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Use of space technology in the United Nations system

Space debris

Special report of the Inter-Agency Meeting on Outer Space Activities on developments within the United Nations system related to space debris

I. Introduction

1. The Inter-Agency Meeting on Outer Space Activities (UN-Space) was established in the mid-1970s as a coordination mechanism with the aim of promoting synergies and avoiding the duplication of efforts related to the use of space technology and applications in the work of United Nations entities. In its resolution 78/72, the General Assembly urged UN-Space, under the leadership of the Office for Outer Space Affairs, to continue to examine how space science and technology and their applications could contribute to the 2030 Agenda for Sustainable Development, and encouraged entities of the United Nations system to participate, as appropriate, in UN-Space coordination efforts.

2. In its special reports, UN-Space has addressed a wide range of themes, including new and emerging technologies, space benefits for Africa, space for agriculture development and food security, space for global health, transparency and confidence-building measures, space weather, partnerships and climate action (see http://un-space.org).

3. At its recent forty-second session, held in Brindisi, Italy, in October 2023, UN-Space decided that its next special report would focus on the topic of space debris (A/AC.105/1318, para. 14).

4. The present report was prepared on the basis of contributions from the following United Nations entities: the Food and Agriculture Organization of the United Nations (FAO), the International Atomic Energy Agency (IAEA), the International Civil Aviation Organization (ICAO), the International Telecommunication Union (ITU), the International Maritime Organization (IMO), the Office for Disarmament Affairs, the Office for Outer Space Affairs, the United Nations Institute for Disarmament

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Research (UNIDIR), the United Nations University and the World Meteorological Organization (WMO).

II. Background

5. Since the beginning of the space age in 1957, humans have successfully launched over 17,000 satellites.[1] These satellites gather and distribute vital data for purposes related to, inter alia, Earth observation, meteorology, early warning systems for disasters, telecommunications, and navigation and positioning. Satellites have become critical infrastructure supporting sustainable life on Earth.

6. Orbital space debris arises from various sources, including non-operational satellites, the upper stages of launch vehicles, carriers for multiple payloads, debris intentionally released during spacecraft separation from a launch vehicle or during mission operations, solid rocket motor effluents, and paint flakes released by thermal stress or small particle impacts. Debris can also be created by collisions and the explosion of spacecraft. Even tiny debris or meteoroids smaller than 1 millimetre can pose a risk to exposed electric harnesses or other vulnerable components and could result in the loss of functions or even break-up of the satellite. This may lead to an unstable, runaway debris situation, known as the Kessler syndrome.

7. In 2023, 212 successful launches[2] and deployments from the International Space Station resulted in approximately 2,900 new satellites being placed in Earth orbit or beyond.[3] These launches resulted in the addition of 377 rocket bodies and objects categorized as "debris" to the orbital population.[4]

8. Also in 2023, the re-entry of 1,982 space objects was recorded; 678 were satellites, 96 were rocket stages and 1,208 were debris.[5] Satellites from large constellations, such as Planet Labs' Flock, SpaceX's Starlink, Spire Global's Lemur and Swarm Technologies' SpaceBEE, accounted for over a third of satellite re-entries in 2023.[6]

9. From 1957 to 2023, a total of 58,000 orbital objects were catalogued, with 28,000 objects remaining in orbit.[7] Of the objects still in orbit, approximately 12,500 were satellites, while the remainder constituted rocket bodies or debris. The total mass of the objects was estimated to exceed 11,500 tons, with satellites comprising approximately 65 per cent of the total mass and rocket bodies comprising approximately 32 per cent. Approximately half of the mass was concentrated in the low Earth orbit.[8]

10. The proliferation of space debris, the increasing complexity of space operations, the emergence of large constellations and the increased risks of collision and interference with the operation of space objects may affect the long-term sustainability of space activities. Space activities are inherently global and efforts to address space debris challenges thus need to be multifaceted, involving technical, regulatory, policy, legal and cooperative measures.

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[1] European Space Agency (ESA), Space safety, "Space debris by the numbers", 6 December 2023.
[2] Available at https://www.space-track.org/.
[3] Database and Information System Characterising Objects in Space website (DISCOS). Available at https://discosweb.esoc.esa.int/.
[4] Ibid.
[5] Available at https://www.space-track.org/.
[6] Ibid.
[7] Ibid.
[8] J.-C. Liou, Chief Scientist for Orbital Debris, National Aeronautics and Space Administration, "U.S. space debris environment and activity updates", presentation at the sixty-first session of the Scientific and Technical Subcommittee, held in Vienna from 29 January to 9 February 2024.

III. Developments within the United Nations system related to space debris

A. Consideration of space debris on the agenda of the Committee on the Peaceful Uses of Outer Space and its subcommittees: how it started

11. In accordance with the decision of the Committee on the Peaceful Uses of Outer Space at its thirty-third session, in 1993 (see A/48/20, para. 87), the Scientific and Technical Subcommittee, at its thirty-first session, in 1994, considered for the first time, on a priority basis, matters associated with space debris under a new item of its agenda, including relevant studies, mathematical modelling and other analytical work on the characterization of the space debris environment (A/AC.105/571, paras. 63–74).

12. In addressing the problem of space debris in its work, the Subcommittee at its thirty-second session, in 1995, agreed to focus on understanding aspects of research related to space debris, including debris measurement techniques, mathematical modelling of the debris environment, characterization of the space debris environment and measures to mitigate the risks of space debris, including spacecraft design measures to protect against space debris.

13. Accordingly, the Subcommittee adopted a multi-year workplan for specific topics to be covered from 1996 to 1998. The Subcommittee agreed that at each session it should review the current operational debris mitigation practices and consider future mitigation methods with regard to cost efficiency (A/AC.105/605, para. 83).

14. At its thirty-third session, in 1996, the Subcommittee agreed to prepare a technical report on space debris that would be structured according to the specific topics addressed by the workplan during the period from 1996 to 1998 and that the report would be carried forward and updated each year, leading to an accumulation of advice and guidance, in order to establish a common understanding that could serve as the basis for further deliberations of the Committee on that important matter (A/AC.105/637 and Corr. 1, para. 96).

15. At its thirty-sixth session, in 1999, the Subcommittee adopted the technical report on space debris (A/AC.105/720) and agreed to have it widely distributed, including by making it available at the Third United Nations Conference on the Exploration and Peaceful Uses of Outer Space (UNISPACE III) and to the Legal Subcommittee at its thirty-ninth session in 2000, international organizations and other scientific meetings (A/AC.105/736, para. 97).

B. Space Debris Mitigation Guidelines of the Committee on the Peaceful Uses of Outer Space

16. At its thirty-eighth session, in 2001, the Scientific and Technical Subcommittee agreed to establish a workplan for the period from 2002 to 2005 (see A/AC.105/761, para. 130), with the goal of expediting the international adoption of voluntary debris mitigation measures. In addition to the plan to address debris mitigation measures, it was envisaged that member States and international organizations would continue to report on research related to and other relevant aspects of space debris.

17. In accordance with that workplan, at the fortieth session of the Subcommittee, in 2003, the Inter-Agency Space Debris Coordination Committee (IADC) presented its proposals on debris mitigation, based on consensus among the members of IADC. At the same session, the Subcommittee began its review of the proposals and discussed the means of endorsing their utilization.

18. At its forty-first session, in 2004, the Subcommittee established a working group to consider comments from member States on the above-mentioned proposals of

IADC on debris mitigation (A/AC.105/823, para. 92). The Working Group recommended that interested member States, observers to the Subcommittee and members of IADC become involved in updating the IADC proposals on space debris mitigation for the Working Group's consideration at the next session of the Subcommittee.

19. At the forty-second session of the Subcommittee, in 2005, the Working Group agreed on a set of considerations for space debris mitigation guidelines and prepared a new workplan for the period from 2005 to 2007 (see A/AC.105/848, annex II, paras. 5 and 6), which was subsequently adopted by the Subcommittee. In 2006, the Working Group approved the revised draft space debris mitigation guidelines and agreed that the guidelines should be submitted to the Subcommittee for its consideration. The Working Group also recommended that the revised draft space debris mitigation guidelines be circulated at the national level to secure consent for their adoption by the Subcommittee at its forty-fourth session, in 2007 (A/AC.105/869, annex II, paras. 5 and 6).

20. At its forty-fourth session, in 2007, the Subcommittee adopted the space debris mitigation guidelines (A/AC.105/890, para. 99). At its fiftieth session, in 2007, the Committee endorsed the space debris mitigation guidelines and agreed that approval by the Committee of those voluntary guidelines would increase mutual understanding on acceptable activities in space and thus enhance stability in space-related matters and decrease the likelihood of friction and conflict (A/62/20, paras. 118 and 119).

21. In its resolution 62/217 of 2007, the General Assembly endorsed the Space Debris Mitigation Guidelines of the Committee, agreed that the voluntary guidelines for the mitigation of space debris reflected the existing practices as developed by a number of national and international organizations, and invited Member States to implement those guidelines through the relevant national mechanisms.

C. Expert group B on space debris, space operations and tools to support collaborative space situational awareness of the Working Group on the Long-term Sustainability of Outer Space Activities

22. At its fifty-second session, in 2009, the Committee agreed that the Scientific and Technical Subcommittee should include, starting at its forty-seventh session, in 2010, a new agenda item entitled "Long-term sustainability of outer space activities" (A/64/20, paras. 160–162). Consequently, in 2010, the Subcommittee established the Working Group on the Long-term Sustainability of Outer Space Activities (A/AC.105/958, paras. 181 and 182).

23. At its fifty-fourth session, the Committee adopted the terms of reference and methods of work of the Working Group (A/66/20, annex II). In accordance with those terms and methods, the Working Group established expert groups on four thematic areas. Expert group B on space debris, space operations and tools to support collaborative space situational awareness was co-chaired by Claudio Portelli (Italy) and Richard Buenneke (United States of America).

24. At its fifty-fifth session, in 2012, the Committee had before it working papers presenting the workplans of the expert groups, including that of expert group B (A/AC.105/C.1/L.325). The working report of expert group B was then made available to the Committee at its fifty-seventh session, in 2014 (A/AC.105/2014/CRP.14). The first draft guidelines were based on the work of the expert groups.

25. Also in 2014, the Chair of the Working Group, Peter Martinez (South Africa), produced a paper (A/AC.105/C.1/L.343) in which it was noted that the expert groups had identified a number of issues relevant to the long-term sustainability of outer space affairs that were still open or for which the current state of knowledge was inadequate to propose candidate guidelines. The expert groups therefore recommended a number of issues as topics for future consideration, contained in that report.

26. In relation to space debris, those topics included a recommendation that the Committee should consider the scientific, technical and legal questions arising from the active removal of space debris. For instance, regulatory issues still to be addressed include the identification of the launching State and the responsible State in relation to a space object, the question of whether it is necessary to obtain the consent of the State or States involved, and the question of who bears the costs and risks of such an activity. The Committee should also consider whether active space debris removal could be undertaken or authorized by a single State, or whether an international framework for active space debris removal under international consensus would be more suitable (see A/AC.105/C.1/L.343, para. 74 (e)).

D. Guidelines for the Long-term Sustainability of Outer Space Activities of the Committee on the Peaceful Uses of Outer Space

27. Following extensive negotiations by the Working Group on the Long-term Sustainability of Outer Space Activities, the Committee, at its sixty-second session, in 2019, adopted the preamble and 21 guidelines for the long-term sustainability of outer space activities (see A/74/20, annex II). The Committee encouraged States and international intergovernmental organizations to voluntarily take measures to ensure that the guidelines were implemented to the greatest extent feasible and practicable. At that session, the Committee also established, under a five-year workplan, a further working group under the agenda item on the long-term sustainability of outer space activities of the Scientific and Technical Subcommittee.

28. In its resolution 74/82, the General Assembly welcomed with appreciation the adoption by the Committee of the preamble and 21 guidelines and emphasized that the Committee served as the principal forum for continued institutionalized dialogue on issues related to the implementation and review of the guidelines.

29. The preamble and many of the guidelines of the Guidelines for the Long-term Sustainability of Outer Space Activities of the Committee relate to space debris. Particularly relevant are guideline B.3 on promoting the collection, sharing and dissemination of space debris monitoring information and guideline D.2 on investigating and considering new measures to manage the space debris population in the long term.

30. The current Working Group on the Long-term Sustainability of Outer Space Activities is considering space debris in relation to all three elements of its terms of reference: identifying and studying challenges and considering possible new guidelines for the long-term sustainability of outer space activities; sharing experiences, practices and lessons learned from the voluntary national implementation of the adopted Guidelines; and raising awareness and building capacity (see A/AC.105/1258, annex II, appendix). As an example, one subset of the overarching themes on challenges currently under consideration by the Working Group focuses on debris mitigation and active debris removal (see, inter alia, A/AC.105/C.1/L.410/Rev.1).

31. The Office for Outer Space Affairs, with financial support provided by the United Kingdom of Great Britain and Northern Ireland, also implements a project entitled "Awareness-raising and capacity-building related to the implementation of the Guidelines for the Long-term Sustainability of Outer Space Activities", through which it supports the implementation of the Guidelines (see https://spacesustainability.unoosa.org/).

E. Space debris in the outcome document of the Summit of the Future

32. In 2021, at the request of Member States, the Secretary-General issued the report entitled "Our Common Agenda" (A/75/982), his vision for the future of international cooperation. It contained a number of proposals under 12 commitments, as developed

by Member States in the declaration on the commemoration of the seventy-fifth anniversary of the United Nations (Assembly resolution 75/1), such as a proposal for "peaceful, secure and sustainable use of outer space", including through a multi-stakeholder dialogue on outer space, under commitment 3, to promote peace and prevent conflicts. In that report, the Secretary-General noted that "a combination of binding and non-binding norms is needed" to address emerging risks to outer space security, safety and sustainability.

33. In 2023, the Secretary-General issued a series of policy briefs to provide more detail on certain proposals contained in the report entitled "Our Common Agenda" and to support Member States in their deliberations as they prepared for the Summit of the Future. Policy brief 7, entitled "For all humanity – the future of outer space governance", contained an examination of the extraordinary changes under way in outer space activities and an assessment of the sustainability, safety and security impacts of those changes on present and future governance. The brief also outlined major trends and provided a practical set of governance recommendations for maximizing the opportunities of outer space while minimizing the short-term and long-term risks in relation to space traffic management, space debris and space resource activities.

34. In particular, in policy brief 7, it was recommended that the Committee on the Peaceful Uses of Outer Space develop a unified regime for space sustainability or consider developing new governance frameworks for various areas of space sustainability, including in relation to space debris, which could include the development of an effective framework for the coordination of space situational awareness, space object manoeuvres and space objects and events, as well as principles for space debris removal that take into account the legal and scientific aspects of space debris removal.

35. The Secretary-General's policy briefs set a framework for preparation for the Summit of the Future. Practical consultations on the preparations for the Summit began in 2023 and were spearheaded by co-facilitators – the permanent representatives of Germany and Namibia to the United Nations – who developed the zero draft of the Pact for the Future. Paragraph 147 of the zero draft contained the following text: "We commit to urgently developing frameworks for international cooperation in the areas of space traffic management, space debris removal, and space resource activities, including coordination of missions and exchange of data and findings from the exploration, exploitation and utilization of the Moon and other celestial bodies, through the Committee on the Peaceful Uses of Outer Space and in consultation with relevant bodies of the United Nations system".

36. The ultimate aim of the intergovernmental deliberations is the adoption at the Summit, to be held on 22 and 23 September 2024, of an ambitious, concise and action-oriented Pact for the Future, including elements on space sustainability.

37. With the objective of contributing to the multi-stakeholder dialogue on outer space and to the space track of the Summit of the Future, the United Nations/Portugal Management and Sustainability of Outer Space Activities Conference was held in May 2024 in Lisbon to address the issues contained in the Secretary-General's policy brief 7, related to outer space activities. Prior to the Conference, two preparatory virtual symposiums, one centred on technical challenges and another focused on policy, held in November 2023 and in March 2024 respectively, involved the consultation of international experts from industry, academia and Member States. In this connection, Portugal presented conference room paper A/AC.105/C.2/2024/CRP.33 to the sixty-third session of the Legal Subcommittee of the Committee on the Peaceful Uses of Outer Space, in April 2024. The report of the Conference will be made available to the Committee at its sixty-seventh session in June 2024.

F. Compendium of space debris mitigation standards adopted by States and international organizations

38. In its resolution 78/72, the General Assembly noted with appreciation that some Member States were already implementing space debris mitigation measures on a voluntary basis, through national mechanisms and consistent with the IADC Space Debris Mitigation Guidelines and with the Space Debris Mitigation Guidelines of the Committee on the Peaceful Uses of Outer Space, and invited other States to implement, through relevant national mechanisms, the Space Debris Mitigation Guidelines of the Committee on the Peaceful Uses of Outer Space.

39. In order to inform States of the instruments and measures that have been implemented by States and international organizations, the Office for Outer Space Affairs maintains the compendium of space debris mitigation standards adopted by States and international organizations (see www.unoosa.org). The compendium has been developed as a contribution of Canada, Czechia and Germany to the Committee on the Peaceful Uses of Outer Space, and in reference to the space debris-related agenda item of its Legal Subcommittee.

40. As of 2024, the respective item on the agenda of the Legal Subcommittee is entitled "General exchange of information and views on legal mechanisms relating to space debris mitigation and remediation measures, taking into account the work of the Scientific and Technical Subcommittee".

G. Research on space debris, safety of space objects with nuclear power sources on board and problems relating to their collision with space debris

41. Deeply concerned about the fragility of the space environment and the challenges to the long-term sustainability of outer space activities, in particular the impact of space debris, which is an issue of concern to all nations, the General Assembly, in its resolution 78/72, considered that it was essential that Member States pay more attention to the problem of the gradually increasing probability of collisions of space objects, especially those with nuclear power sources, with space debris, and other aspects of space debris.

42. In that regard, the General Assembly, in that resolution, called for the continuation of national research on the question, for the development of improved technology for the monitoring of space debris and for the compilation and dissemination of data on space debris, and considered that, to the extent possible, information thereon should be provided to the Scientific and Technical Subcommittee of the Committee on the Peaceful Uses of Outer Space. In its implementation of the mandate, the Office for Outer Space Affairs, in its capacity as secretariat of the Committee, prepares a series of documents containing research on space debris, the safety of space objects with nuclear power sources on board and the problems related to their collision with space debris. The documents are issued in the official languages of the United Nations under the agenda item of the Subcommittee entitled "Space debris".

H. Re-entry of space debris into the atmosphere

43. The Convention on Registration of Objects Launched into Outer Space is one of the five international treaties governing outer space developed under the auspices of the United Nations. Under the Registration Convention, every space object launched into Earth orbit or beyond shall be entered in a registry maintained by its launching State.

44. In its resolution 62/101, the General Assembly recommends enhancing the practice of States and international intergovernmental organizations in registering

space objects and also recommends, with regard to the harmonization of practices, that consideration should be given to the furnishing of additional appropriate information to the Secretary-General of the United Nations on the geostationary orbit location, any change of status of a space object in orbit, such as change of status in operations (inter alia, when a space object is no longer functional), the approximate date of decay or re-entry, the date and physical conditions of moving a space object to a disposal orbit, the date of change in supervision, the identification of the new owner or operator, any change of orbital position and any change of function of the space object.

45. The Office for Outer Space Affairs is responsible for discharging the duties, responsibilities and obligations of the Secretary-General relating to outer space activities, as specified in international legal instruments. These responsibilities involve the timely and effective dissemination of information relating to outer space activities provided by States and international organizations, in particular those that involve the launch, operation, re-entry and possible recovery of space objects (i.e. satellites, probes, crewed spacecraft and non-functional objects such as spent rocket stages).

46. The Office also implements, with financial support provided by the United Kingdom, the project entitled "The Registration Project: supporting implementation of treaty obligations related to the registration of objects launched into outer space" (see the stakeholder study, contained in document ST/SPACE/91, and www.unoosa.org).

47. In the specific case of the re-entry of nuclear-powered satellites, United Nations entities cooperate in the framework of the Inter-Agency Committee on Radiological and Nuclear Emergencies (IACRNE), which is the coordination mechanism seeking to ensure the development and maintenance of consistent and harmonized arrangements for preparedness for and response to nuclear or radiological emergencies.

48. IACRNE develops, maintains and co-sponsors the Joint Radiation Emergency Management Plan of the International Organizations, which describes the inter-agency framework of preparedness for and response to an actual, potential or perceived nuclear or radiological emergency, independent of whether it arises from an accident, natural disaster, negligence, nuclear security event or any other cause.

49. IAEA is the main coordinating body for the development and maintenance of the Joint Plan, which is co-sponsored by the Comprehensive Nuclear-Test-Ban Treaty Organization, the Euro-Atlantic Disaster Response Coordination Centre, the European Commission, the European Union Agency for Law Enforcement Cooperation (Europol), FAO, IAEA, ICAO, the International Labour Organization, the International Criminal Police Organization (INTERPOL), IMO, the Nuclear Energy Agency of the Organisation for Economic Co-operation and Development, the Pan American Health Organization, the United Nations Development Programme, the United Nations Environment Programme, the United Nations Office for the Coordination of Humanitarian Affairs, the Office for Outer Space Affairs, the World Health Organization and WMO.

I. Civil aviation

50. Space debris fragments associated with satellite constellations in low Earth orbit, stage re-entries and on-orbit collisions are known potential risks to the safety of civil aviation, primarily owing to the risk of their physical impact with aircraft upon re-entry. In addition to the re-entry of large space objects, the re-entry of many small objects also poses an increased risk to the safety of civil aviation. "The two principal ways that debris can be hazardous to aircraft are: (a) fragment penetration of a critical aircraft structure or the windshield; and (b) fragment ingestion by an

engine."[9] With the increase of uncontrolled re-entry activity, it is difficult to clearly define where re-entries will occur and how to best mitigate the risks they pose to the safety of civil aviation with minimal impact on airspace systems.

51. The internationally accepted safety approach has been to promulgate ground safety standards only.[10] These standards are based on the probability that a person, anywhere in the world, may become a casualty in the event of a re-entry. However, the size, density and mass of re-entering space objects that may cause casualties on the ground are different from the characteristics of re-entering objects that may pose a danger to aircraft in flight. The primary risk to people on the ground is significantly higher than the risk to aircraft in flight; however, a single incident involving an aircraft can be more impactful than an incident involving people on the ground. For this reason, it is inadequate to simply transpose ground-based risk models for re-entries and associated ground safety standards as a means to ensure the safety of civil aviation. The difficulty of predicting the outcome of a collision between an aircraft and a debris fragment necessitates the use of different metrics to characterize the risks to people on the ground and to the occupants of aircraft.[11]

52. While some States track and predict re-entering objects, the accuracy of those predictions varies greatly over time and, currently, the precise location of an uncontrolled re-entry cannot be predicted with enough accuracy to provide meaningful warnings.[12] The public generally has access to re-entry predictions, and several space entities publish information for upcoming re-entries on public-facing websites. Owing to the large footprint of impact predictions and the variability of locations, the usability of such re-entry information for any meaningful actions by airspace users is questionable. Given the current logistical constraints in terms of information processing and communication, it is impractical to close large volumes of airspace. For this reason, random re-entry predictions are viewed as non-actionable warnings.[13] At best, re-entry predictions can be viewed as safety advisories.

53. Within the context of the United Nations, there are two distinct legal regimes applicable to space and aviation. The Convention on International Civil Aviation (the Chicago Convention) was established primarily to "promote the safe and orderly development of civil aviation", while the Treaty on Principles Governing the Activities of States in the Exploration and Use of Outer Space, including the Moon and Other Celestial Bodies (the Outer Space Treaty) establishes the basic framework of international space law.

54. The primary role of ICAO is to ensure the safe operation of international civil aviation, which means that it has a role in the airspace integration of commercial space transportation operations. In practice, this involves establishing the framework, laid out in the ICAO Standards and Recommended Practices for States, for notifying airspace users of danger areas. One strategy for mitigating risks is to avoid random re-entries in favour of targeted and controlled re-entries. Controlling or targeting re-entries in order to land surviving objects or debris in remote, uninhabited regions would reduce the chances of an incident. States incentivizing or requiring space actors to place a reliable deorbiting system on constellation satellites could dramatically reduce the hazards posed to the safety of civil aviation. If all constellation satellites included a deorbiting system directing debris to remote areas, the casualty expectation for civil aircraft would be lower than for uncontrolled re-entries, even if some such

[9] J. Kenneth Cole, Larry W. Young and Terry Jordan-Culler, "Hazards of falling debris to people, aircraft, and watercraft", Sandia Report SAND-97-0805 (Washington D.C., Sandia National Laboratories, 1997).

[10] United States, Federal Aviation Administration, *Report to Congress: Risk Associated with Re-entry Disposal of Satellites from Proposed Large Constellations in Low Earth Orbit* (2023).

[11] Federal Aviation Administration/Office of Commercial Transportation (AST) and others have continued to sponsor research to improve the ability to predict the outcome of a collision between an aircraft and space vehicle debris.

[12] ARCTOS technical report No. 21-1128/14.1, "Aircraft vulnerability: modelling and quasi-static testing", November 2021, p. 4.

[13] Ibid., p. 2.

systems fail.[14] In addition, using available technology to direct re-entering debris to the safest and least disruptive portions of the global airspace system could lead to increased safety levels for civil aviation.

J. Maritime environment and marine ecosystems

55. IMO is the United Nations specialized agency responsible for developing and adopting measures to improve the safety and security of international shipping, prevent marine and atmospheric pollution from ships and prevent pollution from dumping of wastes at sea.

56. IMO currently has 175 Member States, and more than 130 observers from international organizations and non-governmental organizations representing all maritime interests. IMO has adopted over 50 treaties, the vast majority of which are in force and are globally binding. To supplement the treaties, numerous measures such as guidelines, guidance, recommended practices and codes have been agreed.

57. The Office for the London Convention/Protocol and Ocean Affairs, at IMO, serves as the secretariat of the London Convention and the London Protocol.[15]

58. The London Convention and the London Protocol are the two international treaties of global application that protect the marine environment from pollution caused by the dumping of wastes and other matter at sea.[16] Under the London Protocol, the dumping of all wastes and other materials is prohibited, with the exception of certain listed categories of wastes or other matter – and then only following a rigorous assessment process.

59. The issue of the marine environmental effects of jettisoned waste from commercial spaceflight activities has been on the agenda at meetings of the London Convention and London Protocol governing bodies and at the joint sessions of the London Convention and London Protocol scientific groups for several years, as these matters could potentially fall within the remit of the London Convention and the London Protocol. In 2018, following concerns raised by parties relating to the potential impacts on the marine environment arising from the physical presence of, and the potential for chemical contamination from, such debris, the governing bodies endorsed the decision by the scientific groups to establish an intersessional Correspondence Group on the issue and requested that the secretariat of the London Convention and London Protocol contact the Chair of the Committee on the Peaceful Uses of Outer Space, in order to initiate a dialogue between the two bodies and to encourage an exchange of information on issues of common interest. The Correspondence Group was tasked with collecting further information on the issue, with a view to assessing the impacts of those activities on the marine environment.

60. In subsequent discussions with the secretariat of the London Convention and the London Protocol, the Office for Outer Space Affairs stated that the environmental impacts of space flight activities had been identified as an issue by States participating in the Third United Nations Conference on the Exploration and Peaceful Uses of Outer Space (UNISPACE III), held in Vienna in 1999. At that conference, 33 recommendations were adopted (see A/CONF.184/6), including recommendation 1.a, which states:

> Protecting the Earth's environment and managing its resources: action should be taken: ... (v) To ensure, to the extent possible, that all space activities, in particular those which may have harmful effects on the local and global environment, are carried out in a manner that limits such effects and to take appropriate measures to achieve that objective.

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[14] Ibid.

[15] Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matter 1972 (London Convention), 1996 Protocol to the Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matter, 1972 (London Protocol).

[16] www.imo.org/en/OurWork/Environment/Pages/London-Convention-Protocol.aspx.

61. In 2019, the Committee on the Peaceful Uses of Outer Space was informed of the ongoing work by the London Convention and London Protocol on the issue (see A/AC.105/2019/CRP.11) and the Committee agreed that "the Office for Outer Space Affairs should liaise with the secretariat of the Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matter and its 1996 Protocol, at the International Maritime Organization, on matters relating to the effects on the marine environment of waste jettisoned from commercial spaceflight activities and report on the status of those matters to the Committee at its sixty-third session, in June 2020. In that regard, the Committee noted that it was the responsibility of member States to liaise and coordinate nationally with their respective authorities and departments responsible for the processes under those intergovernmental bodies" (A/74/20, para. 309).

62. In 2021, the London Convention and the London Protocol scientific groups, noting the limited information available for the Correspondence Group to form an opinion on the topic, agreed to hold the Correspondence Group in abeyance, until such time as more information was available.[17]

63. However, in 2023, the scientific groups were provided with an update on the current situation regarding the depositing of space launch vehicle components into the marine environment and efforts to assess the potential impacts, insofar as it had been possible given the very limited information available in the public domain.[18] The groups noted that, in the absence of further information-sharing by Parties, it would likely remain impossible to provide a more comprehensive overview of the nature and scale of the depositing of space launch vehicle components into the marine environment, and therefore of its likely cumulative impacts. The scientific groups thus invited Parties to the London Convention and the London Protocol to report on such activities and on the assessment of their impacts on the marine environment, on a voluntary basis, to future sessions, in order to allow for a more comprehensive overview of the nature and scale of the depositing of space launch vehicle components into the marine environment.[19]

K. Radio frequency spectrum and associated satellite orbit resources

64. ITU has an enabling role in facilitating access to outer space activities. Through its Radiocommunication Sector (ITU-R),[20] ITU regulates the allocation of the radio frequency spectrum and associated satellite orbit resources, thereby ensuring the continued operation of radiocommunication services. Thus, in an increasingly congested space environment, ITU is delivering on its mandate in order to promote the sustainable use of outer space by contributing to the global response to the challenges caused by space debris.

65. The Radio Regulations[21] of ITU govern the radio frequency spectrum and associated satellite orbit resources. This regulatory and technical framework enables satellite network filings to be coordinated and recorded in the ITU Master International Frequency Register. As a result, satellites can operate free from harmful radio interference, supporting various space radio services such as telecommunications, radionavigation or Earth observation. Radio frequencies are also essential for controlling the position and attitude of spacecraft.

66. Space debris, as non-functional, human-made objects in Earth orbit or re-entering the atmosphere, can pose significant risks. While such objects may not actively transmit signals, the associated risks include physical collisions or signal disruption, especially if the objects deviate from their orbital locations as recorded by ITU. This potential

[17] International Maritime Organization (IMO), document LC/SG 44/16, paras. 8.28–8.34.
[18] IMO, LC/SG 46/8/3.
[19] IMO, document LC/SG 46/16, paras. 8.30–8.39.
[20] Available at https://www.itu.int/en/ITU-R/Pages/default.aspx.
[21] Available at https://www.itu.int/pub/R-REG-RR-2020.

interference has the capacity to disrupt the operational capabilities of other satellites, emphasizing the need for effective mitigation measures.

67. Recognizing the risk posed by space debris, in 1993 ITU-R published the first version of the recommendation entitled "Environmental protection of the geostationary satellite orbit" (ITU-R S.1003.2), which was updated in 2003 and 2010. It focuses on minimizing debris release during satellite deployment in the geostationary satellite orbit region and on the removal of such debris to the graveyard orbit, while preventing radio frequency interference with other active satellites. The urgency of mitigating space debris risk has increased recently owing to the surge in satellite launches, particularly in relation to the deployment and operation of large constellations in low Earth orbit and medium Earth orbit.

68. In line with this trend, the ITU Plenipotentiary Conference (ITU PP-22), held in Bucharest in 2022, marked a significant milestone in addressing space sustainability within ITU. A new resolution on the sustainability of the radio frequency spectrum and associated satellite orbit resources used by space services (Resolution 219 (Bucharest, 2022)) underscores the urgent need to review technologies used in satellite networks in the geostationary satellite orbit, as well as the increased numbers of satellites within non-geostationary satellite orbit systems, with a view to addressing them in the Radio Regulations, where necessary, and in the processing of frequency assignments by the ITU Radiocommunication Bureau. The resolution also notes the urgency of addressing issues associated with non-geostationary satellite orbit systems before they are launched and operational.

69. Building on the momentum generated by ITU PP-22, the Radiocommunication Assembly (RA-23), held in Dubai, United Arab Emirates, in 2023, issued a resolution on activities related to the sustainable use of radio frequency spectrum and associated satellite orbit resources used by space services (Resolution ITU-R 74). This resolution not only acknowledges the importance of space debris mitigation efforts and active space debris removal, but also invites and instructs ITU-R and the Radiocommunication Bureau to implement specific actions to actively contribute to these initiatives, which include the development of a new recommendation providing guidance on safe and efficient deorbit and/or disposal strategies and methodologies for non-geostationary satellite orbit space stations involved in radiocommunication services after the end of their life, focusing on the radio frequency spectrum and associated satellite orbit resources used by space services. The resolution also recognizes the importance of ITU maintaining good coordination with the Committee on the Peaceful Uses of Outer Space and with the Office for Outer Space Affairs in order to advance the long-term sustainability of outer space.

70. As part of its preparations for the future, the World Radiocommunication Conference (WRC-23), held in Dubai, United Arab Emirates, in 2023,[22] considered the potential allocation of spectrum to the development of new technologies for the in-orbit servicing of space radiocommunication service spacecraft, including for active space debris removal. Although this innovative activity holds promise for satellite maintenance and for the prolongation of the operational life of such satellites, it also introduces a new dimension of risk – the potential for interference as satellites or objects approach one another in orbit. This stresses the need for the careful study of frequency allocations and for regulations in order to prevent radio interference during these critical operations. In addition to the ongoing studies, there are further considerations that will need to be addressed related to frequency management in the context of space debris mitigation. These include addressing the need to regulate the frequencies used to control a satellite between the end of its functional operation and the completion of its deorbiting manoeuvre.

71. With its role in the management of the radio frequency spectrum and associated orbital resources, and thanks to the recent adoption by its Member States of several

[22] International Telecommunication Union (ITU), Radiocommunication Sector, *Provisional Final Acts*, World Radiocommunication Conference 2023 (WCR-23) (2023).

resolutions, ITU continues to actively contribute to the effort to promote space sustainability.

L. Space security and disarmament

72. As space debris is an increasingly salient topic within multilateral discussions at the United Nations on space security, States have expressed concern over the testing and use of anti-satellite systems, owing to their potential widespread and irreversible impact on the outer space environment. As referenced in the Secretary-General's policy brief 7, entitled "For all humanity – the future of outer space governance", an armed conflict that extends into outer space would significantly increase the potential for space debris and the compromising of critical civilian infrastructure, disrupting communications, observation and navigation capabilities that are vital to the global supply chain.

73. In its resolution 77/41, the General Assembly expressed concern about the impact of destructive direct-ascent anti-satellite missiles on the long-term sustainability of the outer space environment. It also expressed that the use of other destructive anti-satellite systems might have widespread and irreversible impacts on the outer space environment. The Assembly recalled that many States had expressed concern about space debris as the most significant threat to the space environment.

74. In addition, the report of the Secretary-General (A/76/77) on reducing space threats through norms, rules and principles of responsible behaviours, states that:

> Many States regard the possible development of various anti-satellite weapons, either deployed on orbit or launched from systems deployed on the ground, in the air or at sea, as a serious cause for concern. Some regard the development and use of such capabilities as a challenge to the security and sustainability of outer space and as a possible threat to international peace and security.

75. As reflected in the Chair's summary (A/AC.294/2023/WP.22), the working group on reducing space threats through norms, rules and principles of responsible behaviours discussed a recommendation that States should consider refraining from any deliberate act that causes physical damage to or disabling or destruction of other States' space objects, including where such acts are expected to result in the generation of space debris.

76. The open-ended working group discussed further a recommendation that "States should (a) refrain from destructive direct-ascent anti-satellite missile tests, from destructive tests using any other type of counter-space capabilities, or from the development, deployment or use of such capabilities; (b) refrain from deliberately colliding satellites or other on-orbit objects; (c) refrain from any other non-consensual act that destroys or damages the space objects of other States; and (d) refrain from developing, testing, deploying or using weapons in outer space for any purpose, including missile defence systems, as anti-satellite weapons or for use against targets on Earth or in the air, as well as dismantling such systems already available to States".

77. The open-ended working group also discussed establishing a norm or prohibition against launching space vehicles without prior coordination with potentially affected countries, including those whose territories may be potential drop zones of uncontrolled re-entering or launch debris that pose a potential risk of injury to people, damage or destruction to property.

78. Satellites designed for active debris removal have also been discussed in the context of disarmament. Eight general methods of debris management technology have been developed to date; however, the number of operators providing active debris removal services are increasing and new innovative debris removal technologies are emerging.[23] In the light of this, States have increasingly expressed

[23] Thomas J. Colvin, John Karcz and Grace Wusk, *Cost and Benefit Analysis of Orbital Debris Remediation* (Washington D.C., National Aeronautics and Space Administration), 2023.

the need for further clarity and transparency on the utilization of dual-use and dual-purpose technology, as well as the meaning of these terms.[24] In his report on further practical measures for the prevention of an arms race in outer space (A/77/80), the Secretary-General observed that "the dual-use characteristic of most space systems" presents a particular challenge. In his report on transparency and confidence-building measures in outer space activities (A/78/75), it was observed that a number of States supported increased "transparency regarding rendezvous and proximity operations, including active debris removal and on-orbit servicing and manufacturing, including through the provision of advanced notifications".

79. A number of the measures recommended in the report of the Group of governmental experts on transparency and confidence-building measures in outer space activities (A/68/189) addressed limiting orbital debris in the context of risk reduction notifications relating to intentional orbital break-ups. In this connection, the Group recommended that harmful activities that generated long-lived debris should be avoided. The Group further recommended that "[w]hen intentional break-ups are determined to be necessary, States should inform other potentially affected States of their plans, including measures that will be taken to ensure that intentional destruction is conducted at sufficiently low altitudes to limit the orbital lifetime of resulting fragments". The Group further specified that the actions of States should be carried out in conformity with the Space Debris Mitigation Guidelines of the Committee on the Peaceful Uses of Outer Space.

80. UNIDIR works to support multilateral discussions on space security through substantive expertise. In 2023, UNIDIR published a report entitled "To space security and beyond: exploring space security, safety, and sustainability governance and implementation efforts", highlighting the intersectionality between space security, safety and sustainability through the lens of overarching issues such as space debris.[25] Furthermore, the "Lexicon for outer space security" of UNIDIR includes the term "space debris", as well as the term "kinetic physical" counterspace capabilities, in order to inform the international community of the context of intentional debris creation and how it relates to and impacts space security dialogue.[26]

81. Owing to the impact that space debris has on space sustainability, safety and security, it is becoming increasingly important to take stock of all efforts on the issue of space debris within the United Nations. Past endeavours, such as the joint panel discussion of the First and Fourth Committees on possible challenges related to space security and sustainability, have facilitated the exchange of efforts.[27] Acknowledging work within different forums can help avoid the duplication of efforts while mutually reinforcing progress.

M. Space data for management of food and agriculture

82. FAO is dedicated to ending hunger, improving nutrition, raising living standards, improving the efficiency of food production and distribution and fostering better conditions in rural areas, while ensuring the sustainable utilization and management of natural resources.

83. FAO is tasked with collecting, analysing, interpreting and disseminating information related to nutrition, food and agriculture. The FAO Hand-in-Hand initiative, which is aimed at reducing extreme poverty, eliminating hunger, improving nutrition, increasing agricultural productivity and rural living standards and

[24] See conference room papers GE-PAROS/2024/CRP.1 and A/AC.294/2023/WP.22.

[25] Sarah Erickson and Almudena Azcárate Ortega, "To space security and beyond: exploring space security, safety, and sustainability governance and implementation efforts" United Nations Institute for Disarmament Research (UNIDIR) Space Dossier 9 (Geneva, 2023).

[26] Almudena Azcárate Ortega and Victoria Samson, eds., "A lexicon for outer space security" (Geneva, UNIDIR, 2023).

[27] Co-Chair's summary of the joint panel discussion of the First and Fourth Committees, issued on 12 October 2017https://www.unoosa.org/documents/pdf/gajointpanel/Co-Chair_Summary_C1-C4_Joint_Panel_Discussion_Final_2.pdf.

contributing to global economic growth, acknowledges the importance of utilizing the most sophisticated tools available, including those that involve advanced geospatial modelling and analytics. In this context, remote sensing data and positioning information from space platforms have become strategically significant in the Organization's daily operations.

84. Simultaneously, the demand for information derived from remotely sensed data and global positioning services for agricultural development is growing steadily, particularly the requirement for long-term data series and high temporal resolution. Moreover, there is a rising demand for data at an advanced technological level, including very high-resolution and hyperspectral data. The agricultural sector, whose members range from farmers to decision makers, relies increasingly on space data. The implementation of the Sustainable Development Goals in the agricultural sector is also increasingly contingent upon the availability of space data.

85. Numerous ongoing remote sensing and global positioning space programmes at the national and international levels greatly support the activities of FAO and present significant opportunities to advance the Organization's efforts. However, FAO also acknowledges the risks associated with the growing number of human activities in space, which is particularly evident in the proliferation of space. FAO recognizes that an increasing number of redundant missions for Earth observation and positioning systems does not necessarily indicate an improvement in the provision of support services and activities.

N. Meteorology

86. The members of the Coordination Group for Meteorological Satellites, of which WMO is one, rely on the sustainability of the space environment to ensure that their satellite missions remain able to deliver meteorological and space weather data to global forecasting services. In this regard, safety on Earth is intertwined with safety in space. The Coordination Group has, therefore, established a Task Group on Space Environment Sustainability which shall address all aspects of operations in the space environment where the coordination of members of the Coordination Group can help improve the safety and sustainability of space operations for all space actors. The objectives of the Group include establishing best practices covering space traffic coordination, lifetime extensions, end-of-life disposal and the mitigation of space weather risks and effects. A proposal on acceptable space traffic coordination practices may be submitted for consideration by the Committee on the Peaceful Uses of Outer Space.

O. Navigation

87. The International Committee on Global Navigation Satellite Systems (ICG), established in 2005 under the umbrella of the United Nations, promotes cooperation on matters related to civil satellite-based positioning, navigation, timing and value-added services. ICG works to enhance coordination among providers of global navigation satellite systems (GNSS), regional systems and augmentations in order to ensure greater compatibility, interoperability and transparency, and to promote the greater use of GNSS capabilities to support sustainable development, taking into account the interests of developing nations.

88. ICG working groups are currently investigating methods to improve system of system operations, with a focus on the need to assess the adequacy of the current orbital debris mitigation guidelines applicable to GNSS. They have also requested that IADC conduct a study on medium Earth orbit and inclined geosynchronous orbit in coordination with system providers.

89. Within the framework of the ICG workplan, providers continued to give feedback on the 2020 report of IADC that followed a recommendation made at the thirteenth meeting of ICG to study the issue of debris mitigation practices relevant to

the medium Earth orbit and inclined geosynchronous orbit orbital regimes used by global navigation satellite systems. The Working Group is currently developing a response to IADC based on the collection of information on orbital parameters from the providers.

P. Risk tipping point for space debris

90. The increasing amount of space debris in orbit brings attention to an impending risk tipping point, at which a given socioecological system ceases to buffer risks and to provide its expected functions, after which the risk of catastrophic impacts to the system increases substantially. The United Nations University Institute for Environment and Human Security issued the *Interconnected Disaster Risks 2023 Report*, which analysed six interconnected "risk tipping points", selected for their representation of large global issues, one of which was space debris.

91. In the case of space debris, the risk tipping point refers to a critical density of objects in orbit in which the zero population growth of objects would become impossible, as collisions between existing objects would produce debris faster than they can be removed (the Kessler syndrome).

92. After reaching the risk tipping point, Earth orbits would be put on a path to becoming unusable, filled with millions of shards of debris that could damage or destroy any future object launched, so that satellite infrastructure could no longer provide its essential functions.

93. Given that a space debris risk tipping point being reached would have substantial impacts back on Earth, United Nations entities have been working to address the issue. In addition to the actions and advances outlined above, entities also work to conduct outreach and raise awareness on the topic with respect to their areas of work. These efforts include, but are not limited to, speeches, remarks, briefings, workshops, training courses, conferences and media engagements with multi-stakeholder audiences.

94. As outlined in the *Interconnected Disaster Risks 2023 Report*, the growing issue of space debris and the impending risk tipping point is a human-made problem, and is therefore possible to avoid. The report highlights the need for a change and calls on the global community to act now to create the future we want.