United Nations A/AC.105/1146

General Assembly

Distr.: General
28 April 2017

Original: English

Committee on the Peaceful Uses of Outer Space

Space weather

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

I. Introduction

1. The Inter-Agency Meeting on Outer Space Activities (UN-Space) has served as the focal point for inter-agency coordination and cooperation in space-related activities since 1975, with the aim of promoting synergies and collaboration related to the use of space technology and applications in the work of United Nations entities.

2. The General Assembly, in its resolution 71/90, on international cooperation in the peaceful uses of outer space, urged UN-Space, under the leadership of the Office for Outer Space Affairs of the Secretariat, to continue to examine how space science and technology and their applications could contribute to the 2030 Agenda for Sustainable Development, and encouraged entities of the United Nations system to participate, as appropriate, in UN-Space coordination efforts.

3. At its thirtieth session, held in Geneva from 10 to 12 March 2010, UN-Space agreed that the regular report of the Secretary-General on the coordination of space-related activities within the United Nations system, which serves as a strategic tool for the United Nations in the field of space science and technology, should be issued on a biennial basis. It also agreed that in years when there is no report of the Secretary-General, a special report on a selected topic should be considered.

4. In its special reports, UN-Space has addressed the following themes: new and emerging technologies, applications and initiatives for space-related inter-agency cooperation (A/AC.105/843); space benefits for Africa: contribution of the United Nations system (A/AC.105/941); the use of space technology within the United Nations system to address climate change issues (A/AC.105/991); space for agriculture development and food security (A/AC.105/1042); space for global health (A/AC.105/1091); and the role of the United Nations in supporting Member States in the implementation of transparency and confidence-building measures in outer space activities (A/AC.105/1116).

5. At its fifty-ninth session, in 2016, the Committee on the Peaceful Uses of Outer Space welcomed with appreciation the report of the Secretary-General entitled “Coordination of space-related activities within the United Nations

system: directions and anticipated results for the period 2016-2017 — meeting the 2030 Agenda for Sustainable Development" (A/AC.105/1115). The Committee noted the instrumental role of the report in assisting the Committee in its preparations for the fiftieth anniversary of the United Nations Conference on the Exploration and Peaceful Uses of Outer Space (UNISPACE+50) by providing an overview of efforts by United Nations entities with regard to the peaceful uses of outer space.

6. At the same session, the Committee further noted that the Office for Outer Space Affairs, in its capacity as the secretariat of UN-Space, would issue, for consideration by the Committee at its sixtieth session, a special report by UN-Space on space weather in the context of the preparations for UNISPACE+50, and would coordinate with the relevant United Nations entities in the preparation of that report (A/71/20, para. 276).

7. The present report was prepared by the Office for Outer Space Affairs on the basis of contributions received from the following United Nations entities: the International Atomic Energy Agency (IAEA), the International Civil Aviation Organization (ICAO), the World Health Organization (WHO) and the World Meteorological Organization (WMO).

II. Space weather

A. Impacts of space weather

8. The term "space weather" refers to variations in the space environment between the Sun and the Earth (and throughout the solar system), which can affect humans and technologies in space and on Earth. The most dramatic changes are driven by solar events, including 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.

9. Such phenomena have an impact on the dynamics of the near-Earth space environment, specifically the magnetosphere, the ionosphere and the neutral atmosphere, and affect human activities and the operation of terrestrial and space infrastructure, including high-voltage electrical transmission systems and pipelines, and can lead to electrical blackouts, potentially on a continental scale.

10. Changes in the ionosphere 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 ensure communications capability and protection from radiation exposure.

11. Ionospheric delay is the main source of error in using GNSS, especially over the equatorial region. In that connection, ionospheric research is an essential component of the development and implementation of global navigation satellite augmentation systems, as an understanding of the challenges posed by the ionosphere could provide important insights into the development of GNSS. Furthermore, existing data from Global Positioning System (GPS) and GNSS stations are valuable for evaluating aspects of the response of the ionosphere to magnetic storms and other space weather effects.

12. Beyond the Earth, the swelling of the atmosphere as a result of space weather can change satellite orbits, thereby degrading space surveillance and tracking information. This occurs in two ways. Firstly, the space debris population and its evolution are tied to the density of the thermosphere, which is controlled by solar and geomagnetic inputs. Secondly, the ability to predict conjunctions and hence enable collision avoidance depends on accurate knowledge of atmospheric density.

13. Space weather phenomena also lead to increased radiation hazards for astronauts, the charging of spacecraft surfaces and the internal charging of spacecraft components, the degradation of spacecraft solar arrays and materials, the anomalous behaviour of electronic components, the failure of computer memory units, the blinding of optical systems, the degradation or loss of spacecraft tracking information and the anomalous drag and loss of altitude (sometimes also leading to the enhanced erosion or degradation of spacecraft surface materials or coatings by atomic oxygen).

B. Historical space weather events

14. A number of past space weather events have had a significant impact on infrastructure and human activities. The first and the most severe such event on record was the Carrington event, named after the British amateur astronomer Richard Carrington, who observed the intense flare that took place on 1 September 1859. The disturbance from the Sun reached the Earth for a record short time of 17.5 hours and caused a tremendous magnetic storm. Telegraph services in America and Europe were disrupted for several days. Aurora displays were seen at night at unusually low latitudes — in Rome, Havana and Hawaii, and even at the Equator.

15. The Quebec event of 13 and 14 March 1989 was an example of a large-scale technological catastrophe caused by space weather, whose integral loss was estimated to amount to $6 billion. The province of Quebec, Canada, suffered a blackout for approximately nine hours, as its electric power grids collapsed owing to induced currents in long transmission lines. The event also caused the failure of a large $10-million step-up transformer at the Salem Nuclear Power Plant in New Jersey, United States of America, which, fortunately, did not result in a major catastrophe. In addition, the geomagnetic storm disrupted radio communications.

16. Another outstanding geomagnetic storm occurred on 14 and 15 May 1921. During that storm, the magnetic field change rate was about 10 times higher than that of the Quebec event. The storm was triggered by activity in a large sunspot at the centre of the solar disc, and caused a series of short-circuit events resulting in fires. It also damaged the submarine cable, electric power lines and telephone lines on both sides of the Atlantic. Strong magnetic storm effects were experienced by telegraphic and radio communication systems in England, Scotland, Ireland and New Zealand.

17. The so-called “Halloween storms” occurred in October and November 2003 as a result of a series of major solar flares and coronal mass ejections, which created dangerous radiation conditions in the Earth environment and disturbed the geomagnetic field for a week. In the course of the event, solar energy particles intruded the Earth’s magnetosphere and reached the orbit of the International Space Station. Numerous satellite anomalies recorded in 2003 occurred during that period: the GPS-based Wide Area Augmentation System was disabled for 30 hours; an interruption of the power grid occurred in the south of Sweden owing to induced-current effects; climbers in the Himalayas experienced problems with satellite phones; and the United States Coast Guard temporarily shut down the Long-Range Navigation system.

C. Need for international cooperation on space weather

18. Extreme natural events, such as those described above, serve as a warning that the development of technological systems, including space technologies, has reached a point where exposure of such systems to adverse factors of space weather may have catastrophic impacts and result in immense losses. Therefore, there is a clear need to foster more synergy and promote the convergence of common interests in space weather among all stakeholders.

19. A particular feature of extreme space weather events, such as those observed in 1859 and 1921, is that they may also occur during low-amplitude cycles (lower than medium), which makes them difficult to forecast. That demonstrates the need to adapt space and ground-based technological systems to operate under adverse space weather conditions and withstand their impact without failing.

20. Furthermore, as space weather is intrinsically international in its scope of impact, expertise, monitoring and forecasting capabilities developed by multiple nations and stakeholders would benefit from improved coordination. This is especially relevant for filling key measurement gaps, securing the long-term continuity of critical measurements, advancing global forecasting and modelling capabilities, identifying potential risks and developing practices and guidelines to mitigate the impact of space weather phenomena, including on long-term observation of climate change and risk events. In that regard, the aim of the present report is to provide an overview of activities undertaken by United Nations entities and other international and regional organizations related to space weather.

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

A. Committee on the Peaceful Uses of Outer Space

1. Solar-terrestrial physics

21. The Committee on the Peaceful Uses of Outer Space, at its forty-sixth session, in 2003, approved the recommendation of the Scientific and Technical Subcommittee, made at its fortieth session, in 2003, that an agenda item entitled "Solar-terrestrial physics" be included in the agenda for the forty-first session of the Subcommittee, in 2004, as a single issue/item for discussion (A/AC.105/804, annex II, para. 23).

22. In 2004, the Subcommittee agreed that solar-terrestrial physics was important in exploring the solar corona and understanding the functioning of the Sun; understanding the effects that the variability in the Sun can have on the Earth's magnetosphere, environment and climate; exploring the ionized environments of planets; and reaching the limits of the heliosphere and understanding its interaction with interstellar space.

23. The Subcommittee also agreed that, as society became increasingly dependent on space-based systems, it was vital to understand how space weather could affect, among other things, space systems and human space flight, electric power transmission, high-frequency radio communications, GNSS signals and long-range radar, as well as the well-being of passengers in high-altitude aircraft.

24. The Committee, at its forty-seventh session, in 2004, noted that the effects of solar activities and space weather phenomena on the daily lives of humans, on the Earth's environment and on space systems were becoming more apparent and that there was a need to collaborate to develop a better understanding of those effects.

2. International Heliophysical Year 2007

25. The Scientific and Technical Subcommittee, at its forty-first session, in 2004, recommended that an agenda item entitled "Support to proclaim the year 2007 International Geophysical and Heliophysical Year" be included in the agenda for its forty-second session, in 2005 (A/AC.105/823, annex II, para. 14).

26. At its forty-second session, the Subcommittee noted that 2007 would be the fiftieth anniversary of the International Geophysical Year, organized in 1957 to study global phenomena of the Earth and the near-Earth space environment. The Subcommittee agreed that, starting with its forty-third session, in 2006, it would consider an item on the International Heliophysical Year 2007 according to its multi-year workplan (A/AC.105/848, annex I, para. 22).

27. The International Heliophysical Year 2007 was an international endeavour that served to focus worldwide attention on the importance of international cooperation in research activities in the field of solar-terrestrial physics. The specific objectives of the International Heliophysical Year were:

(a) To provide benchmark measurements of the response of the magnetosphere, the ionosphere, the lower atmosphere and Earth's surface to heliospheric phenomena, in order to identify global processes and drivers that affected the terrestrial environment and climate;

(b) To further the global study of the Sun-heliosphere system outwards to the heliopause, in order to understand the external and historical drivers of geophysical change;

(c) To foster international scientific cooperation in the study of heliophysical phenomena;

(d) To communicate the unique scientific results of the International Heliophysical Year to interested members of the scientific community and the general public (A/AC.105/848, para. 187).

28. The year 2017 will mark the sixtieth anniversary of the International Geophysical Year and the tenth anniversary of the International Heliophysical Year.

3. International Space Weather Initiative

29. At its fifty-second session, in 2009, the Committee noted the importance of continuing to build upon the success of the International Heliophysical Year 2007, in particular by deepening the understanding of the function of the Sun and its effects on the Earth's magnetosphere, environment and climate, and noted with satisfaction the agreement reached by the Scientific and Technical Subcommittee at its forty-sixth session to consider, beginning at its forty-seventh session, a new agenda item entitled "International Space Weather Initiative" (ISWI) under a three-year workplan with specific focus on the effects of space weather on the Earth and its impact, inter alia, on communications and transport (A/64/20, para. 155).

30. The following activities constituted the three-year workplan for the item on ISWI of the Subcommittee (A/AC.105/933, annex I, para. 16):

2010 Consider reports on regional and international plans. Encourage continued operation of existing instrument arrays and encourage new instrument deployments

2011 Consider reports on regional and international plans. Identify gaps and synergies in ongoing activities. Encourage continued operation of existing instrument arrays and encourage new instrument deployments

2012 Finalize a report on regional and international plans. Encourage continued operation of existing instrument arrays and encourage new instrument deployments

31. In that context, the United Nations/Ecuador Workshop on ISWI, organized by the Office for Outer Space Affairs and held in Quito from 8 to 12 October 2012, took note of the number of deployed space weather instruments and noted that, from 2005 to 2012, during the time when United Nations workshops were addressing the International Heliophysical Year 2007 (from 2005 to 2009) and ISWI (from 2010 to 2012), 16 space weather instrument arrays had become operational.

4. Expert Group C, on space weather, of the Working Group on the Long-term Sustainability of Outer Space Activities

32. At its fifty-second session, in 2009, the Committee agreed that the 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" (A/64/20, paras. 160-162). Consequently, in 2010, the Subcommittee

established the Working Group on the Long-term Sustainability of Outer Space Activities (A/AC.105/958, paras. 181 and 182), which was welcomed by the Committee at its fifty-third session, in 2010.

33. At its fifty-fourth session, the Committee adopted the terms of reference and methods of work of the Working Group (A/66/20, annex II). As provided for in those terms and methods, the Working Group established expert groups centred around 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). Expert group C was co-chaired by Ian Mann (Canada) and Takahiro Obara (Japan).

34. At its fifty-fifth session, in 2012, the Committee had before it working papers presenting the workplans of the four expert groups, including that of expert group C, on space weather (A/AC.105/C.1/L.326). The working report of expert group C was made available to the Subcommittee at its fifty-first session, in 2014, as a conference room paper (A/AC.105/C.1/2014/CRP.15).

35. At its fifty-ninth session, in 2016, the Committee noted that the Working Group 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 following guidelines relating to space weather (A/71/20, paras. 129 and 130): (a) Share operational space weather data and forecasts (Guideline 16); and (b) Develop space weather models and tools and collect established practices on the mitigation of space weather effects (Guideline 17).

36. The guidelines are aimed at promoting the collection, archiving, sharing, intercalibration, long-term continuity and dissemination of critical space weather data, model outputs and forecasts, the establishment of dissemination networks and the identification and filling of critical gaps in measurements, research and operational models and forecasting tools. They also recommend that satellite designs and mission plans incorporate features enabling them to withstand space weather effects.

5. Expert Group on Space Weather of the Scientific and Technical Subcommittee

37. At its fifty-fifth session, in 2012, the Committee agreed that the Subcommittee should include in its agenda, starting from its fiftieth session, in 2013, a new, regular item entitled “Space weather” (A/67/20, para. 166). At its fiftieth session, in 2013, the Subcommittee noted that, through that item, it could serve as an important advocate for efforts to close existing gaps in the space weather research field (A/AC.105/1038, para. 156).

38. At its fifty-first session, in 2014, the Subcommittee endorsed the agreement by the Working Group of the Whole that an expert group with a rapporteur be set up to inform the Subcommittee on developments under the agenda item on space weather, drawing on the best practices of the work of expert group C, on space weather, of the Working Group on the Long-term Sustainability of Outer Space Activities (A/AC.105/1065, annex I, para. 10). The mandate of the Expert Group on Space Weather is to promote awareness, provide guidance and enable communication and cooperation in space weather-related activities among States members of the Committee and related national and international organizations.

39. At its fifty-second session, in 2015, the Subcommittee noted with satisfaction that during its session, the newly established Expert Group on Space Weather had met under the leadership of Canada (see A/AC.105/C.1/2015/CRP.27) and had presented its multi-year workplan, which was subsequently endorsed by the Subcommittee (see A/AC.105/1088, paras. 163-169). Under its workplan, the Expert Group is to examine reports and other information related to space weather; complete an inventory of stakeholders, review their role in the global space weather

effort and develop cooperation; and promote involvement by member States in providing space weather services and monitoring. The workplan was reviewed at the second meeting of the Expert Group, held from 15 to 17 February 2016 (see A/AC.105/C.1/2016/CRP.17).

40. The Expert Group agreed to continue meeting annually on the margins of the sessions of the Scientific and Technical Subcommittee and to use teleconferences or other means to engage with one another intersessionally. Over the coming year, the Expert Group intended, as its priority task, to continue its work assessing the impact of geomagnetically induced currents on electrical power grids. Members of the Expert Group would seek to actively engage with national critical infrastructure protection agencies and national and international electrical power distribution organizations to be able to better understand, characterize and ultimately examine steps to mitigate space weather damage to that critical infrastructure (A/AC.105/1109, para. 171).

41. At its third meeting, held on the margins of the fifty-fourth session of the Subcommittee, in 2017, the Expert Group agreed to build on the successful outcomes of its space weather workshop held in February 2016, and began to develop a road map for international coordination and information exchange regarding space weather events and the mitigation of its adverse impacts through risk analysis and assessment of user needs.

6. Space weather as a UNISPACE+50 thematic priority

42. The fiftieth anniversary of the first United Nations Conference on the Exploration and Peaceful Uses of Outer Space, held in Vienna in August 1968, will be marked in 2018 by UNISPACE+50, an ambitious Committee undertaking to consider the current status and define the future role of the Committee, its subsidiary bodies and the Office for Outer Space Affairs in promoting international cooperation in the peaceful uses of outer space and in shaping global governance of space activities.

43. In preparation for UNISPACE+50, the Committee endorsed in 2016 the seven UNISPACE+50 thematic priorities (A/71/20, para. 296): (a) Global partnership in space exploration and innovation; (b) Legal regime of outer space and global space governance: current and future perspectives; (c) Enhanced information exchange on space objects and events; (d) International framework for space weather services; (e) Strengthened space cooperation for global health; (f) International cooperation towards low-emission and resilient societies; and (g) Capacity-building for the twenty-first century.

44. The objective under the thematic priority on the international framework for space weather services is as follows: strengthen the reliability of space systems and their ability to respond to the impact of adverse space weather; 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; recognize space weather as a global challenge and the need to address the vulnerability of society as a whole; increase awareness through developed communication, capacity-building and outreach; and identify governance and cooperation mechanisms to support this objective.

45. The implementation mechanism for the thematic priority on the international framework for space weather services is the Expert Group on Space Weather, to be substantively supported by the Office for Outer Space Affairs. At its third meeting, held in February 2017, the Expert Group welcomed its mandate, underlined that important synergies existed between the tasks set out in its existing workplan and the objectives of the thematic priority, and agreed to focus, during the coming year, on the preparation of a report on the mitigation of space weather effects, to be considered by the Subcommittee and the Committee under UNISPACE+50 in 2018.

46. The Expert Group highlighted two main goals through which the Committee could make significant and actionable future contributions towards the mitigation of the adverse impacts of space weather:

(a) There was a need to develop an improved basis for international monitoring, forecasting and warning procedures, especially in the form of more coordinated international communication and coordination of warnings of extreme space weather events. The Expert Group noted that individual Member States had some existing capabilities in that regard upon which to build;

(b) There was a need to define a set of best practices, operating procedures and actions to mitigate the adverse impacts of extreme space weather, which required a prior assessment in each Member State of its exposure to risks from space weather and related socioeconomic impacts, as well as defined operating procedures, developed in partnership with administrations responsible for critical infrastructure and civil protection.

B. United Nations Office for Outer Space Affairs

1. United Nations Programme on Space Applications

47. The United Nations Programme on Space Applications, implemented by the Office for Outer Space Affairs, was established in 1971 to assist Member States with capacity-building in the use of space science, space technology and space applications in support of sustainable development, and to promote international cooperation in outer space activities. Since its inception, the Programme has organized several hundred training courses, workshops, seminars and meetings for the benefit of Member States, including in the area of space weather.

48. It was recognized early in the planning of the International Heliophysical Year 2007 that the understanding of the global ionosphere and its linkage to the near-Earth space environment was limited by the lack of observations in key geographical areas. To address that need, the following series of workshops was held to facilitate collaborations between research scientists in scientifically interesting geographic locations and researchers in countries with expertise in building scientific instrumentation:

(a) United Nations/European Space Agency/National Aeronautics and Space Administration of the United States of America Workshop on the International Heliophysical Year 2007, held in Abu Dhabi and Al-Ain, United Arab Emirates, from 20 to 23 November 2005 (see A/AC.105/856);

(b) Second United Nations/National Aeronautics and Space Administration Workshop on the International Heliophysical Year 2007 and Basic Space Science, held in Bangalore, India, from 27 November to 1 December 2006 (see A/AC.105/882);

(c) Third United Nations/European Space Agency/National Aeronautics and Space Administration Workshop on the International Heliophysical Year 2007 and Basic Space Science, held in Tokyo from 18 to 22 June 2007 (see A/AC.105/902);

(d) Fourth United Nations/European Space Agency/National Aeronautics and Space Administration/Japan Aerospace Exploration Agency Workshop on the International Heliophysical Year 2007 and Basic Space Science, held in Sozopol, Bulgaria, from 2 to 6 June 2008 (see A/AC.105/919);

(e) Fifth United Nations/European Space Agency/National Aeronautics and Space Administration/Japan Aerospace Exploration Agency Workshop on Basic Space Science and the International Heliophysical Year 2007, held in Daejeon, Republic of Korea, from 21 to 25 September 2009 (see A/AC.105/964);

(f) United Nations/National Aeronautics and Space Administration/Japan Aerospace Exploration Agency Workshop on the International Space Weather Initiative, held in Cairo from 6 to 10 November 2010 (see A/AC.105/994);

(g) United Nations/Nigeria Workshop on the International Space Weather Initiative, held in Abuja from 17 to 21 October 2011 (see A/AC.105/1018);

(h) United Nations/Ecuador Workshop on the International Space Weather Initiative, held in Quito from 8 to 12 October 2012 (see A/AC.105/1030);

(i) United Nations/Austria Symposium on Space Weather Data, Instruments and Models: Looking Beyond the International Space Weather Initiative, held in Graz, Austria, from 16 to 18 September 2013 (see A/AC.105/1051);

(j) United Nations/Japan Workshop on Space Weather: Science and Data Products from International Space Weather Initiative Instruments, held in Fukuoka, Japan, from 2 to 6 March 2015 (see A/AC.105/1096).

49. The workshops determined that the deployment of arrays of small instruments, such as magnetometers to measure the Earth's magnetic field, radio antennas to observe solar coronal mass ejections, GNSS receivers, very low frequency (VLF) radio receivers and muon particle detectors, was an important intervention to address the lack of observations. The instrument deployment programme was one of the major successes of the Programme. To date, 16 instrument arrays are operating in more than 112 countries or areas throughout the world to provide global measurements of heliospheric phenomena.

50. Furthermore, a number of science teams emerged from the workshops. The teams were organized to implement so-called "coordinated investigation programmes" and included a lead scientist, who provided the instruments or fabrication plans for instruments in the array. As a result of the Programme activities, scientists from many countries continue to participate in instrument operation, data collection, analysis and publication of scientific results.

51. Upon the completion of activities under the framework of the International Heliophysical Year 2007, the Programme continued coordinating international research aimed at understanding and predicting the impacts of space weather on the Earth and the near-Earth environment through ISWI. Further information on ISWI that emerged from the International Heliophysical Year 2007 to support the Programme in continuing to deploy new instrumentation, developing data analysis processes, developing predictive models and promoting knowledge of heliophysics through education and public outreach is set out in section IV below.

2. International Committee on Global Navigation Satellite Systems

52. 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 nations.

53. Within the framework of the ICG workplan, GNSS applications in low-cost, worldwide ground-based instrument arrays for exploring atmospheric phenomena related to space weather have been considered in the ICG Working Group on Information Dissemination and Capacity-building. In that context, the Office for Outer Space Affairs, as a lead member of the ICG Working Group, is organizing space weather discussion forums to educate the public and policymakers about space weather phenomena, as well as training courses and seminars for students and professionals on space weather data analysis and prediction. Those activities bring together a large number of experts every year, including experts from developing nations, to discuss and act on issues that are also of great relevance to ICG.

3. Other activities of the United Nations Office for Outer Space Affairs

54. In addition to the activities carried out in its capacity as the secretariat of the Committee on the Peaceful Uses of Outer Space and the secretariat of ICG, and in relation to the implementation of the United Nations Programme on Space Applications, the Office engages in a wide range of other activities in the area of space weather.

55. In line with the Dubai Declaration, adopted at the first High-level Forum on space as a driver for socioeconomic sustainable development, held in Dubai from 20 to 24 November 2016, in which participants recognized the importance for States to develop space policies and regulatory frameworks at the national level in accordance with their needs and conforming to international space law, the Office provides capacity-building and targeted technical legal assistance, including in the area of space weather. Technical assistance was also provided in 2015 upon the request of a Member State, which involved the Office offering comments on the national space weather strategy of that State.

56. In preparation for UNISPACE+50, the United Nations/United States of America Workshop entitled “Space Weather: the Decades after the International Heliophysical Year 2007”, will be held in Chestnut Hill, United States, from 31 July to 4 August 2017. The workshop will focus on recent advances made in scientific research by utilizing ISWI instrument data and will begin with a high-level international forum on the economic and societal effects of extreme space weather. It will also provide recommendations to form the basis for the final decision on the way forward in the area of space weather. The workshop is also a flagship event in the preparations for UNISPACE+50.

57. The third International Civil Aviation Organization and United Nations Office for Outer Space Affairs Aerospace Symposium on the theme “Emerging space activities and civil aviation: challenges and opportunities”, to be held in Vienna from 29 to 31 August 2017, will feature a dedicated session on space weather aimed at strengthening cooperation among stakeholders in the space and aviation communities and among the relevant legal and regulatory actors in responding to challenges posed by space weather.

58. The Office plans to include the theme of space weather in the programme of the open informal session of UN-Space, to be held in conjunction with the thirty-seventh session of UN-Space in Geneva in 2017. The open informal sessions are organized with the participation of Member States and other stakeholders to promote dialogue and demonstrate examples of how the United Nations system responds to the selected themes.

C. World Meteorological Organization

59. In June 2008, the WMO Executive Council noted the considerable impact of space weather on meteorological infrastructure and important human activities. It acknowledged the potential synergy between meteorological and space weather services for operational users. The Council agreed that WMO should support international coordination of space weather activities and urged WMO members to provide corresponding resources through secondments and trust fund donations.

60. In May 2010, WMO established the Interprogramme Coordination Team on Space Weather (ICTSW) with a mandate to support space weather observation, data exchange, product and service delivery and operational applications. ICTSW involved experts from 26 different countries and seven international organizations.

61. In May 2011, the World Meteorological Congress acknowledged the need for a coordinated effort by WMO members to address the observational and service requirements for protecting society against the global hazards of space weather.

62. In July 2014, potential space weather services for international air traffic navigation were discussed at the joint session of the WMO Commission for Aeronautical Meteorology (CAeM) and the Meteorology Division of ICAO.

63. In May 2015, the World Meteorological Congress took note of the Four-Year Plan for WMO Coordination of Space Weather Activities, developed by ICTSW in consultation with CAeM and the Commission for Basic Systems. The Congress agreed that WMO should undertake international coordination of operational space weather monitoring and forecasting with a view to supporting the protection of life, property and critical infrastructure, and affected economic activities through an optimized overall effort. The Congress further agreed that, by providing a global intergovernmental framework, WMO would facilitate international commitments and enable the establishment of operational space weather services, in particular in the context of the support to ICAO.

64. In June 2016, the WMO Executive Council approved the Four-Year Plan for WMO Activities Related to Space Weather 2016-2019. The plan identified a set of high-priority activities that were considered necessary and feasible within the four-year time frame, and was aimed at enabling States members of WMO to establish fully operational space weather services, share observation data, products and best practices and ensure interoperability and standardization, as appropriate, to efficiently respond to global space weather-related challenges. The Plan also suggested the engagement of WMO member States through the provision of technical expertise and through financial contributions to the WMO Space Weather Trust Fund. In addition, the Council agreed to replace ICTSW with an Inter-Programme Team on Space Weather Information, Systems and Services in order to pursue the work of ICTSW in close cooperation with the WMO technical commissions, the space weather provider community represented by the International Space Environment Service (ISES), and representatives of users.

65. The responsibility of the Inter-Programme Team is to coordinate space weather activities among the WMO programmes, to maintain linkages with constituent bodies, their relevant subsidiary groups and with partner organizations, and to provide guidance to WMO members. It commenced its work in early 2017 and involves experts from 21 countries and five international organizations as of March 2017.

D. International Civil Aviation Organization

66. Following the reorganization of the secretariat and the panel structure of ICAO in 2014, the Meteorology Panel (METP) was established at the fifth meeting of the 197th session of the Air Navigation Commission (ANC), held on 30 September 2014. The panels of ANC are technical groups of qualified experts formed by ANC. Their purpose is to address specific problems or develop standards related to the planned evolution of air navigation, within specified time frames that cannot be advanced within ANC or through established resources of the ICAO secretariat.

67. The primary responsibilities of METP are to define and elaborate concepts and to develop ICAO provisions for aeronautical meteorological services consistent with operational improvements envisaged by the ICAO Global Air Navigation Plan and in keeping with the Working Arrangements between the International Civil Aviation Organization and the World Meteorological Organization.

68. In April 2015, the Working Group for Meteorological Information and Services Development was established by METP to assess user needs, determine shortfalls, develop operational concepts and define the functional and performance requirements for new meteorological information required to support future operational concepts as defined in the Global Air Navigation Plan. The Working Group employs a requirements development process based on standard, internationally accepted systems-engineering principles. Currently, the Working Group consists of five work streams that are developing requirements on

meteorological information to be included in amendments 78 and 79 to annex 3 to the Convention on International Civil Aviation, on meteorological service for international air navigation, as well as guidance material on implementing the proposed provisions, one of which is the Space Weather Work Stream.

69. At the second meeting of METP, held in Montreal, Canada, from 17 to 21 October 2016, the Standards and Recommended Practices for the new space weather information service (proposed by the Space Weather Work Stream) that are to be proposed for inclusion in amendment 78 to annex 3 to the Convention on International Civil Aviation were reviewed and endorsed. The Standards and Recommended Practices are based on the previously completed Concept of Operations and functional and preliminary performance requirements. In addition, METP endorsed the draft criteria for identifying the providers of space weather information to fulfil the Standards and Recommended Practices. The Space Weather Work Stream will develop a manual on space weather information for international air navigation to support the implementation of the Standards and Recommended Practices by describing the provision and intended use of the information.

70. In March 2017, at the eighth meeting of the 204th session of ANC, the Standards and Recommended Practices for space weather information services were approved for inclusion in a State Letter eliciting comments from States and international organizations. It is expected that, after that consultation process, ANC will review the replies to the State Letter in September and October 2017 and provide a final report to the ICAO Council that includes a recommendation that the Council adopt the Standards and Recommended Practices in February and March 2018, for applicability in November 2018.

71. In parallel with the process for approving the Standards and Recommended Practices, a process for the designation of space weather information service providers has been proposed by METP and endorsed by ANC. The process includes guidance material on criteria to be met by potential service providers and a schedule for establishing space weather information services in support of international air navigation. The process will be undertaken by ICAO and WMO, who will assist in auditing the potential space weather service providers that are able to provide the information required by the proposed Standards and Recommended Practices.

E. International Atomic Energy Agency

72. Cosmic radiation, which comes from the Sun and other celestial objects, accounts for about half of the natural background radiation to which the world population is exposed. Because of its high energy, cosmic radiation could pose a danger to human health, but humans on Earth are shielded from most cosmic rays by the planet’s magnetic field and atmosphere.

73. While interplanetary manned missions that go beyond the Earth’s magnetosphere are not protected from the space environment by the planet’s magnetic shield, the crew on board the International Space Station (ISS) and its Earth-bound analogues still have the limited protection of the magnetosphere. Nevertheless, astronauts and cosmonauts are exposed to high levels of cosmic radiation, which has an adverse effect on the human body. Cosmic radiation can cause a stochastic effect on the human body and has also been linked to a higher incidence of cataracts as a deterministic effect in astronauts and cosmonauts.

74. In 2014, IAEA published *Radiation Protection and Safety of Radiation Sources: International Basic Safety Standards — General Safety Requirements*,[1] as part of its endeavour to protect people and the environment from the harmful effects of ionizing radiation. The IAEA standards outline responsibilities of Governments in

[1] *Radiation Protection and Safety of Radiation Sources: International Basic Safety Standards — General Safety Requirements*, IAEA Safety Standards Series No. GSR Part 3 (International Atomic Energy Agency, Vienna, 2014).

existing exposure situations, such as exposure due to natural sources, and stipulate requirements for occupational exposure of aircrews and space crews due to cosmic radiation. While the requirements of the IAEA standards with respect to dose limits do not apply to individuals in space-based activities, all reasonable efforts should be made to optimize protection for those individuals by restricting the doses they receive, while not unduly limiting the extent of such activities.

75. The standards are jointly sponsored by the European Commission, the Food and Agriculture Organization of the United Nations, IAEA, the International Labour Organization, the Nuclear Energy Agency of the Organization for Economic Cooperation and Development, the Pan American Health Organization, the United Nations Environment Programme and WHO.

F. International Telecommunication Union

76. In November 2015, the World Radiocommunication Conference (WRC) adopted resolution 657, on spectrum needs and protection of space weather sensors, which paved the way for the WRC in 2023 to consider regulatory provisions necessary to provide protection to space weather sensors operating in the appropriately designated radio service that is to be determined on the basis of studies conducted by the Radiocommunication Sector of the International Telecommunication Union (ITU-R).

77. WRC also invited ITU-R to document the technical and operational characteristics of space weather sensors, determine their appropriate radio service designations and conduct any necessary studies on sharing of frequencies for incumbent systems operating in frequency bands used by space weather sensors, with the objective of determining what regulatory protection could be provided that would not place additional constraints on incumbent services.

78. Study Groups 3 and 7 of the ITU Radiocommunication Sector work in the areas related to space weather, since space weather disturbances in the ionosphere affect the propagation of radio waves used in telecommunication and radio navigation, and since a frequency allocation and protection for space weather sensors is required.

G. World Health Organization

79. The World Health Organization is actively working with the Office for Outer Space Affairs and national and regional space agencies to advance the use of space science and technology to achieve the health-related sustainable development goals and targets of Member States. The report on the meeting on the applications of space science and technology for public health organized by WHO and the Office for Outer Space Affairs, held in Geneva from 15 to 16 June 2015 (A/AC.105/1099), identifies the importance of global health priorities and the need for full use of space science and technology for advancing health goals, including the monitoring of health effects due to changes in environment.

IV. Other international and regional cooperation mechanisms related to space weather

A. International Space Weather Initiative

80. The International Space Weather Initiative, which grew out of the International Heliophysical Year 2007, is an international cooperation programme to advance space weather science by combining the deployment of instruments with the analysis and interpretation of space weather data obtained from those instruments in

conjunction with space data, and to advance education and capacity-building in space weather science and communicate the results to the public.

81. The ISWI Steering Committee, supported by the ISWI secretariat, located at the National Aeronautics and Space Administration (NASA) Goddard Space Flight Center, United States, coordinates ISWI activities. A periodic ISWI newsletter is published by the International Centre for Space Weather Science and Education of Kyushu University, Japan, and the ISWI website is maintained by the Bulgarian Academy of Sciences (see www.iswi-secretariat.org). ISWI has established an open data policy, thus all data collected by ISWI instruments are freely available to the public.

B. Coordination Group for Meteorological Satellites

82. The Coordination Group for Meteorological Satellites (CGMS) is the coordination body for space agencies operating meteorological, climate monitoring and environmental satellites in accordance with requirements formulated by WMO and other user communities. CGMS is a forum for global planning coordination, technical harmonization and exchange of information on geostationary, polar orbiting and other satellite systems, with a particular focus on ensuring long-term continuity of space-based observations in support of operational applications (see www.cgms-info.org).

83. CGMS has an interest in space weather, both from the perspective of the impacts of space weather on satellite systems and to support the continuity and coordination of space-based observational capabilities for operational space weather products and services from sensors on meteorological satellites and on space weather satellites. In 2015, CGMS established a Space Weather Task Team, tasked with identifying priorities for CGMS space weather activities and integrating space weather into CGMS activities. In 2016, near-term space weather objectives were integrated into the CGMS High-Level Priority Plan 2016-2020. In pursuing those objectives, CGMS also coordinates its activities with the complementary activities of its member organizations, other international bodies and initiatives, and interfaces with the wider space weather community.

84. The International Radio Occultation Working Group (IROWG) was established as a permanent working group of CGMS in 2009; it is co-sponsored by CGMS and WMO. IROWG serves as a forum for operational and research users of radio occultation data. The Space Weather Subgroup of IROWG represents space weather users of radio occultation data. It facilitates the dual use of radio occultation missions to acquire both atmospheric and ionospheric observations for research and operational purposes. The Subgroup seeks to improve how radio occultation data are used in research and operational contexts. It provides support to atmospheric radio occultation users who are affected by the ionosphere. Reports of the Subgroup are contained in the IROWG workshop minutes, which are available at irowg.org.

C. International Space Environment Service

85. ISES is a collaborative network of space weather service-providing organizations around the globe, organized and operated for the benefit of the international space weather user community. ISES has been engaged in the international coordination of space weather services since 1962. It is a Network Member of the International Council for Science World Data System and collaborates with a number of international organizations. ISES currently comprises 16 regional warning centres around the globe (Australia, Belgium, Brazil, Canada, China, Czechia, India, Indonesia, Japan, Mexico, Poland, Republic of Korea, Russian Federation, South Africa, Sweden and United States) and four associate warning centres (three in China and one in France). The European Space Agency

(ESA) serves as a collaborative expert centre for data and product exchange in Europe.

86. The mission of ISES is to improve, coordinate and deliver operational space weather services. The regional warning centres share data and services among the various centres and provide space weather services to customers in their regions. The centres provide a broad range of services, including forecasts, alerts and warnings of solar, magnetospheric and ionospheric conditions, extensive space environment data, customer-focused event analyses and long-range predictions of the solar cycle. While each centre concentrates on its own region, ISES serves as a forum to share data, exchange and compare forecasts, discuss customer needs and identify the highest priorities for improving space weather services.

D. International Astronomical Union

87. Within the International Astronomical Union (IAU), activities of ISWI are coordinated by Division E (Sun and Heliosphere). The Division is dedicated to the study of the Sun, its variability, activity and dynamics, as well as its impact on the Earth and other bodies located within the heliosphere. It aims to advance knowledge and enhance understanding of the Sun-heliosphere system. The Division has several affiliated commissions and working groups that support these goals, and supports regular symposiums to foster the exchange of ideas.

88. The work of Division E towards its scientific goals is supported by its organizational structure, which currently includes three commissions: Commission E1, on solar radiation and structure; Commission E2, on solar activity; and Commission E3, on solar impact throughout the heliosphere. The Division's Working Group on Impact of Magnetic Activity on Solar and Stellar Environments brings together theorists, modellers and observers in the field of solar, stellar and planetary physics to coordinate and facilitate the interdisciplinary science related to understanding the impact of stellar magnetic activity on the astrospheres of stars. The Inter-Division C-E Working Group on Solar Eclipses acts as a "one-stop shop" for eclipse information.

89. The Inter-Division B-E Working Group on Coordination of Synoptic Observations of the Sun aims to facilitate international collaboration in synoptic long-term solar observations, which includes past, present and future synoptic programmes, preservation, calibration and access to synoptic solar data products. The Working Group provides a forum for discussion of all issues relevant to synoptic long-term observations of the Sun, including, but not limited to, coordination among synoptic programmes in different countries (both in respect to exchange of information and planning for future synoptic programmes) and proper calibration of historical data from different sources.

E. Committee on Space Research

90. The Committee on Space Research (COSPAR) was established by the International Council for Science (ICSU) in 1958. Among its objectives are the promotion of scientific research in space at the international level, with an emphasis on the free exchange of results, information and opinions, and to provide a forum, open to all scientists, for the discussion of problems that may affect space research.

91. In 1998, the decision was taken to create the COSPAR Panel on Space Weather, with the purposes of bridging the gap between the research and applications communities in the space weather field and fostering cooperation in the emerging area of space weather research. The Panel provides expert knowledge on the space environment and encourages the development of predictive techniques capable of forecasting changes in the space environment on a timescale that will allow steps to be taken to address the effects of changes in that environment. The Panel acts as a source of advice to the COSPAR scientific commissions on matters

pertaining to space weather that cross the disciplinary boundaries of those commissions.

F. The Scientific Committee on Solar-Terrestrial Physics

92. The Scientific Committee on Solar-Terrestrial Physics (SCOSTEP) is an interdisciplinary body of ICSU. SCOSTEP promotes the mission of ICSU to strengthen international science for the benefit of society. SCOSTEP runs international interdisciplinary scientific programmes and promotes solar-terrestrial physics research by providing the necessary scientific framework for international collaboration and dissemination of the derived scientific knowledge in collaboration with other ICSU bodies. The ICSU bodies currently represented in the SCOSTEP Bureau are COSPAR, IAU, the International Association of Geomagnetism and Aeronomy, the International Association of Meteorology and Atmospheric Sciences, the International Union of Pure and Applied Physics, the Scientific Committee on Antarctic Research, the International Union of Radio Science and the World Data System.

93. SCOSTEP seeks opportunities for interaction with national and international programmes involving elements of solar-terrestrial physics. It provides guidance to the solar-terrestrial physics discipline centres of the ICSU World Data Centre system. It also attempts to develop and sustain student interest in Sun-Earth connections, to promote efficient exchange of data and information between solar and terrestrial scientists in all countries, and to seek projects and programmes that cross traditional boundaries of geographical regions and focused scientific disciplines. The SCOSTEP secretariat office is hosted by the Centre for Research in Earth and Space Science of York University, in Toronto, Canada.

G. International Living With a Star

94. International Living With a Star (ILWS) is an initiative to stimulate, strengthen and coordinate space research. Contributing organizations include the major space agencies around the world as well as agencies engaged in space science research and space weather services. ILWS objectives include the study of the connected Sun-Earth system, collaboration and coordination of missions and research, and the effective use of data.

COSPAR-ILWS road map

95. In the spring of 2013, the COSPAR leadership and the ILWS Steering Committee commissioned a strategic assessment of how to advance the science of space weather, with the explicit aim of better meeting user needs around the globe. The report, entitled “Understanding space weather to shield society: a global road map for 2015-2025 commissioned by COSPAR and ILWS” is the outcome of that activity.

96. In the mission statement by the COSPAR Panel on Space Weather and the ILWS Steering Committee, an appointed team of experts was asked to “review current space weather capabilities and identify research and development priorities in the near, mid- and long term which will provide demonstrable improvements to current information provision to space weather service users”, thereby expressing a focus on the terrestrial environment. In line with the team’s mission, the report centred on a recommended approach to future developments, including coordination and addressing of key science challenges, space and ground-based data needs, and transition of scientific developments into reliable services.

H. Asia-Oceania Space Weather Alliance

97. The Asia-Oceania Space Weather Alliance (AOSWA) was established in 2010 to encourage cooperation and information-sharing among institutes in the Asia/Oceania region concerned with and interested in space weather. The Asia/Oceania region has become one of the most important regions for space utilities and therefore requires close communication and cooperation to improve space weather activities.

98. The AOSWA secretariat is managed by the Space Weather and Environment Informatics Laboratory of the National Institute of Information and Communications Technology of Japan. The secretariat's functions include organizing meetings, maintaining registries of associates and keeping them informed about matters related to the AOSWA framework through the Internet, newsletters and mailing lists, which allows for the improvement of communication and cooperation among various institutes.

I. European cooperation

99. Scientific cooperation has been encouraged by the European Union through the process of European Cooperation in Science and Technology (COST) actions, such as COST actions 296, 724 and 803, which have strengthened the space weather community in Europe. New space weather services are being developed under the Seventh Framework and Horizon 2020 programmes of the European Union.

100. In 2009, ESA launched the Space Situational Awareness (SSA) Programme, with space weather as one of its three segments, aimed at providing owners and operators of critical space-borne and ground-based infrastructure with timely and accurate information to support mitigation of the adverse impacts of space weather. The SSA Space Weather Service Network includes the SSA Space Weather Coordination Centre, five Expert Service Centres and a data centre that provides access to the space weather service portal and a large data repository. The 39 SSA space weather services, each consisting of multiple elements, enable the detection and forecasting of space weather events and their effects on European space assets and ground-based infrastructure, and target the needs of user domains through the provision of timely and relevant information supporting protection of the sensitive infrastructure.