs (2005-2007): After the adoption of the EU ETS Directive in 2003, each EU country had to define the allocation of its emission allowances and publish its National Allocation Plans (NAPs) by 2004. The EC assessed the plans to ensure they complied with the guidance document (annex to the ETS Directive) and EU rules on state aid and competition, and in a few cases required changes to reduce national caps. The EC issued its decisions on the NAPs from 2004 to 2005. This process (sum of the NAPs) established the EU-wide cap.[77]
- Phase 2 NAPs (2008-2012): Countries had to publish their NAPs by 2006, and the EC issued its decisions on NAPs between 2006 and 2007.
- Phase 3 (2013-2020): In place of the previous system of national caps, the Phase 2013 established a single EU-wide cap on emissions, which was set based on the average total quantity of allowances issued annually in 2008-2012. In addition, the EC defined auctioning as the default method for allocating allowances (instead of free allocation).[78]
- Phase 4 (2021-2030): In July 2015, the EC presented a legislative proposal to revise the EU ETS for the period after 2020 to ensure that 2030 targets are reached.[79] After extensive negotiations, the European Parliament and the Council formally supported the revision in February 2018. The revised EU ETS Directive 2018/410 entered into force in 2018. The EC's legislative proposal was the consequence of a series of extensive consultations, including stakeholder events, and written.[80]

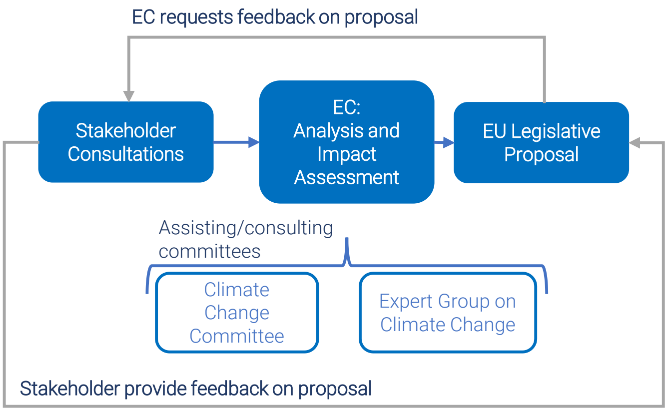

Figure 11: EU ETS Proposal Legislation

Effort-Sharing Regulation

EU Member States (and Iceland and Norway) also have obligations to reduce GHG emissions from sectors not included in the ETS. For sectors such as transport, buildings, agriculture, and waste (which account for approximately 60% of emissions within the EU), countries must reduce emissions by 30% by 2030 (when compared to 2005). The current Effort Sharing Regulation, adopted in 2018, provides Member States with binding targets for 2021-2030 to achieve the target reduction. The targets are adapted to Member States' capacities and range anywhere from 0%-40%.

[76] *Ibid*.
[77] Simone Borghesi & Massimiliano Montini, "The Best (and Worst) of GHG Emission Trading Systems: Comparing the EU ETS with Its Followers" (2016) 4 Frontiers in Energy Research, online: (Link).
[78] The system has been prone to criticism; see Richard Schmalensee & Robert N Stavins, "Lessons learned from three decades of experience with cap and trade" (2017) 11:1 Review of Environmental Economics and Policy 59–79.
[79] One of these measures includes a 2.2% pace increase in the annual allowance reductions. Additionally, more emphasis is placed on Promoting innovation and investment in the industry and power sectors.
[80] European Commission, "Climate change – updating the EU emissions trading system (ETS)", online: *EC* (Link).

4.3.4 Relevance of the Mechanism for the Earth Orbital Environment

Initiatives to reduce GHG emissions at the global level could serve as an inspiration to discuss and tackle the congestion of orbital environment(s).

In order to limit the impact generated by the overuse of the natural environment, scientific research conducted by the IPCC prompted political action and the establishment of an organisation, which aims to stabilise "*greenhouse gas concentrations in the atmosphere at the level that would prevent dangerous anthropogenic interference with the climate system*".[81] The work of the IPCC and the UNFCCC, which now underpins climate policies worldwide, established a 1.5°C threshold-based model. This target was then integrated into the Paris Agreement as a non-legally binding objective for all parties. Similarly, any threshold-based approaches relevant to the Earth orbital environment are based on defining full environmental capacity (currently) available for consumption by all global space actors and is defined as the maximum threshold that still leads to the long-term sustainability of the Earth orbital environment.

In addition, in climate frameworks, annual carbon budgets, the upper limit of GHG emissions that still enables to remain below the threshold of 1.5°C, could also serve as an inspiration to calculate the maximum number of orbital usage within a specific period to sustain a safe and viable orbital environment.

While the world is not on track to meet the 1.5°C target, it should be noted that the work of the IPCC provided unprecedented information to policymakers and the civil society on the origins of climate change as well as the current and future state of global warming. Over the past decades, climate models developed and used by the IPCC have become increasingly more precise and accurate. This could serve as an example to gather support, build consensus, and further improve the calculations relevant to the capacity of the Earth orbital environment. While initiatives undertaken to tackle climate change are not perfect, and are often criticized for not delivering on the declared ambitions, they are relevant examples of efforts in the Earth orbital environment, to better understand how to integrate scientific concepts into policy and governance frameworks.

Beyond the analysed mechanisms used to mitigate GHG emissions, scientists have also developed threshold-based metrics that capture wider considerations, and consider the entire ecological footprint of a nation, including environmental pollution, the use of natural resources, and the demand for resources and services. Scientists initiated the Earth Overshoot Day, the day on which the world's resources for the year exceed the Earth capacity to regenerate these resources. If a nation operates on an ecological deficit, it can lead to irreversible effects on the environment. Similarly, threshold-based models would rely on the foundation that the Earth orbital environment is limited, and its overuse could lead to irreversible effects on the orbital environment such as the Kessler Syndrome.

4.4 Fisheries Management and Conservation

A number of agreements, conventions, international organisations, and regulatory bodies are in place for the management of worldwide and regional fishing activities. For years, authorities have been attempting to regulate (over)fishing with a variety of instruments in order to conserve stocks.

These instruments include fishing quotas, limits on the number of fishing days, and restrictions on the engine power of fishing vessels.

[81] United Nations Conference on Environment and Development (UNCED), *supra* note 56.

4.4.1 International Regulatory Aspects for Fisheries Activities

Generally, several international conventions and agreements regulate the rights of States to authorise their nationals to engage in fishing activities:

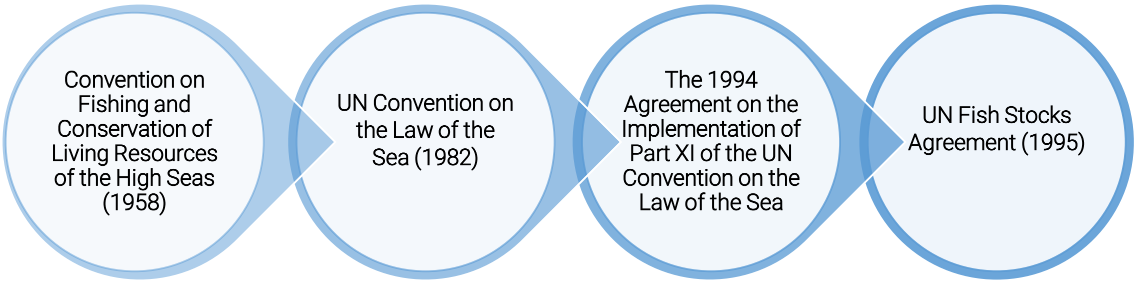

Figure 12: Selected list of Conventions and Agreements on the conservation of living resources

The conservation of living resources and fisheries on the high seas has been initially regulated through the Convention on Fishing and Conservation of Living Resources of the High Seas, established in 1958 as a result of the Conference on the Law of the Sea (UNCLOS I) where four treaties on the law of the sea were concluded.

Under this Convention, all states have the right to fish on the high seas provided they comply with the terms of the convention, and in particular, they take national measures and cooperate with other states to help conserve the living resources of the high seas and establish regional fisheries organizations to this end.

United Nations Convention on the Law of the Sea (UNCLOS)

The four treaties concluded as a result of UNCLOS I were replaced by a single UN Convention on the Law of the Sea (UNCLOS): an international agreement resulted from the third UN Conference on the Law of the Sea (UNCLOS III), which took place between 1973 and 1982, and came into force in 1994, a year after Guyana became the 60th state to ratify the treaty.[82] The sections relating to fisheries are generally accepted by States that are not Parties as customary international law.[83]

The UN Secretariat has no direct operational role in the implementation of the Convention, while bodies established by the Convention itself that play a role in the implementation are: The International Maritime Organization (UN specialized Agency, IMO), the International Whaling Commission, and the International Seabed Authority (ISA).[84]

The Convention splits marine areas into five main zones, each with a different legal status: Internal Waters, Territorial Sea, Contiguous Zone, Exclusive Economic Zone (EEZ), and the High Seas.

Relevant provisions of UNCLOS regarding the high seas include:[85]

- Both coastal and land-locked States enjoy the Freedom of the high seas, including the freedom of navigation, overflight, laying submarine cables and pipelines, and fishing (article 87, section 1 of Part

[82] UN - Division for ocean affairs and the law of the sea, "The United Nations Convention on the Law of the Sea (A historical perspective)", online: UN (Link).
[83] Stefán Ásmundsson, "Freedom of Fishing on the High Seas, and the Relevance of Regional Fisheries Management Organisations (RFMOs)" in *Challenges of the Changing Arctic* (Brill Nijhoff, 2016) 509.
[84] Through the work of IMO, several international conventions add up to the UNCLOS legislation: International convention for the safety of life at sea (SOLAS), International regulations for Preventing Collisions at Sea (COLREG), International convention for the Prevention of Pollution from Ships (MARPOL), International convention on maritime Search and Rescue (SAR).
[85] *United Nations Convention on the Law of the Sea*, 1982 (Link).

VII of UNCLOS). The freedom of fishing is limited by the conditions laid down in section 2 (Articles 116-120). These freedoms must be exercised in line with due regard for the interests of other States in their exercise of the freedom of the high seas, and also with due regard for the rights under the Convention.

- Duty of States to adopt with respect to their nationals, measures for the conservation of the living resources of the high seas (Article 117)
- Duty of the state is to cooperate in the conservation and management of living resources in the areas of high seas and in developing appropriate management measures where nationals exploit similar resources or different resources in the same area. Efforts to reach a management agreement should be done through the establishment of appropriate subregional or regional organizations (Article 118).

In determining the allowable catch and establishing other conservation measures for the living resources on the high seas, States shall take measures to maintain or restore populations of harvested species at levels that can produce the maximum sustainable yield (MSY), taking into account the interdependence of stocks (Article 119).

States are thus asked to engage in global, regional, and sub-regional cooperation in the management and conservation of fisheries on the high seas (where appropriate).[86]

Even in EEZs, where the coastal state retains exclusive sovereignty over exploring, exploiting, and conserving natural resources, countries are still imposed with some obligations. In particular, Article 61 of UNCLOS (*Conservation of the Living Resources*), paragraphs 1, 2, and 3 establishes that the coastal State shall:

- Determine the allowable catch of the living resources in its EEZ;
- Ensure through proper conservation and management measures that the maintenance of the living resources in the EEZ is not endangered by over-exploitation.

The coastal State and competent international organizations (subregional, regional, or global) shall cooperate as appropriate to this end. Furthermore, such measures shall be designed to maintain or restore populations of harvested species at levels that can produce the maximum sustainable yield (MSY), considering the interdependence of stocks and any generally recommended international minimum standards, whether subregional, regional, or global.

United Nations Fish Stock Agreement (UNFSA)

Provisions of UNCLOS relating to the long-term conservation and sustainable management of fish stocks have (*i.a.*) been implemented through the UN Straddling Fish Stocks and Highly Migratory Fish Stocks Agreement (UNFSA), adopted in 1995.[87] The agreement provides a framework (setting out concrete principles) for the management of fish stocks in regions that span wide areas and are of economic and environmental concern (especially vulnerable to overexploitation of those resources) to several states.

UNFSA strengthened the regional mandate by providing that fisheries for straddling and highly migratory fish stocks should be managed through regional and sub-regional organizations. The regulation of fishing and its implementation is mostly conducted by Regional Management Organizations or Arrangements (RFMO/As) or left to the discretion of individual flag States (as in the case of the Arctic, Central, and Southwest Atlantic).

[86] FAO Fisheries and Aquaculture, "Regional fisheries management organizations and deep-sea fisheries", online: *FAO* (Link).
[87] United Nations Conference on Straddling Fish Stocks and Highly Migratory Fish Stocks, *Agreement for the Implementation of the Provisions of the United Nations Convention on the Law of the Sea of 10 December 1982 relating to the Conservation and Management of Straddling Fish Stocks and Highly Migratory Fish Stocks* (1995).

UNSFA establishes the rule that, when a RFMO has competences, conservation and management measures established by the RFMO are relevant for all States, not only the members of the relevant RFMO (Article 8). As a consequence, States that intend to authorise fishing shall become members of the RFMO or agree to apply the measures the RFMO establishes.

Finally, the UN Food and Agriculture Organization (FAO) Conference focused on that matter, and:

- Approved the Agreement to promote Compliance with International Conservation and Management Measures by Fishing Vessels on the High Seas in 1993 (The Compliance Agreement, entered into force in 2003)[88]
- Adopted the 1995 FAO Code of Conduct for Responsible Fisheries[89]

4.4.2 Regional Fisheries Management Organizations and Regional Fisheries Bodies

Fisheries on international high seas are mostly regulated regionally by regional organizations, as well as their Member States. There are currently around 30 regional fisheries bodies worldwide. Some examples of RFMOs and RFBs are the General Fisheries Commission for the Mediterranean (GFCM), the International Commission for the Conservation of Atlantic Tunas (ICCAT), and the Northwest Atlantic Fisheries Organization (NAFO).

Fisheries bodies can have different levels of authority:

- Regional Fisheries Bodies (RFBs), which have limited authority, only provide advice to Member States.
- Regional Fisheries Management Organisations (RFMOs), which are intergovernmental fisheries organizations or arrangements that have the authority and the technical capacity to:
  - Assess the status of fish stocks of commercial value within their area of jurisdiction,
  - Establish fisheries conservation and management measures on the high seas,
  - Set limits on catch quantities and the number of vessels allowed to fish,
  - Conduct inspections and/or regulate the types of gear that can be used.

RFMOs are central to the implementation of the FSA, playing a critical role in the global system of fisheries governance and primary way of achieving cooperation between and among states.

However, most RFMOs only regulate the fishing of particular species, while only five have the legal competence to regulate bottom trawl fishing and of these, only one, the Commission for the Conservation of Antarctic Marine Living Resources (CCAMLR), has taken steps to protect the marine biodiversity of the seabed from the impact of fishing.

Advisory councils may contribute, in close cooperation with scientists, to the collection, supply, and analysis of data necessary for the development of conservation measures.

The European countries are jointly represented at RFMOs by the European Commission. EU plays an active role in 5 tuna-RFMOs and 11 non-tuna RFMOs. This makes the EU one of the most prominent actors in RFMOs worldwide.

[88] Food and Agriculture Organization of the United Nations, "Agreement to Promote Compliance with International Conservation and Management Measures by Fishing Vessels on the High Seas", (24 November 1993).
[89] Food and Agriculture Organization of the United Nations, "Code of Conduct for Responsible Fisheries", online: *FAO* (Link).

Total Allowable Catch (TAC) and Fishing Quotas

Regulators set species-specific Total Allowable Catch (TAC), an upper limit on the amount of fish that can be caught, typically by weight (expressed in tonnes or other numerical units) within a given period. A dedicated portion of the total catch is allocated to fisheries, by countries or regional bodies.

Subsequently, many governments and regional bodies regulate fishing by means of quota-based management systems where the TAC can be divided in exclusive catch shares (quotas). Those quotas are allocated to fishers or individual entities, which are held accountable for their share of the catch.

Those individually-allocated fishing rights programs have been developed under different names, especially referencing the transferability of the rights or the holding subject:

- Individual Transferable Quotas (ITQs), allocate shares to fishers or individual entities and allow shares to be transferred.
- Individual fishing Quotas (IFQs), allocate shares to fishers or individual entities and do not allow shares to be transferred.
- Individual Vessel Quotas (IVQs) allocate shares to individual vessels (with or without the right of transferability).

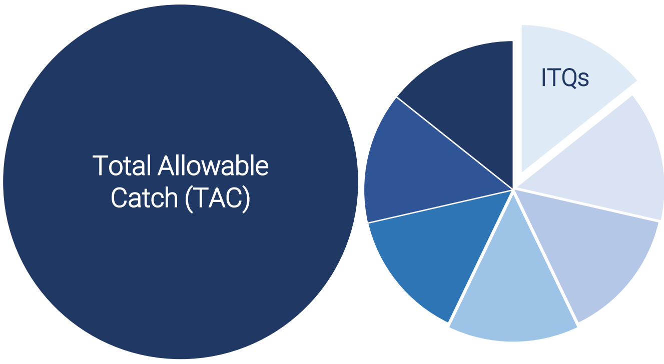

Figure 13: Total Allowable Catch and quotas

TACs and fishing quotas are set through several stages and usually based on scientific recommendations and advice on the stock status based on fishery-biological studies that are provided by advisory bodies on a regular basis.

For example, the International Council for the Exploration of the Sea (ICES), is an intergovernmental body (marine science organization) that provides scientific advice for sustainable management of fisheries and marine resources, mainly in the North Atlantic. Through strategic partnerships, ICES's work in the Atlantic also extends into the Arctic, the Mediterranean, the Black Sea, and the North Pacific Ocean.

ICES defines its interpretation of Maximum Sustainable Yield (MSY) as "maximizing the average long-term yield from a given fish stock while maintaining the stock as productive".[90]

Tradable Permit System in Fisheries Management

Countries distribute their quotas among fishers and entities using different systems, but the majority of ITQs are typically initially allocated as grants/auctions. Once the public institutions allocate the quotas, those can usually be traded freely with other fishers (or entities). Fishery companies can buy, and sell quotas to/from other companies; a feature called transferability.

All the quotas are owned by existing companies and some fishers, e.g., new entrants that haven't been in the industry for generations must thus buy them from holders. ITQs also lead to quota leasing, whereby holders lend their quotas to companies in exchange for quota lease fees – leading to some criticism that permits have become more valuable than fishing itself.

In some cases, countries might have a more active role by setting duration periods on quotas. Therefore, at the end of the period, the quota reverts to the government so that quotas can be re-granted/re-

[90] ICES, "Advice on fishing opportunities" (2021), online: ICES (Link).

auctioned periodically or held in perpetuity. This allows the state to keep a hand on this original resource - the relevant fishery.[91]

When the quota for one species is exhausted, the country must close the fishery for that species.

4.4.3 EU Common Fishery Policy (CFP)

The EU plays a key role in terms of European participation in international fisheries cooperation, in particular through the external dimension of its Common Fisheries Policy (CFP). The EU CFP aims to safeguard the circumstance of its legal framework extending beyond EU vessels operating in international waters. On the basis of the CFP's objectives and good governance principles, the EU engages in numerous multilateral agreements and regional fisheries management organisations (RFMOs), as well as 30 bilateral fisheries agreements.[92]

The primary goal of the CFP, as revised in 2002, is to ensure sustainable fisheries and guarantee incomes and stable jobs for fishers. The 2013 agreed CFP pursues long-term environmental, economic, and social sustainability of fishing and aquaculture activities.

The CFP is a formally enshrined fisheries conservation policy and is decided by qualified majority voting. It remains a "shared competence" of the EU and its member states. The EU CFP sets quotas for individual member states, defining the allowed catch based on different species and types of fish.

EU Fishing Quotas

The EU fishing quotas are implemented in the frame of Total allowable catches (TACs). TACs are usually translated into quota shares, which are then allocated to fishers and entities under Individual quotas (IFQs). TACs are set annually for most fish stocks (every 2 years for deep-sea stocks), following the rules of the common fisheries policy to achieve sustainable fisheries. The negotiations aim to set catch limits, access arrangements, and other conservation and management measures.[93]

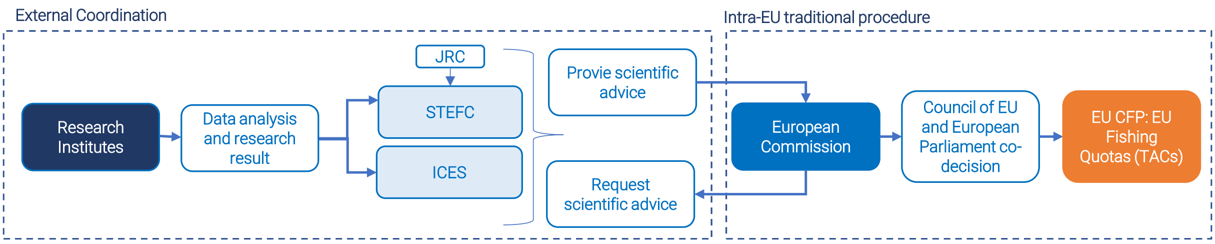

Figure 14: EU Common Fishery Policy and setting of Fisheries Quota (TACs)

When proposing new rules and regulations for fisheries or reviewing existing ones, the EC seeks scientific advice from several scientific bodies.

The basis for the work of these bodies is the data collected by EU Member States under the data collection framework (DCF). TACs and fishing quotas are based on scientific recommendations and advice provided by two main advisory bodies:

- The International Council for the Exploration of the Sea (ICES)
- The Scientific, Technical and Economic Committee for Fisheries (STECF)

[91] Griffin Carpenter, "The accidental privatisation of marine life", online: *New Economics Foundation* (Link).

[92] A CFP was first formulated in the Treaty of Rome. Initially linked to the common agricultural policy, and has gradually become more independent.

[93] SPICe, "How are fishing quotas set? Stage 2: coastal State negotiations", (6 December 2018), online: *SPICe Spotlight* (Link).

STECF is a group of experts, appointed by the Commission for three years, who provide scientific advice on fisheries management. The Commission's Joint Research Centre (JRC) supports the STEFC's scientific work and the implementation of the data collection framework.

Short-term needs for additional knowledge can be addressed through the Commission-funded scientific advice studies (through calls for tenders and calls for proposals). Long-term research projects relevant to fisheries management receive support under EU research framework programmes.

More broadly, TACs are also agreed with non-EU countries for stocks that are shared and jointly managed.

Stocks and fisheries (including TACs and quotas) are mostly managed by means of Multiannual plans (MAPs), which contain goals for fish stock management, helping to ensure the *sustainable exploitation of* those resources. Some plans contain a detailed and tailor-made roadmap for achieving objectives (e.g., MSY), include fishing effort restrictions, and contain specific control rules and technical measures. Following the adoption of EU Fisheries quotas, TACs are then shared between EU countries in the form of national quotas.

Member states can exchange, trade, or transfer quotas, but remain responsible in terms of compliance to CFP and the catch limits (TACs). They must use transparent and objective criteria when distributing national quotas among fishers and are responsible for ensuring that the quotas are not exceeded. When a country's available quota for a species is exhausted, it must temporarily close the fishery.[94]

4.4.4 Relevance of the Mechanism for the Earth Orbital Environment

Several aspects embedded in the international regulation of fisheries and the conservation of (living) resources of the high seas can inform discussions surrounding the Earth orbital environment, and potential frameworks for its exploitation. Differences between physical realities of the high seas and outer space are of course obvious and regulatory parallels between the two environments should be considered with caution as "*mechanical transfer of institutions between different environments cannot serve any useful purpose*" but analogy nevertheless remains a useful tool in paving the way for new rules, keeping in mind the maxim *Ubi Eadem Ratio, Ibi Idem Jus* (Where there is the same reason, there is the same law).[95]

Moreover, the clear ratio behind the regulation of international fisheries is designed with the economic principle, that "*when the safe yield is surpassed, the resource faces probabilistic destruction*" in mind.[96] Considering the Outer Space Treaty instructs States to explore and use space in the interest of all countries and whereby its exploration and use are considered to be the province of all (hu)mankind, the efforts towards the environmental conservation and long-term viability of operations should be at least as strong as in the case of the high seas.

Moreover, a clear distinction between the regime of international fisheries and the discussions related to the Earth orbital environment is the lack of living resources (and thus the absent question of species conservation) that can be eternally exhausted when overexploited. However, with prospects of the Kessler syndrome in certain regions of the Earth orbital environment, one cannot overlook the assessment that "*at high enough levels of economic activity, the resource is destroyed with certainty*".[97]

---

[94] European Commission, "Fishing quotas - EU rules on catch limits and quotas", online: EC (Link).
[95] "The International Law of Outer Space" Manfred Lachs, The Hague (1964) at 21; Philip De Man, *Exclusive Use in an Inclusive Environment: The Meaning of the Non-Appropriation Principle for Space Resource Exploitation* (Springer, 2016); Herbert Broom, *A Selection of Legal Maxims* (London, 1939)
[96] Walker & Gardner, "Probabilistic Destruction of Common-pool Resources", *supra* note 39 at 1149.
[97] *Ibid.*

Of course, certain aspects regarding implementation are clearly different in comparison to the high seas, as regional bodies (if considered) could for instance not be sustained under the same geographic rationale as is the case in the management of fisheries.

Perhaps most importantly, the question and lessons learnt of setting quotas and total allowable catch benchmarks are to be taken into account when discussing any thresholds in the Earth orbital environment. The nondeterministic nature, flexibility, and scientific assessments of global and regional fish stock fostering negotiations on quotas and allowable catch can inform policymakers for any threshold-based frameworks where a trade-off between conservation of the resource and short-term economic benefit from its exploitation is to be taken into account.

5 Threshold-Based Model for a Safe and Sustainable Orbital Environments

As seen in the previous chapter, international efforts for various resources and domains of common concern present a standard approach when such resources are at threat of being overexploited, operations at risk of being unsustainable or where interference might prevent efficient exploitation of the resource.

As the Earth orbital environment is getting increasingly congested, concerns about its long-term sustainability, potential overexploitation, and risk of interference are becoming increasingly clear and shared among policymakers, industry leaders, and academia (see Chapter 3). As noted by recognized US economist Mançur Olson in his influential work, The Logic of Collective Action: Public Goods and the Theory of Groups, "*unless the number of individuals is quite small, or unless there is coercion or some other special device to make individuals act in their common interest, rational, self-interested individuals will not act to achieve their common or group interests*."[98] During the 2021 Session of the UN COPUOS STSC, the delegation of The Netherlands, when discussing the issue of equitable access of the developing member states to GEO noted that: "*GEO orbit has become highly saturated … getting access to space is not limited to GEO. Therefore, our delegation believes that regarding this agenda item, we should consider, at future meetings, to broaden the scope of this agenda item from GEO to LEO, MEO, and other orbits*."[99]

These calls are in line with the first design principle of Sustainable Community-Governed Commons as defined by Ostrom: "*Defining the boundaries of the CPR and of those authorized to use it*".[100]

Moreover, developing metric-based frameworks can also be read in compliance with Paragraph 16 of the LTS Guidelines that compel States and international intergovernmental organizations to "*take measures, through their own national or other applicable mechanisms, to ensure that the guidelines are implemented to the greatest extent feasible and practicable*".

5.1 A metric-based approach: The Space Environment Capacity Concept

As suggested by Harold James, Professor of History and International Affairs at Princeton University, data-driven metrics are the "secret sauce" to successful multilateral mechanisms, thereby "*unless phenomena can be mastered through calculation, they will remain abstractions, fuelling nervousness and recrimination*.", global issues will continue to be dragged into a blame-game spiral.[101] Moreover, economic literature shows that there is "*no cause for optimism with regard to the survival of common-pool resources in environments where no institutions exist to foster cooperative behaviour*."[102]

The Space Environment Capacity Concept has been developed with an ambition to create a metric-based, flexible, and transparent foundation within a wider policy discussion of regulating the Earth's orbital environment, a global common where tensions are increasingly rising and better regulation is necessary.[103]

[98] Mancur Olson, *The Logic of Collective Action* (Harvard University Press, 1971) at 2
[99] Delegation of the Netherlands to UN COPUOS STSC, *Agenda Item 16 - Geostationary Orbit, Statement of The Netherlands* (UN COPUOS STSC, 2021).
[100] Elinor Ostrom, *Design principles and threats to sustainable organizations that manage commons* (1999) at 1.
[101] Harold James, "Multilateralism's Secret Sauce | by Harold James", (3 December 2021), online: *Project Syndicate (Link)*.
[102] Walker & Gardner, "Probabilistic Destruction of Common-pool Resources", *supra* note 39 at 1159.
[103] "Elon Musk criticised after China space complaint to UN", *BBC News* (28 December 2021), online: (Link); note 13.

5.1.1 Overview of the Concept

Some orbital paths can be considered as chokepoints or areas of interest for some operators, as also recognized by the concept of protected regions conceived by the IADC guidelines as these orbits are on the way toward being over-exploited. The Space Environment Capacity Concept relies on the foundation that orbital environments are a limited natural resource and aims to provide an indication of the share of this resource used by space missions and objects in the defined orbital region.

This Policy-tailored overview below has to be read in parallel to the technical and applied papers developed and published by staff of the ESA Space Debris Office, providing the theoretical background and the calculations for the concept, namely:

- Assessment of environmental capacity thresholds through long-term simulations (2021)[104]
- Evaluation of the debris environment impact of the ESA fleet (2021)[105]
- Environment capacity as an early mission design driver (2020)[106]
- Space Traffic Management Through Environment Capacity (2020)[107]
- Application of a debris index for global evaluation of mitigation strategies (2019)[108]

The calculation of the share of the resource used is based on three interrelated levels of operations:

1. Calculation of the current total capacity within the environment (Available Capacity: divided into filled capacity and unfilled capacity);
2. The calculation of the impact of a specific mission on the environment (Capacity Index);
3. The calculation of the impact of all existing missions and objects in orbit on the environment (translated to Filled capacity).

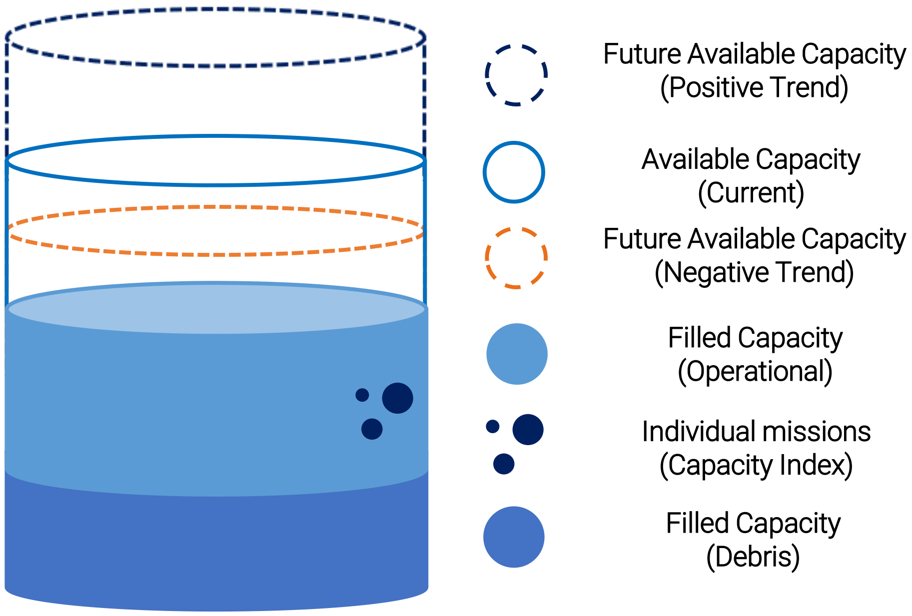

Figure 15: Simplified visual overview of the Space Environment Capacity Concept

[104] Francesca Letizia, Benjamin Bastida Virgili, & Stijn Lemmens, *Assessment of environmental capacity thresholds through long-term simulations* (2021).
[105] Francesca Letizia & Stijn Lemmens, *Evaluation of the debris environment impact of the ESA fleet* (2021).
[106] Francesca Letizia, Stijn Lemmens & Holger Krag, "Environment capacity as an early mission design driver" (2020) 173 Acta Astronautica 320–332.
[107] Stijn Lemmens & Fracesca Letizia, *Space Traffic Management Through Environment Capacity* (2020).
[108] Francesca Letizia et al, "Application of a debris index for global evaluation of mitigation strategies" (2019) 161 Acta Astronautica 3.

The Capacity index or the Environmental Consequences of Orbital Breakups (ECOB) index, is a method to calculate the impact a mission has on the space environment capacity. It is calculated by multiplying

- Collision probability
- Collision effect (severity)
- Explosion probability
- Explosion effect

… leading to an objective metric comparable among all planned and operating missions.

The Available Capacity defines the full environment capacity currently available for consumption by all global space actors and is defined as the maximum threshold leading to long-term sustainability of the space environment. In other words, Available Capacity is the space capacity that can be safely used by operators without leading to irreversible consequences for the environment (e.g., the Kessler Syndrome).

Available capacity is flexible and dependent on environmental and technological developments, whereby:

- New debris generating events would lower the maximum available capacity as both the probability and severity of undesirable events would increase (See Figure 16 – Negative trend)
- New successful debris removal missions as well as improved SSA datasets and collision avoidance algorithms would increase the overall available capacity (See Figure 16– Positive trend).

The Filled capacity represents the share of the available capacity that is used by existing missions and space objects. It is a result of calculating the integral of the capacity index of all existing missions and orbiting debris and therefore:

- The filled capacity increases each time a new mission is launched in LEO and whenever a new collision, breakup, or explosion occurs;
- The filled capacity decreases whenever a space object is deorbited or properly (re)moved.

The Unfilled Capacity is the remainder of available capacity, before reaching the threshold from whereon long-term sustainability would be at risk; capacity that can be filled by new missions.

5.1.2 Objectives of the Concept

The Space Environment Capacity Concept is inherently interwoven with the wider policy domain tackling approaches to ensure the safety and sustainability of space activities, a topic that has been discussed in different international fora, most notably within UN COPUOS, for decades.

A part of these discussions is aimed at improving compliance with guidelines in view of ensuring safety and long-term sustainability and are reflected through the Capacity Concept through a set of initial assumptions in pursuit of its desired outcome:

- Orbits represent a common pool resource as they are universally accessible, not excludable and rival
- The impact of a space mission on orbital capacity can be quantified and put in context in relation to all existing missions and the destination orbital environment
- A space mission consumes capacity beyond its spatial dimensions

… the desired outcome of the Space Environment Capacity Concept is to serve as a tool that enables:

transparent, objective and flexible measurement of the space environment capacity, leading to a safe operational environment for all relevant actors and its long-term sustainability for future generations.

Due to the urgency in terms of the environment’s long-term sustainability, Low Earth Orbit stands out as most relevant for the Concept’s short-term applicability, however, the Concept can be applied to other orbital regimes.

5.2 Drivers & Challenges for Threshold-based Models in the Earth Orbital Environment

In order to scrutinize the Concept, and to identify potential drivers, challenges, limits, and future perspectives, the Research team, based on the undertaken preliminary analysis, undertook an open-ended consultation campaign with 18 experts, representing 11 different international actors.

Through these interviews, the research team gathered various perspectives on a threshold-based approach and the Space Environment Capacity Concept itself, roughly divided into four pillars:

- General comments following the presentation of the Concept;
- Identified Blocking Points for further development and endorsement of the Concept;
- Identified Drivers for further development and endorsement of the Concept;
- The role of public actors in the further development and uptake of the Concept.

The outcomes of these consultations were analysed and translated into topics and questions for an interactive online workshop that gathered the views and opinions of 27 participants who voted on and discussed the implications and perspectives related to threshold-based models in the Earth orbital environment at large while taking note of the developments leading to the Space Environment Capacity Concept.

The five sessions of the workshop tackled:

- Adequacy of the Existing Framework;
- Relevance & Effectiveness of Threshold-based Models;
- Feasibility of a Threshold-based Model;
- Role of Public actors at Large;
- Future Evolution and Next Steps.

A synthesis and an analysis of the outcomes of the interview campaign, the interactive workshop, and internal reflections of the ESPI Research team are presented in the following sections.

An overview of the first session on the adequacy of the existing framework is presented in Section 3.4.

5.2.1 Relevance & Effectiveness of Threshold-based Models

Through interviews, the message outlined by a number of stakeholders was that the underlying theoretical model and calculations of both the capacity index as well as the available capacity would likely hinder the perspectives of the Concept if imposed and defined from the very beginning, especially in light of potential industrial, commercial, political, or national security interests.

However, most stakeholders agreed that the general idea of a metric-based threshold-based model is an interesting policy option that should be further pursued through a neutral and open-ended discussion, whereby the theoretical background of the Space Environment Capacity Concept would provide a basis for kickstarting discussions, elaborations, and negotiations.

Addressing the orbital environment from a physical and capacity perspective can help both public and private actors to materialize the issue of space debris, especially as public institutions (and the general public at large) are not necessarily aware of the scope of the issue. Developing accurate numbers on the capacity of orbital areas, including how crowded they are, what capacity is left, and how each mission affects the environment was considered highly relevant for both public and private actors.

This sentiment was further affirmed by the interactive workshop where the "value of defining maximum orbital capacities" was voted on and received a total score of 3.6 as presented in the below visualization:

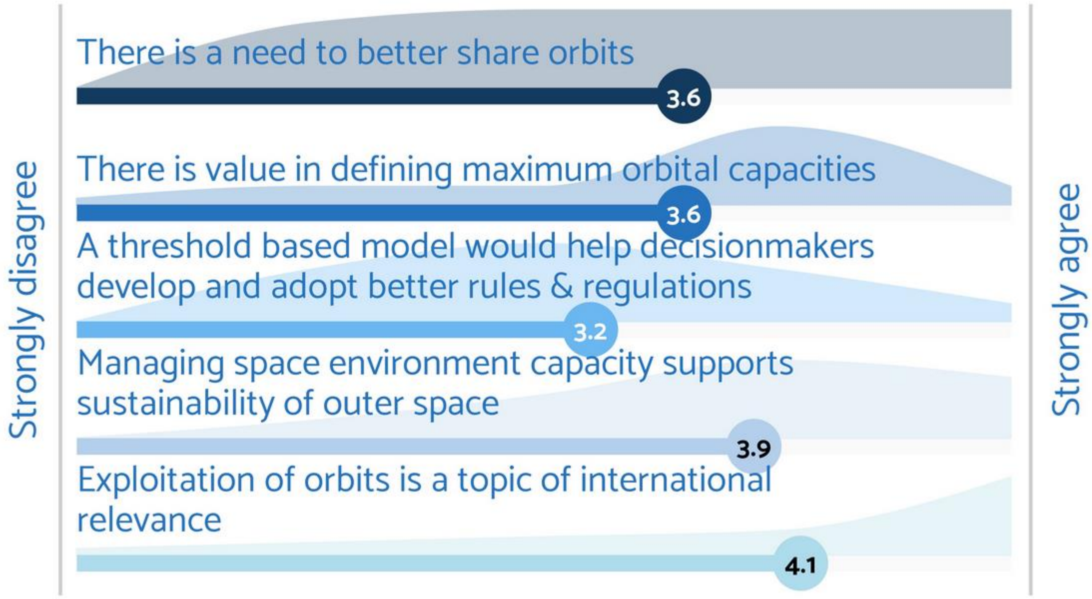

Figure 16: Relevance of threshold models for safe and sustainable orbital environments (aggregated score of 23 votes)

Moreover, the fact the statement that the "*exploitation of orbits is a topic of international relevance*" culminated in a score of 4.1/5, shows the broad recognition that conducting these discussions within international fora is the preferred way forward in discussions on exploiting orbits end ensuring their sustainability.

5.2.2 Feasibility of Threshold-based Models

As the relevance of threshold-based models for orbital environments was generally affirmed both through interviews as well as during the interactive workshop, the question has to move towards the feasibility of frameworks using such a concept. A number of challenges and drivers were identified through individual stakeholder interviews and internal brainstorming and finally tested during the interactive workshop.

Identified Challenges

In addition to the abovementioned challenge related to the mathematical model and calculations of both the capacity index as well as the available capacity (ranking as the second most relevant blocking point), additional challenges were identified throughout the study lifetime and were to a large extent confirmed by the experts attending the workshop as presented below (where 1 equal least and 5 equals most relevant).

Perhaps surprisingly, the complexity of managing such a framework and the compatibility with existing frameworks (e.g., the ITU frequency coordination) was considered the most relevant blocking point in the eyes of the workshop experts. This clearly indicates that if a threshold-based model is to be devised, it needs to be done through a participatory process, with functionality and clarity taking precedence over formalization, where all stakeholders understand the underlying mechanisms and rationales of the framework.

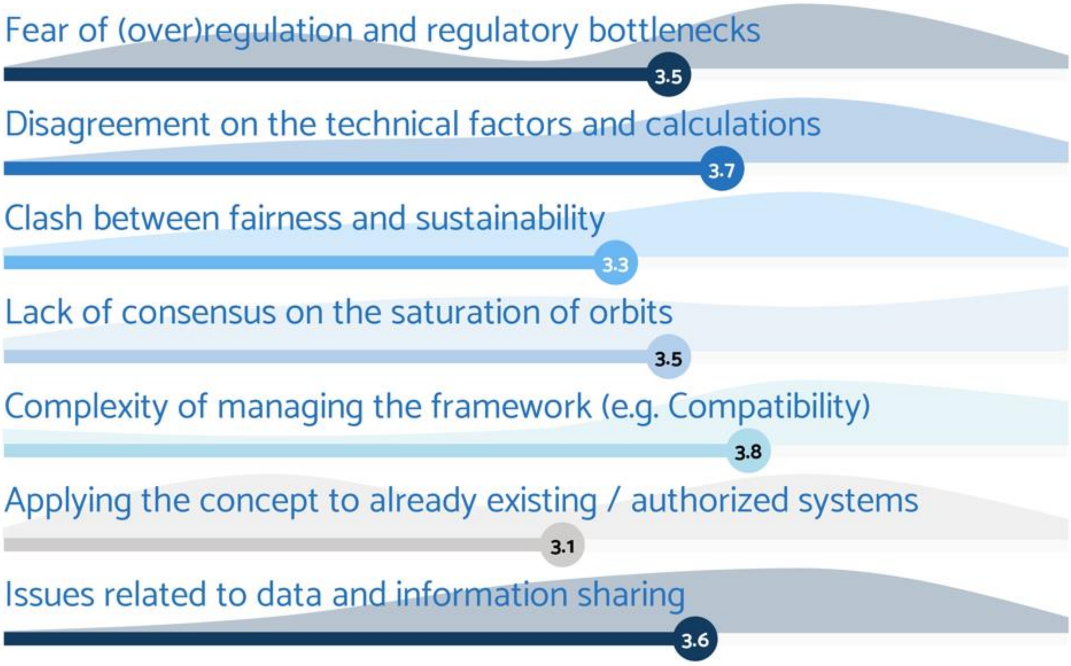

Figure 17: Relevance of identified blocking points (Aggregated score of 21 votes)

Noting the legitimate concern over complexity, one needs to nevertheless remember that e.g. the ITU faced (and continues to face) concerns over the "*complexity of the tasks to be performed by the Union*" with various attempts for structural reforms throughout its lifetime, reminding us that even less-than-perfect systems can provide immense value for international collaboration and should continuously improve.[109]

Applying the concept and framework to already existing and authorized systems (e.g., deployed and upcoming large constellations) was considered the lowest-scoring blocking point, which was in contrast to many of the statements made during the interviews. Interesting to note that votes leading to this aggregate were almost equally divided between two poles and were not distributed linearly as for most other identified blocking points.

Participants seemed to believe the lack of consensus on the saturation of orbits is a legitimate concern that any sort of a threshold-based framework could encounter, and despite not ranking the highest, it is somewhat counterintuitive considering the high concern among the participants themselves when asked whether they are concerned about the saturation of orbits (see below).

Upon further reflection and discussions, the result seems to be influenced by earlier discussions on the disagreement over mathematical models and calculations, as the question was not understood as the oversaturation of orbits *per se*, but rather as the (exact) level of their saturation.

Moreover, during the interviews, an often-cited concern was the potential rigidity with regard to an initially defined "Available" or "Full" capacity within threshold models. However, the Space Environment Capacity Concept, as an example of a threshold-based approach in the Earth orbital environment, includes **flexibility by design** as "Available Capacity" is based on long-term environmental and technological trends thus embedding another identified principle for managing a common "*individuals affected by operational rules can participate in modifying operational rules*".[110]

[109] ITU, *Final Acts of the Plenipotentiary Conference (Nice, 1989)* (ITU, 1989).
[110] Ostrom, *supra* note 100 at 2.

Figure 18: Level of concern about the saturation of orbits (Aggregated score of 20 votes)

Nevertheless, as pointed out by one of the participants, irrespective of the technical blocking points, political will ultimately holds the most weight. With enough political will at the highest level of international politics, a consensus on the technical issues could be achieved much sooner. This is in line with conclusions developed among various common pool resource experts, whereby institutional change occurs when relevant political actors perceive gains from such change.[111]

Identified Drivers

Following the discussion and elaboration on the blocking points, the attention, therefore, turned to drivers which could either spark or in some instances further catalyse political will towards considering a threshold-based framework inspired by the Space Environment Capacity concept.

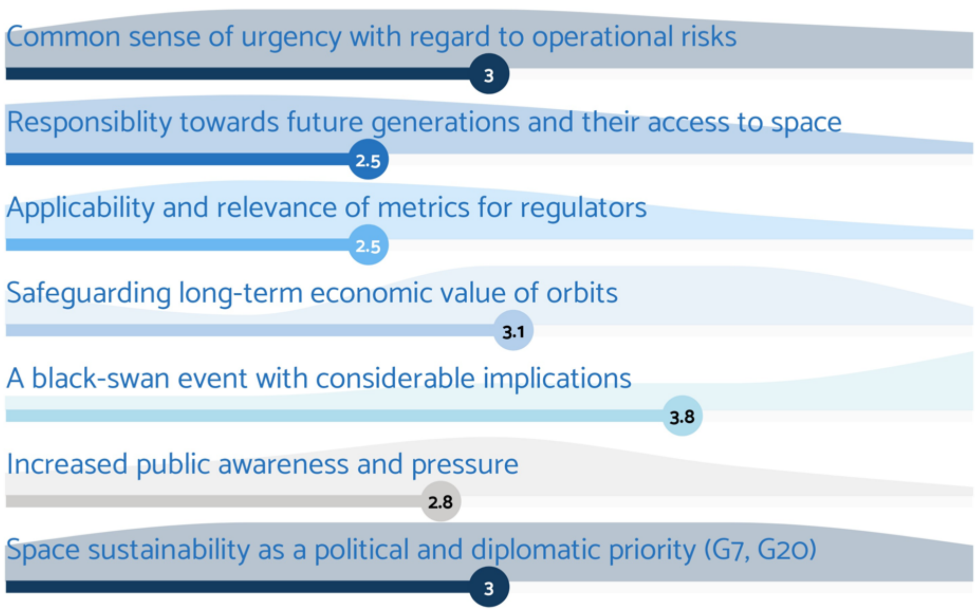

Figure 19: Relevance of identified drivers (Aggregated score of 21 votes)

As clearly demonstrated, the relevance of drivers is considered of lesser weight compared to the identified blocking points across the board – nevertheless none of the drivers ranked in the lower half of relevance, with the two lowest-scoring drivers receiving an aggregated score of 2.5 (whereby 1 equal least relevant and 5 equals most relevant). The fact that drivers score notably lower than blocking points can be, based on discussions during the interview campaign, be assigned to the bleak perspectives of multilateral

[111] Arun Agrawal, "Sustainable Governance of Common-Pool Resources: Context, Methods, and Politics" (2003) 20 Annu Rev Anthropol 243–62 at 3.

rulemaking in general, however, despite clear setbacks, there are nevertheless some signs that steady progress on that front is being made when resolute efforts are pursued.[112]

The potential of a black swan event with considerable implications (e.g., economic damages, threat to human life) was considered as the main event that could drive policymaking forward, with a score of 3.8 and as noted by one participant, a black swan event would also raise the relevance of other drivers, as it would e.g. inevitably raise public awareness and pressure on policymakers.

There was wide divergence on the importance of space sustainability becoming a political and diplomatic priority, a trend that can be identified in the recent past, perhaps most notably manifested through the G7 commitment to the safe and sustainable use of space in June 2021.[113]

Finally, the common sense of urgency regarding operational risk also saw a notable divergence in terms of the views held by the stakeholders attending the workshop and ultimately confirms that the challenges related to the mathematical model and calculations would indeed be prominent in the nascent stages of any threshold-based frameworks regarding orbital environments.

5.2.3 Role of Public Actors At Large

As the Space Environment Capacity concept was conceived and is, at its current stage, further developed by a team within the European Space Agency's Space Debris Office, the role of public actors, and space agencies, in particular, needs to be further explored.

Throughout the interviews, public actors were considered extremely important, however, the views on what this role might need to be were diverging, from soft approaches through incentives and promotion to strictly defined mechanisms whereby procurement would be conditioned on compliance and public actors would be considered regulators rather than champions or advocates of threshold-based approaches.

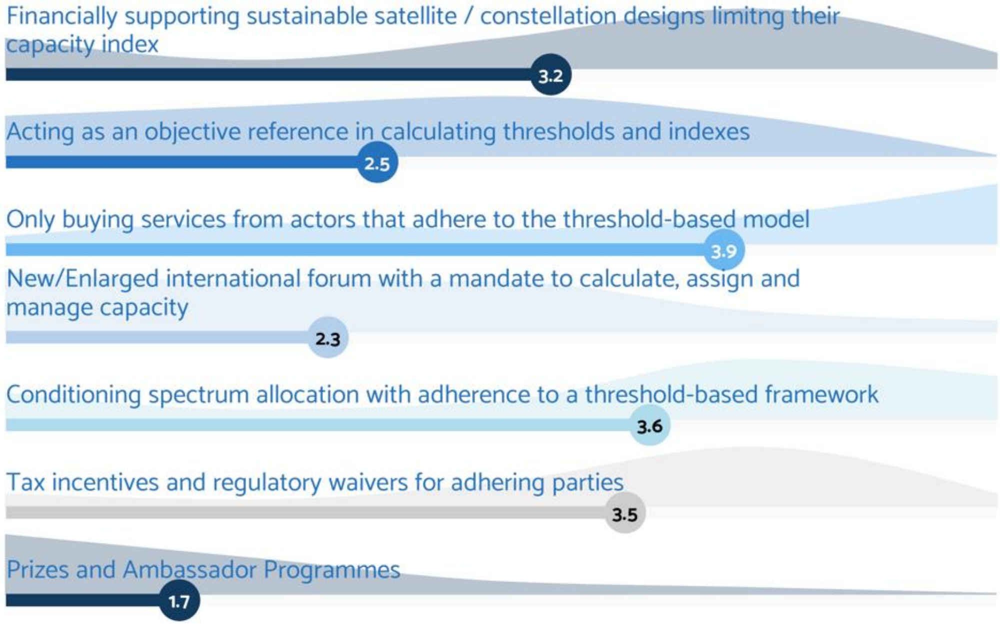

Figure 20: Relevance of potential public initiatives to successfully conceive and implement a threshold-based framework (Aggregated score of 19 votes)

[112] For additional information see: ESPI, "UN resolution on norms of responsible behaviours in space", online: *European Space Policy Institute* (Link) ; Theresa Hitchens, "Biden's space policy nominee backs ban on destructive ASAT testing, pushes norms", (13 January 2022), online: *Breaking Defense* (Link)
[113] note 20.

As clearly illustrated by the votes, the relevance of incentives or actions with a financial or economic component such as financial support for sustainable design practices, tax incentives, regulatory waivers, and tailored procurement mechanisms were considered most relevant.

Purely PR and social responsibility-based incentives such as prizes or ambassador programmes were on the opposite end of the spectrum ranking lowest in terms of relevance of public initiatives (while also being by far the lowest ranking option across all questions posed in the workshop).

During the open-ended discussion on the role of public actors, some held the view that it is in fact not private actors that should be incentivized, as they are highly aware of safety issues and are playing a major role in sustainability concerns, the goal should rather be a better level of state compliance with safety guidelines.

As another participant highlighted, "*an international regulation represents the best and only solution*" while another noted that combining the mission risk index with liability would indeed be an interesting option, which is also reflected by the high score received by the "regulatory waiver" option in the poll.

Moreover, the participants were also asked about their perception of potential developments driving sustainability in outer space along the dimensions of "impact" and "feasibility", which crystalized "Better SSA Capabilities, Data and Services" as the clear outlier considered both most impactful and most feasible by the workshop participants.

Figure 21: The grid represents the perceived Impact and Feasibility of developments driving sustainability in outer space (Aggregated score of 20 votes)

The identified high impact and feasibility of SSA-related developments are in line with design principles for organisations that manage commons as identified by Ostrom. The design principles consider "*Developing a system for monitoring members' behaviour*" and "*Monitors, who actively audit CPR conditions and user behaviour, are accountable to the users and/or are the users themselves*" as cornerstones to successfully managing commons.[114]

On the other hand, some stakeholders wonder whether better data and services will actually have an impact (or improve) the behaviour of actors in LEO and adherence to end of life measures, as current

[114] Ostrom, *supra* note 82; Jay Walljasper, "Elinor Ostrom's 8 Principles for Managing A Commons", online: *On the Commons (Link)*.

trends do not offer any promises of causality; perhaps in line with scepsis that larger quantities of data directly alleviate topical challenges or impact behaviour, increasingly discussed both in business and academic circles.[115]

The other end of the spectrum is not as clear - the least feasible option (An international legally binding regulation for space sustainability) is nevertheless considered the third most impactful while the least impactful is the fourth most feasible (Creation of an economically viable debris-removal economy).

The only other option clearly positioned in the upper half of the grid both in terms of feasibility and impact is increased funding for R&D and services aimed at space safety and sustainability.

5.2.4 Future Evolution and Next Steps

Following discussions on the role of public actors at large, the workshop moved on to the future evolution and next steps based on the premise that a threshold-based model is a desired overarching strategic direction. First a set of "inward-looking" options was tested, while the second set was aimed at external actions, public engagement, and diplomatic initiatives.

Among the set of proposed steps, actions, and potential policies, the option considered most relevant was the one where space agencies and operators would apply the concept to their own missions and make the calculations publicly accessible. An early example of such an initiative can already be seen in the 2021 paper "*Evaluation of the debris environment impact of the ESA fleet*" presented at the 8th European Conference on Space Debris.[116] Moreover, a credible entity publishing statistics and acting as a reference for all existing space objects would also be highly relevant in the eyes of the participants.

Figure 22: Relevance of potential actions that could further spur the development of a theoretical threshold-based framework (Aggregated score of 20 votes)

As illustrated above, increased funding for the development and uptake of technologies is also considered well in the upper half of the relevance scale and reflects the similar option in Figure 19, thereby confirming consistency of the votes and scales across individual polls.

[115] Byung-Chul Han, *Psychopolitics: Neoliberalism and New Technologies of Power* (Verso Books, 2017) at 68; Adam Votava, "Why is data science failing to solve the right problems?", (12 November 2020), (Link).
[116] Letizia & Lemmens, *supra* note 105.

In terms of externally-oriented actions and initiatives, their relevance (on average) scored substantially lower compared to the first set of potential steps and initiatives. By far the most relevant option to pursue according to the workshop participants is to promote the idea of threshold-based models through existing fora such as the IADC, UN COPUOS, IAF, and the IAA.

The option to promote a coalition of scientists, civil society, and think tanks that would jointly promote threshold-based frameworks was mentioned several times during the interviews but gathered less enthusiasm among workshop participants.

Figure 23: Relevance of potential actions that could further spur the development of a theoretical threshold-based framework (Aggregated score of 18 votes)

As many interviewees asked for a clarification with regard to the relationship between the Space Environment Capacity concept and the Space Sustainability Rating initiative, an option to combine various existing initiatives into an existing framework was offered, however, the response among the workshop participants was somewhat neutral. As noted by one participant, mapping all current activities, and clarifying their interplay would be highly relevant, however, consolidating them into a single initiative runs the risk to unite various opponents to its individual components.

The development of a single state or regional actor taking leadership and creating a network of bilateral international agreements was considered as least relevant among the participants but sparked a number of responses. One participant noted that even if this is the least relevant development it is probably the most likely outcome, mentioning SSA data-sharing agreements as an example of this approach.

Another participant complemented that bilateral framework building has its limits due to the clear opposition of certain countries and their diplomatic doctrine, against such initiatives, while it was also noted that the European Union generally prefers taking actions through a multilateral approach and diverging from it on this topic cannot be reasonably expected.

Another noted concern during the consultation campaign was that a bilateral approach creates a system of non-equal parties, whereby some countries would be opposed to such a clearly unilateral initiative by default.

6 Paving The Way For A Threshold-Based Approach To Space Safety and Sustainability

An analysis of the views and insights shared by stakeholders during the interview campaign and the interactive workshop leads to the conclusion that a threshold-based approach to space safety and sustainability is worth further developing, exploring, and refining, *(see Figure 16)* with the Space Environment Capacity concept acting as a relevant basis, although admittedly still at an early stage, in particular from a policy and diplomatic standpoint. Such developments would require further discussions, improvements, and participatory design processes.

Nevertheless, it must be highlighted that any effort for developing a threshold-based model in the Earth orbital environment is an ambitious, complex, and laborious journey facing a number of challenges along the way. Such effort will require the preparation and implementation of a suitable action plan involving practical initiatives and activities organised along two interwoven dimensions:

- Developing and fostering scientific & technical consensus on the technical relevance, feasibility, and theoretical foundations of threshold-based models (with the Space Environment Capacity Concept representing a manifestation of such a model) as a tool to measure the safety and sustainability of operations in outer space
- Translating the policy ambition behind threshold-based models aimed at space safety and sustainability into a political and diplomatic tool by engaging with policymakers and policy experts, promoting its relevance, advocating its adoption, and using it as a diplomatic asset.

As certain aspects of these two dimensions are interdependent, it needs to be understood that developments on the scientific and technical front represent enablers for political and diplomatic action which can provide further impetus and legitimacy in the public policy sphere, feeding into existing discussions on space debris and space traffic management.

Moreover, if ESA is to build on top of the work done on the Space Environment Capacity Concept, it must take the Agency's mandate into account when discussing the relevant roles, responsibilities, and steps to be taken in joint efforts toward ensuring a safe and sustainable operational environment.

6.1 Building International Scientific and Technical Consensus

Maturing relevant models & engaging with the international scientific community

It is widely recognized that rigorous scientific work needs to be at the heart of any relevant, legitimate, and trustworthy discussions on environmental thresholds and targets (*see Figure 16*). The consultations identified that the Space Environment Capacity Concept provides a solid foundation for further elaborating a threshold-based model with an ambition to identify possible limits to the Earth orbital environment.

Further engagement with experts working on complementary and converging topics, related to the oversaturation of the orbital environment and the relevance of threshold-based models is therefore crucial. These efforts can further improve the theoretical backbone and mathematical models, explore synergies with existing initiatives and also build their collective legitimacy (*see Figure 17*).

Namely, the two activities of paramount importance in that regard are:

- Defining Available Capacity, whereby the goal should be to jointly develop and define the available capacity threshold for the Earth orbital environment(s). Inspired by climate targets or TAC's, an agreed scientific metric should be identified as an appropriate baseline and the boundaries of the current environment and trends should be loosely defined to enable relevant policy-related activities.
- Discussions on Sustainable Capacity Budgets, whereby following a devised metric and the definition of currently available capacity, discussions on sustainable capacity budgets for the coming years and decades should be advanced, based on the existing environmental realities and projections. As increasingly improved SSA data, collision avoidance, and engineering advancements alter our understanding and risk-management of environmental realities, the budget would continuously adapt to reflect these changes.

Inspired by the IPCC model, which gradually gained relevance since its official creation in 1988, this engagement with the international scientific community could serve as a first step towards the establishment of an international scientific forum to study trends related to the Earth orbital environment and provide policymakers with regular scientific assessments on the environment, implications of current activities and potential future risks. Considering the IPCC's evolution, a similar scientific body could be jointly fostered or formally established by existing institutions, for example, the UNCOPUOS (or its Scientific and Technical Subcommittee), the ITU, and/or the IADC.

Enabling a Calculation Environment & Foster a Better Understanding of the Space Environment

Taking stock of ESA's own efforts in evaluating the debris environment impact of the ESA fleet, and the ongoing ESA-funded study to design software to assess the impact of a space mission on the space environment and its contribution to the overall capacity, through an open software platform, efforts must be made to assure buy-in from a wide array of stakeholders.[117]

A platform allowing all operators could provide environmental impact comparisons between spacecraft and constellation designs and build simulations, while also informing policymakers on the current state of play. Dedicated training courses (e.g., MOOCs) in collaboration with industry organizations and research institutions, would further promote the concept and train interested stakeholders in calculating the environmental impact of satellite fleets and individual satellites, creating a community of informed and competent stakeholders.

Despite early calculations and their underlying models perhaps facing criticism due to their uncertainty – one should be reminded that international frameworks on climate change have developed in parallel to constant improvements to statistical models and methodologies that continue to be redesigned and improved to this day.

Driving by Action: The Development of Threshold-based Approaches Through Agency Buy-In

Building upon ESA's existing calculations of the fleet's environmental impact (using the Space Environment Capacity Concept) and publicly communicating these calculations by the Agency's Executive would put the threshold-based approach under the spotlight (*see Figure 22*), and further bolster the Agency's image as a responsible space actor and a pioneer in efforts to ensure a safe and sustainable Earth orbital environment.

Moreover, as a space agency, ESA has a clear role in embedding such concepts across the programme it manages and fosters. In this context exploring opportunities within the framework of its PROTECT accelerator to sustain some of the activities identified herein would provide the accelerator with a valuable

[117] Camilla Colombo et al, *Design of a software to assess the impact of a space mission on the space environment* (2021).

policy dimension, providing narrative and showcasing urgency, to legitimize technological and capacity needs developed through the accelerator and driving design and R&D related priorities and decisions.[118]

Finally, in view of workshop participants (*see Figure 20*), using measurable references to the capacity of orbital environments and how each mission affects the environment as a factor in ESA's procurement processes, would offer the most incentive to the manufacturing industry and service providers to pursue increasingly sustainable design practices and align their operations with future threshold-based approaches.

6.2 Translating and Promoting the Concept as a Policy and Diplomatic Tool

Positioning the threshold-based approach on agendas of relevant international bodies

Consistent with the outcome of the interactive workshop where participants overwhelmingly held the opinion that the exploitation of orbits is a topic of international relevance, a wide participatory process is paramount to any hopes to define a widely accepted threshold-based model.

As such, a model can only be successful if general consciousness about the Earth orbital environment as a limited natural resource at risk can be developed. As suggested by the participants of the workshop (*see Figure 23*) sustained campaign of technical and scientific presentations of concepts pursuing and proposing threshold-based approaches must be positioned on agendas of relevant national, regional (APRSAF, AfSA), and international fora (UN COPUOS, IADC), focusing on:

- Promoting the notion of the Earth orbital environment as a limited natural resource (e.g., using the ESA Space Environment Report),
- Proposing a threshold-based model as a tool to measure sustainability of operations in the Earth orbital environment (building on top of the Space Environment Capacity concept).

It is widely held that the policy impact of scientific concepts requires effective science communication. Literature on science communication suggests that scientists often overestimate the scientific literacy of stakeholders outside the scientific community, in particular policymakers. In Europe, most civil servants and government officials have backgrounds in social sciences. In addition, scientists often target their peers when they present their research and rarely share their findings with the general public.[119]

In order to raise awareness about threshold-based approaches to the Earth orbital environment, the communication strategy needs to embrace these findings, employing narrative building, and storytelling, to sustain engaging discussions while communicating the underlying concerns and proposed solutions.

These engagements, despite being based on technical and scientific efforts, are central to any activities taken at policy level and serve as a litmus test for sustained diplomatic efforts as they would (i) both reveal positions and drivers and reservations that various stakeholders might have against such approaches, and (ii) enable to adapt the approach accordingly and address any identified shortcomings or concerns during the design process.

Mapping Diplomatic Positions & Ambition Related to Threshold-based Models for International Cooperation

Developing and fostering an internationally accepted metric for measuring space sustainability and defining orbital capacity will already require directed awareness-raising campaigns, and continuous

[118] European Space Agency, "Protection of space assets", online: *ESA Vision* <https://vision.esa.int/protection-of-space-assets/>.
[119] Pryce R Davis & Rosemary S Russ, "Dynamic framing in the communication of scientific research: Texts and interactions" (2015) 52:2 Journal of Research in Science Teaching 221–252; Adam Wellstead, Paul Cairney & Kathryn Oliver, "Reducing ambiguity to close the science-policy gap" (2018) 1:2 Policy Design and Practice 115–125; Rick Hartz & Jim Chappel, *Worlds Apart: How the Distance Between Science and Journalism Threatens America* (First Amendment Center, 1998).

discussions between a diverse set of international scientific, industry, and policymaking communities on its own. However, any efforts towards using such a metric for international coordination or management of activities in the Earth orbital environment will encounter further challenges and will require continuous diplomatic and political efforts at national and European levels.

A mapping exercise of diplomatic positions and ambitions related to potential threshold-based models can provide much-needed insights into the feasibility of pursuing efforts aiming to establish threshold-based concepts as the basis for coordination or management frameworks of activities in outer space The exercise should include and involve a wide spectrum of initiatives undertaken by relevant partners at Agency and Member State level, as well as through existing international fora (UN COPUOS, ITU, UNGA, G7, G20, IADC, APRSA, AfSA).

The exercise would provide value to interested Member States as an element toward a strategy-setting roadmap, defining the course of action to be taken should the threshold-based approach be identified as a relevant diplomatic priority.

Engagement with ESA Member States and the European Union

Furthermore, ESA could also explore options how its work on threshold-based models (notably the Space Environment Capacity Concept) supports existing efforts in the area of space sustainability, for example, (i) the upcoming German Space Strategy, focusing on sustainability and space debris, (ii) the Safety, Security and Sustainability of Outer Space (3SOS) public diplomacy initiative launched by the EEAS, (iii) a host of activities fostered by the United Kingdom to promote space sustainability or (iv) the development of the EU strategy for safe and sustainable use of space.[120]

As ESA is first and foremost a programme management agency, further diplomatic ambition aimed at establishing international mechanisms and frameworks, should be defined with full unanimity of the ESA Council and pursued in close cooperation with ESA Member States, passing the torch to policy actors whenever relevant and considered beyond the scope of ESA's mandate and the Agency's reach.

[120] SPD, Alliance 90/The Greens, FDP, *"Dare More Progress - Alliance for Freedom, Justice and Sustainability" - Coalition Agreement of the 24th Government of the Federal Republic of Germany* (2021) (Link); Jeff Foust, "EU agency starts space sustainability initiative", (15 September 2019), online: *SpaceNews* (Link); European Commission, "Space traffic management – development of an EU strategy for safe and sustainable use of space", online: *EC* (Link); UK Space Agency, "UN and UK sign agreement to promote space sustainability", (26 January 2021), online: *GOVUK* (Link); note 104.

Annex A – FCFS Mechanism for Space Services

Evolution of the FCFS Approach within the ITU and its Interplay with Equitable Access

Several ITU Conferences and other relevant international events have led to the current ITU Legal Framework, with an overview of the most significant developments related to it provided below.

Administrative Radio Conference (Geneva, 1959)

In 1959, the Participants in the Administrative Radio Conference have: [121]

- Revised Article 1 of the Radio Regulations (RR) to incorporate new definitions in response to the swift advances in radio engineering and the emergence of new radio services, namely the space service, the earth-space services, and the radio astronomy service,
- Decided to allocate within the Frequency Allocation Table, frequencies for space research purposes only (1% of the Frequency Allocation Table),
- Published recommendation 36 related to the Convening of an Extraordinary Administrative Radio Conference to allocate Frequency Bands for Space Radiocommunication Purposes (special WARC to deal with issues of space communications),
- Continued the practice of FCFS also in relation to space services,
- Recognized that an adequate number of frequencies for outer space had become an urgent task due to the rapid growth of activity in space (Resolution 5 and Resolution 7 recognised the interest of the ITU in space communications).

UNGA Resolution 1721 (XXI), 1961

In 1961, the UN General Assembly released Resolution 1721, which affirmed that:[122]

- "Communication by means of satellites should be available to the nations of the world as soon as practicable on a global and non-discriminatory basis",
- "The exploration and use of outer space should be for the betterment of mankind and to the benefit of all States irrespective of the stage of their economic or scientific development."

Extraordinary Administrative Radio Conference (EARC), 1963

In 1963, the Extraordinary Administrative Radio Conference, also known as World Space Radiocommunication Conference, was the first conference on space radiocommunications called by ITU. The Conference was attended by more than four hundred delegates from seventy ITU Member States. Member States, whereby the Conference:[123]

- Allocated more frequencies (both exclusive as well as shared) for space services and for radio astronomy, not only for scientific purposes but also for commercial use (15% of the Table of Frequency Allocations),
- Adopted notification and registration procedures for space services but continued the practice of the FCFS approach.

During the Conference, several developing countries, stressed the need to implement the provisions of UNGA Resolution 1721, and expressed the view that the old inequitable practice of FCFS should be

[121] ITU, "Radio Conferences", online: *History of the ITU Portal* (Link).
[122] UN General Assembly, *UNGA Resolution 1721 (XVI). International co-operation in the peaceful uses of outer space* (1961).
[123] ITU, *Final Acts of the extraordinary administrative radio conference to allocate frequency bands for space radiocommunication purposes* (1963).

replaced by prior planning so that all countries may have equitable access to the radio frequency spectrum. For instance:

- Cuba: "principles guaranteeing equitable participation by all countries in the space radiocommunication service have not been adopted",
- The Democratic and Popular Republic of Algeria Kuwait The United Arab Republic: "The effective implementation of the United Nations Resolution on the International Co-operation on the peaceful uses of outer space (Resolution No. 1721 (XVI)) must eventually be based on the establishment, by Members and Associate Members of the Union, of world-wide plans concerning all categories of space service which will provide for the equitable participation of all countries of the world in such service in the spirit of the above-mentioned Resolution".

As a consequence of several criticisms, the 1963 EARC adopted Recommendation 10A, which recognized that "All members of the ITU have an interest in and right to an equitable and rational use of frequency bands allocated to space communications" and recommended that "the utilization and exploitation of the frequency spectrum for space communications be subject to international agreements based on principles of justice and equity permitting the use and sharing of allocated frequency bands in the mutual interest of all nations".[124]

This Recommendation created a new trend, which had repercussions in the following WARCs.

World Administrative Radio Conference for Space Telecommunications (Geneva, 1971)

In 1971, the World Administrative Radio Conference for Space Telecommunications took place in Geneva, as envisioned in the 1959 ARC, whereby the Conference: [125]

- Reviewed Article 9A of RR (present Article 11 of RR), named "Notification and Recording in the Master International Frequency Register of Frequency Assignments to Stations in the Space and Radio Astronomy Services" and adopted a new procedure of advance publication and pre-notification co-ordination for space services.

As a result of the Conference, the practice of FCFS persisted, but several developing countries continued to express their concern regarding this practice. Criticism resulted in the adoption of two Resolutions (presently Resolution 2 and 507 of RR):

- Resolution Spa 2-1:
  - "All countries have equal rights in the use of both the radio frequencies allocated to various space radiocommunication services and the geostationary satellite orbit for these services",
  - "The registration with the ITU of the frequency assignments for space radiocommunication services and their use should not provide any permanent priority for any individual country or group of countries and should not create an obstacle to the establishment of space systems by other countries".
- Resolution Spa 2-2:
  - "Stations in the broadcasting-satellite service (BSS) shall be established and operated in accordance with agreements and associated plans adopted by World or Regional Administrative Conferences (WARC, RARC)".

[124] ITU, "Radio Conference on Space Communications: Rewarding Results" (1963) 30:12 Telecommunication Journal 366–368.
[125] ITU, "Radio Conferences - WARC-71", online: *History of the ITU Portal* (Link).

Plenipotentiary Conference (Spain, 1973)

During the Plenipotentiary Conference in 1973 discussion continued to be dominated by significant concerns of many developing countries, mainly regarding the FCFS practice. As a result, Member States added Article 33(2):[126]

> "In using frequency bands for space radio services Members shall bear in mind that radio frequencies and the GSO are limited natural resources, that they must be used efficiently and economically so that countries or groups of countries may have equitable access to both in conformity with the provisions of the RR according to their needs and the technical facilities at their disposal"

World Administrative Radio Conference (WARC, Geneva, 1977)

The 1977 WARC was a specialized world radio conference mainly organized to pursue the objective to develop a plan for BSS (a priori frequency assignment plan for BSS). More than one hundred countries participated in the conference and elaborated on a plan that would ensure that orbital positions would be available to developing countries when they were eventually ready to launch and use broadcasting satellites (equitable access to the spectrum). As a result, the Final Act of the Conference: [127]

- Established a Plan for BSS in Regions 1 and 3 (the whole world except the Americas), replacing the FCFS approach used previously,
- Adopted a set of principles to govern the BSS in Region 2 (the Americas), pending the holding of a regional radio conference and establishment of a detailed plan,
- Established a method for making changes in the Plan.

World Administrative Radio Conference (WARC, Geneva, 1979)

During the 1979 WARC, developing countries continued to affirm that efforts regarding equity should be continued.[128]

Therefore, the Conference led to a major modification of the Radio Regulations in order to meet new challenges of rapidly changing radio technologies and to provide a better sharing of spectrum and orbit resources among developed and developing countries. Major changes in the frequency allocations for the space services were adopted.

In addition, Resolution 3, named "Relating to the Use of the Geostationary-Satellite Orbit and to the Planning of Space Services Utilizing It", specified that a special Space WARC should convey no later than 1984.[129]

Plenipotentiary Conference (Nairobi, 1982)

Significant achievements in light of interests pursued by developing countries were reached at the Plenipotentiary Conference in 1982. Specifically:[130]

- The Final Act established the Independent International Commission for World-Wide Telecommunications Development.
- Article 33(2) was revised as follows:

[126] ITU, "Plenipotentiary Conference (Málaga-Torremolinos, 1973)", online: *History of the ITU Portal* (Link).
[127] ITU, "Radio Conferences - WARC SAT-77", online: *History Portal of the ITU* (Link).
[128] ITU, "Radio Conferences - WARC-79", online: *History Portal of the ITU* (Link).
[129] ITU, *Final Acts of the World Administrative Radio Conference (Geneva, 1979)* (ITU).
[130] ITU, "Plenipotentiary Conference (Nairobi, 1982)", online: *History Portal of the ITU (Link)*.

> "In using frequency bands for space radio services Members shall bear in mind that radio frequencies and the geostationary satellite orbit are limited natural resources and that they must be used efficiently and economically, in conformity with the provisions of the Radio Regulations, so that countries or groups of countries may have equitable access to both, taking into account the special needs of the developing countries and the geographical situation of particular countries."

The revised article reoriented the focus from "their needs and the technical facilities at their disposal" to "the special needs of the developing countries and the geographical situation of particular countries".

World Administrative Radio Conference Orbital Conferences (WARC ORB, Geneva, 1985) – first session

The WARC Orbital Conferences took place in Geneva in two sessions (1985 and 1988) following a request of developing countries in WARC 1979, in light of their concerns about future access to the GSO.[131]

The 1985 WARC ORB had the main goal to reconcile the principle of guaranteed and equitable access with that of the efficient and economic use of two limited natural resources (The Geosynchronous orbit and the radio frequency spectrum).[132]

It focused on the plan for FSS, adopting a dual planning approach with 11 planning principles:

- Allotment Plan for FSS in expanded bands (at least one allotment for each country providing domestic services),
- Improved Procedures for the (undefined) Multilateral Planning Meetings (MPMs) for conventional bands.

Technical parameters, criteria, and regulatory procedures were left to be addressed during the second session.

Moreover, this session also focused on BSS, specifically adopting:

- Appendix 30 of the BSS Plan for All Services and Associated Plans for BSS in Region 1, 2 and 3[133]
- Appendix 30 A of the BSS Plan for Associated Plan for the Feeder Links for BSS for Region 2

World Administrative Radio Conference (WARC ORB, Geneva, 1988) – second session

The second session of the 1988 WARC ORB had the objective to provide equitable and guaranteed access by all countries to the GSO and the space services utilising this orbit.[134]

The discussion mainly aimed to translate and implement the decisions of the 1985 WARC (principles) into a practicable and workable Allotment Plan for both FSS and BSS.[135] They defined the Allotment Plan (Part A and Part B), which was decided to have a duration of at least 20 years.

Specifically, the Conference resulted in:

- Appendix 30A or BSS Plan for the broadcasting-satellite service feeder-link plan for Regions 1 and 3 (to complement the feeder-link plan for Region 2 incorporated into the Radio Regulations in 1985),
- Appendix 30B or FSS Plan. The Appendix was then modified by the WRC in 2007 to reflect the most recent technology developments.

[131] ITU, "World Administrative Radio Conference on the use of the geostationary-satellite orbit and the planning of the space services utilizing it (1st session) (Geneva, 1985)", online: *History Portal of the ITU* (Link).
[132] Richard E Butler, "ORB(1) : guaranteeing equitable access to the orbit" (1985) 52:11 Telecommunication Journal 589–590.
[133] ITU, "First session of WARC ORB(1)" (1985) 52:11 Telecommunication Journal 591–593.
[134] ITU, "World Administrative Radio Conference on the use of the geostationary-satellite orbit and the planning of the space services utilizing it (2nd session) (Geneva, 1988)", online: *History Portal of the ITU* (Link).
[135] In particular, FCFS rule changed for FSS (6.4 GHz and 14/11 GHz) and BSS (12GHz).

These decisions complemented the related world agreement adopted in 1977 for direct BSS and FSS.

Plenipotentiary Conference (Nice, 1989)

The Plenipotentiary Conference in 1989 agreed to adopt a permanent constitution for the ITU.[136] Furthermore, the High-Level Committee (HLC) was created to carry out an in-depth review of the structure and functioning of the ITU to recommend reforms enabling the ITU to respond to the challenges of the new telecommunications environment.[137]

Additional Plenipotentiary Conference (Geneva, 1992)

Follow the publication of the HLC report, called "Tomorrow's ITU: The challenges of change", the Plenipotentiary Conference in 1992 adopted structural reforms in compliance with HLC recommendations:[138]

- Organization of the ITU into three bureaus (or sectors), one each for Radiocommunications, Telecommunication Standardisation, and Development. These functions were previously carried out by IFRB, CCIR, CCITT, and BDT.
- Each Sector would have an Advisory Group, drawn from member States as well as the private sector, to advise the director of the Bureau on the work of his/her Sector.

Furthermore:

- Change of the full-time 5-member IRFB into a part-time 9-member Radio Regulations Board (RRB).
- The Specialised Secretariats of the IFRB and the CCIR were merged and transformed into a Bureau for Radiocommunications (BR).
- The CCIR Director became the Director of the new bureau as well as the Secretary of the RRB.
- The Specialised Secretariat of the CCITT was transformed into the Telecommunication Standardisation Bureau (TSB).
- The Administrative Council was renamed the Council and was entrusted with more policy matters.
- A regular cycle of conferences was established to help the ITU rapidly respond to new technological advances.

Plenipotentiary Conference (Kyoto, 1994)

The Plenipotentiary Conference in 1994 adopted the currently applicable ITU Constitution and Convention (CC) as accepted at the Geneva Special Plenipotentiary in 1992, including:[139]

ITU Article 44 CC, called "Use of the Radio-Frequency Spectrum and of the Geostationary-Satellite and Other Satellite Orbits" has recognized the main principle of efficient use and equitable access to spectrum/orbit resources. Particularly:

1. Member States shall endeavour to limit the number of frequencies and the spectrum used to the minimum essential to provide in a satisfactory manner the necessary services. To that end, they shall endeavour to apply the latest technical advances as soon as possible.
2. In using frequency bands for radio services, Member States shall bear in mind that radio frequencies and any associated orbits, including the geostationary-satellite orbit, are limited natural resources and that they must be used rationally, efficiently, and economically, in conformity with the provisions of

[136] ITU, "Plenipotentiary Conference (Nice, 1989)", online: *History Portal of the ITU* (Link).
[137] ITU, *supra* note 109.
[138] *Report of the High Level Committee to review the structure and functioning of the International Telecommunication Union (ITU) - Tomorrow's ITU: The Challenges of Change* (ITU, 1991); ITU, "Additional Plenipotentiary Conference (Geneva, 1992)", online: *History Portal of the ITU* (Link).
[139] ITU, *Final Acts of the Plenipotentiary Conference (Kyoto, 1994)* (ITU, 1994).

the Radio Regulations, so that countries or groups of countries may have equitable access to those orbits and frequencies, taking into account the special needs of the developing countries and the geographical situation of particular countries.

Furthermore, following Resolution 18 (Kyoto, 1994) which called for an in-depth review of the ITU allocation procedures, ITU adopted resolutions regarding the submission of due diligence information (administrative due diligence) to the Bureau regarding:

- The identity of the satellite network and the spectrum manufacturer for the reservation of orbit and spectrum capacity without actual use (before the end of the 7 years period (Resolution 49, WRC-12),
- Any further change (e.g., deorbiting of satellite, moving of satellite to another orbital location (Resolution 552, WRC-12).

Others:

- The Plenipotentiary Conference 1998 made some changes to the ITU Constitution and Convention, allowing private entities to participate in the ITU as Sector Members.
- The Plenipotentiary Conference 2002 slightly revised the ITU Constitution and Convention; strengthened the provisions dealing with private entities' participation.
- The Plenipotentiary Conference 2018 decided to admit academia to participate in the work of the ITU.
- The World Radiocommunication Conference 2019 adopted Resolution to enable developing countries to apply for new orbital locations to replace those in the broadcasting satellite Plan that have been rendered unusable since the Plan was developed.[140]
- Similar modifications are expected in World Radiocommunication Conference 2023 for the Fixed Satellite Service Plan.

An overview of (recent) criticism of the ITU model at UN COPUOS

The ITU FCFS approach is also criticized in other international fora, most prominently within the framework of UN COPUOS (STSC, LSC). In particular, criticisms with regard to the FCFS model as a key factor in restricting long-term access to space.

In April 2021, during the UN COPUOS's Scientific and Technical Subcommittee's (STSC), fifty-eighth session (19-30 April 2021) Item 16, titled "Examination of the physical nature and technical attributes of the geostationary orbit and its utilization and applications, including in the field of space communications, as well as other questions relating to developments in space communications, taking particular account of the needs and interests of developing countries, without prejudice to the role of the ITU", focused on the issue of equitable access of the developing Member States to GSO pursuant to paragraph 5 of General Assembly Resolution 75/92 ("Continuity of the work of the COPUOS and its subsidiary bodies").

Among several statements taking stock of the FCFS system, the below can be highlighted as most relevant in light of this report:

- Iran: "The Islamic Republic of Iran, in line with the views of a number of COPUOS Member States, believes that current utilization of geostationary orbit (GSO) does not ensure equitable access of all member states to this limited natural outer space orbit resource. Current ITU Radio Regulation is mainly established based on the concept of "first come first serve" which gives the priority to the

[140] ITU, *Provisional Final Acts of the World Radiocommunication Conference 2019 (WRC-19)* (ITU, 2019).

primary users of this orbit. This concept can restrict and prevent access to use certain frequency bands and orbital positions by those members who reach the satellite technology with delay."[141]

- Pakistan: "While for other spectrum i.e., unplanned band where the technology is mature, the current utilization of Geostationary Orbit is on the first come first served basis that has made this natural resource unattainable for countries that do not have the technology or are late in their application to ITU."[142]
- Indonesia: "We also would like to reiterate our views on GSO as a limited natural resource having certain characteristics and conditions, possessing strategic and economic value for the countries that use it. The GSO should therefore be utilized in a rational, balanced, efficient, and equitable manner, in accordance with the principles of outer space law. The exploitation of GSO without considering those principles will risk saturation. Considering such risk, we should consider GSO as a specific area and special part of outer space which need specific technical and legal governance."[143]
- Kenya: "Kenya notes and supports the view that the geostationary orbit, as a limited natural resource clearly in danger of saturation, must be used rationally, efficiently, economically, and equitably as fundamental principle in safeguarding the interests of developing countries and countries with a certain geographical position."[144]

In May/June 2021, during the Legal Subcommittee of the UN COPUOS, Agenda item 6(b) titled "The character and utilization of the GSO, including consideration of ways and means to ensure the rational and equitable use of the geostationary orbit without prejudice to the role of the ITU" was addressed by several Member States, namely:

- Iran: clarifies "why the sufficiency of the current regime regulating the use of this orbit is in question and why many States are not able to locate even one satellite with economical characteristics in this orbit". In particular, it was mentioned that the technical characteristics of the Plan resources "go back to many years ago and the latest available development in technology has not been taken into account" and that some frequency bands "were not considered in the establishment of Plan resources, due to the technological limitation of that time".[145]
- Indonesia: "There are some problems in relation to the utilization of GSO as a limited natural resource, among others limited frequencies and the amount of coordination needed with the affected satellite networks, especially in adjacent positions, which make things difficult for newcomers to get access to this orbit spectrum resource. These problems reveal inequalities, inefficiencies, and bureaucratic congestion in the utilization of the GSO which become a disadvantage for securing access for all countries, including developing countries, countries with a specific geographical situation, equatorial countries as well as newcomers."[146]
- South Africa: "South Africa recognises that the International Telecommunication Union (ITU) has made some provisions to address the issue of equitable access to the geostationary satellite orbit through the use of satellite plans in which each country is guaranteed access to certain spectrum and a geostationary orbital location for use by fixed- and broadcasting-satellite services." "(…) "this

[141] Delegation of the Islamic Republic of Iran to UN COPUOS, *CRP on the Issue of Equitable Access of the Developing Member States to Geostationary Orbit under STSC Agenda Item 16* (2021) (Link).
[142] Delegation of Pakistan to UN COPUOS, *Statement of Pakistan Delegation - 58th Session of the Scientific & Technical Subcommittee (STSC) - Agenda Item 16* (2021) (Link).
[143] Delegation of Indonesia to UN COPUOS, *Statement of Dr. Robertus Heru Triharjanto - 58th Session of the Scientific & Technical Subcommittee (STSC) - Agenda Item 16* (2021) (Link).
[144] Delegation of Kenya to UN COPUOS, *Intervention by Kenya on the Agenda Item 16 - 58th Session of the Scientific & Technical Subcommittee (STSC) - Agenda Item 16* (2021) (Link).
[145] Delegation of the Islamic Republic of Iran to UN COPUOS, *Statement of the delegation of The Islamic Republic of Iran Before the sixtieth Session of The Legal Subcommittee of COPUOS - Agenda Item (6.b): The character and utilization of the geostationary orbit* (2021) (Link).
[146] Delegation of Indonesia to UN COPUOS, *Intervention made by the Delegation of the Republic of Indonesia on the Agenda Item 6b - 60th Session of the Legal Subcommittee* (2021).

achieves little, in practice, of ensuring equitable access to the orbit/spectrum resource by developing countries."[147]

Proposed solutions to better balance efficiency and equity in the spectrum management process include, among others:

- Re-establishing a working group for agenda item 6(b) (Iran)
- Facilitating the work of the Legal Subcommittee on this issue, by addressing it, in both the Legal and the Scientific and Technical Subcommittee (Iran).
- Inviting the ITU-R to cooperate on studies related to this issue and to comment on the effectiveness and feasibility of the solutions proposed by the Legal Subcommittee (Iran).
- Developing a comprehensive legal regime as an elaboration of the existing sui generis regime governing the utilization of GSO to complement and support the work of the ITU (Indonesia).

Despite diverging views on both the content and the appropriate forum for these discussions, a number of concerns about the sufficiency of the current provisions governing the utilization of the GSO in providing equitable access to all Member States, continue to be raised regularly by Member States whose economic and technological development does not allow them to yet deploy fully leverage their rights under the RR or that their rights are impaired due to existing application processes.

[147] Delegation of South Africa to UN COPUOS, *Statement by South Africa - 60th Session of the Legal Subcommittee - Agenda Item 6(b)* (2021) (Link).

Annex B – Tradability of Space Environment Capacity

Developing a threshold-based model in the Earth orbital environment can also provide positive ripple effects, as working with transparent quantifications may incentivize space debris removal (as successfully removed debris clears up filled capacity) or enable a capacity trading scheme whereby (e.g.) increasing sustainability by lowering the Capacity Index would allow an operator to trade unused allocation.[148]

Governments have tried to create various models to manage common-pool resources such as (i) centralized and administrative approaches (e.g., national parks, forests, etc), (ii) approaches based on technologies and standards, and (iii) market-based mechanisms such as taxes, fees, or tradable quotas to ensure efficient and sustainable use of the resource.[149]

Proponents of market-based approaches have often linked the deterioration of common-pool resources to a lack of well-defined property rights. They see privatization and trading as tools to increase the efficient use of CPRs, promote innovation, and avoid the tragedy of the commons.[150] According to the OECD, "different types of tradeable permits have proven relatively effective in the management of natural resources, such as fisheries and water, as well as in pollution abatement. In order to introduce tradable permits, setting a limit on access to the resource is essential. Then, rights are allocated based on this limit. Users that do exceed the limit can face fines or penalties, including losing access to the resource.[151]

However, it is worth noting that the introduction of tradeable permits associated with the granting of ownership or property rights could, in an orbital environment, be considered contentious from a legal perspective, as well as complex to implement and enforce.

Tradability under Threshold-based Models in Orbital Environments

The Space Environment Capacity Concept, as an option for a threshold-based approach in the Earth orbital environment, does not predetermine orbital slots and is not (by default) based on the idea of property rights. Therefore, if viable, tradability of space capacity must be assessed on the basis of the following principles:

- Outer Space is an environment as any other and orbits represent limited natural resources within that environment;
- Relevant actors would be able to obtain an appropriate level of orbital capacity based on their needs, taking long-term sustainability of the environment into account;
- Relevant actors would not be in possession of any exclusive usage or property rights over utilised orbits, but rather to a designated portion of the defined capacity;
- Activities would only be limited in light of due regard to the interests of other parties, in line with Article IX of the OST;
- Free shares of obtained capacity within a determined orbital environment could be traded or bartered among interested parties, without prejudice to orbital altitudes and inclinations.

Ideas regarding the creation of orbital fees, orbital taxes, or tradeable permits in space to mitigate debris creation, have already been promoted in the past, but despite their comprehensive elaboration and solid

[148] Stijn Lemmens and Francesca Letizia, Space Traffic Management Through Environment Capacity
[149] Nives Dolsak, "Tradable permits for common-pool resources: an assessment" (2007) 24:6 The Review of Policy Research 541–566.
[150] *Ibid*.
[151] Tom Tietenberg, *The Tradable Permits Approach to Protecting the Commons: What Have We Learned?*, (SSRN, 2002).

arguments in terms of their economic viability, often have the limitation of building a nexus to an individual object in a specific orbital slot (e.g., the Orbital-use fee approach):

Orbital-use fee approach: "*It can be economically efficiently addressed via incentive-based solutions, such as fees or tradable permits per year in orbit, analogous to carbon taxes or cap and trade (8, 10–12). Incentives should target objects in orbit—rather than launches—because orbiting objects are what directly imposes collision risk on other satellites.*"[152] "*Orbital-use fees could be straight-up fees or tradeable permits, and they could also be orbit-specific, since satellites in different orbits produce varying collision risks. Most important, the fee for each satellite would be calculated to reflect the cost to the industry of putting another satellite into orbit, including projected current and future costs of additional collision risk and space debris production—costs operators don't currently factor into their launches*."[153]

It should be noted that whether or not capacity allocations can be tradable under the existing legal framework, this question might give rise to blocking points for some states if tradability is to be integrated into an international cooperation mechanism by design.

Spectrum trading: An inspirational model?

The idea of space environmental capacity trading should be presented as akin to spectrum trading, a mechanism where rights to the use of spectrum are transferred from one party to another.

Historical Background on Spectrum Trading

In 1900, the Marconi Company started to exploit the radio spectrum for commercial purposes and provided radiotelegraphy services for ships at sea. The monopolistic use of the spectrum by Marconi prompted governments to regulate the use of the radio spectrum. Due to increased interference, governments adopted the Radio Regulations, a treaty that established principles for radio spectrum management based on the allocation of licenses by national spectrum management authorities to specific users.[154]

The command-and-control approach

This system is often referred to as the command-and-control approach, which is a centralised and administrative approach to spectrum management where government entities are assigning usage rights of the spectrum to specific users and for specific uses.[155] Under the command-and-control model, spectrum trading is often not possible between licensees. To allocate frequency bands to a new user, the regulatory body or spectrum manager has to be informed and the spectrum has to be returned so it can be reassigned.[156]

Most experts converge on the inefficiency of the command-and-control approach, in particular at a time of rapid technological innovation. For example, the command-and-control approach led to an underutilisation of specific spectrum bands and overutilisation of other bands.[157] This approach does not favour an efficient use of the spectrum. Others hold the view that the centralized command-and-control approach often slows down or hampers the introduction of new technologies and their derived

[152] Karin Vergoth, "Solving the space junk problem", (26 May 2020), online: *CU Boulder Today* (Link).
[153] CIRES, "Solving the Space Junk Problem", (20 May 2020), online: *CIRES* (Link).
[154] Peter Anker, *Radio spectrum management: from government to governance: Analysis of the role of government in the management of radio spectrum* TU Delft, 2018).
[155] Cong Xiong et al, "Spectrum Trading for Efficient Spectrum Utilization" (2014) 1:1 EAI Endorsed Transactions on Wireless Spectrum, online: (Link).
[156] Martin Cave & William Webb, eds, "Spectrum trading" in *Spectrum Management: Using the Airwaves for Maximum Social and Economic Benefit* (Cambridge: Cambridge University Press, 2015) 113.
[157] Xiong et al, *supra* note 155.

services.[158] Moreover, this centralised model also faces criticism for halting competitive new entrants, preventing efficient use of the limited natural resource, and slowing down innovation.[159]

The market-based approach

In 1959, Ronald Coase, later awarded the Nobel Prize in Economic Science, published a paper on the U.S. FCC arguing that the rights to use spectrum should be bought and sold freely.[160] Coase believed that the use of market mechanisms to manage spectrum was more efficient than the traditional and centralized command-and-control approach. Coase believed that the establishment of clearly defined property rights was essential to the introduction of a market for radio spectrum licenses. Market mechanisms include:

- Auctions, in which regulatory bodies allocate unused spectrum to the highest bidder. However, the winner is only awarded the rights of use and cannot further trade or lease their brand on the market.[161] Auctions were also a great source of revenue for governments. For instance, from 1994 to 2010, FCC-sponsored auctions in the U.S accounted for over USD 52 billion in revenues deposited in the US Treasury.[162] It was noted that "*auctions employ a price mechanism to allocate spectrum and can be used to increase efficiency and revenue maximisation*".[163]
- "Beauty contests", are competitive and comparative tenders where the regulatory body sets a number of criteria under which it makes the assignment and invites proposals from potential future licensees. The licenses are reviewed by a jury and the "best" proposal is awarded a license.[164] These mechanisms are often no different from auctions as criteria for the contest can include financial resources or a fee. The difference lies in the fact the auctions make the price mechanism exclusive and central.[165]
- Trading, is a process where licensees trade, lend, or lease the rights to use spectrum to unlicenced parties on the market.

One of the initial drivers to incentivize using a market model (and trading) was to develop a tool to solve interference issues and achieve efficiency.[166] It is further noted that the need for institutions to manage the spectrum but should have boundaries, arguing that their control should be narrow and limited.[167] However, some experts go even further and argue that regulatory bodies should only monitor the proper functioning of competition instead of attributing rights of use for specific usage and technology.[168]

First market approaches were only considered by governments in the 1980-1990s during the liberalisation wave by gradually introducing auctions, leasing, and trading.[169] Coase's approach was the foundation for the introduction of spectrum trading in most countries. The first tradable permits were issued in New Zealand. According to the OECD, governments worldwide have been slow to establish and allow spectrum trading due to concerns regarding potential increased risks of interference, windfall gains, anti-

---

[158] Randall Berry, Michael L Honig & Rakesh Vohra, "Spectrum markets: motivation, challenges, and implications" (2010) 48:11 IEEE Communications Magazine 146–155.
[159] Tomasso Valletti, "Spectrum trading" (2001) 25 Telecommunications Policy 655–670.
[160] Robert Hahn, "Ronald Harry Coase (1910–2013)" (2013) 502:7472 Nature 449–449.
[161] Xiong et al, *supra* note 155.
[162] Robert B Kelly & Ann J LaFrance, "Spectrum Trading in the EU and the US - Shifting Ends and Means" in *ICLG: Telecommunication Laws and Regulations* (ICLG, 2012).
[163] Andrea Prat & Tommaso M Valletti, "Spectrum auctions versus beauty contests: Costs and benefits" (2001) 91:4/5 Rivista di politica económica 59–110.
[164] Martin Cave, "Spectrum Auctions" *Ingenia* (November 2000), online: Ingenia (Link).
[165] Prat & Valletti, *supra* note 163.
[166] Wolter Lemstra et al, "Two perspectives on trading in radio spectrum usage rights: Coase and Commons compared" (2015) 11:2 Journal of Institutional Economics 437–457.
[167] Rajen Akalu & Adriana Diaz Arias, "Assessing the policy of spectrum trading in the UK" (2012) 14:1 info 36–54.
[168] Valletti, *supra* note 159.
[169] Ryszard Struzak, *Spectrum market or spectrum commons?* (Kyiv, Ukraine, 2007).

competitive behaviour, disruptive effects on consumers, compromission of public interest objectives such as national security, public safety, and emergency response.

The Commons' approach

Besides the market approach, another approach emerged as an alternative to the command-and-control approach: the Commons' approach.[170] **The Commons' approach can be characterized as unlicensed allocations in which the band can be shared by different applications and service providers as long as they follow certain rules (e.g., use of specific standards, etc).** The Spectrum Commons approach considers that new technologies can enable the management of spectrum, without the intervention of the government.[171] Popular examples include Wi-Fi or Bluetooth where interference is managed by the technology itself and the adoption of standards (e.g., the IEEE 802.11 standard).[172] This approach is also called "license-exempt".[173]

In the early 2000s, the commons and market-based approaches were heavily debated. According to Faulhaber, former chief economist at the FCC, advocates of the Commons approach argued that a market for licenses would have significant transaction costs and dispute resolution for interference would be very expensive. Market and property rights advocates argued that issues related to transaction costs and dispute resolution in the commons system were not considered and simply based on hopes that regulatory bodies would solve them.[174] **It was emphasised that market approaches can co-exist with commons approaches as long as spectrum is not highly scarce.**[175] Martin Cave et al., further outlined this idea by arguing that spectrum should be unlicensed when there is little probability of congestion. However, congestion is likely on key parts of the spectrum and this model can easily lead to a tragedy of the commons if not properly coordinated or managed. They argue that there should be a mix of licensed and unlicensed spectrum depending on potential congestion.[176] It is considered that economists tend to favour a market-based regime while engineers usually prefer a commons-based regime to promote new technologies.[177]

The figure below depicts spectrum management approaches:

Figure 24: Spectrum Management Approaches

[170] Jerry Brito, "The spectrum commons in theory and practice" (2007) Stan Tech L Rev 1.
[171] Chris Doyle, Martin Cave & William Webb, eds, "Market solutions" in *Essentials of Modern Spectrum Management* The Cambridge Wireless Essentials Series (Cambridge: Cambridge University Press, 2007) 37.
[172] Lemstra et al, "Two perspectives on trading in radio spectrum usage rights", *supra* note 166.
[173] Chris Doyle, Martin Cave & William Webb, eds, "How the commons works" in *Essentials of Modern Spectrum Management* The Cambridge Wireless Essentials Series (Cambridge: Cambridge University Press, 2007) 203.
[174] Gerald R Faulhaber, "The question of spectrum: Technology, management, and regime change" (2005) 4 J on Telecomm & High Tech L 123.
[175] Gerald R Faulhaber & David J Farber, "Spectrum management: Property rights, markets, and the commons" in *Rethinking rights and regulations: institutional responses to new communication technologies* (MIT Press Cambridge, MA, 2003) 193.
[176] Doyle, Cave, & Webb, *supra* note 173.
[177] Faulhaber & Farber, *supra* note 175.

Spectrum trading markets

In theory, spectrum trading is a market-based mechanism for spectrum assignment, which allows buyers and sellers to trade or lease their rights to use spectrum. In practice, different models and market structures can enable leasing and trading of spectrum with varying degrees of regulation and restrictions.

Before trading was allowed, in order to make bands available for new users, regulatory bodies would conduct reallocation based on a clear-and-relocate process, in which they clear some bands and relocate the cleared bands to new users through auctions or beauty contests.[178]

While spectrum trading market structures can vary, they usually comprise spectrum sellers, who are selling, leasing, and exchanging licenses with spectrum buyers. Transactions can also be conducted through spectrum brokers. Often, a regulatory body is involved in the spectrum market, either to assign first-time rights to use spectrum, ensure proper competition, or solve disputes.

Three models of spectrum trading can be identified:

- Secondary spectrum trading markets

Spectrum licenses are first allocated by a government entity through a first come first served mechanism or through auctions or beauty contests. In a secondary spectrum trading market, spectrum licensees can trade or lease (sub-letting license rights to third parties) their rights to use spectrum to other stakeholders. Licensees usually trade with buyers directly.

Secondary spectrum markets adopt market mechanisms for efficient use of the spectrum. However, it is usually only perceived as an evolution of the command-and-control approach and does not function as a commodity market. The regulator usually has a strong role in the market and can impose restrictions.[179] It is important to note that secondary trading is not necessarily allowed for all radio frequency bands. The regulator can make trading feasible only for specific bands. In addition, transactions may have to be filed with the regulator for approval, which may increase inefficiency by introducing delays and increasing transaction costs.[180]

- Exchange-based Spectrum Trading Markets

The spectrum exchange (like the NYSE for instance) collects offers to sell spectrum from current spectrum licensees and collects offers to buy spectrum from unlicensed parties. It also publicizes prices and anonymizes trading entities. The spectrum exchange determines the winning bid and transfers usage rights from the seller to the buyer. The market maker facilitates trading and acts as a dealer that holds an inventory of spectrum for negotiating and speculating. Exchange-based spectrum trading markets are more liberalized than secondary spectrum trading markets.[181]

- Two-Tier Spectrum Trading Markets

The two-tier spectrum trading market is divided in two. The upper-tier spectrum market comprises trades exchanged between spectrum owners as in a commodities market. The lower tier comprises trades to rent or lease spectrum to service providers through a spot market managed by spectrum brokers. Trades in the upper-tier market are usually negotiated over long-term scale (months, years of spectrum use) while

[178] Xuanheng Li et al, "Collaborative Spectrum Trading and Sharing for Cognitive Radio Networks" in Wei Zhang, ed, *Handbook of Cognitive Radio* (Springer, 2018).
[179] Xiong et al, *supra* note 155.
[180] Randall Berry, Michael L Honig & Rakesh V Vohra, "Spectrum Markets: Motivation, Challenges, and Implications" in Jacob K Goeree & Martin Bichler, eds, *Handbook of Spectrum Auction Design* (Cambridge: Cambridge University Press, 2017) 785.
[181] Xiong et al, *supra* note 155; Carlos E Caicedo & Martin BH Weiss, *The viability of spectrum trading markets* (IEEE, 2010).

trades in the lower tier are negotiated over short-term scales (hours, minutes of spectrum use). In two-tier spectrum markets, the market for spectrum is separated from the market for wireless services.[182]

It is important to note that spectrum as a tradable commodity is distinct from other commodities due to its geographical specificity, its reusability, its non-storable aspects, and the way that interference can reduce its value if it is not regulated appropriately.[183] This is also the case of orbital capacity if a trading scheme is to be applied to a threshold-based framework for orbital environments.

Overall, most experts converge on the fact that spectrum trading can enable more efficient use of the spectrum. Spectrum trading can enable new entrants to rapidly develop their business, foster innovation, and investments in new technologies, and promote risk-taking so that market actors remain competitive.[184] Scarcity is the variable that makes spectrum trading necessary in order to avoid interference and avoid a tragedy of the commons.[185]

National examples

National laws on radio communications or spectrum management are usually clear about whether spectrum trading is allowed or not. Spectrum rights are (i.a.) allowed in Australia, New Zealand, Canada, the United States, Guatemala, and the UK. The EU also allows Member States to trade spectrum.[186]

The development of the UK model is analysed below to present the implementation perspective at national level.

Spectrum trading in the United Kingdom

In 2001, the UK commissioned a report to review radio spectrum management in the UK, which became known as the Cave Report. Based on principles defined by Coase, the report recommended increasing the use of market-based mechanisms rather than administrative processes and advocated for a "selective deregulation of spectrum use" to ensure efficient use of the spectrum. It is recommended to use a market approach for commercial uses of spectrum and administrative approaches for public services. The report also recommended allowing secondary spectrum trading for the wireless market. The Cave Report outlined that Ofcom, the UK regulatory body, should be responsible for defining the bundle of rights, interference coordination requirements for each license, and assigning first licenses through auctions.

Additionally, in 2003, Ofcom, looking to carry out its duty to ensure the optimal use of the spectrum, published a consultation document on spectrum trading. Following consultations, in 2004, Ofcom released a statement outlining that spectrum trading will be gradually introduced in the UK and detailed the licence classes that would be tradable, the types of transfer that will be allowed for each licence class, and described the process that should be followed to trade. The statement also explained the steps that Ofcom will take to facilitate the trading process, including publication of relevant information in a wireless telegraphy register and modification of certain licences.[187]

In order to legalise spectrum trading and give it a regulatory framework, Ofcom had to make regulations under the powers conferred by section 168 of the Communications Act of 2003, which stated that *"OFCOM may by regulations authorise the transfer to another person by the holder of a wireless telegraphy*

[182] Berry, Honig & Vohra, *supra* note 180.
[183] Carlos E Caicedo Bastidas, "Spectrum Trading: Market-Based Architectures for Dynamic Radio Frequency Spectrum Access" (2013) 3 Journal of Information Policy 485–500.
[184] Cave & Webb, *supra* note 156.
[185] Berry, Honig & Vohra, *supra* note 180.
[186] European Commission, "Regulating the radio spectrum", online: *EC* (Link).
[187] OFCOM, *Statement: Spectrum Trading and Wireless Telegraphy Register Regulations* (OFCOM, 2004).

licence, or the holder of a grant of recognised spectrum access, of rights and obligations arising by virtue of such a licence or grant".[188] Additionally, Ofcom had to make regulations under section 170 of the Communications Act of 2003 to create and maintain a register. The section stated that *"OFCOM may by regulations make provision for the establishment and maintenance of a register of relevant information"*.[189]

In December 2004, the Wireless Telegraphy Regulations (also called Spectrum Trading Regulations) were adopted and allowed spectrum trading in six sectors: business radio, fixed links, fixed wireless access, public wireless network, spectrum access, concurrent spectrum access. Other licence classes were gradually added such as maritime and satellite bands.

The Spectrum Trading Regulations of 2004 states that Ofcom has to validate a trade for it to take place and outlines the criteria Ofcom takes into account to validate a trade. Most of these criteria relate to compliance with the wireless telegraphy licence, international obligations, and national security.

Today, the trading framework allows both leasing and transfers. Transfers can be total or partial.

- A transfer means the licensee gives up all rights and obligations to the spectrum. The buyer agrees to transfer the licence to the buyer, then both the seller and the buyer apply to Ofcom, Ofcom approves the trade, revokes the licence of the seller, and grants to licence to the buyer. Afterwards, the buyer pays the seller.
  - Outright transfer: rights and obligations to the spectrum are transferred from the seller to the buyer. The seller no longer has any rights or obligations.
  - Concurrent transfer: rights and obligations to the spectrum are transferred to the buyer. The seller still retains the rights and obligations to the spectrum. It enables spectrum sharing. The number of concurrent transfers is not limited to one band.
  - Total transfer: All the rights and obligations are transferred.
  - Partial transfer: only a portion of the rights and obligations are being transferred.

For satellite services, tradable licences come with the following modalities:

Licence class	Outright transfer	Concurrent transfer	Total transfer	Partial transfer
Permanent Earth Station	Yes	Yes	No	Yes
Transportable Earth Station	Yes	Yes	No	Yes
Satellite Earth Station Network	Yes	Yes	Yes	No
Satellite (Earth Station) (Non-Fixed Satellite Service)	Yes	Yes	Yes	No
Satellite (Earth Station) (Non-Geostationary)	Yes	Yes	Yes	No
Satellite (Complementary Ground Components of a Mobile Satellite System)	No	Yes	Yes	No
Global Navigation Satellite System (GNSS) Repeaters	Yes	Yes	Yes	No

Table 2: Modalities of tradable licences

[188] legislation.gov.uk, "Communications Act 2003", online: The National Archives (Link).
[189] *Ibid.*

- A lease means that the licensee remains responsible for the spectrum and compliance with license requirements, including activities conducted by the leaseholder. The buyer does not have a license but has the right to use spectrum. Sellers trade with buyers directly. Leasing is allowed for business radio and spectrum access license types. The lessor is required to have written contracts with leaseholders and make them available to Ofcom on request.

When a transfer is done, data is uploaded to online registries: the Wireless Telegraphy Act Register (WTR) and the Transfer Notification Register (TNR). However, the price is not published on the registry.

Spectrum held by the government or public services ("Crown bodies") cannot be licensed by Ofcom. The government holds spectrum in the form of Recognized Spectrum Access (RSA). Trading of RSA is regulated by the Wireless Telegraphy Regulations of 2009.

While the initial ideas of Coase were embraced by Ofcom, spectrum trading remains strongly controlled in the UK. Market mechanisms are used to maximise the efficiency of spectrum use but the regulatory body still plays a strong role in the allocation process.[190] As a result, spectrum trading in the UK is based on market-based mechanisms while still relying on an administrative approach.

Conclusions

The underlying theoretical models and implications can arguably also be relevant for a potential trading scheme under a threshold-based approach in the Earth orbital environment, as assigning economic value to assigned/utilized capacity may further incentivize responsible behaviour and increasingly efficient use of the orbital environment.

Moreover, trading of capacity within such a framework could represent an additional driver in favour of the model as it would create a new asset class, foster further growth in the space economy, and also provide revenue, which could be redistributed towards efforts aimed at long-term sustainability of outer space.

Finally, the bureaucratic complexity of a trading system and the fact that its implementation does not represent a defining factor within a threshold-based approach leads to a conclusion that at this stage of the policy-building process, tradability should be embedded as an optional element, and not considered as a prerequisite for its development or success.

[190] Akalu & Diaz Arias, *supra* note 167.

Acknowledgment

The authors would like to express their gratitude to the experts and officials who agreed to be interviewed for this report under the Chatham House Rule and provided their highly appreciated opinions and perspectives. In addition, we would like to thank the ESPI Director, Jean-Jacques Tortora, and ESPI Research Manager, Sebastien Moranta, for their guidance and continuous support, as well as the whole ESPI team for constructive and fruitful exchanges. The list is provided in the alphabetical order of institutions with which the interviewees are associated:

List of Interviewees	
Stefano Antonetti	Vice President, Business Development, D-Orbit
David Bertolotti	Director of Institutional and International Affairs, Eutelsat
Stefano Agnelli	Director of European Institutional Affairs, Eutelsat
Natália Archinard	Space portfolio, Federal Department of Foreign Affairs of Switzerland Chair, Scientific and Technical Subcommittee, UNCOPUOS (2021)
Marc Becker	Policy Officer, SSA Department, German Space Agency at DLR
Manuel Metz	Head, SSA & Space Debris Research Group, German Space Agency at DLR
Alexandre Vallet	Chief, Space Services Department, ITU
Yvon Henri	Member, Radio Regulation Board, ITU
Chuen Chern Loo	Head of Space Publication and Registration Division, ITU
Setsuko Aoki	Professor, Keio University Law School Chair, Legal Subcommittee, UNCOPUOS (2021)
Patricia Conti	Director for Economic Affairs, Luxembourg Space Agency
Ruth Pritchard-Kelly	Senior Advisor for Regulatory Affairs, OneWeb
Peng Zhao	Government Affairs and Policy (APAC), OneWeb
Cécil Ameil	Director of Regulatory Affairs, SES
Amelie Werbrouck	Associate Regulatory Counsel EMEA, SES
Pascal Wauthier	Space Operations Senior Vice President, SES
Gilles Doucet	President, Spectrum Space Security
Bleddyn Bowen	Lecturer in International Relations, University of Leicester

Furthermore, the authors would like to express their gratitude to the experts and officials who agreed to participate in the interactive online workshop that took place on 30 November 2021 and provided their highly appreciated opinions and perspectives under the Chatham House Rule. The list is provided in the alphabetical order of institutions with which the participants are associated:

List of Workshop Participants	
Patrick Chatard-Moulin	Policy Officer, European External Action Service
Delphine Miramont	Policy Officer, EARSC
Charles Galland	Policy Manager, Eurospace
Stijn Lemmens	Space Debris Analyst, Space Debris Office, ESA
Francesca Letizia	Space Debris Engineer, Space Debris Office, ESA
Volker Schaus	Space Debris Engineer, Space Debris Office, ESA
Joao Alves	Head, SSA Unit, European Union Satellite Centre (SatCen)
Stefano Agnelli	Director of European Institutional Affairs, Eutelsat
Flora Seube	European Affairs Junior Manager, Eutelsat
Sebastien Moranta	Research Manager, ESPI
Tomas Hrozensky	Resident Fellow, ESPI
Natalia Archinard	Space portfolio, Federal Department of Foreign Affairs of Switzerland Chair, Scientific and Technical Subcommittee, UNCOPUOS (2021)
Manuel Metz	Head, SSA & Space Debris Research Group, German Space Agency at DLR
Marius Stanciu Manolescu	EUSTM Project Coordinator, GMV
Alexandre Vallet	Chief, Space Services Department, ITU
Yvon Henri	Member, Radio Regulation Board, ITU
Chuen Chern Loo	Head, Space Publication and Registration Division, ITU
Setsuko Aoki	Professor, Keio University Law School Chair, Legal Subcommittee, UNCOPUOS (2021)
Muriel Hooghe	Senior Project Manager, Space Safety, Luxembourg Space Agency
Brian Weeden	Director, Program Planning, Secure World Foundation
Ian Christensen	Director, Private Sector Programs, Secure World Foundation
Gilles Doucet	President, Spectrum Space Security
Andrea Cardellicchio	Head of Commercial Development, Telespazio
Erberto Ruggiero	Government to Government Initiatives, Telespazio
Stephen Plant	Regulatory & Policy Manager, UK Space Agency
Andrew Ratcliffe	Chief Engineer within the Office of the Chief Engineer, UK Space Agency
Sam Toms	Economist & Senior Policy Manager, UK Space Agency

About the Authors

Matija Renčelj is a Resident Fellow at the European Space Policy Institute (ESPI). Prior to joining ESPI, he spent two years at the European Space Agency (Strategy Department), and previously worked at the European Commission (Cabinet-level), a corporate law firm, and in the aviation industry. He holds an LL.M. in Air & Space Law from McGill University and a law degree from the University of Ljubljana.

Sara Dalledonne is a Resident Fellow at the European Space Policy Institute (ESPI). Prior to joining ESPI, she worked at the Institute of Air and Space Law (McGill University) as Research Assistant. She holds an L.L.M. in Air and Space Law from McGill University, an L.L.M. in International Trade Law from the International Training Centre of the ILO (University of Turin) and a 5-year Law degree from University of Bologna.

Clémence Poirier is a Resident Fellow seconded by CNES at the European Space Policy Institute (ESPI). She holds a master's degree in International Relations, International Security and Defence and a bachelor's degree in Foreign Applied Languages from University Jean Moulin Lyon III, France.

Lina Pohl is a Resident Fellow seconded by DLR at the European Space Policy Institute (ESPI). Prior to joining ESPI, she worked at the DLR International Relations Department as Assistant to the Head of Department and as Research Assistant. She holds a Master in Political Science from the University of Cologne.

About ESPI

Policy & Strategy | Economy & Business | Security & Defence | International & Legal

ESPI is the European think-tank for space. The Institute is a not-for-profit organization based in Vienna, World capital of space diplomacy, providing decision-makers with an informed view on mid to long-term issues relevant to Europe's space activities since 2003.

ESPI is supervised by a General Assembly of member organizations and supported by an Advisory Council of independent high-level experts.

ESPI fulfils its objectives through various multi-disciplinary research activities leading to the publication of books, reports, papers, articles, executive briefs, proceedings and position papers, and to the organisation of conferences and events including the annual ESPI Autumn Conference.

Who we are	What we do
Independent think-tank specialised in space policy	Research and analysis on major space policy issues
Multinational team with interdisciplinary expertise	Monitoring of global space trends and policy developments
Part of a network of European and international partners	Organization of thematic conferences and workshops

Download our reports, check our events and subscribe to our newsletter online

www.espi.or.at

Schwarzenbergplatz 6 | A-1030 Vienna, Austria | (Entrance: Zaunergasse 1)
Phone +43 1 718 11 18 - 0 | E-Mail: office@espi.or.at

www.espi.or.at