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Report of the Working Group on the Long-term Sustainability of Outer Space Activities

Working paper by the Chair of the Working Group

The Working Group on the Long-term sustainability of outer space activities was established in 2010 at the 47th session of the Scientific and Technical Subcommittee of the Committee on the Peaceful Uses of Outer Space. The Working Group was tasked in its terms of reference (A/66/20, annex II) with the preparation of a report on the long-term sustainability of outer space activities, the examination of measures that could enhance the long-term sustainability of such activities and the preparation of a set of best-practice guidelines.

This report summarizes the results of the activities of the Working Group on the Long-term Sustainability of Outer Space Activities. Drawing on a number of inputs from member States, international intergovernmental organizations and international organizations with permanent observer status of the Committee, and other relevant international bodies and organizations, the Working Group produced a Compendium of voluntary guidelines for the long-term sustainability of outer space activities that are not legally binding under international law (document reference). This Compendium begins with a preamble that addresses the background, definition, scope, objectives and status of the guidelines, as well as their implementation, review and updating. Thereafter follow the guidelines that address: (a) the policy and regulatory framework for space activities; (b) the safety of Space operations; (c) international cooperation, capacity-building and awareness; and (d) scientific and technical research and development in support of the long-term of the long-term sustainability of outer space activities. During its mandate, the Working Group agreed on the texts of twenty-one guidelines. In addition to these agreed guidelines, the Working Group also considered the texts of an additional seven draft guidelines, but was unable to reach consensus on these texts within the term of its mandate.

This report, which should be read as a companion document to the compendium, presents an overview of how the work of the Working Group was conducted, the topics addressed by the Working Group and the resulting twenty-one agreed guidelines. The report also addresses the need for a dedicated consultative process within the Committee on the Peaceful Uses of Outer Space to continue consideration of those guidelines which could not be finalised within the mandate of the Working Group, as well as to consider the procedures for the updating of agreed guidelines or for the proposal of topics for new guidelines in the future.

I. The long-term sustainability of outer space activities and the Committee on the Peaceful Uses of Outer Space

1. The Earth's orbital space environment constitutes a finite resource that is being used by an increasing number of States, international intergovernmental organizations and non-governmental entities. 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. Addressing these developments and risks requires international cooperation by States and international intergovernmental organizations to avoid harm to the space environment and the safety of space operations.

2. Space activities are essential tools for realizing the achievement of the Sustainable Development Goals. Hence, the long-term sustainability of outer space activities is of interest and importance for current and emerging participants in space activities, in particular for developing countries.

3. Over the years, the Committee on the Peaceful Uses of Outer Space has considered different aspects of the long-term sustainability of outer space activities from various perspectives. Building on those previous efforts and other relevant related efforts, the Working Group on the Long-term Sustainability of Outer Space Activities of the Scientific and Technical Subcommittee has developed a set of voluntary guidelines with a view to setting out a holistic approach to promoting the long-term sustainability of outer space activities. The guidelines comprise a compendium of internationally recognized measures for, and commitments to, ensuring the long-term sustainability of outer space activities and, in particular, enhancing the safety of space operations.

4. The development of voluntary guidelines is premised on the understanding that outer space should remain an operationally stable and safe environment that is maintained for peaceful purposes and open for exploration, use and international cooperation by current and future generations, in the interest of all countries, irrespective of their degree of economic or scientific development, without discrimination of any kind and with due regard for the principle of equity. The purpose of the Compendium is to assist States and international intergovernmental organizations, both individually and collectively, to mitigate the risks associated with the conduct of outer space activities so that present benefits can be sustained, and future opportunities realized. Consequently, the implementation of the guidelines for the long-term sustainability for outer space activities should promote international cooperation in the peaceful use and exploration of outer space.

II. Establishment of the Working Group and its terms of reference

5. At its fifty-second session in 2009, the Committee agreed that its Scientific and Technical Subcommittee should include, starting from its forty-seventh session in 2010, a new agenda item entitled "Long-term sustainability of outer space activities" and it proposed a multi-year workplan that was to culminate in a report on the long-term sustainability of outer space activities and a set of best-practice guidelines for presentation to and review by the Committee (A/64/20, paras. 161 and 162). Consequently, in 2010, the Subcommittee established the Working Group on the Long-term Sustainability of Outer Space Activities, and elected Peter Martinez (South Africa) as the Chair of the Working Group (A/AC.105/958, paras. 181 and182).

6. The Working Group's terms of reference, scope and methods of work were agreed at the fifty-fourth session of the Committee in 2011 (A/66/20, annex II). The Working Group was tasked to consider current practices, operating procedures, technical standards and policies associated with the long-term sustainability of outer

space activities, throughout all the phases of a mission life cycle. The Working Group was to take as its legal framework the existing United Nations treaties and principles governing the activities of States in the exploration and use of outer space; it was not to consider the development of new legally binding instruments.

7. The Working Group was further tasked to produce a report on the long-term sustainability of outer space activities and a consolidated set of voluntary and not legally binding guidelines that could be applied by States, international intergovernmental organizations, national non-governmental organizations and private sector entities to enhance the long-term sustainability of outer space activities for all space actors and for all beneficiaries of space activities. The guidelines should:

(a) Create a framework for possible development and enhancement of national and international practices pertaining to enhancing the long-term sustainability of outer space activities, including, inter alia, the improvement of the safety of space operations and the protection of the space environment, giving consideration to acceptable and reasonable financial and other connotations and taking into account the needs and interests of developing countries;

(b) Be consistent with existing international legal frameworks for outer space activities and should be voluntary and not be legally binding;

(c) Be consistent with the relevant activities and recommendations of the Committee and its Subcommittees, as well as of other working groups thereof, United Nations intergovernmental organizations and bodies and the Inter-Agency Space Debris Coordination Committee and other relevant international organizations, taking into account their status and competence.

III. Procedural summary of the work of the Working Group

8. The Working Group examined the long-term sustainability of outer space activities in the wider context of promoting sustainable development on Earth, taking into account the concerns and interests of all countries, in particular those of developing countries, and consistent with the peaceful uses of outer space.

9. The Working Group took as its legal framework the existing United Nations treaties and principles governing the activities of States in the exploration and use of outer space, in particular article VI of 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).

10. The Working Group invited and received contributions from States members of the Committee, relevant international intergovernmental organizations with permanent observer status to the Committee, international non-governmental organizations with permanent observer status to the Committee, United Nations entities, and other relevant international bodies and organizations. The Working Group received contributions from States members of the Committee, as well as from

11. Inputs of national non-governmental organizations and private sector entities were also obtained through relevant States members of the Committee and in special workshops organized by the Working Group in 2012 and 2013.

12. The Working Group took into consideration discussions within the Committee and its Subcommittees on the long-term sustainability of outer space activities, as well as progress made by the other working groups of the Subcommittees, such as the activities and recommendations being undertaken in the Working Group on the Use of Nuclear Power Sources in Outer Space (see for instance The Safety Framework for Nuclear Power Source Applications in Outer Space, A.AC.105.934) and also the work of the Scientific and Technical Subcommittee and the Inter-Agency Space Debris Coordination Committee on orbital debris mitigation (see for instance Space Debris Mitigation Guidelines of the Committee on the Peaceful Uses of Outer Space, A/62/20, annex).

13. The Working Group also established a liaison with the Group of Governmental Experts on Transparency and Confidence-Building Measures in Outer Space Activities established in implementation of General Assembly resolution 65/68. During the fiftieth session of the Scientific and Technical Subcommittee in 2013, the Chair of the Group of Governmental Experts, Viktor Vasiliev, briefed the Working Group on the progress made by the Group of Governmental Experts towards meeting its mandate to develop a report and a set of proposed voluntary transparency and confidence-building measures for States to consider implementing in their conduct of outer space activities. Following the conclusion of the work of the Group of Governmental Experts and the adoption of its report (A/68/189), the Working Group considered the linkages of its work with the recommendations contained in the report of the Group of Governmental Experts.

14. The Working Group met during the annual sessions of the Scientific and Technical Subcommittee and the Committee. The Working Group also used opportunities provided by intersessional coordination events, such as meetings, teleconferences, electronic meetings and workshops, as feasible and agreed.

15. As provided for in its terms of reference and methods of work, the Working Group established expert groups to expedite its work:

(a) Expert group A, "Sustainable space utilization supporting sustainable development on Earth", was co-chaired by Enrique Pacheco Cabrera (Mexico) and Filipe Duarte Santos (Portugal), and included approximately 40 experts;

(b) Expert group B, "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), and included approximately 70 experts;

(c) Expert group C, "Space weather", was co-chaired by Ian Mann (Canada) and Takahiro Obara (Japan), and included approximately 40 experts;

(d) Expert group D, "Regulatory regimes and guidance for actors in the space arena", was co-chaired by Anthony Wicht (Australia), who was succeeded by Michael Nelson (Australia), and Sergio Marchisio (Italy), and included approximately 50 experts.

16. In line with their specific topics, expert groups A through D compiled information and provided analysis on current practices, procedures and cross-cutting issues associated with the long-term sustainability of outer space activities. The expert groups also identified a number of gaps in existing approaches.

17. On the basis of their findings, the expert groups recommended a number of candidate guidelines for the consideration of the Working Group. The expert groups also identified a number of issues relevant to the long-term sustainability of outer space activities that are still open or for which the current state of knowledge is inadequate to propose candidate guidelines. The expert groups therefore recommended these issues as potential topics for future consideration by the Committee and its Subcommittees. The findings and recommendations of the expert groups are contained in the four Expert Group Reports issued in 2014 (A/AC/105/C.1/2014/CRP.13, A/AC/105/C.1/2014/CRP.15, A/AC/105/C.1/2014/CRP.16, and A/AC.105/2014/C.14).

18. The main findings of the expert groups provided the basis from which initial candidate guidelines were developed. Additional candidate guidelines were also proposed by a number of States members of the Working Group. All candidate guidelines were then taken into consideration for the development of a compendium of guidelines for the long-term sustainability of outer space activities.

19. Given the large amount of work before the Working Group, from 2015 to 2017, in addition to the meetings during the annual sessions of the Scientific and Technical Subcommittee and the Committee, the Working Group held five intersessional meetings in Vienna, as a way to advance its work.

20. During its examination of topics within its terms of reference, the Working Group noted linkages between its work and the thematic priorities of the fiftieth anniversary of the United Nations Conference on Exploration and Peaceful Uses of Outer Space (UNISPACE+50).

21. The guidelines duly take into account the relevant recommendations contained in the report of the Group of Governmental Experts on Transparency and Confidence-Building Measures in Outer Space Activities (A/68/189) and could be considered as potential transparency and confidence-building measures.

22. The Working Group also identified a number of issues requiring further consideration by the Committee and/or its Subcommittees, with a view to possibly developing additional guidelines in future. These issues are listed in section VI of the present report.

23. At the 59th session of the Committee in 2016, the Working Group agreed on a first set of twelve guidelines (A/71/20, annex) to be included in a Compendium of Guidelines for the Long-Term Sustainability of Outer Space Activities.[1] The Working Group further agreed that it would continue discussion of the preambular text of the Compendium and the remaining draft guidelines and also discuss procedures for the introduction and consideration of new guidelines and for the updating of guidelines in the Compendium in future. The Working Group agreed to extend the work plan by a further two years with a view to completing the Compendium. At the 55th session of the Scientific and Technical Subcommittee in 2018, the Working Group agreed that consensus had been reached on the text of the preamble and nine further guidelines (A/AC.105/1167, annex) for inclusion in the Compendium. The Working Group agreed that such inclusion did not prejudge any final decisions on the Compendium of guidelines or methods of future work, pending consideration of those issues at the sixty-first session of the Committee on the Peaceful Uses of Outer Space. In addition to the agreed guidelines referred above, the Working Group also considered the texts of an additional seven draft guidelines, but was unable to reach consensus on these texts within the term of its mandate.

IV. Guidance for States and international intergovernmental organizations

24. During its mandate the Working Group reached consensus on a Compendium of Guidelines for the Long-term Sustainability of Outer Space Activities. This Compendium begins with a preamble that addresses the background, definition, scope, objectives and status of the guidelines, as well as their implementation, review and updating. Thereafter follow the guidelines that address: (a) the policy and regulatory framework for space activities; (b) the safety of Space operations;(c) international cooperation, capacity-building and awareness; and (d) scientific and technical research and development in support of the long-term of the long-term sustainability of outer space activities. In addition to the agreed guidelines, the Working Group also considered the texts of an additional seven draft guidelines, but was unable to reach consensus on these texts within the term of its mandate.

25. The guidelines are based on a substantial body of knowledge, as well as the experiences of States, international intergovernmental organizations and relevant national and international non-governmental entities. Therefore, the guidelines are relevant to both governmental and non-governmental entities. They are also relevant to all space activities, whether planned or ongoing, as practicable, and to all phases of a space mission, including launch, operation and end-of-life disposal.

26. The guidelines are intended to support the development of national and international practices and safety frameworks for conducting outer space activities

[1] The annex summarizes the work carried out by the Experts Groups and the Working Group in the development of the guidelines. It does not represent consensus text of the Working Group.

while allowing for flexibility in adapting such practices and frameworks to specific national circumstances.

27. The guidelines are also intended to support States and international intergovernmental organizations in developing their space capabilities through cooperative endeavours, as appropriate, in a manner that reduces to a minimum or, as feasible, avoids causing harm to the outer space environment and the safety of space operations, for the benefit of current and future generations.

28. The existing United Nations treaties and principles on outer space provide the fundamental legal framework for the guidelines.

29. The guidelines are voluntary and not legally binding under international law, but any action taken towards their implementation should be consistent with the applicable principles and norms of international law. The guidelines are formulated in the spirit of enhancing the practice of States and international organizations in applying the relevant principles and norms of international law. Nothing in the guidelines should constitute a revision, qualification or reinterpretation of those principles and norms. Nothing in the guidelines should be interpreted as giving rise to any new legal obligation for States. Any international treaties referred to in the guidelines apply only to the States parties to those treaties.

30. The agreed guidelines are grouped into four categories as follows:

A. Policy and regulatory framework for space activities

Guideline A.1

Adopt, revise and amend, as necessary, national regulatory frameworks for outer space activities

Guideline A.2

Consider a number of elements when developing, revising or amending, as necessary, national regulatory frameworks for outer space activities

Guideline A.3

Supervise national space activities

Guideline A.4

Ensure the equitable, rational and efficient use of the radio frequency spectrum and the various orbital regions used by satellites

Guideline A.5

Enhance the practice of registering space objects

B. Safety of space operations

Guideline B.1

Provide updated contact information and share information on space objects and orbital events

Guideline B.2

Improve accuracy of orbital data on space objects and enhance the practice and utility of sharing orbital information on space objects

Guideline B.3

Promote the collection, sharing and dissemination of space debris monitoring information

Guideline B.4

Perform conjunction assessment during all orbital phases of controlled flight

Guideline B.5

Develop practical approaches for pre-launch conjunction assessment

Guideline B.6

Share operational space weather data and forecasts

Guideline B.7

Develop space weather models and tools and collect established practices on the mitigation of space weather effects

Guideline B.8

Design and operation of space objects regardless of their physical and operational characteristics

Guideline B.9

Take measures to address risks associated with the uncontrolled re-entry of space objects

Guideline B.10

Observe measures of precaution when using sources of laser beams passing through outer space

C. International cooperation, capacity-building and awareness

Guideline C.1

Promote and facilitate international cooperation in support of the long-term sustainability of outer space activities

Guideline C.2

Share experience related to the long-term sustainability of outer space activities and develop new procedures, as appropriate, for information exchange

Guideline C.3

Promote and support capacity-building

Guideline C.4

Raise awareness of space activities

D. Scientific and technical research and development

Guideline D.1

Promote and support research into and the development of ways to support sustainable exploration and use of outer space

Guideline D.2

Investigate and consider new measures to manage the space debris population in the long term

V. Topics for future consideration

31. Draft guidelines on which consensus was not reached within the Working Group extended workplan from 2016 to 2018, could be considered by the Subcommittee under its agenda item on long-term sustainability of outer space activities or through another agreed mechanism.

32. The Working Group agreed that further work was necessary to develop and acquire shared positions on aspects of information exchange reflected in the guidelines:

(a) The practical issues and modalities, as appropriate, relating to the exchange of relevant information on space objects and events in near-Earth space obtained from different authorized sources, in order to achieve harmonized and standardized record-keeping on space objects and events in outer space;

(b) The circumstances resulting in changes of space objects' status in operations and in the orbital positions of space objects;

(c) Information to be provided for pre-launch conjunction assessment; and

(d) Information to be furnished to support addressing risks from uncontrolled re-entries of space objects.

33. The Working Group recommended that the Committee may periodically review and revise these guidelines to ensure that they continue to provide effective guidance to promote the long-term sustainability of outer space activities. Proposals for revising this set of guidelines may be submitted by a member State of the Committee, for consideration by the Committee.

34. The expert groups identified a number of issues relevant to the long-term sustainability of outer space affairs that are still open or for which the current state of knowledge is inadequate to propose candidate guidelines. The expert groups have therefore recommended issues as topics for future consideration by the Committee and its Subcommittees. These topics are contained in the Expert Group Reports (A/AC/105/C.1/2014/CRP.13, A/AC/105/C.1/2014/CRP.15, A/AC/105/C.1/2014/CRP.16, and A/AC.105/2014/CRP.14). The Working Group recommended that the Committee consider how best to examine these topics for further consideration and other topics which may arise.

Annex I

Matters addressed by the Working Group and its expert groups

Summary by the Chair of the Working Group

Note: This annex summarizes the work carried out by the experts groups and the Working Group in the development of the guidelines. It does not represent consensus text of the Working Group.

A. Policy and regulatory framework for space activities

1. States bear international responsibility for national activities in outer space and for the authorization and continuing supervision of such activities, which are to be carried out in conformity with applicable international law. At present, there exist a wide range of regulatory practices and procedures which relate to the long-term sustainability of outer space activities. These practices and procedures vary in many respects. Some are binding obligations, and some are non-binding. Some are internationally applicable, others are designed for application only in particular countries. Regulation is undertaken in some instances by governments, in others by international organizations, and in still other instances by particular industries or communities.

1. Regulatory practices and supervision of national space activities

2. The development of national regulatory frameworks provides an opportunity to promote behaviours that enhance the long-term sustainability of outer space activities. In this regard, it is important to encourage advisory input from participants in space activities likely to be affected by any regulatory developments.

3. Regulation of space activities may involve multiple regulatory bodies dealing with different issues pertaining to, inter alia, launch safety, on-orbit operations, radio frequency usage, remote sensing activities, end-of-life disposal and controlled items. For this reason, it is important to ensure that appropriate communication and consultation mechanisms are in place within and among the competent bodies that oversee or conduct space activities. Communication within and among relevant regulatory bodies can promote regulations that are consistent, predictable and transparent so as to ensure that regulatory outcomes are as intended.

4. Regulations should address risks to people and property and should provide clear guidance to participants in space activities under the jurisdiction and/or control of a particular State.

5. Existing international standards and recommended practices can complement regulation. These include standards published by ISO, the Consultative Committee for Space Data Systems, and national standardization bodies and recommended practices published by IADC and the Committee on Space Research (COSPAR).

6. Dissemination of information and appropriately targeted outreach and education can assist all participants in space activities in gaining a better appreciation and understanding of the nature of their obligations, which can lead to improved compliance with the existing regulatory framework and the practices currently being employed to enhance the long-term sustainability of outer space activities. This is particularly valuable where the regulatory framework has been changed or updated, resulting in new obligations for participants in space activities.

7. The following guidelines address these issues:

- *Guideline A.1 Adopt, revise and amend, as necessary, national regulatory frameworks for outer space activities;*

- *Guideline A.2 Consider a number of elements when developing, revising or amending, as necessary, national regulatory frameworks for outer space activities; and*
- *Guideline A.3 Supervise national space activities*.

2. Spectrum protection

8. Radio frequency communications play a key role in space activities. Radio waves not only convey commands to satellites, but also allow satellites to transmit data back to Earth and to provide services that are critical to the normal functioning of the modern information society. Radio frequency interference can interrupt or impede the performance of satellites and result in the loss of data or disruption of services. In addition, a number of space-based systems for Earth observation rely on certain regions of the electromagnetic spectrum and are susceptible to interference from artificial sources of electromagnetic radiation.

9. As the radio frequency spectrum is a finite resource which crosses national boundaries, international coordination and cooperation is needed to ensure that this resource is used in a rational and equitable manner, in accordance with the Radio Regulations and Recommendations of the International Telecommunication Union.

10. Even with existing international mechanisms for cooperation, further work is needed to ensure that countries or groups of countries have equitable access to radio frequencies, to ensure that space activities are conducted in such a way as to prevent harmful interference with the space activities of other States and international intergovernmental organizations, and to improve measures for prompt resolution when cases of harmful radio frequency interference do occur.

11. The following guideline addresses these issues:

- *Guideline A.4 Ensure the equitable, rational and efficient use of the radio frequency spectrum and the various orbital regions used by satellites*

3. Registration information

12. The Convention on Registration of Objects Launched into Outer Space, adopted by the General Assembly in its resolution 3235 (XXIX) of 12 November 1974 and entered into force on 15 September 1976, is one of the five international treaties governing outer space developed under the auspices of the United Nations. As of 1 January 2018, there were 67 States parties to the Registration Convention and three signatory States. There were also three international intergovernmental organizations that have declared their acceptance of the rights and obligations under the Convention. States not parties to the Convention can use General Assembly resolution 1721 B (XVI) of 1961 as the basis for voluntary registration submissions.

13. Under the Registration Convention, every space object launched into Earth orbit or beyond shall be entered in a registry maintained by its launching State. The Convention defines "launching State" to mean (a) a State that launches or procures the launching of a space object; or (b) a State from whose territory or facility a space object is launched.

14. General Assembly resolution 62/101 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 in operations (inter alia, when a space object is no longer functional). Further, resolution 62/101 recommends that, following the change in supervision of a space object in orbit the State of registry, in cooperation with the appropriate State according to article VI of the Outer Space Treaty, could furnish to the Secretary-General additional information, such as: the date of change in

supervision; the identification of the new owner or operator; any change of orbital position; any change of function of the space object.

15. The lack of comprehensive information on objects launched into orbit results in a patchy and incomplete picture of what is in orbit and where. This affects space situational awareness, and ultimately safety too, if a potentially hazardous situation arises and inadequate information is available to identify a space object and/or its operators, or it is unclear under whose jurisdiction and/or control] the object falls. The importance of the link between supervision and registration is therefore underlined. Providing appropriate and accurate information about space objects, as recommended by General Assembly resolution 62/101, requires a close link between the operator of the space object and the supervising State. It is desirable that the State of registry should also be the State initially responsible for the supervision of space operations of a given space object.

16. The following guideline addresses the above issues:

- *Guideline A.5 Enhance the practice of registering space objects*

B. Safety of space operations

17. The Working Group and its expert groups identified a number of areas in which guidance could be provided to States and international intergovernmental organizations to improve the safety of space operations.

1. Contact information for entities responsible for controlling spacecraft or sharing information on space objects and orbital events.

18. Informal and internal directories of contact information for and submissions to the register of space objects of the Office for Outer Space Affairs are not the most complete with regard to current identities of spacecraft operators, owners, supervising States or web links to official information on space objects. When contact information for entities responsible for spacecraft operations is provided, it may not reflect the supervising State and may not be updated in a timely fashion.

19. Resolution 62/101 recommends that the Office for Outer Space Affairs should make public through its website the contact details of the focal points, however such information has not yet been posted. In addition, submissions to the register of space When an orbital close approach is predicted after conjunction assessment or a trajectory adjustment is performed for orbital collision avoidance, timely notifications are important. It is also important to have timely coordination between relevant entities responsible for spacecraft operations and conjunction assessment.

20. Contact information facilitates coordination between relevant entities to make appropriate trajectory adjustment decisions. This contact information can also allow States with space monitoring capabilities to provide close approach notifications to potentially affected spacecraft operations entities, allowing them to make timely decisions on trajectory adjustments for collision avoidance. Moreover, entities with information on debris-producing events can also use contact information to share this information with other entities responsible for launch operations, spacecraft operations or conjunction assessment.

21. Although the national regulations of some States require private-sector satellite operators to provide contact information to entities that control spacecraft, there is no commonly agreed practice for States to compile and share this contact information with other States for the purpose of timely coordination for collision avoidance.

22. The following guideline addresses these issues:

- *Guideline B.1 Provide updated contact information and share information on space objects and orbital events*

2. Accuracy of orbital data

23. The accuracy of orbital data depends on a variety of factors, such as the quantity and accuracy of the measurements used, the distribution of measurements over the orbit determination arc, the geographical distribution of tracking sensors, and the suitability of the orbit determination and propagation techniques.

24. For functional objects, orbital data are usually obtained by traditional means, such as processing of ground control station trajectory measurements derived from telemetry. An increasing number of functional space objects use on-board navigation techniques, but the required accuracy of the orbital data is mainly dictated by mission or operational requirements, and these do not necessarily meet the spaceflight safety requirements. For space objects with no functioning on-board equipment, the only direct sources of orbital information are entities processing measurements acquired by radar and active, as well as passive, optical instruments. Radars constitute the primary source of information for large objects in LEO, while passive electro-optical sensors provide the majority of data for objects in high-altitude orbits.

25. The current geographical distribution and capabilities of these sensors are limited and, in many cases, do not permit the timely derivation of orbits of suitable quality for conjunction analysis and subsequent decisions on collision avoidance manoeuvres. The problem becomes even more pronounced given the increasing number of small-sized intact space objects such as CubeSats.

3. Standards for sharing orbital information

26. Receiving, accumulating, sharing and distributing orbital information is necessary for ensuring the safety of orbital operations and for the determination and analysis of physical characteristics of space debris objects.

27. Strictly speaking, orbital information not accompanied by an assessment of its precision or calculated with simplified motion models should not be used when a decision about a potential collision avoidance manoeuvre is being made. Simplified motion models introduce a significant margin of error into the assessment of the predicted centre of mass position of the approaching object.

28. The existing, internationally recognized orbital information standards offer a considerable degree of flexibility for the description of both the data and the models for obtaining them. However, the formal use of information provided in line with those standards does not necessarily result in a correct conclusion, because the models used to process the basic measurement data, including models for accuracy estimation, may differ from one another.

29. The following guideline addresses these issues:

- *Guideline B.2 Improve accuracy of orbital data on space objects and enhance the practice and utility of sharing orbital information on space objects*

4. Space debris mitigation

30. The current space debris environment is deteriorating due to an increasing number of orbital objects, despite worldwide efforts to reduce that increase through the implementation of internationally agreed debris mitigation standards and guidelines. Orbital space debris arises from various sources: non-operational satellites, 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 or by the explosion of spacecraft or the upper stages of launchers. Since 2007, major collision events (both accidental and intentional) have significantly increased the proportion of collision-induced debris in the overall debris population.

31. Objects larger than about 10 cm in diameter in low-Earth orbits (LEO) and larger than about 1 metre in the geostationary orbit (GEO) can be detected and tracked with

ground-based sensors. The number of objects that are too small to detect from the ground but pose a significant risk to space missions is far larger. Even tiny debris or meteoroids smaller than 1 mm can pose a risk to exposed electric harnesses or other vulnerable components, possibly resulting in the loss of functions or even in a break-up.

32. Operational space objects comprise just five per cent of the overall catalogued population. The remainder of catalogued space objects have the potential to cause catastrophic collisions, yielding large-sized fragments that could lead to further catastrophic collisions. In some orbital regions this may cause an unstable, runaway situation often denoted as the Kessler syndrome, where the increase in the amount of debris from collisions exceeds the reduction due to orbital decay.

33. In 2007, the General Assembly, in its resolution 62/217, endorsed the Space Debris Mitigation Guidelines of the Committee on the Peaceful Uses of Outer Space. The Guidelines represent the first international consensus to reduce space debris and are an important step in providing all spacefaring nations with guidance on how to mitigate the problem of space debris. These qualitative guidelines are based on the technical content and the basic definitions of the Space Debris Mitigation Guidelines of the Inter-Agency Space Debris Coordination Committee (IADC).

34. A number of States are also using the IADC Space Debris Mitigation Guidelines, the European Code of Conduct for Space Debris Mitigation, and standard 24113:2011 (Space systems: space debris mitigation requirements) of the International Organization for Standardization (ISO) as a reference in their regulatory frameworks for national space activities. In this regard, some States have taken measures to incorporate internationally recognized guidelines and standards related to space debris in their national legislation.

35. At a technical level, States that have implemented national mechanisms for space debris mitigation use a range of approaches and concrete actions to mitigate space debris, including the improvement of the design of launch vehicles and spacecraft, end-of-life operations (including passivation and placing satellites into disposal orbits), and the development of specific software and models for space debris mitigation.

5. Space debris monitoring

36. Given the large number of potentially dangerous space debris objects, the complex evolution of both individual objects and their population as a whole, and the vast volume of near-Earth space over which the objects are scattered, regular monitoring of the situation in near-Earth space is extremely challenging and requires significant financial, technical and human resources.

37. No State in the world is currently able to provide a complete and constantly updated picture of the situation in orbit on its own. Thus, there is an objective need to combine capabilities in this area.

38. Space debris monitoring data cannot be correctly interpreted and used without understanding the methodology used to produce such data. This fact must be taken into account during the planning, sharing and collaborative use of data. Therefore, a key aspect of international cooperation in the investigation of the man-made space debris environment in near-Earth space is the development and harmonization of common approaches to evaluating the quality of the data, interpreting them and assessing their potential use for specific tasks.

39. Currently, only a few States carry out regular observations of space debris in near-Earth space. The development of common, mutually agreed approaches to verifying the information received from other parties and fusing data from different sources in a qualified way has been and remains a relevant issue. Furthermore, there is no international mechanism for exchanging verified information that might be used by different countries which do not carry out observations themselves, but have scientific and technical personnel capable of utilizing such information.

40. Another aspect of the problem is the lack of standard approaches to representing measurement data, which are primary in nature, and derived products on space debris, which include orbital information (i.e. centre-of-mass motion parameters), estimations of mass, size, attitude motion parameters relative to the centre of mass, and reflection characteristics.

41. The following guideline addresses these issues:

- *Guideline B.3 Promote the collection, sharing and dissemination of space debris monitoring information*

6. Conjunction assessment

42. More than 1,000 functional spacecraft in orbit today are joined by tens of thousands of pieces of space debris. The orbital collision of the functional Iridium 33 and non-functional Cosmos 2251 in February 2009 proved that a catastrophic satellite collision is a realistic possibility. Today an increasing number of spacecraft operators are attaching greater importance to avoiding collisions. Conjunction assessment can be divided into two categories: prelaunch screening and orbital conjunction assessment.

43. Launch vehicle operators are encouraged to avoid collisions during the system's launch phase and are expected to plan launch windows to avoid potential conjunctions with orbital objects. Some launch vehicle operators adjust launch times by screening for collisions with the International Space Station; a few of them also screen for collisions with functioning spacecraft. Some conjunction assessment organizations offer prelaunch collision avoidance screening services to assist launch vehicle operators in performing screenings and adjusting launch times. However, there are gaps in this process.

44. For example, there are no common standards to represent planned orbital insertion phase trajectories (i.e. before injection of all payloads into final orbits) and associated uncertainties for use in conjunction assessment analysis as described above. There is also no common practice for performing conjunction assessment analysis during the actual orbital insertion phase (until initial orbital insertion of all payloads). Even with the capability to perform conjunction assessment, the ability to adjust launch trajectories is limited by launch vehicle design and technology, and cannot be addressed by a guideline. Precise orbital insertion is often limited by fundamental technical constraints. Further technical research and development would be required to address this gap.

45. There are various ways to address conjunction assessment in the orbital phases. Some operators are able to perform conjunction assessments themselves. Other operators work with appropriate organizations capable of performing conjunction assessments to screen the orbital parameters of functioning spacecraft against other space objects to identify potential conjunctions. Some operators interact directly with other operators to perform conjunction assessments and collision avoidance manoeuvres for spacecraft for which they are responsible.

46. The following guideline addresses these issues:

- *Guideline B.4 Perform conjunction assessment during all orbital phases of controlled flight*

7. Prior notice of launches and controlled re-entries

47. During launches of space objects or controlled de-orbiting of space objects it is possible to provide prior notice for areas where surviving fragments of launch vehicle stages or spacecraft might fall. The projected ground impact area and time of fall can be estimated during the planning of the launch or while planning the controlled re-entry of a space object.

48. The value of furnishing such information in the context of the long-term sustainability of outer space activities is twofold:

(a) Prior notice of controlled re-entries of large spacecraft is a safety issue. Timely notices enable the reduction of risks of possible injuries or damage to assets on the Earth's surface and in its airspace;

(b) Such notices are one of the measures to enhance transparency and trust between States, demonstrate responsible behaviour and enable appropriate awareness of such events.

49. The practice of providing special notices in aviation and maritime navigation is well developed and in current use. These notices contain, inter alia, information on danger zones in air and maritime areas that for a certain period of time can constitute a danger for aircraft and ships.

50. Only a few States currently have the technical capability to monitor the uncontrolled re-entry of objects into the Earth's atmosphere, and no State has the technical capability to predict the location and time of an uncontrolled re-entry with sufficient accuracy to issue actionable warnings.

51. The following guideline addresses these issues:

- *Guideline B.5 Develop practical approaches for pre-launch conjunction assessment*

8. Space weather effects on space systems

52. Space weather is the collection of changes in the Earth's natural environment and space-based and terrestrial infrastructure caused by solar events that alter the solar system space environment. These solar events include: flares, the sudden eruptions of energetic photons and charged particles from the Sun's surface; coronal mass ejections, in which the Sun typically sheds billions of tons of mass of its atmosphere as magnetized plasma; and the solar wind, the continuous outflow of charged particles that race through the solar system at around 400 to 800 km/s or more. On Earth, these charged particles and high-energy photons have an impact on the dynamics of the near-Earth space environment, specifically the magnetosphere, ionosphere, and even the neutral atmosphere, and affect the operation of terrestrial and space infrastructure.

53. These space weather phenomena lead to increased radiation hazards for astronauts, charging of spacecraft surfaces and internal charging of spacecraft components, degradation of spacecraft solar arrays and materials, anomalous behaviour of electronic components, failure of computer memory units, blinding of optical systems, degradation or loss of spacecraft tracking information, anomalous drag and loss of altitude.

54. Space weather also causes changes in the ionosphere that disrupt high-frequency communications and alter the signals of global navigation satellite systems (GNSS). Commercial flights over the poles must reroute, at considerable expense, to protect crews from radiation exposure and to assure communications capability. Solar coronal mass ejections can disrupt the Earth's magnetic field, leading to electrical blackouts, potentially on a continental scale. Since global banking and finance rely on timing signals from GNSS, loss of this service due to a solar storm would lead to disruptions of this economic sector, with unforeseeable secondary impacts. Space weather can also adversely affect some terrestrial infrastructure, including high-voltage electrical transmission systems and pipelines.

55. Additionally, swelling of the atmosphere as a result of space weather can change satellite orbits, thereby degrading space situational awareness information. This occurs in two ways. Firstly, the space debris population and its evolution are tied to the altitude-dependent density of the atmosphere, which is dependent upon solar effects. Secondly, the ability to predict conjunctions and hence enable collision avoidance also depends on accurate knowledge of atmospheric density.

56. The following guideline addresses these issues:

- *Guideline B.6 Share operational space weather data and forecasts*

9. Models and tools for space weather prediction

57. Significant improvements in the mitigation of space weather effects can be obtained from a synergistic approach to the monitoring of space weather in the heliosphere that includes the modelling of space weather dynamics, the generation of space weather forecasts, studies of the impacts of space weather on technological systems, and the development and implementation of technical standards for the design and manufacture of vulnerable terrestrial and space-based infrastructure, including satellites.

58. A variety of Earth-based and space-based sensors are used to gather information about the conditions on the Sun, the interplanetary space environment, the Earth's magnetosphere, radiation belts and the ionosphere. These observations must be integrated to provide comprehensive situational awareness of space weather. These data are also used for space weather modelling and forecasting.

59. A variety of models have been developed to address different phenomena that contribute to space weather. These include models for sunspots, solar flares, solar coronal mass ejections, the solar corona, and the solar wind. There are also models for the interaction of these solar phenomena with the interplanetary space environment and with the Earth's magnetosphere, the Van Allen radiation belts and the Earth's ionosphere and atmosphere.

60. The risks posed by space weather phenomena to space systems may be mitigated from an engineering and operations perspective through implementing certain design approaches, technical standards and operational practices that reduce or avoid the adverse effects of space weather on operational space systems.

61. The long-term improvement of space weather services requires coordinated, committed partners from around the world. International cooperation is necessary to create a shared satellite-based system for critical observations, to maintain reliable access to regional data, to advance service capabilities, and to ensure the global consistency of the end products that are delivered to users of space weather information and data services. There is an urgent need to adopt a coordinated approach to the collection, collation, and access to key data, metadata, design guidelines, space weather models and forecasts, and the reporting of the occurrences of space weather effects and related information, such as records of operational satellite anomalies.

62. The following guideline addresses these issues:

- *Guideline B.7 Develop space weather models and tools and collect established practices on the mitigation of space weather effects*

Trackability of space objects

63. Space objects that are difficult to track during their operational stage and after completion thereof pose risks of collision with other space objects. The wide use of small-size space objects (in particular, objects known as nano- and picosatellites) is becoming increasingly more feasible thanks to technological developments. Due to the importance of these small-size space objects to all space programmes, in particular for developing countries and emerging spacefaring countries, the use of small-size space objects is expected to increase in the future. Hence it is important to promote design approaches that improve the trackability of space objects and facilitate accurate and precise determination of their position in orbit, regardless of their physical and operational characteristics. It is also important to consider the end-of-life disposal of space objects after the end of their mission to limit their long-term presence in heavily utilized orbital regions of outer space, in furtherance of the long-term sustainability of space activities.

64. The following guideline addresses these issues:

- *Guideline B.8 Design and operation of space objects regardless of their physical and operational characteristics*

Uncontrolled re-entries of space objects

65. In most cases the atmospheric re-entry of space objects is uncontrolled. Some re-entries involve potentially hazardous space objects, such as incapacitated spacecraft and launch vehicle stages, that have large mass or carry hazardous materials or substances on board. Moreover, not all States and international intergovernmental organizations which exercise jurisdiction over space objects forecast to re-enter the atmosphere have the relevant technical capabilities and resources for tracking these objects and generating information on their trajectory, or for assessing the risks associated with uncontrolled re-entries, To some extent such risks may be mitigated during the design phase through applying design techniques to minimize the risk associated with fragments of space objects surviving uncontrolled re-entry. Another way to mitigate the risks associated with uncontrolled re-entries is through States and international intergovernmental organizations cooperate to build capacity in the area of monitoring uncontrolled space object re-entries, associated risk assessment and timely dissemination of relevant information and the designation of appropriate entities that are authorized to provide, request and receive such information.

66. The following guideline addresses these issues:

- *Guideline B.9 Take measures to address risks associated with the uncontrolled re-entry of space objects*

Use of laser beams passing through outer space

67. Laser beams passing through near-Earth outer space are used for a number of applications, inter alia, for high-precision measurements of the range to reference space objects equipped with special laser retroreflectors, refining the theory of lunar motion, establishing optical communication channels, and as an illuminator during optical observations of space objects which are not sunlit. In addition, the use of ground-based and space-based lasers to address the problem of space debris has also been proposed in several projects. In order to avoid potentially harmful accidental illumination of passing space objects by laser beams, it would be prudent for entities emitting such laser beams to observe certain precautionary measures, without imposing any unreasonable restrictions on their use in practical and research applications.

68. The following guideline addresses these issues:

- *Guideline B.10 Observe measures of precaution when using sources of laser beams passing through outer space*

C. International cooperation, capacity-building and awareness

1. International cooperation

69. As the exploration and use of outer space is to be carried out for the benefit and in the interest of all countries, it is crucial that international cooperation should address equitable access to the benefits of outer space activities for purposes of human development. International cooperation may take many forms, including the sharing of data, capacity-building activities in technical and legal fields, and support for countries wishing to establish their own national capacities for outer space activities.

70. The following guideline addresses the above issues:

- *Guideline C.1 Promote and facilitate international cooperation in support of the long-term sustainability of outer space activities*

2. Exchange of experience and capacity building

71. The sharing of experiences and expertise acquired by entities engaged in space activities should be regarded as instrumental in the development of effective measures to enhance the long-term sustainability of outer space activities. In this regard, the information and data-sharing practices and experiences of both governmental and non-governmental entities constitute useful inputs for the development of procedures for the compilation and effective dissemination of information.

72. Developing countries with emerging space programmes can benefit greatly from capacity building activities provided by entities from other countries with experience in the conduct of space activities. Such capacity building activities can be oriented toward achieving efficient technical capabilities, standards, regulatory frameworks and governance methods that support the long-term sustainability of outer space activities.

73. The following guidelines address these issues:

- *Guideline C.2 Share experience related to the long-term sustainability of outer space activities and develop new procedures, as appropriate, for information exchange*
- *Guideline C.3 Promote and support capacity-building*

3. Awareness

74. Institutional and public awareness of space activities, space applications, and the benefits they bring to sustainable development should be promoted, with special attention being paid to the needs of young people and future generations. Information-sharing and education offer the best opportunities for raising the profile of sustainable space utilization in support of sustainable development on Earth.

75. The following guideline addresses the above issues

- *Guideline C.4 Raise awareness of space activities*

D. Scientific and technical research and development

1. Space activities and sustainable development on Earth

76. Space technologies can play a key role in economic development, social development and environmental protection, the three pillars of sustainable development. They offer valuable tools for supporting sustainable development, the benefits of which are to be leveraged for all humankind. Space-based applications such as Earth observation, global navigation satellite systems, and telecommunications provide objective data and information, which may improve the understanding of trends, assist with the evaluation of needs, and contribute to better-informed decision-making.

77. Space activities themselves should also have minimal negative impact on the Earth or the space environment. The promotion and development of technologies that minimize the environmental impact of launching space assets and maximize the use of renewable resources and the reusability or repurposing of existing space assets can support these efforts.

78. The following guideline addresses these issues:

- *Guideline D.1 Promote and support research into and the development of ways to support sustainable exploration and use of outer space*

2. Managing the space debris population in the long-term

79. Given the large number of potentially dangerous space debris and the complex evolution of both individual objects and their population as a whole, as well as the

vast volume of the near-Earth space where the objects are scattered, regular monitoring of the situation in the near-Earth space is extremely challenging and requires significant financial, technical and human resources.

80. Meanwhile, the emergence and development of new technologies makes it possible to engage an increasing number of researchers from different countries in monitoring of the near-Earth space. No State in the world is currently able to provide a complete and constantly updated picture of the situation in orbit on its own. Thus, there is an objective need to combine capabilities in this area. The tools and technologies of optical observations of objects in the near-Earth space are no longer financially costly and are available to all interested states, which make it quite feasible to ensure the widest possible participation to study the man-made debris in the near-Earth space, especially in the high orbits (geostationary and highly elliptical orbits), where the space debris population is less characterized.

81. The following guideline addresses these issues:

- *Guideline D.2 Investigate and consider new measures to manage the space debris population in the long term*