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Committee on the Peaceful Uses of Outer Space

Thematic priority 4. International framework for space weather services

Note by the Secretariat

I. Introduction

1. The Committee on the Peaceful Uses of Outer Space, at its fifty-ninth session, in 2016, in preparation for the fiftieth anniversary of the first United Nations Conference on the Exploration and Peaceful Uses of Outer Space (UNISPACE+50) endorsed seven thematic priorities (A/71/20, para. 296).

2. The objectives under thematic priority 4, on the international framework for space weather services, are to strengthen the reliability of space systems and their ability to respond to the impact of adverse space weather; to develop a space weather road map for international coordination and information exchange on space weather events and their mitigation, through risk analysis and assessment of user needs; to recognize space weather as a global challenge and the need to address the vulnerability of society as a whole; to increase awareness through developed communication, capacity-building and outreach; and to identify governance and cooperation mechanisms to support this objective.

3. The implementation mechanism for thematic priority 4 is the Expert Group on Space Weather of the Scientific and Technical Subcommittee, to be substantively supported by the Office for Outer Space Affairs of the Secretariat.

4. The Committee, at its sixtieth session, in 2017 (A/72/20, para. 328), noted that reports on each of the UNISPACE+50 thematic priorities would be prepared by the Secretariat and issued in the six official languages of the United Nations for submission to the Committee and its subcommittees at their sessions in 2018, in close coordination with the mechanisms working under each of the UNISPACE+50 thematic priorities.

II. Background

A. Space weather as a global challenge: why States need to act

5. Recent research has revealed a renewed understanding of both the high likelihood of, and potentially catastrophic impacts arising from, a severe space weather event and the effects it could have on critical infrastructure and the global

economy. Following the approach defined by the Committee on Space Research (COSPAR) and International Living With a Star (ILWS) in the road map document,[1] the effects of space weather on technological infrastructure can broadly be defined in terms of three impact pathways relating to impacts on the large electrically conducting infrastructure (e.g. power lines, railways and pipelines): through the effects of geomagnetically induced currents; through ageing and malfunction of space and ground assets; and through irradiation by energetic particles in the form of space radiation, impacts on satellite drag and direct impacts on radio wave and other communication transmissions.

6. The largest potential socioeconomic impacts arise from space weather driven geomagnetically induced currents in electrical power networks examples include the collapse of the Hydro-Québec power network in Canada during a space storm in 1989 and, more recently, the collapse of the power network in Malmö, Sweden, in 2003. The direct impacts from a collapse of the electrical power grid are damage to the infrastructure and loss of service. More significant are flow-down impacts, which include the loss of any services that rely on the availability of electricity, which, in the interconnected economy of the twenty-first century could quickly lead to extreme impacts. Such loss of power can also result in extensive damage to property and infrastructure, as well as loss of life.

7. Global reliance on space-based assets is increasing for communication and positioning services, as well as for Earth observation. Space radiation during severe space storms can damage satellite systems and even cause their total loss, either immediately at impact or eventually through increased ageing. Even temporary loss of services from global navigation satellite systems (GNSS) would have an impact on numerous transportation sectors and potentially the global financial system, which relies on accurate timing.

8. Space-based monitoring from satellites is a critical aspect of numerous Earth observation applications, including monitoring the effects of global climatic change, for ground- and space-based situational awareness, for coordinating responses to natural disasters and, more generally, for safety and security. With the recent rapid growth in the number of space actors in both space-faring nations and emerging space nations, and especially from the private sector, there is also a pressing need for satellite reliability to avoid a further build-up in space debris.

9. Storm-time ionospheric disturbances can disturb or interrupt navigation satellites and high-frequency communication signals through upper atmospheric scintillation and thermospheric effects. This can occur not only at high latitudes (in the auroral zone and near the poles), but also at middle latitudes and close to the equator as a result of the dynamics of ionospheric plasma bubbles. Such disturbances have impacts on any services or safety mechanisms that rely on accurate position information or the integrity of communication pathways, affecting, for example, airline operations, especially on long-distance flights over the poles.

10. There are a number of assessments of the magnitude of the socioeconomic impacts from space weather. The potential magnitude of the impacts have been assessed in a number of recent studies, including one by the Royal Academy of Engineering of the United Kingdom of Great Britain and Northern Ireland.[2] and in a European Space Agency cost-benefit analysis.[3] All have established that space

[1] Carolus J. Schrijver and others, "Understanding space weather to shield society: a global road map for 2015–2025 commissioned by COSPAR and ILWS", *Advances in Space Research*, vol. 55, No. 12 (2015), pp. 2745–2807.

[2] See also, for example, Edward J. Oughton and others, "Quantifying the daily economic impact of extreme space weather due to failure in electricity transmission infrastructure", *Space Weather*, vol. 15, No. 1 (2017), pp. 65–83.

[3] "A cost-benefit analysis of the SSA programme", 29 September 2016. Presentation available from the Global Space Economic Forum section of the European Space Agency website (www.esa.int/).

weather is a high-impact threat with a high likelihood of occurrence, and some[4] have explicitly highlighted additional flow-down impacts occurring outside the direct regions of electrical power loss, mainly owing to the interconnectedness of both the current infrastructure and the economy.

11. Indeed, one study[5] focused on the large coronal mass ejection from the Sun in July 2012, which had hit the Stereo-A spacecraft of the National Aeronautics and Space Administration (NASA) of the United States of America. It was predicted that the 2012 event could have had enormous technological impacts on Earth, perhaps even greater than the famous 1859 Carrington storm; luckily, the event missed Earth by about a week of solar rotation.[6] In one recent study,[7] it was assessed that the likelihood of a very severe space storm on Earth in the next decade could be as large as ~3–10 per cent.

12. Such understanding has resulted in the prioritization of an appropriate national response to the space weather threat in some countries and in the development of appropriate national action plans and protocols for the protection of critical infrastructure. However, this needs to be expanded into a coordinated global effort.

13. Overall, there is an immediate and urgent need to assess the vulnerability of terrestrial and space-based infrastructure to space weather. However, this will require further study on the drivers for and the impacts of severe space weather. An increased scientific understanding of the processes themselves will lead to more accurate space weather services and to more accurate risk and socioeconomic impact assessments. In parallel, engineering risk assessments and mitigation approaches also need to be developed. In the twenty-first century, the economies of countries are intimately connected, both regionally and globally. Therefore, even those countries in which the domestic space weather risk is perceived to be low will benefit from a global approach to mitigating space weather risks. Mitigating the effects of severe or extreme space weather is thus a matter of global importance.

14. The Committee on the Peaceful Uses of Outer Space is an effective body for international policy coordination with a demonstrated interest in all aspects of space weather. States, with the active involvement of the various international entities engaged in space weather activities, should develop increased coordination in both resilience analysis and scientific research with a view to improving future space weather services and impact mitigation. In summary, potentially catastrophic impacts arising from the natural hazard of severe or extreme space weather require a response from the international community, and that is why globally coordinated action is needed. Information about the most advanced scientific research and detailed socioeconomic and technical impact assessment studies, as well as preparatory activities within civil protection administrations, is needed to ensure that States know what to do to protect their infrastructure. By focusing on accurate and actionable space weather warnings, States will know when to act. Improved outreach, communication, capacity-building and global coordination are needed to ensure that States have the capability and the detailed knowledge required to know how to act. How to achieve the goal of thematic priority 4 to develop an international framework for space weather services within the framework of the Committee in the period 2018–2030 is discussed in sections V and VI below.

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[4] Oughton and others, “Quantifying the daily economic impact of extreme space weather due to failure in electricity transmission infrastructure”.

[5] D. N. Baker and others, “A major solar eruptive event in July 2012: defining extreme space weather scenarios”, *Space Weather*, vol. 11, No. 10 (2013), pp. 585–591.

[6] Ibid.

[7] Pete Riley and Jeffery J. Love “Extreme geomagnetic storms: probabilistic forecasts and their uncertainties”, *Space Weather*, vol. 15, No. 1 (2017), pp. 53–64; see also J. P. Eastwood and others, “The economic impact of space weather: where do we stand?” *Risk Analysis*, vol. 37, No. 2 (2017), pp. 206–218.

B. Mitigation of space weather risks: States must know what to do

15. Mitigation of space weather risks requires a detailed assessment of the impact pathways, combined with vulnerability, risk and socioeconomic impact assessments. These, in turn, require quantification of and benchmarks for the magnitude of the driving space weather phenomena and assessments of the level of likelihood, including an assessment of, for example, the design requirements needed to withstand a "100-year storm". Space weather impacts are not confined to extreme events; more moderate space weather can have significant impacts as well. In general, States must assess their vulnerabilities and assess the needs of their users, so they know what they can and should do to protect against the adverse effects of space weather.

16. A science-driven approach to the mitigation of space weather effects increases confidence in risk and socioeconomic impact assessments and in the accuracy of their results. As discussed, for example, in the road map document commissioned by COSPAR and ILWS,[8] despite very significant recent improvements in the understanding of the drivers of extreme space weather, scientists are still a long way from being able to offer high-precision forecasting of impending severe space weather.

17. Future (and hopefully more accurate) assessments of the impacts of (both extreme and ordinary) space weather, as well as improvements to the accuracy of space weather forecasts, must be underpinned by advances in the scientific understanding of the complex physical processes in the coupled Sun-Earth system.

18. There should be a periodic reassessment, perhaps every five years, and updates of a global space weather science road map, using as a baseline the 2015 road map document commissioned by COSPAR and ILWS.

19. COSPAR, perhaps through its Panel on Space Weather, provides an obvious vehicle for such a mechanism of regular science progress assessment and consequent road map updates. The results could be reported to the Committee on the Peaceful Uses of Outer Space for dissemination to States so that they can consider taking the appropriate steps needed to implement new recommendations.

20. As highlighted by the Expert Group on Space Weather in the report on its work (A/AC.105/C.1/2016/CRP.17), the approved guidelines for the long-term sustainability of outer space activities (for more details, see paras. 53–57 below) already provide a definition of the initial basis for the beginning of the required action. Similarly, at the United Nations/United States of America Workshop on the International Space Weather Initiative: the decade after the International Heliophysical Year 2007, held in Boston, United States, from 31 July to 4 August 2017, the participants recognized that the guidelines for the long-term sustainability of outer space activities relating to space weather, namely guidelines 16 and 17, provided the basis for future action (A/AC.105/1160, para. 29).

21. Progress in the implementation of the guidelines for the long-term sustainability of outer space activities relating to space weather (see, for example, guideline 17, paras. 17.2 and 17.3) needs to be encouraged within States.

22. Actions to protect against the adverse impacts of space weather require increased government understanding of the risks and the political will to act, as well as the engagement of national critical infrastructure protection and other administrations. Increased understanding of space weather risks has resulted in the prioritization of an appropriate national response to the space weather threat in some countries and in the development of appropriate national action plans and protocols for the protection of critical infrastructure in those countries. For example, in the United States, this included the release of the National Space Weather Strategy and Action Plan in 2015 and the executive order dated 13 October 2016, on coordinating efforts to prepare the nation for space weather events. The North American Electric

[8] Schrijver and others, "Understanding space weather to shield society: a global road map".

Reliability Corporation, an international regulatory authority, followed with regulations aimed at protecting the integrity of the electrical grid in North America. Those efforts have been coordinated throughout the United States Government under the auspices of the Space Weather Operations Research and Mitigation Subcommittee.[9] In the United Kingdom, socioeconomic and other impact studies resulted in space weather being entered on the National Risk Register of Civil Emergencies, with the consequent development of dedicated space weather services at the Met Office Space Weather Operations Centre and related mitigation activities within civil protection administrations. However, such efforts of individual countries need to be expanded into a more global and, where appropriate, more coordinated effort. Such overviews of implementation involving multiple space weather stakeholders at the regional level has already begun in Europe, for example, with the establishment by the European Science Foundation of the Space Weather Assessment and Consolidation Working Group. A similar overview of the global effort could be undertaken within the framework of the Committee on the Peaceful Uses of Outer Space, through the agenda item on space weather of the Scientific and Technical Subcommittee.

23. This can be promoted by additional communication and exchange of information and by sharing best practices in the assessment of impacts and by sharing definitions of the physical parameters associated with different levels of intensity, including worst-case assessments and characterization of the levels of intensity of the relevant maximum physical parameters, such as, for example, a "100-year storm". Given that different types of infrastructure can be affected by different physical processes and parameters, these levels of intensity must be defined for each impact pathway. For example, a severe space radiation storm might not be associated with large geomagnetically induced currents.

24. In relation to space weather impacts on aviation, the International Civil Aviation Organization (ICAO) is in the process of defining space weather requirements, relating in particular to potential interruptions to high-frequency communication and impacts from ionospheric storms and radiation levels. Improved communications and expert information exchange with ICAO in relation to space weather impact reduction would be very valuable. This could be achieved through a new coordination mechanism in which ICAO and other international organizations with space weather expertise, such as the World Meteorological Organization (WMO), the International Space Environment Service (ISES) and COSPAR, would be represented.

III. Developing a space weather road map for international coordination and information exchange on space weather events and their mitigation, through risk analysis and assessment of user needs

25. Effective progress in advancing space weather services requires coordinated global actions that will serve to focus efforts on the needed forecasting, monitoring and awareness raising with the goal of protecting life, property and critical infrastructure. These efforts will build upon the many important recommendations already contained in the approved guidelines for the long-term sustainability of outer space activities, which will increase States' capacity to have the detailed knowledge required to know when to act.

26. As noted in section II above, the approach where States are encouraged to follow the guidelines for the long-term sustainability of outer space activities relating to space weather is important in this regard.

[9] www.sworm.gov

27. It is important that future international coordination focus on establishing a sound scientific basis for such forecasts and knowledge and that the capabilities for international space weather warnings be advanced.

28. This could include the development of a concept for space weather information protocols, including a potential early warning system for identifying and communicating potentially or existing severe and/or potentially catastrophic space weather events, to be implemented through the coordination of, and developed by, existing space weather service providers and international bodies such as WMO and ISES and through the activities of other national space weather service providers.

29. The following is proposed as a road map for international coordination and information exchange on space weather events and their mitigation, through risk analysis and assessment of user needs (including references to the paragraphs in the relevant guidelines for the long-term sustainability of outer space activities):

(a) Product and service priorities:

(i) Identify the highest priority product and service improvements needed for global and regional awareness during space weather events (see guidelines 16 and 17, paras. 16.1, 16.3, 16.4, 16.6, 16.7 (c) and 17.2 (d));

(ii) Include representation from all major application sectors, including aviation, electric power, satellites, communication and navigation, to assess product and coordination needs (see guidelines 16 and 17, paras.16.6, 17.2 (a), (b), (c) and (e), 17.4 and 17.7);

(iii) Define common measures of product quality to be applied to the information shared during extreme events (see guideline 16, para.16.7 (a));

(b) Information communication protocol:

(i) Refine and/or augment numerical scales to characterize the severity of events (see guideline 17, para. 17.2 (a));

(ii) Recommend levels to activate specific communication procedures (see guideline 16, para. 16.7 (d));

(iii) Promote the establishment of real-time communication mechanisms among warning centres (see guideline 16, paras. 16.1, 16.6 and 16.7 (b), (c) and (d));

(iv) Develop best practices for warning centres during extreme events (see guideline 16, paras. 16.6 and 16.7 (b), (c) and (d));

(v) Provide training to ensure broad utilization of available information (see guideline 17, para. 17.2 (f));

(c) Response procedures:

(i) Promote the inclusion of space weather risk into national hazard and risk registries;

(ii) Encourage the exercising of coordination mechanisms under test conditions (see guideline 16, para. 16.7 (a));

(iii) Promote the sharing of model results, as well as the development of skill tests for forecast model comparisons (see guideline 16, paras. 16.6 and 16.7 (a) and (b));

(iv) Conduct post-event analyses to refine capabilities and document product effectiveness (see guideline 16, paras. 16.7 (a) and (b));

(d) Product sustainment and improvement and risk assessments:

(i) Maintain global and regional observing requirements and the analysis of observation gaps (see guidelines 16 and 17, paras.16.1, 16.2, 16.3, 16.5 and 17.1);

(ii) Maintain real-time access to interoperable data and data products (see guideline 16, paras. 16.1 and 16.4);

(iii) Develop and improve space weather models and tools (see guideline 17, paras. 17.1 and 17.2);

(iv) Collect established practices on the mitigation of space weather effects (see guideline 17, para. 17.2 (c));

(v) Encourage risk and socioeconomic impact studies to establish priorities for coordinated actions, recognizing regional and geographical differences among States in space weather impacts; and increase awareness that the interconnectedness of twenty-first century terrestrial infrastructure can create space weather threats for all States regardless of the severity of the direct domestic threats to their infrastructure from space weather (see guideline 17, para. 17.7);

(e) Improved understanding of fundamental physical processes that cause extreme space weather (see guideline 17, para. 17.1):

(i) Increase global coordination of space agencies, and perhaps space weather agencies, with respect to space- and ground-based infrastructure, with a view to implementing the recommendations in the document on the road map for the period 2015–2025 commissioned by COSPAR and ILWS;[10]

(ii) Maximize the development of new knowledge and promote new fundamental scientific discoveries through the contemporaneous and coordinated operation of ground- and space-based instruments and collaborative research, such as within the framework of the NASA Great Observatories programme, for space weather science and basic science research;

(f) Promote capacity-building in relation to space weather services (see guideline 25):

(i) Promote training and capacity-building in relation to space weather services, data collection and the understanding of impacts, effects and mitigation of space weather through cooperation between developed and developing States and between space-faring and aspiring space-faring States (see guidelines 17 and 25, para. 17.2 (f));

(ii) Promote space weather data collection and the development of space weather services in all States as part of a global effort to mitigate the adverse impacts arising from space weather (including capacity-building and instrument development and operation within the International Space Weather Initiative (ISWI)).

30. According to the road map outlined above, progress in the implementation of the approved guidelines for the long-term sustainability of outer space activities relating to this topic needs to be encouraged within States.

31. The capacity of States to know when to act could be improved, for example, through the development of an international framework for coordinating space weather warning capabilities. This could be achieved cooperatively through agencies and organizations within States or in partnership with other United Nations entities such as WMO and ICAO.

32. The space weather domain has the benefit that there presently exists a unique fleet of scientific spacecraft and ground-based infrastructure, which does not fulfil the requirements of a future operational system for space weather services but allows scientific progress to be made towards the definition of a global and sufficient operational system. Renewed international coordination is needed to ensure the creation of such an operational network, as well as its long term operation, including the identification and filling of key measurement gaps.

33. This observational effort could be complemented by cooperation between the developers of models for both understanding the physical processes that cause

[10] Schrijver and others, "Understanding space weather to shield society: a global road map".

extreme space weather and dedicated forecasts and the already provided service functions of existing national forecast centres. By focusing on scientifically defined metrics for improved benchmarking and model and forecast comparisons, further steps can be taken towards the achievement of the goal of improving actionable warnings for use by civil protection administrations in response to threats of impending severe space storms.

34. Any progress in model development and prediction advancement and any improvement of space weather services and forecasts by enhancing user utility will require a renewed focus on the advancement of science research and the removal of barriers for the transition of research to operations. A more holistic approach to the relationship between research and operational space weather services, which moves away from the linear research-to-operations and operations-to-research relationships, will be essential for a more efficient transition of the latest research into operational services.

IV. Action for resilience against extreme space weather

A. Towards an international framework for space weather services

35. Improving space weather services is an important target of thematic priority 4 and of those guidelines for the long-term sustainability of outer space activities which relate to space weather. There are several elements of the space weather ecosystem, all of which are needed to reach that target. The relatively new and still quite undeveloped field of space weather (much like an inexperienced archer) will initially have to spend a lot of effort to reach the outer areas of the target (i.e. science, modelling and observations) before the middle area of the target — improved space weather services — can be reached. Only through the intelligent assessment and communication of growing skills can the very centre of the target, a mature global space weather service, eventually be reached.

36. A combination of advances in science understanding, model functionality and improved observations, with synergistic activities to validate and assess performance of models against metrics, will pave the way forward towards the goal of improved space weather services. Improvements in dissemination activities will ideally include comparison and cross-calibration. Users in each of these activities communicate with users in the other activities, especially as the users can and should constantly become aware of the potential for new service functionality based on advances in science and higher-fidelity models, even prior to their final transition to a fully operational product.

37. Efforts have already begun towards implementing the science and modelling end of this approach. For example, the COSPAR Panel on Space Weather is considering revising its mandate to include coordination of these activities through dedicated international space weather action teams.

38. Operational entities would of course remain responsible for the delivery and roll-out of new operational products, but it is hoped that international space weather action teams can drive an innovative approach to a faster transition of the very latest research into the service domain with as few barriers and as efficiently as possible. When supported by other service providers and by other international bodies oriented towards implementation, such as WMO, ISES and ICAO, this model could offer a route to an accelerated delivery of improved international space weather services. Overall, increased connectivity between operational needs and advances in scientific research, which can be used to improve future operational services, is recommended.

39. The international space weather action team approach is also intended to link users and model developers and promote a fast and efficient prototyping approach to the transition of the latest research to operations.

40. Progress in the implementation of relevant guidelines for the long-term sustainability of outer space activities on the topic of mitigation, risk analysis and assessment of user needs (for example, guideline 17, paras. 17.1 and 17.4-17.7) needs to be encouraged among States.

B. Increasing awareness through developed capacity-building and outreach

41. It is critical to increase awareness through developed communication, capacity-building and outreach during the period 2018–2030 in order to develop the capacity to protect against the impact of space weather.

42. The Office for Outer Space Affairs is actively engaged in capacity-building activities related to space weather. In conjunction with the International Heliophysical Year 2007, the Office, through the United Nations Programme on Space Applications, organized a series of workshops to address the lack of observations in key geographical areas to be able to fully understand the global ionosphere and its linkage to the near-Earth space environment and to foster collaboration between research scientists in scientifically interesting geographical locations and researchers in countries with expertise in building scientific instrumentation.

43. The full list of workshops dedicated to space weather activities and organized by the Office for Outer Space Affairs is available in a special report of the Inter-Agency Meeting on Outer Space Activities on developments within the United Nations system related to space weather (A/AC.105/1146, para. 48), which was prepared by the Office in its capacity as the secretariat to the Inter-Agency Meeting on Outer Space Activities, which is the inter-agency coordination and cooperation mechanism that promotes synergies and collaboration related to the use of space technology and applications in the work of United Nations entities.

44. The instrument deployment programme was one of the major successes of the programme. To date, 18 instrument arrays from eight countries (Armenia, Brazil, France, Germany, Israel, Japan, Switzerland and the United States) are operating in more than 100 countries or areas throughout the world to provide global measurements of heliophysics phenomena. As a result of the Office’s activities, scientists from many countries continue to participate in instrument operation, data collection, analysis and the publication of scientific results.

45. Upon the completion of activities under the framework of the International Heliophysical Year 2007, the programme continued through ISWI.

46. Additionally, the ISWI steering committee is coordinating the ISWI schools, which are aimed at promoting the work of students on space weather that can lead to PhD research projects, as well as work in an international context, giving rise to publications.

47. The ISWI activities are consistent with guideline 17 of the guidelines for the long-term sustainability of outer space activities, according to which States and international intergovernmental organizations support and promote cooperation and coordination of space weather activities through practical measures such as encouraging training on and knowledge transfer relating to the use of space weather data, taking into account the participation of countries with emerging space capabilities (para. 17.2 (f)).

V. Identifying governance and cooperation mechanisms

48. The international community is increasingly becoming aware of space weather and the potential impact of an extreme weather event on critical infrastructure and global economy. The issue is of such a high level of importance that it requires the dedicated and focused attention of a new coordination mechanism.

49. This new coordination mechanism must leverage existing infrastructure, capacity and action plans, yet deliver high-level overview of collective international progress towards mitigating the threat from extreme space weather. Representation, collaboration and coordination between research organizations, space weather service providers and users, and critical infrastructure protection agencies and organizations are essential. If this coordination mechanism is established through a new coordination body, it should also have a mandate to assess progress in the implementation of United Nations guidelines and best practices relating to space weather, assess progress in the implementation of appropriate scientific and research road maps and provide a forum for ensuring a periodic review of such guidelines and action plans informed by the very latest and most accurate scientific research and knowledge.

A. Current activities of the Committee relating to space weather

50. There is a long history of United Nations actions to promote international cooperation and collaboration in relation to the peaceful uses of outer space. Given the growing awareness of the space weather threat, it would be appropriate for the Committee on the Peaceful Uses of Outer Space to promote an improved and coordinated international response to space weather.

51. In this context, UNISPACE+50 represents a very timely opportunity to strengthen the mandates of the Committee to better address current developments and challenges in outer space activities and to determine the thematic priorities to be implemented on a global scale, in cooperation with all relevant stakeholders, in the period 2018–2030.

52. The Scientific and Technical Subcommittee at its forty-ninth session, in 2012, agreed that an item on space weather should be introduced as a regular item on its agenda (A/AC.105/1001, para. 226). Following the success and conclusion of the work of expert group C, on space weather, of the Working Group on the Long-term Sustainability of Outer Space Activities, the Committee at its fifty-seventh session, in 2014, endorsed the creation of the Expert Group on Space Weather. The Expert Group reports to the Subcommittee and, with the substantive support of the Office for Outer Space Affairs, serves as the implementation mechanism for thematic priority 4.

B. Guidelines for the long-term sustainability of outer space activities pertaining to space weather

53. The Working Group on the Long-term Sustainability of Outer Space Activities was established by the Scientific and Technical Subcommittee in 2009. The Working Group established, as part of its terms of reference and methods of work, expert groups in four thematic areas: sustainable space utilization supporting sustainable development on Earth (expert group A); space debris, space operations and tools to support collaborative space situational awareness (expert group B); space weather (expert group C); and regulatory regimes and guidance for actors in the space arena (expert group D).

54. Expert group C of the Working Group submitted to the Scientific and Technical Subcommittee at its fiftieth session, in 2012, a working paper on space weather (A/AC.105/C.1/L.326), which served as the basis for the development by the Working Group of a set of guidelines for the long-term sustainability of outer space activities relating to space weather.

55. At its fifty-ninth session, in 2016, the Committee noted that the Working Group on the Long-term Sustainability of Outer Space Activities had made substantial progress in developing a set of guidelines for the long-term sustainability of outer space activities and agreed that consensus had been reached on the text of the a number of guidelines (A/71/20, paras. 129 and 130), including the following two

guidelines relating to space weather, both of which are described in more detail above (for the full text of the two guidelines, see the annex to the present document): guideline 16 (Share operational space weather data and forecasts); and guideline 17 (Develop space weather models and tools and collect established practices on the mitigation of space weather effects).

56. It is proposed that the guidelines referred to above be considered as the first steps in the mandate on improving global protection and resiliency against the adverse effects of space weather.

57. There is an urgent need to establish a process that can promote, and assess the progress in, the implementation of the existing guidelines relating to space weather and any additional guidelines that might be developed in the future by the Committee on the Peaceful Uses of Outer Space in relation to space weather. This could be achieved by the establishment of an international coordination group on space weather, in which case the mandate should include promoting, and monitoring the progress in the implementation of, those guidelines.

C. Activities relating to space weather in the framework of the International Committee on Global Navigation Satellite Systems

58. 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 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 in particular the interests of developing countries. The Office for Outer Space Affairs is the executive secretariat of the International Committee.

59. ICG, in cooperation with the Institute for Scientific Research at Boston College, in the United States, and the Abdus Salam International Centre for Theoretical Physics, Italy, co-organized and co-sponsored a series of outreach workshops on space weather effects on GNSS operations since 2009. The lectures were designed to give both theoretical and practical training on the physics of space weather and its effects on GNSS, through, for example, equatorial electrodynamics, scintillations and other ionospheric irregularities.

60. In 2017, participants in the Workshop on the International Space Weather Initiative noted the success of ICG as a model for targeted cooperation and interoperability and for the avoidance of the duplication of efforts at the global intergovernmental level (A/AC.105/1160, para. 27). The global footprint of space weather actors in national and international organizations is very extensive; many of the dedicated and well-advanced implementation plans are being developed or acted upon. Other models for the required international coordination mechanism should be considered as well.

D. Future governance and cooperation mechanisms required to achieve the 2030 vision

61. In order to achieve the objective defined in paragraph 2 above, there is a pressing need to define a mechanism for a future coordinated approach for actions within and between States, United Nations entities, other international intergovernmental and non-governmental organizations and space weather stakeholders, including academia and industry.

62. As the space weather activities currently being undertaken by these multiple stakeholders are rather fragmented, there is a pressing need for a mechanism that can deliver the appropriate global coordination, monitoring and guidance needed to

mitigate the effects of space weather and for the development of improved international space weather services.

63. The mechanism must promote improved coordination and minimize duplication of effort. There is need for high-level oversight in relation to communication and coordination between the multitude of space weather players; such oversight does not currently exist.

64. This oversight must recognize that many of the space weather organizations and stakeholders exist independently within States and their national authorities and within the United Nations and other international intergovernmental organizations, with various jurisdictions and mandates and with different independently established governance.

65. The emphasis for the new coordination mechanism must hence be in the form of an improved understanding of the threats from space weather and the approaches that can be taken to mitigate such threats. The focus should be on improved international coordination and communication, but not on governance or implementation.

66. Therefore, it is proposed in section VI below that consideration be given to establishing an international coordination group for space weather as a potential coordination mechanism. If established, the coordination group would report to the Committee on the Peaceful Uses of Outer Space through the agenda item on space weather of the Scientific and Technical Subcommittee. It is envisaged that the coordination group would supersede, and effectively represent a rechartering of, the existing Expert Group on Space Weather.

67. If established, the new coordination group should include representation from appropriate international agencies and bodies that are stakeholders and/or implement services in the field of space weather. The details would be defined in the future in the mandate and terms of reference of the coordination group.

68. The mandate of the coordination group could be expanded beyond that of the existing Expert Group on Space Weather to enable it to make recommendations to be approved by the Scientific and Technical Subcommittee for consideration and adoption by the Committee on the Peaceful Uses of Outer Space at the annual sessions of those two bodies.

69. In parallel with the workplan of the Committee, it is expected that COSPAR will examine its space weather activities, in particular in the context of the COSPAR Panel on Space Weather. This could develop into providing a scientific support function of the proposed coordination group.

70. That would be consistent with the recommendation made at the coordination meeting of the Office for Outer Space Affairs and COSPAR. The meeting, having considered the contribution of the scientific community to the work under thematic priority 4, assessed that COSPAR should be given an ex officio role in a potential future international coordination group on space weather, where the scientific foundation would be secured through capacity-building and awareness-raising on a global scale. It was noted that, in that regard, cooperation and coordination of the Panel on Space Weather and the COSPAR Panel on Capacity-building, teaming up with the Prince Sultan bin Abdulaziz International Prize for Water, Scientific Committee on Solar-Terrestrial Physics (SCOSTEP), WMO, ISES, the International Union of Geodesy and Geophysics, the International Astronomical Union and the Office for Outer Space Affairs, would be important in promoting adequate scientific knowledge worldwide and, in particular, cross-sectoral and cross-cutting efforts (A/AC.105/2017/CRP.25, para. 37).

71. In order to secure adequate scientific information in support of a possible international coordination group on space weather and in support of the establishment of an international cooperation mechanism for space weather awareness and mitigation, the coordination meeting of the Office for Outer Space Affairs and

COSPAR recommended that, in implementing thematic priority 4, the functions of the following should be taken into account: the Expert Group on Space Weather, in particular its role of bringing the science and service provider communities together; COSPAR, as coordinator and facilitator on the science side; and the Office for Outer Space Affairs, as the entity connecting the various relevant communities to the Committee on the Peaceful Uses of Outer Space, the General Assembly and other relevant entities in the United Nations system (A/AC.105/2017/CRP.25, para. 40).

72. In advancing the recommendations in section VI below, the Expert Group on Space Weather and the Office of Outer Space Affairs should organize a series of active outreach meetings and workshops for the international space weather research and service communities, to enable those communities to provide input in this process.

73. The Expert Group on Space Weather has undertaken a series of outreach events, including an expert group workshop held in Vienna in April 2017 and town hall meetings at the European Geosciences Union General Assembly held in Vienna in April 2017, at the Chapman Conference on Dayside Magnetosphere Interactions held in Chengdu, China, in July 2017 and at International Astronomical Union Symposium 335, entitled "Space Weather of the Heliosphere: Processes and Forecasts", held in Exeter, United Kingdom, in July 2017. The work of the Expert Group was also presented at the United Nations/United Arab Emirates High-level Forum: Space as a Driver for Socioeconomic Sustainable Development, held in Dubai, United Arab Emirates, from 6 to 9 November 2017. Further outreach is planned for the upcoming European Space Weather Week in Ostend, Belgium, to be held from 27 November to 1 December 2017.

74. The draft mandate and terms of reference of the coordination group would be developed during the period 2018–2019 and would the focus of a proposed international workshop on space weather to be held in 2019. Ideally, the workshop could also focus on communicating the importance of space weather to the critical infrastructure protection administrations in States and could bring together the space weather user community, researchers and modellers with emergency management and emergency preparedness administrations.

VI. Recommendations

75. In accordance with the objectives of thematic priority 4 and consistent with a number of approved guidelines for the long-term sustainability of outer space activities relating to space weather, the recommendations below are important in providing additional opportunities:

(a) To stimulate and support scientific research with a view to achieving fast progress in the global ability to accurately predict space weather events;

(b) To stimulate cooperation among States for the free exchange of space weather data and forecasts;

(c) To increase communication between the scientific and space weather service communities, as well as industry and users;

(d) To promote the fast transition of new scientific research into improved and more accurate space weather services that meet user needs.

76. The activities of expert group C, on space weather, under the activities relating to the long-term sustainability of outer space activities, and the subsequent activities of the Expert Group on Space Weather, which reports to the Scientific and Technical Subcommittee under its agenda item on space weather, have demonstrated a clear need for increased international collaboration to increase international preparedness and resilience against the threat of the adverse effects of space weather on ground- and space-based technology and infrastructure.

77. The participants in the United Nations/United States of America Workshop on the International Space Weather Initiative validated the view of the Expert Group on Space Weather and recommended that the new coordination mechanism should be established through the UNISPACE+50 process and substantially supported by the Office for Outer Space Affairs (A/AC.105/1160, para. 45 (a) and (f)).

78. Consistent with these activities, it is recommended that a space weather road map should be developed for international coordination and information exchange on space weather events and their mitigation, through risk analysis and assessment of user needs.

79. The recommendations in the paragraph below are intended to achieve the following outcomes:

(a) Creation of an international coordination mechanism of operational space weather services, including monitoring, forecasting and awareness-raising;

(b) Coordination and/or communication of early warning systems and protocols for action during and following the impacts of, severe space weather events;

(c) Improved impact assessments and improved scientific understanding of the effects arising from severe space weather;

(d) Overall expanded and more coordinated action from States to mitigate the effects of space weather, including efforts promoting capacity-building, and to raise awareness of space weather impacts and opportunities to contribute to the global effort.

80. Considering those objectives, the following is recommended:

(a) A new international coordination mechanism for space weather should be established, within existing resources;

(b) The international coordination mechanism should have a mandate to promote increased high-level coordination on space weather and to promote increased global resilience against space weather effects;

(c) Consideration should be given to the creation of an international coordination group for space weather as the basis for the required international coordination mechanism. The coordination group could consist of representatives from States members of the Committee on the Peaceful Uses of Outer Space, with participation from appropriate international space weather entities. The coordination group could report to the Scientific and Technical Subcommittee under its agenda item on space weather and would be expected to have a substantial involvement from COSPAR, for example, through ex officio membership. The mandate of the coordination group could be expanded beyond that of the existing Expert Group on Space Weather to enable the coordination group to make recommendations to be approved by the Scientific and Technical Subcommittee for consideration and adoption by the Committee on the Peaceful Uses of Outer Space at the annual sessions of those two bodies. If the establishment of the coordination group is approved by the Committee, the activities of the Expert Group on Space Weather could be transitioned to the coordination group during the period 2020–2021, and the coordination group would then act and operate in line with its mandate and terms of reference during the period 2021–2030;

(d) Specific tasks to be completed through the new international coordination mechanism should be those listed in the road map presented in section III above;

(e) The new international coordination mechanism could act to guide space weather policy and could promote the implementation of space weather guidelines and best practices. There should be high-level coordination between international space weather stakeholder organizations that implement services;

(f) The participants in the Workshop on the International Space Weather Initiative highlighted the importance of a number of items that needed to be addressed, including the identification of the most important data to be shared; joint efforts of the international entities, including COSPAR, ICAO, the International Geographical Union, the International Global Navigation Satellite System Service, the International Union of Radio Science, SCOSTEP and WMO; and increasing awareness on impacts of space weather phenomenon (A/AC.105/1160, para. 32). That point should be considered highly relevant;

(g) The new international coordination mechanism should promote and take an overview of progress in the implementation of the guidelines for the long-term sustainability of outer space activities pertaining to space weather;

(h) The existing activities of the Expert Group on Space Weather should continue during the period 2018–2020, with its mandate being expanded to include the task of considering the approach to be used to deliver new international coordination. The Expert Group would also develop the draft terms of reference, mandate and structure of the proposed coordination group, in close collaboration with the COSPAR Panel on Space Weather and the Office for Outer Space Affairs;

(i) An international workshop on space weather, with the participation of States and their national authorities and international space weather research and services organizations, space weather users and governmental and non-governmental critical infrastructure protection organizations, should be organized in the middle of the year 2019. The workshop would have the goal of raising the profile of the importance of space weather impacts among member States and would consider the basis for new international coordination on space weather, including, if appropriate, proposals for the draft terms of reference and mandate of the proposed coordination group. The workshop should be organized by the Expert Group on Space Weather and the COSPAR Panel on Space Weather, with the support of the Office for Outer Space Affairs;

(j) The related recommendations in paragraph 30 of the report of Workshop on the International Space Weather Initiative (A/AC.105/1160) should also be considered relevant;

(k) In line with the report of the coordination meeting of the Office for Outer Space Affairs and COSPAR coordination meeting in support of the preparations for UNISPACE+50 (A/AC.105/2017/CRP.25), COSPAR is expected to take responsibility for assessing scientific research and developing scientific road maps. COSPAR is expected to share the results with the Committee on the Peaceful Uses of Outer Space. Road-mapping for space weather services should, however, be coordinated in the context of the new international coordination mechanism. Pursuant to the earlier recommendation of the Expert Group on Space Weather (A/AC.105/C.1/2016/CRP.17), the road map commissioned by COSPAR and ILWS[11] should be adopted as the initial scientific road map;

(l) The scientific road map is expected to be reviewed on a regular basis and updated by COSPAR, supported by appropriate representation from the international space weather community. Updates prepared every five years would be able to take account of the latest developments in scientific research, new developments in the deployment of ground- and space-based observing network infrastructure and take account of the latest developments in modelling and forecasting capabilities in relation to user needs;

(m) The Scientific and Technical Subcommittee should further promote the importance of global implementation of the guidelines for the long-term sustainability of outer space activities pertaining to space weather (guidelines 16 and 17);

(n) The participants in the Workshop on the International Space Weather Initiative also considered the importance of international coordination on space

[11] Schrijver and others, "Understanding space weather to shield society: a global road map".

weather and made a series of recommendations on the subject (A/AC.105/1160, paras. 33–45), which should also be applicable;

(o) The participants in the Workshop on the International Space Weather Initiative recommended (A/AC.105/1160, para. 45 (c)) that a process should be identified and adopted whereby ISWI activities are recognized by and reported to the Scientific and Technical Subcommittee under its agenda item on space weather. That recommendation should be considered particularly relevant.

Annex

Guidelines for the long-term sustainability of outer space Activities* of direct relevance to space weather

Guideline 16. Share operational space weather data and forecasts

16.1 States and international intergovernmental organizations should support and promote the collection, archiving, sharing, intercalibration, long-term continuity and dissemination of critical space weather data and space weather model outputs and forecasts, where appropriate in real time, as a means of enhancing the long-term sustainability of outer space activities.

16.2 States should be encouraged to monitor space weather continuously and to share data and information with the aim of establishing an international space weather database network.

16.3 States and international intergovernmental organizations should support the identification of data sets critical for space weather services and research and should consider adopting policies for the free and unrestricted sharing of critical space weather data from their space- and ground-based assets. All governmental, civilian and commercial space weather data owners are urged to allow free and unrestricted access to and archival of such data for mutual benefit.

16.4 States and international intergovernmental organizations should also consider sharing real-time and near-real-time critical space weather data and data products in a common format, promote and adopt common access protocols for their critical space weather data and data products, and promote the interoperability of space weather data portals, thus promoting ease of data access for users and researchers. The real-time sharing of these data could provide a valuable experience for sharing in real time other kinds of data relevant to the long-term sustainability of outer space activities.

16.5 States and international intergovernmental organizations should further undertake a coordinated approach to maintaining the long-term continuity of space weather observations and identifying and filling key measurement gaps, so as to meet critical needs for space weather information and/or data.

16.6 States and international intergovernmental organizations should identify high-priority needs for space weather models, space weather model outputs and space weather forecasts and adopt policies for free and unrestricted sharing of space weather model outputs and forecasts. All governmental, civilian and commercial space weather model developers and forecast providers are urged to allow free and unrestricted access to and archival of space weather model outputs and forecasts for mutual benefit, which will promote research and development in this domain.

16.7 States and international intergovernmental organizations should also encourage their space weather service providers to:

(a) Undertake comparisons of space weather model and forecast outputs with the goal of improved model performance and forecast accuracy;

(b) Openly share and disseminate historical and future critical space weather model outputs and forecast products in a common format;

(c) Adopt common access protocols for their space weather model outputs and forecast products to the extent possible, to promote their ease of use by users and researchers, including through interoperability of space weather portals;

(d) Undertake coordinated dissemination of space weather forecasts among space weather service providers and to operational end users.

* A/71/20, annex.

Guideline 17. Develop space weather models and tools and collect established practices on the mitigation of space weather effects

17.1 States and international intergovernmental organizations should undertake a coordinated approach to identifying and filling gaps in research and operational models and forecasting tools required to meet the needs of the scientific community and of the providers and users of space weather information services. Where necessary, this should include coordinated efforts to support and promote research and development to further advance space weather models and forecasting tools, incorporating the effects of the changing solar environment and evolving terrestrial magnetic field as appropriate, including within the context of the Committee on the Peaceful Uses of Outer Space and its subcommittees, as well as in collaboration with other entities such as the World Meteorological Organization and the International Space Environment Service.

17.2 States and international intergovernmental organizations should support and promote cooperation and coordination on ground- and space-based space weather observations, forecast modelling, satellite anomalies and reporting of space weather effects in order to safeguard space activities. Practical measures in this regard could include:

(a) Incorporating current and forecast space weather thresholds into space launch criteria;

(b) Encouraging satellite operators to cooperate with space weather service providers to identify the information that would be most useful to mitigate anomalies and to derive recommended specific guidelines for on-orbit operations. For example, if the radiation environment is hazardous, this might include actions to delay the uploading of software, implementation of manoeuvres etc.;

(c) Encouraging the collection, collation and sharing of information relating to ground- and space-based space weather-related impacts and system anomalies, including spacecraft anomalies;

(d) Encouraging the use of a common format for reporting space weather information. In relation to the reporting of spacecraft anomalies, satellite operators are encouraged to take note of the template proposed by the Coordination Group for Meteorological Satellites;

(e) Encouraging policies promoting the sharing of satellite anomaly data related to space weather-induced effects;

(f) Encouraging training on and knowledge transfer relating to the use of space weather data, taking into account the participation of countries with emerging space capabilities.

17.3 It is acknowledged that some data may be subject to legal restrictions and/or measures for the protection of proprietary or confidential information, in accordance with national legislation, multilateral commitments, non-proliferation norms and international law.

17.4 States and international intergovernmental organizations should work towards the development of international standards and the collection of established practices applicable for the mitigation of space weather effects in satellite design. This could include sharing of information on design practices, guidelines and lessons learned relating to mitigation of the effects of space weather on operational space systems, as well as documentation and reports relating to space weather user needs, measurement requirements, gap analyses, cost-benefit analyses and related space weather assessments.

17.5 States should encourage entities under their jurisdiction and/or control to:

(a) Incorporate in satellite designs the capability to recover from a debilitating space weather effect, such as by including a safe mode;

(b) Incorporate space weather effects into satellite designs and mission planning for end-of-life disposal in order to ensure that the spacecraft either reach their intended graveyard orbit or de-orbit appropriately, in accordance with the Space Debris Mitigation Guidelines of the Committee on the Peaceful Uses of Outer Space. This should include appropriate margin analysis.

17.6 International intergovernmental organizations should also promote such measures among their member States.

17.7 States should undertake an assessment of the risk and socioeconomic impacts of adverse space weather effects on the technological systems in their respective countries. The results from such studies should be published and made available to all States and used to inform decision-making relating to the long-term sustainability of outer space activities, particularly with regard to mitigating the adverse impacts of space weather on operational space systems.