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**Committee on the Peaceful
Uses of Outer Space
Scientific and Technical Subcommittee
Fifty-third session
Vienna, 15-26 February 2016
Item 11 of the provisional agenda*
Space Weather**

**Space Weather Workshop and Second Meeting of
Space Weather Expert Group, 15 to 17 February 2016:**

**Report on Work and Review of Work Plan of the
Space Weather Expert Group**

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Executive Summary

1. A combined space weather workshop and meeting of the Space Weather Expert Group was organized on the margins of the 53rd session of the Scientific and Technical Subcommittee (STSC) of the United Nations Committee on the Peaceful Uses of Outer Space (COPOUS) from 15-17 February 2016. The Workshop provided background information to member states and their experts to enable them to review *the current space weather activities in member States and related national and international organisations*. In particular it provided the necessary information to enable the Expert Group to review the global space weather effort and to promote increased international collaboration consistent with the Expert Group mandate. The Expert Group noted the increasing number of Member States, and the value to these states, of undertaking both risk and socio-economic impact assessments of their vulnerability to space weather effects. Such studies would inform their future actions in relation to critical infrastructure protection, and where appropriate, the results could be reflected on their risk registers. The Expert Group notes that since national

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economies are connected both regionally and globally, even countries with a perceived low domestic space weather risk can benefit from a global approach to mitigating space weather risks.

2. The workshop provided a forum for the Expert Group to examine *the report and conclusions of the LTS Expert Group C on space weather (A/AC.105/C.1/2014/CRP.15)* and other information related to space weather including the recent report from the COSPAR-ILWS Roadmap team “*Understanding Space Weather to Shield Society*”¹. The Expert Group endorses the approach outlined in the COSPAR-ILWS report for the development of new activity, including new observations and modeling, targeting improved space weather data products and services. The Expert Group further affirms the recommendation from the COSPAR-ILWS Space Weather Roadmap team that the pathway leading to Geomagnetically Induced Currents (GICs) (Pathway I) be pursued as a first priority, and that such activities be pursued with the goal of obtaining geomagnetic activity forecasts more than 12 hours ahead. The Expert Group affirms that the pathways leading to the targets of space radiation and ionospheric impacts (Roadmap Pathways II and III) are also very important, and these should be examined in due course. The Expert Group notes in particular the additional significant impacts arising from space weather effects on GNSS, as well as the work being completed by ICAO which highlights the importance of space radiation effects for aviation. The Expert Group reached a consensus identifying initial *recommendations and best practices to identify mechanisms to promote their implementation, including an assessment of prioritization*, consistent with the Expert Group mandate, and these are described in this CRP.

3. In its work the Expert Group also noted the importance of several overarching themes in relation to this goal and to the need:

- a) To make better use of existing data and models for space situational awareness, now-casting, and forecasting;
- b) For new scientific research for improved space weather forecasting;
- c) For improved fidelity of severe space weather scales and indicators in forecast products, the need for regional forecast products, and (as appropriate) ongoing or increased access to real-time data;
- d) To promote increased collaboration between research and operational communities to transition new research findings into improved space weather products including situational awareness, now-casting, and forecast products.

4. The Expert Group also finds that there is significant synergy between its planned future activities and those in relation to Space Weather under consideration for UNISPACE+50 (as outlined for example in “*Fiftieth anniversary of the United Nations Conference on the Exploration and Peaceful Uses of Outer Space: the Committee on the Peaceful Uses of Outer Space and global space governance*” A/AC.105/C.1/2016/CRP.4). The Expert Group proposes to examine recommendations for actions with due regard to these evolving potential synergies and hence with due consideration and reference to the timelines defined for the UNISPACE+50 planning schedule.

¹ Schrijver et al., *Advances in Space Research* 55, 2745 (2015) <http://dx.doi.org/10.1016/j.asr.2015.03.023>

5. The Expert Group confirms that it will continue to operate by continuing with its existing work plan and mandate for the coming year. In terms of the schedule, the Expert Group proposes that Task 1 be extended into a second upcoming year thereby extending the period for completion of this item from year 1 to year 1-2. The Expert Group will report on its further activities to the STSC at its 54th session in February 2017.

I. The Continuing and Growing Importance of Space Weather

6. Space weather is entering a new era where science promises significant advances in space weather services covering the areas of Space Situational Awareness, now-casting and environment specification, as well as space weather forecasting. At the same time, recent scientific advances have highlighted the increased impact as well as an increased likelihood of adverse space weather impacts on both terrestrial and space-based systems and services. The Expert Group re-affirms the need for increased international cooperation and coordination, accompanied by clear and actionable recommendations, to deliver significant advances in the fidelity of space weather services with tangible positive impacts.

7. Such scientific advances are being developed contemporaneously with the expansion in the utilisation of space, including space actors from both governmental and private sectors, from an expanding number of space-faring nations. Fortunately, the ever increasing demands and needs for improved space weather services is accompanied by potential for parallel increases in the collective international capabilities in the provision of space weather services. The Expert Group noted that tangible benefits can be obtained from actions which lead to either *i) The creation of direct advances (or a new) space weather data product, or ii) The pursuit of new scientific research leading to new understanding which subsequently significantly improves (or creates a new) space weather products.* The Expert Group also notes that since the national economies of member states are connected both regionally and globally, even countries with a perceived low domestic space weather risk can benefit from a global approach to mitigating space weather risks.

8. Noting the contemporaneous changes to the nature of space utilisation in the modern era, and the opportunity to develop improved space weather services and data products, the Expert Group notes the opportunity to reflect the ongoing and future importance of space weather in planning the UNISPACE+50 activities in 2018. Recognising this synergy, the Expert Group will take due consideration of the timetable for development of activities associated with the 50th anniversary of UNISPACE-1 during UNISPACE+50 when conducting its work.

9. The Expert Group continues to endorse the importance and need for space weather observations, forecast models, and services. Through international cooperation and coordination it continues to seek to identify priority areas and make recommendations targeting tangible improvements to space weather services and forecast models. With the increasing need for improved space weather services, such activities could be a powerful future focus for the STSC in relation to the selection of thematic priorities for the future work of COPUOS from 2018 to 2030.

II. Recommendations and Progress on Space Weather Expert Group Work Plan Tasks

10. As approved at the February 2015 United Nations Committee on Peaceful Uses of Outer Space (COPUOS) STSC, an Expert Group on Space Weather was formed and operates under the terms of its initial work plan approved by the STSC at its 52nd session in February 2015. Progress in relation to each of these elements of the Work Plan is described below.

1. *Examine the report and conclusions of the LTS Expert Group C on space weather (A/AC.105/C.1/2014/CRP.15) and other information related to space weather including the recent report from the COSPAR-ILWS Roadmap team “Understanding Space Weather to Shield Society”. The group will examine the guidelines, recommendations and best practices to identify mechanisms to promote their implementation, including an assessment of prioritization. [year 1]*

In recognition of new scientific understanding of both the increased likelihood and increased severity of space weather impacts, the Expert Group presents the following findings for the consideration of the COPUOS Member States:

i) The Expert Group recognised the value to member states of undertaking both risk assessments and socio-economic impact assessments of their vulnerability to space weather effects. Such studies would inform their future actions in relation to critical infrastructure protection, and where appropriate the results could be reflected on their risk registers.

Such studies should cover the impacts arising from space weather in the form of geomagnetically induced currents, space radiation, and ionospheric effects including interruptions to communications and impacts on GNSS systems. Recognising the complex interplay and coupling of space weather impacts on highly coupled modern technological infrastructure, such studies should ideally include both impacts on infrastructure and the socio-economic consequences. For example, the latter can arise from interruptions to services and capabilities arising from damage or interruptions to space-based services.

If the results from these risk and socio-economic impact studies were available in advance of UNISPACE+50 in 2018, then future space weather-related action plans that may be developed during UNISPACE+50 would be informed by the outcomes of these studies.

ii) The Expert Group endorses the approach defined in the COSPAR-ILWS Roadmap “*Understanding Space Weather to Shield Society*” [Schrijver et al., *Advances in Space Research* 55, 2745 (2015)<http://dx.doi.org/10.1016/j.asr.2015.03.023>] as the basis for examining the development of new scientific advances directed to understanding and mitigating the impacts arising from space weather.

The Expert Group endorses the Roadmap approach of examining three different pathways through which the sun-Earth connection drives space weather impacts, and endorses the philosophy that the space weather processes resulting in geomagnetically induced currents (GICs) in electrical power grids (Pathway I) should be addressed as the first priority with the goal of providing forecasts of geomagnetic activity more than 12 hours ahead.

The Expert Group considers that the first step in “*promoting implementation*” could be to obtain and collate information from COPUOS member states through liaison with their respective Civil Protection Agencies, especially in relation to power grid effects, monitoring, modelling, and assessing GIC impacts arising from space weather.

The Expert Group recognises the demonstrated value to Member States of liaison and engagement with their Civil Protection Agencies, and related assessments of their state of understanding, and preparedness for mitigating the risk from space weather-driven effects. Such information could be provided to the Expert Group as appropriate through the relevant national Expert. Countries who have yet to nominate an Expert (or Experts) to participate in the work of the Space Weather Expert Group are reminded that they are welcome to do so.

The Expert Group noted the increased level of national activity in modelling GIC impacts in a number of Member States, and that such information can be made available through collaboration to support the development of similar initiatives in other member states.

Through this effort and the sharing of relevant information within the Expert Group, and between nations, the *Expert Group wishes to promote* the development and use of best practices.

Where information is available in relation to regulatory procedures which are already in place, the *Expert Group further encourages* the sharing of this information as well.

Through this activity *the Expert Group further hopes to promote* increased awareness of the potential threats that can arise from space weather hazards, including GICs.

iii) The Expert Group affirms the importance of access to critical space weather data and model outputs. In particular, the Expert Group encourages all Member States to adopt an open data policy for critical space weather data, model outputs and forecasts. Wherever possible, respecting the needs of commercial operators, this could also include space weather impact data, including GIC loads in power grids and satellite anomaly data.

This is consistent with the conclusions of the LTS Expert Group C report on space weather (A/AC.105/C.1/2014/CRP.15), in particular proposed candidate Guidelines 1 and 3, and their related recommended practices, as described in the LTS Expert Group C report:

“Guideline 1: Space weather entities, and member states and national and international organisations, should support and promote the collection, archiving, sharing, inter-calibration and dissemination of critical space weather data.

Guideline 3: Member States and their national and international agencies should support and promote the coordinated sharing and dissemination of space weather model outputs and forecasts.”

iv) In the context of the review of the COSPAR-ILWS Roadmap the Expert Group also reviewed the high level data in the context of Pathway I which leads to the generation of GICs. *The Expert Group notes* the significant work *contained*

within that report examining data needs for each of the space weather pathways in the Roadmap, and endorses the basis of the measurement needs outlined in the report. In terms of prioritisation of these needs, the Expert Group intends to continue its assessment of prioritisation over the coming year and therefore recommends an extension of the period of topic 1 in its work plan to cover not only the first (current) year but also the second upcoming year of the Expert Group activities.

v) In its work the Expert Group noted the importance of several overarching themes in relation to the need:

- a) To make better use of existing data and models for space situational awareness, now-casting, and forecasting;
- b) For new scientific research for improved space weather forecasting;
- c) For improved fidelity of severe space weather scales and indicators in forecast products, the need for regional forecast products, and (as appropriate) ongoing or increased access to real-time data;
- d) To promote increased collaboration between research and operational communities to transition new research findings into improved space weather products including situational awareness, now-casting, and forecast products.

These actions are consistent with the conclusions of the LTS Expert Group C on space weather (A/AC.105/C.1/2014/CRP.15)), in particular proposed candidate Guideline 2: “Member States and their national and international agencies should support and promote further coordinated development of advanced space weather models and forecast tools in support of user needs” and the related recommended practices described in the LTS Expert Group C report.

2. *Complete an inventory of relevant United Nations organizations, including the World Meteorological Organisation (WMO) and International Civil Aviation Authority (ICAO) and others, and those within States members of the Committee and national and international organizations. Identify and assess their role in the global space weather effort, promote coordination and communication between them, and ensure that the efforts of STSC are complementary. [years 1-2]*

During the Space Weather Workshop and Expert Group Meeting, held on the margins of the 53rd session of the Scientific and Technical Subcommittee (STSC) of the United Nations Committee on the Peaceful Uses of Outer Space (COPOUS), there were a series of presentations covering recent work being completed in Member States and their national and international organisations.

The Expert Group noted a continuing expansion in the collective international capacity, and identified a number of themes which are common to many. The Expert Group concluded that there could be significant benefit from promoting collaboration and increased communication between these entities.

Consistent with the first priority consideration of the space weather which drives GICs, and the examination of the related hazards, and noting expansion of activities in a large number of member states **the Expert Group reached a consensus** that it would organise a series of follow-on meetings dedicated to pursuing collaboration and increased communication on the GIC topic. These

would most likely be held via teleconference, nominally approximately every three months, with participation from researchers and space weather service providers active in studying or with an interest in GICs. A number of important opportunities were identified, including but not limited to:

- a) exchange of information and details of activities relating to the development of GIC models;
- b) approaches to the definition of worse case storm conditions as input to GIC models;
- c) approaches to modelling associated with assessing GIC impacts, definition of worst case storms;
- d) approaches to definitions of standard operating procedures in relation to the GIC hazard;
- e) new or developing regulatory requirements in relation to space weather impacts on power grids;
- f) potential sharing of information, respecting the sensitivity of commercial GIC data, in relation to GICs observed in power grids in member states;
- g) the development of strategies to promote access to GIC impact data from power companies;
- h) actions for promoting the space weather GIC hazard to national and international power distribution companies and organisations;
- i) potential creation of an informal register of companies within Member States who are already actively engaged in assessing the GIC hazard within Member States with a view to increased communication between them;
- j) promotion of better understanding amongst power distribution companies of new knowledge relating to assessing the hazard from the dB/dt imposed by the dynamics of the magnetosphere and ionosphere on their grid;
- k) communication about the regional and latitudinal differences in power grid response to the GIC threat;
- l) increased understanding that there are regional and local time differences in the grid response to different solar wind and magnetic storm conditions, reflecting increasing knowledge that there can be GIC impacts at all latitudes and not just under the nightside auroral zone.

Experts from a number of member states also noted that in addition to national civil protection authorities and bodies responsible for national power grid infrastructure, there are also a number of regional and international power grid and power distribution administrations. The Expert Group agreed that it would take steps for national experts to try to liaise with these international power distribution organisations to promote dialogue in relation to the space weather GIC hazard.

The Expert Group re-iterates that Space Weather can have a wide range of impacts not only on power grids and other infrastructure as a result of geomagnetic disturbances, for example GICs in power grids, pipeline corrosion, and in some railway networks, but also in relation to space radiation and the effects of

ionospheric disturbances. In relation to the development of new science knowledge towards the mitigation of space weather effects, the Expert Group noted that Pathways II and III from the COSPAR-ILWS Roadmap relate to these important additional impacts and agreed these need to be examined in detail in the future.

The Expert Group also received a presentation in relation to radiation effects and impacts for aviation. Recognising that work in this area is rapidly developing within ICAO, potentially including regulatory requirements, radiation monitoring, and space weather data products, forecast and warnings tools, the Expert Group noted that this should be an important priority area for its future deliberations.

Recognising the significant and wide ranging potential impacts of space weather on GNSS, the Expert Group noted that this should also be a future area for high priority deliberations.

3. *Recognizing the impacts of space weather, the group will promote increased and expanded member State involvement in providing space weather monitoring, from the ground and in space, and in developing, advancing, and sharing and delivering space weather services. [years 2-4]*

This is upcoming work for the Expert Group in the upcoming years. However, the Expert Group has already noted in its review of the COSPAR-ILWS Roadmap and in its review of current national and international activities during the Workshop that there are already areas where a small investment could lead to significant advances in space weather service capabilities. For example, in relation to monitoring GICs the Expert Group noted new research which indicates that the strongest geo-electric fields which are driven by magnetosphere-ionosphere coupling and geomagnetic disturbances (GMD) can be very localised in nature. Such localisation, as well as the strong correlation between observed GIC load and dB/dt measured by proximal ground-based magnetometers points to the value of sufficiently dense coverage of magnetometers for GIC monitoring. Having such data feeds available would in real-time would also significantly improve the now-casting services and the monitoring of situational awareness for potential GIC hazards for power company operators and space weather service providers.

In general, the Expert Group recommends the coordination and sharing of outputs from space weather forecasts produced in the Member States. The goal from this activity will be to drive innovation and improvements in space weather models, and improve the fidelity of the space weather forecasts and warnings that are issued to users.

The ***Expert Group affirms*** the importance of validation of space weather models and data products against observational data. Where such data is not currently available or collected, priority should be given to the development and deployment of appropriate new instrumentation. In this context, the Expert Group believes that the research component is vital to improving future reliability of forecast models and services.

These actions are consistent with the conclusions of the LTS Expert Group C report on space weather (A/AC.105/C.1/2014/CRP.15)), in particular the 4th proposed recommended practice in relation to Guideline 3 which states:

“3.4 Member States and their national and international agencies should encourage their space weather service providers to:

- (i) *Undertake comparisons of space weather model and forecast outputs with a goal of assessing their metrics and comparative performance towards the goal of improved model and forecast accuracy.*
 - (ii) *Openly share and disseminate historical and future critical space weather model outputs and forecast products in a common format.*
 - (iii) *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.*
 - (iv) *Undertake coordinated dissemination of space weather forecasts among space weather service providers and to operational end users.”*
4. *The group will report yearly to the STSC on its progress, on important issues which have been identified, and where specific action is recommended. The group will also make a recommendation for its continuing and future work plan.*

The Expert Group proposes to continue to operate on the same work plan and with the same mandate for the coming year as approved by the 52nd session of the Scientific and Technical Subcommittee (STSC) of the United Nations Committee on the Peaceful Uses of Outer Space in February 2015. The Expert Group proposes that Task 1 be extended into a second upcoming year changing the period from [year 1] to [year 1-2].
