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Item 11 of the provisional agenda*
Space weather

Non-Consensus Paper of the Expert Group on Space Weather on the Survey of the State of Member State Preparedness, and Current and Future Activities and Needs for Space Weather Impact Mitigation

Report submitted by the Rapporteur of the Expert Group on Space Weather

Preamble

In accordance with the extension of the mandate of the Expert Group on Space Weather endorsed by the Scientific and Technical Subcommittee at its 58th session, to finalize the survey of the state of Member State preparedness, and recommendations for improved international coordination for space weather impact mitigation, Members of the Expert Group used the intersessional period to consolidate and evaluate input on the "Draft Report of the Expert Group on Space Weather: Survey of the State of Member State Preparedness, and Current and Future Activities and Needs for Space Weather Impact Mitigation": (A/AC.105/C.1/2021/CRP.14). The Expert Group considered input from delegations at the 58th session of the Subcommittee as well as additional formal written input from Member States in the subsequent period up to September 19th 2021.

The Expert Group consolidated its consensus recommendations in the "Draft Final Report of the Expert Group on Space Weather: Towards Improved International Coordination for Space Weather Services": (A/AC.105/C.1/L.401), which was submitted to the Subcommittee for consideration at its 59th session in 2022.

In addition, a subset of the Expert Group updated the "Draft Report of the Expert Group on Space Weather: Survey of the State of Member State Preparedness, and Current and Future Activities and Needs for Space Weather Impact Mitigation" (A/AC.105/C.1/2021/CRP.14) into the "Non-consensus Paper of the Expert Group on Space Weather: Survey of the State of Member State Preparedness, and Current and Future Activities and Needs for Space Weather Impact Mitigation", shared in this Conference Room Paper Report (A/AC.105/C.1/2022/CRP.10). Although the content and recommendations in this paper did not gain full consensus in the Expert Group,

the information is presented to the Member States of the Scientific and Technical Subcommittee for their information and as background as it relates to work in the space weather domain within COPUOS.

EXECUTIVE SUMMARY

In this report, the Expert Group on space weather of the Scientific Technical Subcommittee provides an update for the Scientific and Technical Subcommittee following the analysis of data collected from two surveys of COPUOS member States, and from an additional survey of international organizations active in, or impacted by, space weather. These surveys were issued by the Expert Group on space weather for the purposes of assessing the state of Member State preparedness, and their related current and future activities, and their needs for improved space weather impact mitigation. The results show that responding Member States support developing future actions and improved international coordination to address the challenges and risks associated with space weather, and to mitigate their impacts on the modern technology upon which they increasingly rely.

COPUOS itself has previously recognized that space weather has the potential to significantly impact both space and ground-based critical infrastructure and identified it as international concern in the Guidelines for the Long-Term Sustainability of Outer Space Activities (LTS) (A/AC.105/C.1/L.366), in particular B.6 and B.7, and the LTS 2.0 Working Group, and Thematic Priority 4: International Framework for Space Weather Services for UNISPACE+50 (A/AC.105/1171).

The survey questions were constructed and grouped to reflect the priorities of the approved LTS space weather guidelines including specifically: services and operations, data and observations, research, and mitigation. Survey responses were received from 40 Member States and 24 international organisations. This report therefore provides Member States with the outcomes from assessment of the survey results, and makes recommendations for the consideration of the Subcommittee in relation to the mitigation of the effects of adverse space weather.

Specifically, for the benefit of Member States, this report provides an overview of the Expert Group's findings from these surveys and formulates six high-level recommendations, R.1-6, and a further series of domain specific recommendations, A.1-3, B.1-3, C.1-3, D.1-4, and E.1, for the consideration of Member States and the Subcommittee.

Overall, there was a consistently strong message in the survey responses of the need for continued and improved coordination in all domains of space weather. The following high-level recommendations, based on specific recommendations within this report, are intended to progress international coordination and implementation of the LTS Guidelines. The six high level recommendations R.1-R.6 reached consensus within the Expert Group and are also provided for the consideration of Member States in all official languages in the "*Draft Final Report of the Expert Group on Space Weather: Towards Improved International Coordination for Space Weather Services*" (A/AC.105/C.1/L.401):

Recommendation R.1: ***The Expert Group recommends that the Subcommittee requests the Secretariat to send a letter, on behalf of the Committee on the Peaceful Uses of Outer Space, to the leadership of the Committee on Space Research (COSPAR), the International Space Environment Service (ISES) and the World Meteorological Organisation (WMO), proposing that they lead efforts to improve global coordination of space weather activities in consultation and collaboration with other relevant actors and international organisations, including the Committee on the Peaceful Uses of Outer Space. The Expert Group further recommends Member States who are also members of, or are represented at, COSPAR, ISES or WMO engage with these organizations to encourage a response to the Committee on the Peaceful Uses of Outer Space outlining the efforts they***

will undertake towards the goal of establishing a potential path forward to improve global coordination and collaboration;

<u>Recommendation R.2:</u> The Subcommittee identify a central repository for access by all States members of the Committee to best practices, techniques, training materials, and standards, for space weather services, observations, research, mitigation approaches, capacity-building activities, and socioeconomic impact and risk assessment studies. The repository could also serve as a compendium for space weather information to support States members as they implement the Guidelines for the Long-term Sustainability of Outer Space Activities relating to space weather;

<u>Recommendation R.3:</u> Consistent with Guidelines for the Long-term Sustainability of Outer Space Activities pertaining to space weather, the Expert Group recommends the Subcommittee consider enhanced consultation with space agencies and international organizations to coordinate space weather satellite missions in support of sustained space-based observations for space weather services and research which address international space weather needs;

<u>Recommendation R.4:</u> Recognizing the ongoing activity relating to the implementation of the Guidelines for the Long-term Sustainability of Outer Space Activities and to support implementation of Guidelines B6 and B7, the Expert Group recommends that the Subcommittee encourage the Working Group on the Long-term Sustainability of Outer Space Activities of the Scientific and Technical Subcommittee consider further analysis of the survey results and the additional domain specific recommendations in conference room paper A/AC.105/C.1/2022/CRP.10 for possible inclusion in future guidelines. In parallel, the Expert Group recommends those States members of the Committee who have not yet participated in this process to engage with this activity and to consult with the relevant international organizations as needed to facilitate implementation of the Guidelines;

<u>Recommendation R.5:</u> The Scientific and Technical Subcommittee should continue to include on its agenda an item on Space Weather; and

<u>Recommendation R.6:</u> Bilateral and multilateral cooperation involving States and international intergovernmental organizations in space weather should be encouraged. New mechanisms and/or forums for cooperating in space weather activities should be identified, including by considering the participation of industry and States with emerging capabilities in space weather;

States members of the Committee and other space weather actors are invited to provide voluntary contributions to advance the recommendations of the Expert Group within existing resources.

The implementation of these recommendations in the COPUOS context would lead to improved implementation of the space-weather related LTS Guidelines in Member States, and an improved global resilience and preparedness against the adverse impacts of space weather. Such an implementation is also consistent with building resilient societies through better coordination and the forging of global partnerships which are key challenges in the 21st century and which are an integral part of meeting the commitments set by the three key UN global frameworks: the Sendai Framework for Disaster Risk Reduction 2015 –2030, the 2030 Agenda for Sustainable Development, and the Paris Agreement on Climate Change.

1. INTRODUCTION

COPUOS has recognized that space weather has the potential to significantly impact both space and ground-based critical infrastructure and identified it as an international concern in the Guidelines for the Long-Term Sustainability of Outer Space Activities (A/AC.105/C.1/L.366), in particular B.6 and B.7, and the LTS 2.0

Working Group, and Thematic Priority 4: International Framework for Space Weather Services for UNISPACE+50 (A/AC.105/1171). A high-level goal of these initiatives is to promote communication between COPUOS Member States and relevant UN bodies and international organizations undertaking space weather observations, research or operational service activities, to improve coordination and efficiency towards addressing the risk posed by space weather. For the benefit of delegations, a glossary of terms is provided in Appendix A.

The LTS Guidelines underscore the need for continuous space-based and ground-based measurements and focused research efforts to improve modelling and forecasting capabilities of space weather events. The guidelines also promote the development of appropriate mitigation strategies, and developing an understanding of the space weather vulnerabilities of the technological systems within Member States. Noting that the impacts on various technological systems can be more or less severe depending on location, system design, and event severity, the LTS guidelines also propose the assessment and implementation of appropriate mitigation strategies based for example on detailed socioeconomic impact studies. The LTS guidelines further promote standards for coordinated exchange and dissemination of space weather observations, research, and forecast products. As recognized by Member States by the adoption of the LTS guidelines (e.g., B.7.7 and B.7.2.f) international collaboration and cooperation can help Member States in developing their response to the space weather threat.

At its 57th session, the UN COPUOS Subcommittee recommended that the Expert Group on Space Weather continue its work in accordance with the recommendations contained in the Expert Group's progress report (A/AC.105/C.1/2020/CRP.13), including recommendations that the Expert Group will complete intersessional work to compile a report to be submitted to the Subcommittee at its 58th session that assesses the activities of the multiple international space weather entities in the context of the LTS Guidelines, in particular B.6 and B.7, and the LTS 2.0 Working Group, and provide recommended best practices for their implementation, and assess potential future approaches for the consideration of the Committee in relation to the mitigation of the effects of adverse space weather. Consistent with this action, this report provides an update for Member States on the findings from surveys undertaken to assess activities towards LTS implementation, both of Member State's current and future activities, and those of related national and international organizations involved in space weather.

Two Member State surveys, and one survey of the international organizations with activities in the space weather ecosystem, were defined, distributed, and responses collected, by a dedicated team drawn from within the Expert Group. The Expert Group coordinated the distribution and collection of responses to two COPUOS Member State Surveys: Part 1 was directed at a high level assessment of Member State activities, while Part 2 used the contact details for space weather domain experts provided in Part 1 to collect data on the specific activities within each Member State, additionally providing an opportunity to identify areas targeted for future expansion, improvement, and/or which could be implemented effectively in the context of improved international collaboration. The Expert Group further circulated a separate international organizations (IO) survey to 63 international organizations who are engaged in activities focussed on, or impacted by, space weather. The 24 responses received from this international organization survey further informed the preparation of this report.

2. BACKGROUND

Given the growing international appreciation for the severity of the space weather threat, the UN COPUOS has focussed on promoting and developing an improved and coordinated international response to space weather including the formation of a permanent agenda item on space weather at the STSC in 2013, and a space weather Expert Group was subsequently established in 2014 with a Rapporteur reporting to

the Subcommittee. The work of the Expert Group built significantly upon the success of previous work of the Subcommittee when in 2009 it agreed to establish an agenda item on the Long-Term Sustainability of Outer Space Activities (LTS). The LTS work was supported by the establishment of Expert Group C on space weather and which was instrumental in developing the LTS guidelines B.6 and B.7. The Expert Group on Space Weather also drafted the Thematic Priority 4 (TP4): International Framework for Space Weather Services for UNISPACE+50 (A/AC.105/1171). The TP4 report includes a roadmap (Section III, para. 29) which was developed to further aid the implementation of the LTS guidelines, with full traceability to LTS guidelines B.6 and B.7. This roadmap remains relevant in the context of this report, and for completeness and for ease of reference it is included in Appendix B of this report.

3. OBJECTIVE OF THE REPORT

This report provides a brief summary of the findings and analysis of the Expert Group on Space Weather's two 2020 Surveys of the COPUOS Member States, and that of relevant international space weather organisations, regarding their space weather activities. The report provides baseline data on the current state of space weather activities in responding Member States and their future plans and interests, and provides recommendations to support further implementation of Long Term Sustainability (LTS) Guidelines specifically related to space weather, Guidelines B.6 and B.7.

Consistent with the proposal from the expert group on space weather to the 924th meeting of the Subcommittee, this report additionally contains recommendations highlighting opportunities for the more efficient global coordination of space weather activities. Through its survey of international organizations involved in, or impacted by, space weather the Expert Group has also begun to map the international space weather actors and their mandates and linkages, seeking to identify gaps and opportunities, and recommend actions to be taken by States members of the Committee and other relevant space weather actors to improve coordination.

4. SURVEY ACTIVITY

Consistent with the proposal from the Expert Group to the Subcommittee at its 924th meeting in February 2020, COPUOS Member States were invited to complete an initial on-line high level Member State space weather survey (hereafter Survey 1). The survey questions related to current space weather activities in the Member States, and to their future aspirations and planning in the space weather domain. The survey questions were constructed and grouped to reflect the priorities of the approved LTS space weather guidelines including specifically: services and operations, data and observations, research, and mitigation. The invitation to complete the survey was generously circulated by the Canadian Permanent Mission in Vienna to Member States via email, the survey being generously hosted online by the Australian Bureau of Meteorology, and the results analysed by a small working group drawn from members of the Expert Group. Overall 40 responses from 95 COPUOS Member States were analysed (42 per cent response rate) providing a basis from which to assess the global trends in planning and actions towards space weather preparedness within those responding COPUOS Member States.

Survey 1 also requested that Member States provide the names of national domain experts who could be approached for in a follow-on survey focussed on technical implementations in Member States. A follow-on survey (hereafter Survey 2) was thereby sent to those 30 Member States who provided contacts (often multiple contacts) identified in their response to Survey 1. The responses from Survey 2 continue to be analysed by the Expert Group, however, the responses received at the time of writing provided additional valuable input to this report. Finally, a survey of international organizations involved in space weather (hereafter referred to as the IO Survey) was also circulated to a list of 63 international organizations (IO, IGO and

NGO), including relevant UN bodies for example those outlined in the 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). The IO Survey was generously set up and hosted using Survey Monkey by the World Meteorological Organisation (WMO). The response from 24 of these international organizations provided further information which was analysed by the Expert Group and informed and aided the preparation of this report. Copies of the questions posed in Survey 1 and 2, and the IO Survey, are provided for the information of delegations in Appendix C. Those Member States and international organizations responding to Survey 1 and the IO Survey, respectively, are listed in Appendix D.

The Expert Group also notes with appreciation the administrative support provided by the United States in support of the intersessional activities, and additionally provided in support of the analysis of the survey results.

5. SUMMARY FINDINGS

Overall, 40 Member States responded to part 1 of the survey (Survey 1). Some of the key highlights of the statistics from those Member States who responded are:

- There is already routine space weather data collection among responding Member States, with 88 per cent of responding Member States reporting they collected data, but significantly of that 88 per cent more than 50 per cent indicated that they would welcome assistance in improving their capabilities further. It also seems likely that amongst the states who did not respond to the survey, the proportion who are not active in space weather data collection could be significantly higher.
- 90 per cent of responding Member States are involved in space weather research, and of those 39 per cent would welcome support in developing their capabilities further. Only 3 per cent indicated no interest in space weather research.
- 70 per cent of responding Member States produced space weather services, and of those 56 per cent would be interested in receiving assistance to develop them further. An additional 15 per cent do not generate space weather services, but welcome assistance in developing them. A further 10 per cent gain space weather services from other Member States. Only 5 per cent have no interest in space weather services.
- While 55 per cent of responding Member States had completed some assessments of space weather risk, with a further 23 per cent reporting assessments in progress, only 35 per cent indicated that their State's National Risk Register currently included space weather.
- 20 per cent of respondents had completed a space weather socioeconomic impact assessment in their nation, with a further 8 per cent reporting such an impact assessment in progress. A further 30 per cent plan to do so, and an additional 30 per cent would welcome assistance in doing so. Only 3 per cent expressed no interest in completing such an assessment.
- Indeed, only 30 per cent of responding Member States reported that they had domestic organizations or agencies in critical infrastructure sectors (e.g., energy and resources, transport, communications, space, logistics) that are undertaking activities to mitigate the impacts of space weather. Of the remainder, 25 per cent indicated they have organizations which could - and of those 92 per cent would welcome assistance in developing it. Only 3 per cent of responding Member state against space weather impact and are not interested in future assistance in developing it.
- 53 per cent of responding Member States involved in both domestic and international capacity-building activities, a further 15 per cent only involved domestically, and a further 13 per cent only involved internationally. Other responding nations are either planning to become involved domestically or

internationally, or welcome assistance. Only 3 per cent of responding Member States have no interest. Overall, respondents' interest in capacity-building provides a potential basis for expanding space weather activities to more Member States, and to a greater level of activity within each state, with appropriate planning and cooperation likely to lead to a greater global impact.

Overall, the survey respondents indicate a resounding interest in space weather activities, underpinned by a clearly growing appreciation of the threat that space weather poses to economically-important activities in their Member States. It further indicates the perception in the responding Member States of the value of actions which would lead to more efficient and improved cooperation between Member States, especially for example in the context of the implementation of the LTS Guidelines relating to space weather.

Although many Member State space weather products and services are closely linked to their sovereign capabilities and interests, many service providers often produce regional and global products derived from regional (e.g., Latin America, Europe) and global observing networks (e.g., IGS) or satellite observations. The survey responses provided by international organizations involved in space weather activities also indicate there is considerable existing, and planned, activities in the development of space weather services and to provide regional and global coordination aligned with the LTS Guidelines. Given the scope and diversity of the activities of these International Organisations it is clear that increased coordination between them would be a major step forward. Indeed, the survey responses from these International Organizations indicated in many cases their own desire and need for improved coordination between them.

Responses from the international organizations provided information and valuable context for future actions in the COPUOS context in the space weather domain. For example, SCOSTEP and PRESTO are actively addressing the issue of supporting space weather data sharing, AOSWA continues to promote the provision of space weather services for domestic users by countries within the Asia - Oceania region, ISO provides documented standards for many space weather parameters and phenomena, ITU-R ensures the continuous availability of radio frequency resources free from harmful radio interference to maintain the long-term continuity of space weather observations, IUGG provides space weather data services through international consortia such as IAG, SILSO-WDC collects, archives, shares, and inter-calibrates data critical to space weather to ensure its long-term continuity and dissemination, ISGI ensure the homogeneity of long term space weather data series through their responsibility for IAGA geomagnetic indices derivation and dissemination, ALAGE's work towards a regional level agreement will significantly improve capacity-building in the Latin American region for space weather, within the WMO the IPT-SWeISS' collaboration with ISES and ICAO has supported the development and implementation of the space weather advisory service for aviation, and CGMS' charter and activities directly addresses LTS Guideline B.6 and the efforts of its member agencies to establish a common satellite anomaly database is aligned LTS Guideline B.7. We note there that the WMO is currently reviewing the administrative approach it will take to address space weather needs within the WMO context, including a potential new body to assess space weather needs to replace the IPT-SWeISS. WMO has been engaged in the Expert Group discussions.

Many responding international organizations also expressed strong support for improved coordination of these efforts. For example, SCOSTEP expressed a need for improved connection between space weather parameters required by users and those that can be modelled and predicted, ISES suggested that standardisation has not kept pace with the rapid increase in shared information content and the technical advances of communication methods, AOSWA perceive the need for education of stakeholders in some Asia-Oceania countries about the importance of space weather monitoring, ISO suggests closer cooperation is needed in the development and consensus of new normative documents related to the space radiation environment and radiation risks to astronauts during long-term space flights, IUGG expressed concern over the lack of

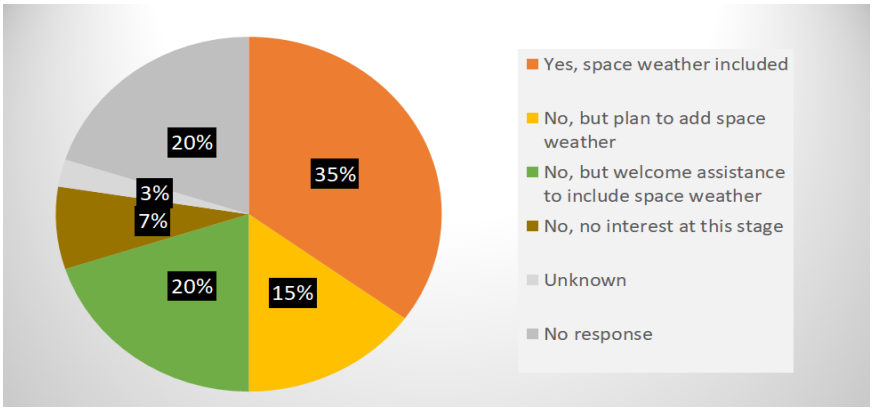
international coordination and funding support for observation infrastructure and capacity-building among developing countries, ALAGE suggested there should be international effort to increase the amount of publicly available space weather data, while INTERMAGNET suggest there is a need to increase the cadence of near real time geomagnetic observing networks for space weather applications.

The sentiments expressed above by responding international organizations demonstrate the existence of many space weather activities related to the LTS Guidelines B.6 and B.7, however, a number of respondents also indicated that improved coordination is desirable. Implementation of the LTS Guidelines could also be aided through the improved promotion and access to best practices. For example, the ICAO Aviation Space Weather Advisory Service is generally considered a good example of global coordination in space weather services that promotes cooperation and coordination among the four operational global centres, to provide harmonious, consistent and well-calibrated advisories and forecasts to international aviation users. Member States and international organizations should consider leveraging such examples for provision of space weather services to other industry sectors such as satellite and power grid operators and asset owners.

In this report, the findings from the surveys are collated into five different domains, in subsections A-E below, and with major findings and recommendations outlined for each domain. The scope and grouping of these domains of space weather impact and action was drawn directly from the LTS guidelines, in support of the goal that the survey results could be used to aid the development of strategies within the COPUOS and elsewhere which would provide a resource to assist help COPUOS and its Member States achieve a more efficient and faster implementation of the relevant LTS guidelines.

A. Mitigation of space weather including risk assessments and socioeconomic impact studies

70 percent of responding Member State (MS) (28 Members) indicated an understanding that space weather is a risk to their critical national infrastructures and their wider national economy, but with different MS at different stages in the process of developing that understanding, as summarized in Figure 1.



Responses to "Does MS National Risk Assessment include space weather?"

FIGURE 1. Member State responses to question "Does MS National Risk Assessment include space weather?"

Figure 1 shows the responding Member States undertaking relevant work on national risk assessments and socioeconomic studies which has been completed or is in progress, where work is planned, or where assistance from other Member States is welcomed. Overall, Figure 1 shows that 70 per cent of responses indicate interest in space weather as a factor to be included in national risk assessments and 87 per cent of responses indicate interest in understanding the socioeconomic impact of space weather. The higher interest in the latter suggests that socioeconomic studies are an important factor in making the case to consider space weather as a risk factor.

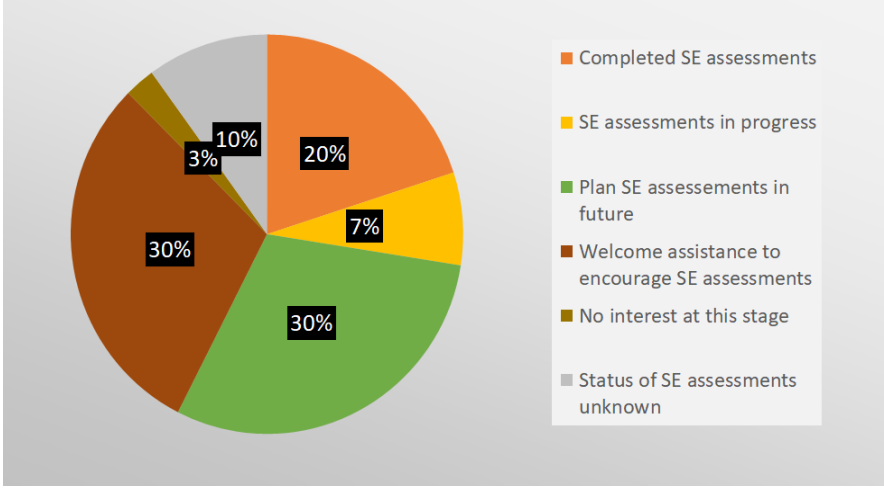


FIGURE 2. Member State responses to question: “Has MS commissioned socio-economic (SE) assessments of space weather impacts?”

Significantly, as shown in Figure 2, very few responding MS indicated no interest in space weather as an issue for inclusion in national risk assessments or socioeconomic studies “at this stage”. That last caveat is important as some of these “no interest” responses may indicate a lack of awareness, e.g. in one such case the respondent noted that there is currently “no perception of the threat that the effects of space weather may represent for the critical infrastructure in our country”. Note that Figure 2 also shows that some respondents did not comment on, or know, whether space weather is included in their national risk assessment or whether there is interest or work on its socioeconomic impacts. This could be improved by actions which continue to raise MS awareness of the potential impacts of space weather on infrastructure within their jurisdictions.

The geographic distribution of the MS responses (not shown) indicates that there is a widespread interest in assessments of the risks from, and socioeconomic impacts of, space weather, with responses from many responding Member States in the Americas, Asia and Europe, and also from Australia and New Zealand in Oceania. However, there were responses from only a few MS in Africa and the Middle East, which suggests that these are regions where awareness of space weather risks might need to be raised, and/or examples of where the different latitudinal and regional risks arising from space weather need to be better understood within all MS. This especially in respect of ensuring the resilience of the critical national infrastructures (e.g. power, mobile communications) now being developed in these countries. This need for resilience against space weather has been identified by ISWI as an issue to be addressed as part of UN Sustainable Development Goal 9 (Build resilient infrastructure, promote inclusive and sustainable industrialization and foster innovation).

The Survey 1 responses discussed above show that many responding Member States see the need for better understanding of the socioeconomic impacts of space weather so that they can assess where measures are needed to improve the resilience of their national infrastructures, and, where appropriate, to include space weather as a significant natural hazard to be considered, alongside existing natural hazards, in national risk assessments. However, this is very much a work in progress with responding Member States at different stages in that progress. The MS responses suggest that it would be very beneficial to establish a process to support and encourage that progress by sharing good practice in risk assessment and socioeconomic analysis. These activities require significant support not just from space weather scientists, but also from relevant engineering communities (to understand space weather impacts on technological systems), from civil contingencies experts (to understand the wider societal consequences of those impacts) and from economists (to quantify those consequences in monetary terms). Thus any process to share good practice must involve this wide range of expertise, and not be limited to science and technology expertise.

Recommendation A.1: To progress implementation of paragraph 7 of LTS guideline

B.7 ("States should undertake an assessment of the risk and socioeconomic impacts of adverse space weather effects on the technological systems"), the Expert Group recommends that the Subcommittee identify a repository that enables and encourages the exchange and sharing of good practices by relevant technical and policy experts within Member States, having established expertise, with other Member States in the COPUOS.

In approving the LTS guidelines, Member States already highlighted the importance of undertaking national space weather socioeconomic impact assessments. The Expert Group also notes the importance of adopting a cost-benefit value proposition for space weather preparedness. Costs arising from the implementation of any new space weather protections should be significantly less than the potential cost-savings arising from the mitigation of the risk. This should apply to governmental investments, as well as those in the private, commercial, and non-profit sectors. The Expert Group considers that future space weather impact studies should be expanded to domain specific studies which embrace this value proposition. One recent excellent example relates to the assessment of the costs of mitigating space weather impacts on the electric power grid in the United States of America.

Recommendation A.2: The Expert Group recommends that the Subcommittee encourage Member States to undertake domain specific cost-benefit-analyses associated with the mitigation of space weather impacts on their national infrastructure, as appropriate to their individual national needs and their domains of largest space weather risk.

The Expert Group also recognizes that these new space weather protections may be achieved by improved design of systems vulnerable to space weather (e.g. use of error correction codes to improve resilience of digital systems on satellites), as well as by operational measures in response to forecasts (e.g. strengthening satellite operations teams when adverse space weather is forecast). This principle should be applied to all systems vulnerable to space weather, not just satellites. To this end, Member States should encourage entities under their jurisdiction and/or control to incorporate the capability to recover from a debilitating space weather effect into all vulnerable systems, both space-based and ground-based.

Recommendation A.3: To strengthen the implementation of LTS guideline B.7, the Expert Group recommends that the Subcommittee recommends Member States should, wherever feasible, undertake activities to establish national disaster response and mitigation and recovery plans for space weather. The Expert Group recommends that the Subcommittee should further identify a repository that enables and encourages the exchange and sharing of best practices in the development of national response plans for space weather.

B. Space weather services and operations

An overview of the Member State survey results shows 70 per cent of responding Member States provide space weather services, of which over one third would welcome assistance to improve those capabilities. The remaining 30 per cent of responding Member States do not provide or produce space weather services, however, half of these would welcome assistance to develop this capability, with a third receiving their space weather information from other MS.

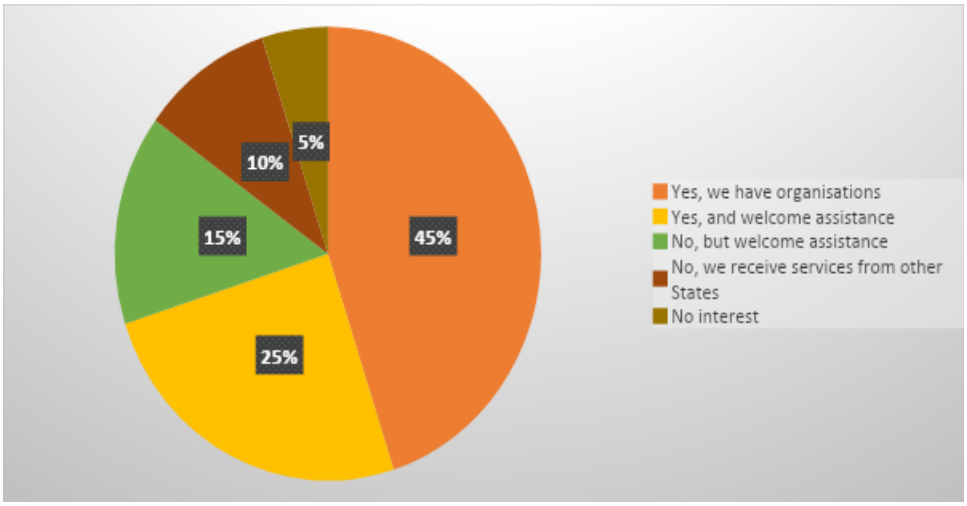


FIGURE 3. Member State responses to question: "Does your State have domestic organisations or agencies (officially recognized by national authorities or otherwise, e.g., Met agencies, space agency, research and academic institutes, industry) that provide Space Weather Services to warn of the adverse effects of space weather?"

Many responding Member States have officially recognized space weather service providers, a large proportion being formally recognized over recent years. Responding Member States with officially recognised space weather service providers reported whole-of-government approaches as a best practice to space weather preparedness, including improved interdepartmental communications, improved data collection and national space weather service provision, better communication and more effective liaison with appropriate regional and global international space weather organisations, and overall to an increased capacity to develop and implement effective space weather mitigation strategies dedicated to improved space weather preparedness. Benefits are numerous and can include: more effective communications between research, critical infrastructure, user, and forecast and service providers; the development of more effective operational strategies towards mitigation, including through liaison to critical infrastructure protection administrations; a more effective and smooth transition and translation of improvements in research and knowledge into new and actionable information and forecast products. National examples of good practice include through the Space Weather Operations, Research and Mitigation Interagency Working Group (SWORM; www.sworm.gov) in the United States of America which coordinates US Federal Government department and agency activities to meet the goals and objectives specified in the US National Space Weather Strategy and Action Plan (NSW-SAP). Examples in other nations include through national space weather centres such as within the meteorological organisations of a number of responding Member States, or through other national entities or mechanisms.

A number of the officially recognized Member State space weather service providers are a consortium of, or supported by, institutes and organizations within the Member State, such as research and academic institutes (e.g., Argentina, Austria, Chile, Mexico, Ukraine), government organizations (e.g., Australia, Indonesia, Malaysia,

Norway, Peru), radio and communication authorities (e.g., Korea, Japan, Pakistan, Peru) and meteorological agencies (e.g., Australia, Finland, The Netherlands, Philippines, United Kingdom, United States, and potentially Norway in the future). These consortia typically deliver services to support national interests including services for ionospheric propagating signals such as GNSS and HF radio, space-based assets and operations, military operations, and increasingly, services to support critical infrastructure such as power grids. Some Member State space weather providers are members of international organizations involved in space weather service activities such as ISES, WMO, CGMS, and ICAO, and a number of respondents expressed the view that a greater cooperation between international organisations in the space weather domain would be of value to the global space weather enterprise.

Recommendation B.1: The Expert Group recommends that the Subcommittee identify whole of government coordination as a best practice for Member States to continue to improve coordination of space weather service organisations, agencies, and institutes within their nations. The Expert Group further recommends that Member State space weather service providers contribute to, and participate through active membership in, international bodies coordinating service activities such as WMO and ISES.

As a result of the diverse range of organizations and institutes contributing to, or supporting, space weather service providers within Member States, there are a diverse range of observing systems supporting these services. Member State space weather products and services are a reflection of the observing systems that underpin them. In addition, products and services are often a reflection of the geographic location and space weather phenomena specific to that region. Furthermore, products and services are often a reflection of the research interests and capabilities of the contributing institutes and organisations. Although the Member State locations and specific interests necessarily results in a diverse range of products, and there is some consistency with products and services across Member States (e.g., a number of Member States utilize the NOAA/SWPC scales in their products), a baseline set of standardized products would be advantageous for communicating to governments and industry on a global scale with consistent terminology. This would lead to a more coordinated and more coherent global response to space weather events.

Recommendation B.2: The Expert Group recommends that the Subcommittee encourages Member States to contribute to, and participate through active membership in, international organizations promoting the development and adoption of space weather standards, including, but not limited to, ISO, WMO, ISES, and ICAO.

Recommendation B.3: The Expert Group recommends that the Subcommittee consider how support could be provided for Member States seeking to develop or expand their space weather service capabilities. For example, through the provision of best practices and/or advice relating to the transition of data from diverse observing systems into operational products and services, including data currently being collected by institutes in the academic sector.

Further implementation of LTS Guidelines B.6 and B.7 could also come from capitalizing on the strengths of the various international organizations participating in space weather activities. For example, the ISES constitution highlights that one of its functions is to facilitate international communication and service coordination regarding space weather, particularly during periods of enhanced activity and in the event of extreme space weather, and promote standardization and harmonization of products and services among ISES members. Increased involvement of other international organizations and Member States in these activities, could significantly improve global coordination. More specifically, cooperation and coordination in the development of global standards for product and messaging for extreme space weather events would facilitate implementation of the guidelines and assist Member State governments when implementing space weather mitigation response

procedures. For Member States who are considering the expansion and/or establishment of space weather observations, Member States could engage through active membership with International Space Weather Initiative (ISWI) as an entry point.

Recommendation B.4: The Expert Group recommends that the Subcommittee encourage Member States continue to participate in activities related to the coordination of their national observing systems with those in other nations with the goal of establishing networks with global coverage. The Expert Group further recommends that the Subcommittee encourage Member States to contribute to, and participate through active membership, in international organizations promoting the global coordination of observing systems such as, but not limited to, ISES, IGS, CGMS, and WMO, and to ensure data sets identified by these organizations as being key to the provision of space weather services of many Member States are maintained.

Recommendation B.5: The Expert Group recommends that the Subcommittee encourage Member States continue to contribute to identifying and promoting best practice for dissemination and delivery of consistent and well-calibrated space weather advisories and forecasts to a wider range of industry sectors. The Expert Group further recommends that the Subcommittee recommends Member States pursue this objective, in part, by active membership of international organizations promoting the coordination of dissemination and delivery of space weather advisories and services, and by encouraging cooperation among Member States and international organizations in establishing these services. For example, the model for space weather advisories for aviation developed through ICAO could be considered for implementation in other industry sectors.

Some international organizations suggested the need for increased utilisation of coordinated portals for the delivery of various space weather services and information. In addition, increased promotion of space weather to Member States through COPUOS would further assist the implementation of the guidelines within Member States. One potential mechanism could be implementation of a repository that promotes the relevant activities of Member States and international organizations towards the implementation of LTS Guidelines B.6 and B.7 to support Member State participation and global coordination. Such a portal could provide the latest news on space weather activities specific to the implementation of the guidelines and structure the information in terms of operations and services, data, research, and mitigation practices. The repository could provide links to best practices and relevant existing portals for the respective domains.

Recommendation B.6: The Expert Group recommends that the Subcommittee should identify a repository that promotes activities of other Member States and international organizations towards implementation of LTS Guidelines B.6 and B.7, including latest news, links to best practices, and relevant existing portals to assist Member States align their space weather activities with these guidelines.

C. Space weather measurements and observations

The ability to observationally characterize the global terrestrial response to space weather remains key to both space weather situation awareness and to the ability to advance science research required to deliver improved space weather services. The response to space weather drivers is global, and this requires a global effort to properly characterize the disturbances which have adverse impacts on terrestrial and space-based assets. Global coverage of critical space weather parameters is also required to understand the hazard that these phenomena have on different elements of technological infrastructure, coupled with appropriate sector specific risk and impact assessments.

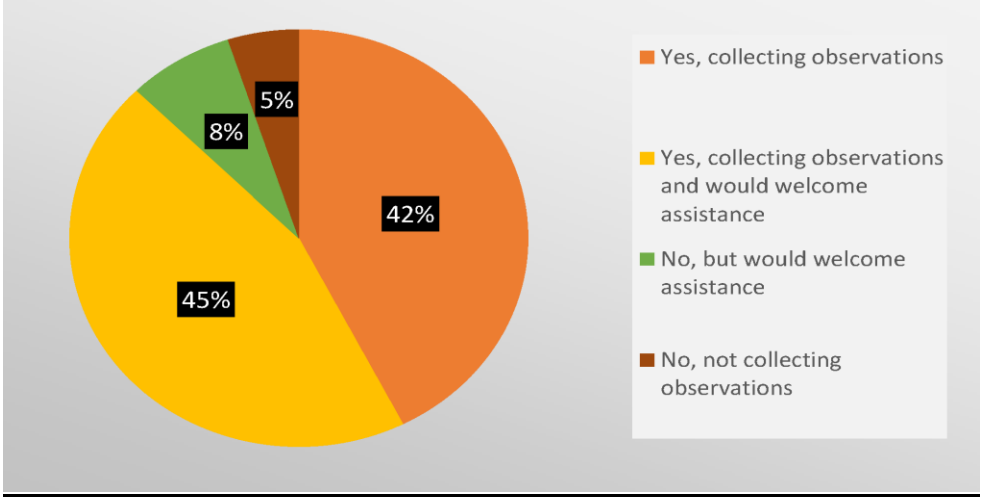


FIGURE 4. Member State responses to survey question about their collection of space weather observations.

An overview of the Member State survey results shows 88 per cent of responding Member States collect space weather data, of which more than half would welcome assistance to improve those capabilities. The remaining 12 per cent of responding Member States indicated they do not collect space weather observations; however, more than half of these would welcome assistance to develop this capability. The survey demonstrates that there is support from the responding COPUOS Member States not only to participate in the global endeavour of space weather monitoring, but also to further develop and expand this observing network in support of Member State needs.

Moreover, survey responses from international organizations, including some with UNCOPUOS observer status, indicate a clear willingness to assist in coordinating the sharing of space weather data and promote international collaboration to support the collection and dissemination of space weather observations. Further analysis of the survey responses revealed an imbalance in data collection across different regions. North America and Europe have well-established organizations collecting and disseminating space weather observations. Whereas responding Member State organizations collecting space weather data across Latin America and the Asia-Oceania region, with the exceptions of Japan and Australia, are more recently established and would welcome and benefit from increased international cooperation and capacity-building. For example, ground-based networks currently provide a unique capability for truly global space weather monitoring. Maintaining and enhancing regional ground-based instrumental networks measuring space weather critical data (e.g. magnetometers, ionosondes, riometers, GNSS receivers, neutron monitors, etc.) is a key component of global monitoring, and represents a mechanism through which Member States can contribute to the international space weather monitoring endeavour. Measures should be taken to establish capacity-building and support which help Member States to contribute measurements from their jurisdiction to providing global space weather situational awareness. Regional international organizations, like the Asia-Oceania Space Weather Alliance (AOSWA) or the Latin American Association of Space Geophysics (ALAGE in Spanish), can also promote observational collaboration s, capacity-building and data exchange towards this goal. The recent study [1] commissioned by the European Space Science Committee (ESSC) of the European Science Foundation can also provide a model for coordination of space weather related activities using examples from the European context.

[1] “Assessment and recommendations for a consolidated European approach to space weather – as part of a global space weather effort”, Opgenoorth, H. J, et al., J. Space Weather Space Clim., **9**, A37. https://www.swsc-journal.org/articles/swsc/full_html/2019/01/swsc190036/swsc190036.html.

The Expert Group believes that COPUOS should adopt a philosophy which promotes not only the ongoing and continuous monitoring of space weather in States Members, and promotes the expansion of that monitoring in Member States with established space weather monitoring, but also provides support and capacity-building which facilitates the introduction of new monitoring in Member States who are not currently making space weather observations within their jurisdictions.

Recommendation C.1: The Expert Group further recommends that the Subcommittee encourages Member States to contribute to, and participate through active membership in, international organizations promoting a global approach to the collection of key space weather data, and to work with international organizations including, but not limited to, WMO, CGMS, ISES, WDS, GIRO, INTERMAGNET, IGS, ISWI, NMDB, and within appropriate regional consortia, such as ALAGE, AOSWA, etc, to promote improved coordination towards the goal of delivering a global observing network.

Mechanisms to promote continuous and expanded global space weather monitoring, the open sharing of data, and the filling of measurement gaps, consistent with guidelines B.6-2 and B6-5 could include the Secretariat, on behalf of the Subcommittee, promoting the development of enhanced inter-organization coordination. As outlined in the summary of the overarching recommendations, the Expert Group recommends that this could be achieved by the ecretariat, on behalf of the Subcommittee, contacting the WMO, ISES and COSPAR with a request for them to jointly facilitate a process, to deliver the required improved international coordination. In the context of space weather measurements, international stakeholder organizations with active roles in this domain include, but not limited to, in addition to WMO, ISES and COSPAR include IGS, CGMS, GIRO, INTERMAGNET, NMDB, IAG, SILSO-WDC, and IHDEA. They could be consulted, as part of this process, to discuss the definition of the key elements of a global observing network. Member States are further encouraged to engage with these organizations to ensure their data sets contribute to this activity, or to help to define how measurement gaps might be filled.

This is especially important where such data sets are identified as critical for “filling key measurement gaps, so as to meet critical needs for space weather information and/or data” (LTS Guidelines B.6-5). Where appropriate such assessments could be made in the context of advice from the national entity responsible for space weather (see also recommendation B.1 above) including an assessment of how such transitions might be achieved in the context of each Member State’s needs and used, for example, towards the mitigation of space weather risks.

Using a comparison with development of coordinated global monitoring in relation to terrestrial weather developed through the World Meteorological Organization (WMO), improved coordination towards establishing a stable and comprehensive global observing network is also required in the space weather domain. For example, WMO, a specialized UN organization with nearly 200 Member States, has regulated its support to space weather activities. In 2019, the Eighteenth World Meteorological Congress approved the second Four-Year Plan for WMO Coordination of Space Weather Activities (2020-2023) outlining the implementation of space weather services and applications that will provide significant benefits to WMO Members in more precise observations and improved services. Moreover, Cg-18 approved incorporation of space weather observations into the new WMO Unified Data Policy, for which approval will be sought at the 2021 Extraordinary Congress. If approved, the new WMO Unified Data Policy will provide the foundation for identifying core observations required for Space Weather Services, which will be detailed in the WMO Technical Regulations. Identification of the core observations will be undertaken in concert with WMO Members’ Space Agencies and the CGMS Space Weather Coordination Group.Similar strategic and action plans have been developed in a number of other entities focussed on the implementation of space weather services, including, but not limited to, International Space Environment Service (ISES), CGMS, IGS, and others. A mechanism to coordinate these actions and to maximize

efficiencies by establishing a global approach to achieving improved global space weather coverage, and the continuous and expansion of space weather observing systems is needed. In addition to WMO activities, those of other international organizations focussed on space weather monitoring is essential. With the advance of planning for space weather monitoring in the WMO, it is now extremely timely for the Subcommittee to take a role in facilitating improved interactions between the relevant space weather entities towards the goal of establishing an expanded and coordinated global space weather observing network.

As discussed above, and in the summary of the overarching recommendations, the Expert Group recommends that this could be achieved by the Secretariat, on behalf of the Subcommittee, contacting the WMO, ISES and COSPAR with a request for them to jointly facilitate a process to deliver the required improved international coordination of observing systems and data centres and that delivers internationally agreed platforms and standards for accessing operational and archival space weather data. As mentioned above, international stakeholder organizations with active roles in this domain include, but are not limited to, WMO, ISES, IGS, CGMS, GIRO, INTERMAGNET, NMDB, IAG, SILSO-WDC, and IHDEA. This pathway should consider other relevant international activities to maximize coordination and efficiencies and minimize duplication of efforts. Member States are further encouraged to engage with these organizations to ensure their data sets contribute to this activity.

Recommendation C.2: The Expert Group recommends that the Subcommittee encourage Member States to promote actions which lead to better coordination of observing systems within Member States, consistent with the implementation of LTS Guideline B.6.5. For example, the transition of data sets derived from observing networks maintained for research, for example in the academic sector, into standard data products which are made continuously, permanently, and operationally in support of national space weather needs. The Expert Group further recommends that the Subcommittee encourage Member States to contribute their space weather observations to global observing systems, and through active membership in international organizations coordinating them, including, but not limited to, WMO, CGMS, IHDEA, INTERMAGNET, GIRO, NMDB, promote the permanent establishment of global space weather observing networks. In this context, and consistent with the implementation of LTS Guidelines B.6.1 -5 and B.7.1-2, the data sets should be made openly and easily accessible using standard access protocols and formats.

D. Space weather research

We received 40 responses to Member State survey 1, which we finalized in January 2021. Only 4 (10 per cent) of these member states currently do not conduct any space weather research, and out of those four, one (3 per cent) has no interest, and two (5 per cent) would welcome assistance. Out of the 36 (90 per cent) responses that do undertake space-weather research, 14 (35 per cent) would welcome further assistance. This gives a total of 16 (40 per cent) responding countries interested in further assistance conducting space weather research. There are no discernible patterns by region/area or the stage in their scientific development with regards to the category of the responses given above (for example, the number of negative responses is too low to discern if the country’s wealth could be a factor). All these responses are summarized in Figure 5.

In addition, we note that some countries, which we certainly know are carrying out active space weather related research, did not respond to the survey. Thus, we note that the total global envelope of active space weather research and observation activity may be larger than that represented in the results from our survey.

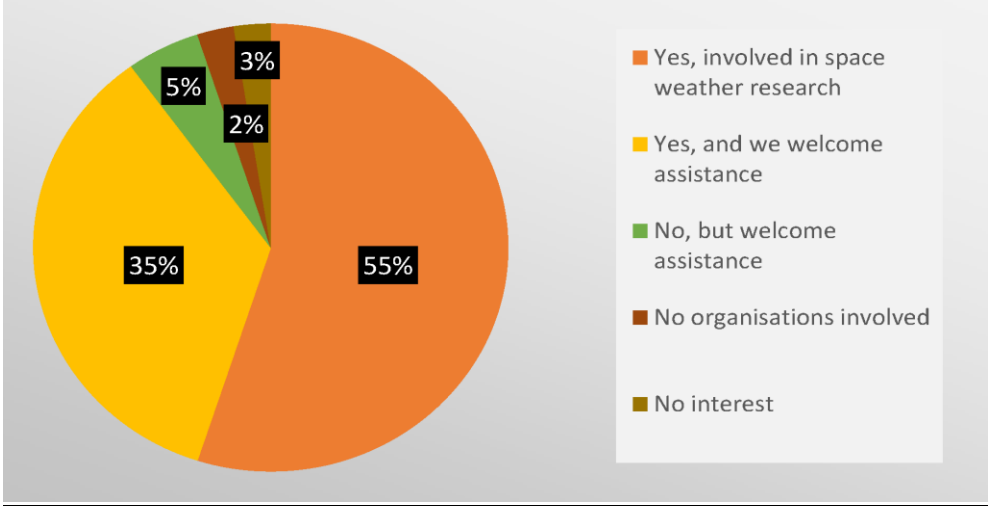


Figure 5: A summary of the response received from the 40 member-state responses regarding space-weather research being undertaken in each member state country.

As further recommended below, such coordination could be tailored around the combined needs of multiple Member States, where and when sufficient understanding of the potential impacts which they are susceptible to, exists. One could particularly consider such collaboration on a regional basis between neighbouring countries, or between countries operating comparable infrastructure susceptible to or, indeed, vulnerable from similar space weather impacts.

Findings/Observations: With regards to space-weather research activities, out of 24 international organizations that had responded by 16 December, 2020, 14 had characterized themselves as being involved in space-weather research. Of those 14, three were governmental organisations, eight were non-governmental organisations, one was an inter-governmental organisation, and two were international groups/associations. Some of the key responses for future avenues of space weather related investigations focussed around a lack of “know-how” and best practice on space-weather models, collaborations on modelling of the Earth’s space environment and its comparison to Mars, and the need to link all the different model domains to allow for better direct modelling of the coupled processes: starting from the sources of space weather at/near the Sun, their propagation and interaction in the heliosphere and the effectiveness of the impact of the resulting space weather drivers at Earth (and other planets, but with the primary focus of being at Earth). The need for closer collaboration between different disciplines is a frequently identified gap in the current space weather activities.

One response offering global scientific coordination came from the Committee on Space Research (COSPAR) Panel on Space Weather (PSW). COSPAR is the international organisation that assists in the coordination of the research (science and modelling) related to space-weather topics and completing the Sun-Earth/Sun-planetary chains. COSPAR has been a UN COPUOS permanent observer organization since 1962 and there is a strong relationship between COSPAR and the UN. The majority of the world’s space faring countries participate in COSPAR.

Recommendation D.1: In accordance with LTS guideline B7.1 and in particular B7.2.f, the Expert Group recommends that the Subcommittee encourage Member States to coordinate their efforts within and between their national organizations involved in space weather research, for example, though the development of national space weather plans and/or roadmaps. The Expert Group further recommends that the Subcommittee encourage Member States to contribute to, and participate through active membership in, international organizations promoting the advancement of space weather research and the development of advanced space weather models including, but not limited to, COSPAR, SCOSTEP, IAU, IUGG, IAGA. For example, providing national inputs to international space weather science roadmap activities.

Scientific models of the various coupled plasma regimes at the Sun, in the solar wind, and the geospace environment (both empirical and physics based) are the basis of space-weather services in many of those countries pursuing space weather research. A key gap identified by COSPAR is that operational models for the medium-term prediction of periods of enhanced solar activity, e.g., beyond eruptive monitoring of solar ejecta, leading to major space weather disturbances at Earth are distinctly lacking. In order not to duplicate efforts - or to share efforts in reasonable portions for individual member-states - it could be envisaged that member states team-up and coordinate their respective efforts and collaboration in terms of zones or regions of comparable space weather impact vulnerability. For example, it is likely that countries located at higher latitudes will be motivated to participate in research into auroral current systems at high auroral or sub-auroral latitudes, which can lead to GIC impacts on power-lines. Noting, however, that recent research has identified space weather impacts on the power grid at low-latitudes for example as a result of solar wind dynamic pressure effects. Coordinated regional research could for example follow certain pathways of space weather effects due to either magnetic, radiation or ionospheric effects, often - but not always - originating from different solar or heliospheric source mechanisms, or from different interactions within parts of the coupled geospace or planetary system. Thus one should strive to develop a collaboration between member states, which are pursuing active or emerging space weather activities, where equal attention is given to the development of better science understanding (LTS B7.1 and COSPAR), improvement of existing models (LTS B7.1 & B7.2) and the sharing of relevant data (B6.1). This could include actions by Member States and their national and international organizations to identify common avenues to address certain space weather impacts of particular concern for their geographical location or the common character of their space weather-susceptible infrastructure.

With the background of this particular input from COSPAR we note that with the exception of a general statement in LTS B7.1 most of the LTS guidelines under B6.1. and B7.1. primarily deal with the coordination or sharing of already existing space weather models and data, for the benefit of better global predictions and prognoses. The international coordination of “knowledge-gap-filling” science efforts, potentially resulting in considerable improvements of existing space weather model and prediction capabilities, should be seen as a fundamental “sine qua non” activity, allowing for all other LTS space weather-related guidelines to be addressed in due course. We propose that Member States, for example through active involvement in COSPAR, work to stimulate and carry out scientific activity to fill present space weather-enabling knowledge gaps (in the physics of the Sun, the heliosphere, and geospace, or other relevant planetary environments) in order to improve the existing space weather models and also to include more and better data, identified on the basis of these scientific efforts. The Expert Group specifically notes the value of the work being undertaken by COSPAR in producing and updating the COSPAR Space Weather Science Roadmap. [2] In particular, the development of International Space Weather Action Teams (ISWAT) with the goal of identifying and filling knowledge gaps in the coupled Sun-to-Earth chain, and delivering improved specification and forecasting in space weather impact pathways in response to user needs.

Recommendation D.2: The Expert Group recommends that the Subcommittee encourage Member States continue to coordinate work within their nation on the “filling of the identified research gaps” that are needed to better understand the whole Sun-to Earth/Sun-to-planet chain of space-weather events and their resulting impacts. The Expert Group further recommends that the Subcommittee encourage Member States contribute to, and participate through active membership in, regional consortia and international organizations including, but not limited to, COSPAR,

[2] See for example Schrijver, C. J., et al. “Understanding space weather to shield society: A global road map for 2015–2025 commissioned by COSPAR and ILWS.” Advances in Space Research 55.12 (2015): 2745-2807. See also the International Space Weather Actions Teams (ISWAT) initiative established by COSPAR https://www.iswat-cospar.org/iswat-cospar.

SCOSTEP, ALGAE, AOSWA, etc, to achieve this goal at a global level. Further noting the formal MOU signed between UN OOSA and COSPAR, active engagement with the COSPAR ISWAT and Space Weather Roadmapping activities would be especially valuable for achieving this goal.

On a global level, avenues could be explored into some form of a unified model or rather a pipelining/linkage of models covering the Sun-to-Earth/Sun-to-planet chain. Such models could better connect the data and modelling of the various coupled regimes for a more-complete understanding of the space-weather phenomena and to better model the entire chain of events for the various space weather impacts. This global approach should allow for comparison and "ensemble" model runs using different approaches (from empirical, to physics-based, to data assimilative and even AI-based) in order to accomplish best practices of "envelope-" or probability-predictions for the varying space weather scenarios (compare to, and as an extension of, LTS Guidelines B.6.7.a and B.7.1).

Recommendation D.3: The Expert Group recommends that the Subcommittee encourages Member States contribute to benchmarking activities assessing the different model approach and their relative performance. A good national example is the space weather scoreboard hosted by the CCMC in the United States. The Expert Group further recommends that the Subcommittee encourage Member States contribute to international benchmarking activities, through their active membership in international organizations including, but not limited to, the COSPAR ISWAT initiative.

As the process of the advancement of model fidelity is not strictly a one -way-street from "knowledge-base" to proper "modelling" to "sharing of relevant data and predictions", we furthermore recommend that the activities following LTS B7.1, B7.2 and B6.1 are coordinated in the form of an iterative loop, where any improvements in the knowledge base eventually also lead to subsequent improvement of models, data-collection, and space weather predictions. This first part of the iterative loop is usually referred to as "research-to- operations" (R2O). On the other hand, any changes in best practices of the space weather service organisations, results of model comparisons with data, and any additions or changes in the user-requirements of space weather service end-users must be fed back to the scientific efforts, defining the pathway to an optimisation of physics-based and empirical models. This second part of the iterative loop is usually referred to as "operations-to-research" (O2R). A global coordination of the full R2O2R (...2O2R...) should be the ultimate approach which is adopted in the development of improved future global space weather activities.

The close and strong relationship between UN COPUOS Member States and COSPAR (primarily addressing and coordinating scientific efforts and progress in space weather understanding and prediction) should be further strengthened - working out how each organization can best complement the other in the necessary R2O-O2R iterative loop of global inter-related space weather activities and avoiding the duplication of effort.

Recommendation D.4: The Expert Group recommends that the Subcommittee encourage Member States to contribute to the activities transitioning research-to-operations (R2O) and from operations-to-research (O2R). The Expert Group further recommends that the Subcommittee encourage Member States to pursue this objective, in part, by active membership in international organizations promoting the transition of research to operations (and back) in the R2O-O2R iterative loop including, but not limited to, within the COSPAR ISWAT initiative.

E. Space Weather Capacity Building

Distinct from the aforementioned LTS guidelines specifically addressing space weather, LTS guideline C.3 calls for the promotion and support of capacity-building efforts. As is the case for many space issues, COPUOS Member States may have limited bandwidth to be engaged in every subgroup and organization. In relation to

space weather, there is a vibrant international community, across multiple organizations, engaging in efforts to promote research and operations. Connecting interested Member States into that community fits directly into guideline C.3's mandate.

In responding to the survey question concerning capacity-building, the Member States indicated varying levels of engagement from no current activities or interest to multiple activities both domestically and internationally. Over three-quarters of responding states are engaged in some type of capacity-building activities either domestically, internationally, or the vast majority: both. Of the responding states without any activities, four out of the five are planning, or would like assistance planning activities.

The most common method of domestic capacity-building is through post-secondary education curricula in universities, and often in consultation with research institutions like space agencies, laboratories, or weather services. Some responding states also provide space weather related curriculum to primary and secondary schools, and via public lectures.

Internationally, multiple organizations are mentioned in capacity-building initiatives: The International Space Weather Initiative, The International Astronomical Union, The International Union of Geodesy and Geophysics, the International Association of Geodesy, the International Committee on GNSS, EUMETSAT, the World Meteorological Organization, the European Space Agency, and the International Civil Aviation Organization. Responding states maintain a wide array of cross-organizational memberships in these organizations. Multiple responding states also cite direct capacity-building efforts from other states as key to the development of their domestic space weather capacity. Finally, some responding states indicate that space weather capacity-building is included in national policy to mitigate space weather risk.

The processes which could be adopted within the Subcommittee to promote the development of this expanded capacity-building to support space weather domain needs in Member States remains to be fully determined. Related activities could encompass the compilation of training and capacity-building initiatives and making such available to Member States, for example within a repository, or be achieved via discussions among and between member states leveraging access to existing initiatives and/or initiating additional capacity-building as required. As described above, there are additional capacity-building opportunities relating: to standards; to access to best practices; to support Member States in their establishment and expansion of space weather monitoring, services, and research; and to aid the completion of risk and socioeconomic assessments relating to space weather impacts. Member States interested in growing their domestic space weather capacity should be able to express that interest and be connected to the existing networks of international organisation, either through more capable member states or through an Expert Group.

Recommendation E.1: The Expert Group recommends that the Subcommittee should identify a repository which can provide Member States with easy access to best practices and information about space weather, including relevant training material, as part of an integrated space weather capacity-building initiative. The Expert Group further recommends that the Subcommittee encourage Member States contribute to, and participate through active membership in, international organizations promoting capacity-building, for example through the International Space Weather Initiative (ISWI), or through other UN capacity-building activities. The Expert Group also recommends that the Subcommittee recommends Member States' capacity-building activities be transitioned into openly available standard training materials available to all.

6. CONCLUSIONS AND THE WAY FORWARD

Each of the sectorial recommendations in the Summary Findings in section 5 above, spanning the topics in subsections A-E and which formed the foci for the Member State survey, target specific opportunities to promote improved global space weather preparedness within COPUOS Member States. These foci were also written to aid Member States in the implementation of the space weather-related LTS guidelines B.6 and B.7 within their jurisdictions, as well as through their active membership of relevant international organizations relating to space weather.

The responses to the international organization (IO) survey further highlight the potentially important role which IOs can play in helping Member States with the successful implementation of a number of the LTS Guidelines. Indeed, many of the IOs responded explicitly by stating that improved international coordination would be of value in helping them to achieve their goals, to aid them in going beyond their current levels of activity, and which, if enacted, would lead to improved global preparedness against the threat of the adverse impacts from space weather.

The recommendations in subsections A-E in section 5 above also clearly point to a number of common themes. Consolidated efforts towards the implementation of these themes in the context of the Subcommittee offer a route forward which can deliver improved preparedness against the threat of space weather. This will assist Member States in their implementation of the LTS Guidelines, and will also deliver improved international coordination towards this goal. Specifically, we group the findings and recommendations from this report and develop them into four overarching recommendations, each of which can be used as the basis to guide future work. We envisage that these overarching themes can provide the initial basis from which the specific recommendations from sections A-E above can be implemented by their translation into specific actions.

Recognizing the significant expertise and activities of international bodies involved in space weather, the Subcommittee, with the active support of Member States, needs to take specific steps to facilitate improved communication between the international organizations which are involved in facilitating the development, coordination, and/or implementation of space weather services. The Expert Group notes that the space weather ecosystem is extremely diverse, with a large number of organizations from various administrations and jurisdictions being active within the domain. While this breadth of activity is a major advantage for the international community, their diversity and the variety of organizations to which they report introduces major challenges. In particular, to achieve effective coordination of activities between them with due regard to efficiency and minimisation of duplication requires a renewed effort to improve communications between them. Ideally, a mechanism should be sought and established to deliver a more formalized basis for future more coordinated activities. Based on common agreement, the outcome could be that clearer lines of responsibility are established and distributed among the stakeholder international organizations in the space weather ecosystem, and through which more efficient implementation of advances can be implemented.

To achieve this goal, the Subcommittee should seek and request the collective support of key international organizations involved in the domains of research, observations, services, and the development of standards, and promote improved coordination between the relevant space weather organizations which are active in these domains.

<u>Recommendation R.1:</u> The Expert Group recommends that the Subcommittee requests the Secretariat to send a letter, on behalf of the Committee on the Peaceful Uses of Outer Space, to the leadership of the Committee on Space Research (COSPAR), the International Space Environment Service (ISES) and the World Meteorological Organisation (WMO), proposing that they lead efforts to improve global coordination of space weather activities in consultation and collaboration with other relevant actors and international organisations, including the Committee on the Peaceful Uses of Outer Space. The Expert Group further recommends Member States who are also members of, or are represented at, COSPAR, ISES or

WMO engage with these organizations to encourage a response to the Committee on the Peaceful Uses of Outer Space outlining the efforts they will undertake towards the goal of establishing a potential path forward to improve global coordination and collaboration;

(Note that this recommendation relates to the implementation of the earlier recommendations in section 5, subsections A-E: ***A.1; A.2; A.3; B.1, B.2, B.3; B.4; B.5; C.1; C.2; D.1; D.2; D.3; D.4; E.1***)

Note further, in the context of Recommendation R.1 that the report "Thematic Priority 4: International Framework for Space Weather Services for UNISPACE+50 (A/AC.105/1171), developed by the Expert Group on space weather for UNISPACE+50, already provides a roadmap for further implementation of the LTS guidelines, with full traceability to LTS guidelines B.6 and B.7. This roadmap remains relevant in the context of the overall implementation of recommendation R.1 from this report, and as mentioned earlier the details of this roadmap from the Thematic Priority 4 report are cited in Appendix B of this report for completeness and for ease of reference.

The recommendations in subsections A-E in section 5 of this report also highlight the importance of best practices and making relevant information available to all Member States. The sharing of information from and between Member States promotes the global preparedness of all nations in response to the threat of space weather, provides for improved communication and closer collaboration, and promotes and facilitates capacity-building among the States members of the committee.

The secretariat should canvass Member States for their interest in supporting the implementation of such sharing and to examine approaches through which this can be delivered in the COPUOS context.

Recommendation R.2: The Subcommittee identify a central repository for access by all States members of the Committee to best practices, techniques, training materials, and standards, for space weather services, observations, research, mitigation approaches, capacity-building activities, and socioeconomic impact and risk assessment studies. The repository could also serve as a compendium for space weather information to support States members as they implement the Guidelines for the Long-term Sustainability of Outer Space Activities relating to space weather;

(Note that this recommendation relates to the implementation of the earlier recommendations in section 5, subsections A-E**: A.1; A.2; A.3; B.3; B.6; E.1**)

The responses to the space weather surveys, and input obtained by the Expert Group in international conferences such as COSPAR 2021, clearly demonstrated the importance of continued space-based observations in support of space weather services and research. In relation especially to the development of a fleet of international satellites, the Expert Group noted in the space agency context th e success of the prior International Solar Terrestrial Physics (ISTP) program, as well as more recently that of the International Living With A Star (ILWS) program. Noting the important role that CGMS to play in relation to coordinated space weather monitoring, the Expert Group nonetheless noted an apparent gap in the global coordination of satellite and space missions in particular in relation to space weather missions being operated, implemented, and planned by national and international space agencies in the space weather domain. While such space missions are only one component of the required international collaborations in the space weather ecosystem, space missions implemented by space agencies remain a key element of global efforts. Facilitation of information sharing and cooperation between space agencies is needed in order to advance space weather science, provide continuous and new space weather monitoring and alerts, and improve the global preparedness against the threat of space weather. Such activity could encompass mission development to address research needs and related observational gaps, and as appropriate and with relevant partners, to consider partnerships with other related programs which deliver new space weather services in response to global user needs.

<u>Recommendation R.3:</u> Consistent with Guidelines for the Long-term Sustainability of Outer Space Activities pertaining to space weather, the Expert Group recommends the Subcommittee consider enhanced consultation with space agencies and international organizations to coordinate space weather satellite missions in support of sustained space-based observations for space weather services and research which address international space weather needs;

(Note that this recommendation relates to the implementation of the earlier recommendations in section 5, subsections **A-E: C.2; D.2**)

Overall, an overarching major conclusion derived from the surveys was an appreciation of the ongoing importance of space weather to COPUOS Member States. Member State surveys 1 and 2, and the information collected from the survey of the international organizations involved in space weather, all highlight the high level of interest in developing expanded services aided by improved international collaboration. Further analysis of the two Member State surveys, as well as the results from the IO survey, in the context the work of the Working Group LTS 2.0 and in support of the recommendations above suggest that it is very important that work on space weather within COPUOS be continued.

<u>Recommendation R.4:</u> Recognizing the ongoing activity relating to the implementation of the Guidelines for the Long-term Sustainability of Outer Space Activities and to support implementation of Guidelines B6 and B7, the Expert Group recommends that the Subcommittee encourage the Working Group on the Long-term Sustainability of Outer Space Activities of the Scientific and Technical Subcommittee consider further analysis of the survey results and the additional domain specific recommendations in conference room paper A/AC.105/C.1/2022/CRP.10 for possible inclusion in future guidelines. In parallel, the Expert Group recommends those States members of the Committee who have not yet participated in this process to engage with this activity and to consult with the relevant international organizations as needed to facilitate implementation of the Guidelines;

(Note that this recommendation relates to the implementation of the earlier recommendation ***R.1***)

<u>Recommendation R.5:</u> The Scientific and Technical Subcommittee should continue to include on its agenda an item on Space Weather; and

<u>Recommendation R.6:</u> Bilateral and multilateral cooperation involving States and international intergovernmental organizations in space weather should be encouraged. New mechanisms and/or forums for cooperating in space weather activities should be identified, including by considering the participation of industry and States with emerging capabilities in space weather;

Appendix A. Glossary of Acronyms

ALAGE	Asociación Latinoamericana de Geofísica Espacial (Latin American Association of Space Geophysics)
AOSWA	Asia Oceania Space Weather Alliance
CCMC	Community Coordinated Modelling Center (NASA modeling facility)
CGMS	Coordination Group for Meteorological Satellites
COPUOS	Committee on the Peaceful Uses of Outer Space (UN body)
COSPAR	Committee on Space Research (scientific committee, under the auspices of the International Science Council; promotes scientific research in space at an international level)
ESSC	European Space Science Committee
EUMETSAT	European Organisation for the Exploitation of Meteorological Satellite (European operational satellite agency for monitoring weather, climate and the environment from space)
GIC	Geomagnetically Induced Currents
GIRO	Global Ionospheric Radio Observatory
GNSS	Global Navigation Satellite Systems (generic name for satellite navigation systems such as GPS, Galileo, Glonass and Beidou)
HF	High Frequency (radio signals with frequencies between 3 and 30 MHz)
IAG	International Association of Geodesy (international scientific association under the auspices of IUGG)
IAGA	International Association of Geomagnetism and Aeronomy (international scientific association under the auspices of IUGG)
IAU	International Astronomical Union (international scientific union under the auspices of the International Science Council)
ICAO	International Civil Aviation Organisation (UN agency)
IGO	Inter-Governmental Organization
IGS	International GNSS Service (scientific service under auspices of IAG)
IHDEA	International Heliophysics Data Environment Alliance
ILWS	International Living with a Star (international scientific programme)
INTERMAGNET	International Real-time Magnetic Observatory Network
IO	International organisation
IPT-SWeISS	Inter-Programme Team on Space Weather Information, Systems and Services (WMO working team)
ISES	International Space Environment Service
ISGI	International Service for Geomagnetic Indices (scientific service under auspices of IAGA)
ISO	International Standards Organisation
ISTP	International Solar Terrestrial Physics (international scientific programme)
ISWAT	International Space Weather Action Teams (of COSPAR)
ISWI	International Space Weather Initiative
ITU-R	International Telecommunications Union, Radiocommunication Sector
IUGG	International Union of Geodesy and Geophysics (international scientific union under the auspices of the International Science Council)
LTS	Long-term sustainability
MOU	Memorandum of Understanding
MS	Member State
NGO	Non-governmental organisation
WMO	World Meteorological Organisation

Appendix B. Roadmap for the Implementation of LTS Guidelines B.6 and B.7: Extract from the report on "Thematic Priority 4: International Framework for Space Weather Services for UNISPACE+50 (A/AC.105/1171)" - Section III, para. 29;

(approved LTS Guideline references updated)

29. The following is proposed as a roadmap for international coordination and information exchange on space weather events and their mitigation, through risk analysis and assessment of user needs, including traceability to the relevant guidelines on 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 LTS guidelines B.6.1, B.6.3, B.6.4, B.6.6, B.6.7(c), B.7.2(d);

(ii) Include representation from all major application sectors, including aviation, electric power, satellites, communication, and navigation, to assess product and coordination needs. See LTS guidelines B.6.6, B7.2(a), B.7.2(b), B.7.2(c), B.7.2(e), B.7.4, B.7.7;

(iii) Define common measures of product quality to be applied to the information shared during extreme events. See LTS guideline B.6.7(a).

(b) **Information communication protocol**

(i) Refine/augment numerical scales to characterize the severity of events. See LTS guideline B.7.2(a);

(ii) Recommend levels to activate specific communication procedures. See LTS guideline B.6.7(d);

(iii) Promote the establishment of real-time communication mechanisms among warning centers. See LTS guidelines 16.1, 16.6, 16.7(b), 16.7(c), 16.7(d);

(iv) Develop best practices for warning centers during extreme events. See LTS guidelines B.6.6, B.6.7(b), B.6.7(c), B.6.7(d);

(v) Provide training to ensure broad utilization of available information. See LTS guideline B.7.2(f);

(c) **Response procedures**

(i) Promote the inclusion of space weather risk is included in national hazard and risk registries.

(ii) Encourage the exercising of coordination mechanisms under test conditions. See LTS guideline B.6.7(a);

(iii) Promote the sharing of model results, and promote development of skills tests for forecast model inter-comparisons. See LTS guidelines B.6.6; B.6.7(a); B.6.7(b);

(iv) Conduct post-event analyses to refine capabilities and document product effectiveness. See LTS guidelines B.6.7(a), B.6.7(b).

(d) **Product sustainment and improvement and risk assessments**

(i) Maintain global and regional observing requirements and the analysis of gaps. See LTS guidelines B.6.1, B.6.2, B.6.3, B.6.5, B.7.1;

(ii) Maintain real-time access to interoperable data and data products. See LTS guidelines B.6.1, B.6.4;

(iii) Develop and improve space weather models and tools. See LTS guidelines B.7.1, B.7.2;

(iv) Collect established practices on the mitigation of space weather effects. See LTS guideline B.7.2(c);

(v) Encourage risk and socio-economic impact studies to establish priorities for coordinated actions, recognising regional and geographical differences in space weather impacts between Member States, and that the interconnectedness of 21st century terrestrial infrastructure can create space weather threats for all Member States regardless of the severity of the direct domestic threats to their infrastructure from space weather. See LTS guideline B.7.7.

(e) **Improved understanding of fundamental physical processes which cause extreme space weather (LTS guideline B.7.1)**

(i) Increase global international coordination of space agency, and potentially space weather agency, space- and ground-based infrastructure with a view to implementation of the 2015-2025 COSPAR/ILWS Roadmap [e.g., Schrijver et al., "Understanding space weather to shield society: A global road map for 2015–2025 commissioned by COSPAR and ILWS", Adv. Space Res. 55(12), 2745 (2015)];

(ii) Maximise development of new knowledge and promote new fundamental scientific discoveries through contemporaneous and coordinated operation of ground- and space-based missions and research within a "Great Observatory" for space weather science and science research.

(f) **Promote capacity building for space weather in COPUOS Member States (LTS guideline C.3)**

(i) Promote training and capacity building in relation to space weather services, data collection, and the impacts, effects and mitigation of space weather through cooperation between developed and developing nations, and space-faring and aspiring space-faring nations. See LTS guidelines B7.2(f), C.3;

(ii) Promote space weather data collection and the development of space weather services in all Member 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)).

Appendix C. Copies of the Survey Questions Posed in Member State Surveys 1 and 2, and in the International Organisation Survey

C.1 Member State Survey 1 (Survey 1)

United Nations
Expert Group on Space Weather

Member State Survey – Request for Information

The United Nations (UN) Committee on the Peaceful Uses of Outer Space (COPUOS) Scientific and Technical Subcommittee (STSC) Expert Group on Space Weather requests your Member State to complete a brief survey to aid in the generation of baseline data on the current state of space weather activities in Member States. The UN Expert Group on Space Weather will use these data to inform a report to be submitted to the STSC at its 58th session outlining the current state of space weather activities and providing recommendations for implementation of Long-Term Sustainability (LTS) Guidelines specifically related to space weather, Guidelines B.6 and B.7.

Background: COPUOS has recognized that space weather has the potential to significantly impact both space and ground-based critical infrastructure and identified it as international concern in the Guidelines for the Long-Term Sustainability of Outer Space Activities (A/AC.105/C.1/L.366), in particular B.6 and B.7, and the LTS 2.0 Working Group, and Thematic Priority 4: International Framework for Space Weather Services for UNISPACE+50 (A/AC.105/1171). A high-level goal of these initiatives is to promote communication between COPUOS Member States and relevant UN bodies and international organisations undertaking space weather observations, research or operational service activities to improve coordination and efficiency.

The LTS Guidelines underscore the need for continuous space-based and ground-based measurements and focused research efforts to improve modelling and forecasting capabilities of space weather events. Broad participation from countries and international organizations around the globe helps Member States understand both the drivers and the impacts of space weather, thereby improving Member States' capacity to predict and mitigate severe space weather events. The LTS Guidelines further identify the need for Member States to understand their risks from adverse space weather and consider appropriate utilisation of space weather services to mitigate these risks.

I/we agree that data and information collected from this survey (which may include personal information such as names and contact details of individuals) will be shared and distributed amongst the UN Expert Group on Space Weather for the purposes outlined above towards fulfilling its mandate. I/we agree that I am authorised to provide this information for this purpose.
O Agree
O Don't agree

Instructions: For each of the nine questions, please select a radio button to indicate the answer that best reflects the position of your Member State. If needed, please use the text boxes to provide supplementary information (e.g. further explanation, document links, points of contact).

Please provide the name of your Member State:

Please provide the name of the person completing this survey:

Please provide the contact email of the person completing this survey:

Q1.1	Has your State undertaken a national assessment of the risks that natural hazards pose for the critical infrastructures (e.g. energy, transport, communications, etc.) of your country?	O Yes, National Risk Assessment completed O Yes, National Risk Assessment in progress O Yes, plans to develop National Risk Assessment O No, but welcome assistance to formulate plans O No, no interest at this stage O Unknown *If no or unknown, skip to question 1.3*
Q1.2	Does your State's National Risk Assessment include space weather?	O Yes, space weather included O No, but plan to add space weather O No, but welcome assistance to include space weather O No, no interest at this stage O Unknown
Q1.3	Does your State have **domestic organisations or agencies in critical infrastructure sectors** (e.g., energy and resources, transport, communications, space, logistics) that undertake activities to mitigate the impacts of space weather?	O Yes, we have organisations that presently mitigate against space weather O Yes, and we welcome assistance to improve our mitigating capabilities O Yes, we have organisations that could mitigate against space weather O No, we do not have organisations that mitigate against space weather O No, but welcome assistance to mitigate space weather O No, no interest at this stage O Unknown

Q1.4	Does your State have **domestic organisations or agencies involved in the collection of space weather observations** (ground or space-based – for example data types click here)?	O Yes, we have organisations that collect space weather observations O Yes, and we welcome assistance to improve our observing capabilities O No, we do not collect space weather observations O No, but welcome assistance to improve our observing capabilities O No, no interest at this stage O Unknown
Q1.5	Does your State have **domestic organisations or agencies involved in space weather research** activities?	O Yes, we have organisations involved in space weather research O Yes, and we welcome assistance to improve our research capabilities O No, we do not have organisations involved in space weather research O No, but welcome assistance to undertake space weather research O No, no interest at this stage O Unknown
Q1.6	Does your State have **domestic organisations or agencies** (officially recognized by national authorities or otherwise, e.g., Met agencies, space agency, research and academic institutes, industry) **that provide Space Weather Services** to warn of the adverse effects of space weather?	O Yes, we have organisations providing space weather services O Yes, and welcome assistance to improve our service capabilities O No, we receive services from other States O No, but welcome assistance to develop domestic service capabilities O No, no interest at this stage O Unknown
Q1.7	Has your State commissioned any **assessments of the socioeconomic impacts** of adverse space weather effects on the technological systems in your country?	O Yes, we have completed socio-economic assessments O Yes, we have socio-economic assessments in progress O No, but we plan to do so in the future O No, but welcome assistance to encourage such assessments O No, no interest at this stage O Unknown

Q1.8	Does your State have **domestic organisations or agencies that provide domestic or international capacity-building activities** related to space weather observations, research, or operational services (capacity-building activities include education, training and sharing of appropriate experience, information, data, tools and management methodologies and techniques, as well as the transfer of technology). [ ]	O Yes, capacity building provided **internationally** O Yes, capacity building provided **domestically** O Yes, capacity building provided **internationally** and **domestically** O No, but planning **international** capacity building activities O No, but planning **domestic** capacity building activities O No, but welcome assistance to develop capacity building activities O No, no interest at this stage O Unknown
Q1.9	Would your State like to participate in a more detailed follow-up survey regarding your space weather observations, research, services, mitigation strategies and coordination of these activities with the international community? If you indicate 'Yes', the UN Expert Group on Space Weather will use the contact information to distribute more detailed follow-up surveys to the relevant organisation(s) you provide. [Name: Organization: Email:]	O Yes, please send survey to contact details provided O No, no interest at this stage

OPTIONAL 1: The UN Expert Group on Space Weather would welcome points of contact in any of the relevant organizations referenced above. Please provide any points of contacts you are willing to share here.

[ ]

OPTIONAL 2: The UN Expert Group on Space Weather would welcome access to any publicly available documents referenced above (i.e. National Risk Assessment, Space Weather Section of National Risk Assessment, and Socioeconomic Impact Analyses, etc.). Please provide links to the documents and/or an email for a point of contact

Q1.4: Summary of space weather observation types

The table below summarises some different types of space weather observations, both ground-based and space-based observing systems that may be supported at a national level or by consortia of nations. We have omitted some high-profile systems such as solar wind measurements, since there are currently only a very few of these systems and they are well-known to the international community, including the survey team.

Type of measurement	Notes
Geomagnetic observatories and variometers	Intermagnet and SuperMag are global coordinators in these areas
Ionosondes	
HF radars	e.g. SuperDARN
GNSS receivers	e.g. national networks, IGS is a global coordinator
Riometers	
Fabry-Perot interferometer	
Satellite accelerometers	
Neutron monitors	NMDB is a global consolidator in this area
Satellite particle and radiation monitors	
Satellite-based solar monitoring (optical and radio)	
Ground-based solar observations (optical and radio)	

C.2 Member State Survey 2 (Survey 2)

United Nations
Expert Group on Space Weather

Member State Survey II – Request for Information

From: Expert Group on Space Weather, of the United Nations (UN) Committee on the Peaceful Uses of Outer Space (COPUOS).
We thank your national representative to COPUOS for responding to the Expert Group's initial survey of space weather activities in COPUOS Member States. As part of that response, you have been nominated as an appropriate point of contact for a more detailed survey about space weather observations, research, and services in your Member State. Thank you for agreeing to participate in this survey.

To provide some background, COPUOS has recognized that space weather is an international concern in the Guidelines for the Long-Term Sustainability (LTS) of Outer Space Activities (A/71/20), in particular B.6 and B.7, and the LTS 2.0 Working Group, and the Expert Group report Thematic Priority 4: International Framework for Space Weather Services for UNISPACE+50 (A/AC.105/1171).

The LTS Guidelines underscore the need for continuous space-based and ground-based measurements and focused research efforts to improve modelling and forecasting capabilities of space weather events. Broad participation from countries and international organizations around the globe helps Member States understand both the drivers and the impacts of space weather, thereby improving Member States' capacity to predict and mitigate severe space weather events.

To support these improvements the Expert Group on Space Weather is seeking data on Member State space weather activities. These data will inform a report to be submitted to the COPUOS Scientific and Technical Subcommittee at its 58th session (which is expected to take place in February 2021, subject to any constraints required by the pandemic) outlining the current state of space weather activities and providing recommendations for implementation of LTS Guidelines B.6 and B.7.

I/we agree that data and information collected from this survey (which may include personal information such as names and contact details of individuals) will be shared and distributed amongst the UN Expert Group on Space Weather for the purposes outlined above towards fulfilling its mandate. I/we agree that I am authorised to provide this information for this purpose.
O Agree
O Don't agree

INSTRUCTIONS: The survey is partitioned into sections. Please address all sections that fall within your expertise. For each question, please select a radio button to indicate the answer that best reflects the position in your Member State to the best of your knowledge. If needed, please use the text box at the end of the section to qualify your answers or provide supplementary information. We would welcome suggestions for alternative points of contact for any sections that you consider to be outside your expertise.

Please provide the name of your Member State:

Please provide the name of the person completing this survey:

Please provide the contact email of the person completing this survey:

Section 1. National approach to space weather risk to critical infrastructure

In this section we ask questions to gain insight into how your Member State is approaching the global trend to consider space weather as one of the natural hazards that national governments should address as part of their wider risk governance for critical infrastructure and associated technologies, and subsequent mitigation practices for space weather. If this area is outside your expertise, please go to Section 2.

Q1.1	**For the critical infrastructures shown to the right, please tick the radio button of each infrastructure for which the relevant operators and regulators in your Member State are aware of the adverse effects of space weather on these infrastructures. If you tick a button, please use the text box below to summarise the level of awareness for that infrastructure.**	O communications O satellite systems O electrical power O aviation O land and maritime transport O logistics O resource exploitation O resource pipelines
Q1.2	**For each of the generic technologies shown to the right, please tick the radio button if your Member State has any programmes or plans to investigate the impact of space weather on these technologies.**	O GNSS O HF radio O Electronic devices O SATCOMS O ARGOS O AIS
Q1.3	**Do the operators of the infrastructures above receive space weather forecasts and products for mitigation of space weather? If yes, please provide contact details and a web site in the text box below.**	O yes, from domestic providers O yes, from external providers O yes, both domestic and external providers O no O don't know
Q1.4	**Do the operators and regulators of the infrastructures above have any policies for sharing anomaly data (e.g. satellite anomalies, GIC monitoring data, transformer and voltage instability) with other operators, space weather service providers, or researchers? If yes, please use the text box below to provide a reference to any available documents.**	O yes, openly available O yes, subject to anonymisation O yes, subject to confidentiality agreements O no O don't know
Q1.5	**Does your Member State have any policies to coordinate the collection and archiving of anomaly data? If yes, please use the text box below to provide a reference to any available documents.**	O yes O no O don't know

Please use the box below to provide additional textual information where you wish to provide further information relevant to any of the questions above.

Section 2. National coordination of space weather products and forecasts.

In this section we ask questions that seek insight into how your Member State is approaching delivery, exchange and archiving of space weather products and forecasts, and coordination of these activities both within your Member State and with other Member States or international organisations (IO). If this area is outside your expertise or you are not aware of domestic space weather service providers, please go to Section 3.

Q2.1	**Does your Member State have processes to coordinate space weather service activities between service providers within your Member State?**	O Yes, we have formal coordination processes O Yes, we have draft processes O No, but we are planning to develop processes O No, we do not have processes O Don't know
Q2.2	**Are there any processes to coordinate the activities of your domestic space weather providers with other Member States or international organizations (e.g., WMO, ISES, ICAO)? If yes, please list in text box below.**	O Yes, we have formal coordination processes O Yes, we have draft processes O No, but planning to develop processes O No, we do not have processes O Don't know
Q2.3	**Do your domestic space weather providers openly share space weather product and service information within your Member State?**	O Yes O No O Somewhat O Mostly O Don't know
Q2.4	**Do your domestic space weather providers openly share this information with other Member States or IO (e.g., WMO, ISES, ICAO)? If yes, please list in text box below.**	O Yes O No O Somewhat O Mostly O Don't know
Q2.5	**Do your domestic space weather providers use common access formats for easy exchange and interoperability of space weather product and service information?**	O Yes O No O Somewhat O Mostly O Don't know
Q2.6	**Do your domestic space weather providers archive space weather product and service information?**	O Yes O No O Somewhat O Mostly O Don't know
Q2.7	**Have your domestic space weather providers identified critical data sets required to produce and deliver space weather product and service information?**	O Yes O No O Somewhat O Mostly O Don't know
Q2.8	**Have your domestic space weather providers identified data gaps required to produce and deliver space weather product and service information?**	O Yes O No O Somewhat

		O Mostly O Don’t know

Please use the box below to provide additional textual information where you wish to provide further information relevant to any of the questions above.

Section 3. National coordination of space weather observations.

In this section we ask questions that seek insight into how your Member State is approaching recording, exchanging and archiving space weather observations and coordination of these activities both within your Member State and with other Member States or international organisations (IO). If this area is outside your expertise or you are not aware of domestic organisations recording space weather observations, please go to Section 4.

Q3.1	**Are there any plans, or existing processes, to coordinate the activities of your domestic organisations involved in space weather observations within your Member State?**	O Yes, existing O No, but planned O No plans O Don't know
Q3.2	**Are there any plans, or existing processes, to coordinate the activities of your domestic organisations involved in space weather observations with other Member States or IO (e.g., INTERMAGNET, SUPERMAG, IGS, SUPERDARN, NMDB, etc.)? If yes, please list in text box below.**	O Yes, existing O No, but planned O No plans O Don't know
Q3.3	**Do your domestic organisations involved in space weather observations openly share this information within your Member State?**	O Yes O No O Somewhat O Mostly O Don't know
Q3.4	**Do your domestic organisations involved in space weather observations openly share this information with other Member States or IO (e.g., INTERMAGNET, SUPERMAG, IGS, SUPERDARN, NMDB, etc.)? If yes, please list in text box below.**	O Yes O No O Somewhat O Mostly O Don't know
Q3.5	**Do your domestic organisations involved in space weather observations use common access formats for easy exchange and interoperability of this information?**	O Yes O No O Somewhat O Mostly O Don't know
Q3.6	**Do your domestic organisations involved in space weather observations archive this information?**	O Yes O No O Somewhat O Mostly O Don't know
Q3.7	**Have your domestic organisations involved in space weather observations identified critical observation data sets required to produce space weather products and services?**	O Yes O No O Somewhat O Mostly O Don't know
Q3.8	**Have your domestic organisations involved in space weather observations identified observations data gaps required to produce improved space weather products and services?**	O Yes O No O Somewhat O Mostly O Don't know
Q3.9	**Have your domestic organisations involved in space weather observations contributed to any of the space weather observations requirements surveys produced and circulated by WMO, ISES, or CGMS?**	O WMO O ISES O CGMS O Don't know

Please use the box below to provide additional textual information where you wish to provide further information relevant to any of the questions above.

Section 4. National Coordination of space weather research.

In this section we ask questions that seek insight into how your Member State is approaching space weather research activities, and coordination of these activities both within your Member State and with other Member States or international organisations (IO). These questions are further specific to the production, exchange and archiving of space weather model outputs and information resulting from this research. If this area is outside your expertise or there you are not aware of domestic organisations undertaking space weather research, please go to Section 5.

Q4.1	**Are there any plans, or existing processes, to coordinate the activities of domestic organisations undertaking space weather research within your Member State?**	O Yes, existing O No, but planned O No plans O Don't know
Q4.2	**Are there any plans, or existing processes, to coordinate the activities of domestic organisations undertaking space weather research with other Member States or IO (e.g., COSPAR/ISWAT, SCOSTEP/PRESTO, Horizon Europe, etc)? If yes, please list in text box below.**	O Yes, existing O No, but planned O No plans O Don't know
Q4.3	**Do domestic organisations undertaking space weather research openly share research/model output information within your Member State?**	O Yes O No O Somewhat O Mostly O Don't know
Q4.4	**Do domestic organisations undertaking space weather research openly share research/model output information with other Member States or IO (e.g., COSPAR/ISWAT, SCOSTEP/PRESTO etc)? If yes, please list in text box below.**	O Yes O No O Somewhat O Mostly O Don't know
Q4.5	**Do domestic organisations undertaking space weather research use common access formats for easy exchange and interoperability of research/model output information?**	O Yes O No O Somewhat O Mostly O Don't know
Q4.6	**Do domestic organisations undertaking space weather research archive research/model output information?**	O Yes O No O Somewhat O Mostly O Don't know
Q4.7	**Have domestic organisations undertaking space weather research identified critical data sets required for scientific research, modelling and operational outputs?**	O Yes O No O Somewhat O Mostly O Don't know
Q4.8	**Have domestic organisations undertaking space weather research identified data gaps required for improved scientific research, modelling and operational outputs?**	O Yes O No O Somewhat O Mostly O Don't know
Q4.9	**Do domestic organisations undertaking space weather research participate in COSPAR/ISWAT, SCOSTEP/PRESTO activities? If yes, please list in text box below.**	O Yes O No O Don't know

Please use the box below to provide additional textual information where you wish to provide further information relevant to any of the questions above.

Section 5. Further information

Thank you for answering the questions in any of the previous sections. In this section we give you the opportunity to provide any further information that you think may be relevant to (a) the sharing of operational space weather data and forecasts, (b) collaboration in the development, verification and validation of space weather models and tools, and (c) sharing of good practices on the mitigation of space weather effects. If you have further insights in any or all of these topics, and are willing to share those insights, please use the text box below to do so.

Such additional insights might, for example, include:

- Are there any cross-cutting issues that we should consider?
- Areas where you would welcome international assistance in developing plans for coordination of space weather services, observations and/or research?
- Insights into legal and commercial sensitivities that need to be respected when sharing information on space weather impacts.

Annex: Summary of space weather observation types

The table below summarises the types of space weather observations that we ask you to consider in Section 3. In this table, we focus on ground-based and space-based observing systems that are supported at a national level or by consortia of Member States. We have omitted some high-profile systems such as solar wind measurements, since there are currently only a very few of these systems and they are well-known to the international community, including the survey team.

Type of measurement	Notes
Geomagnetic observatories and variometers	Intermagnet and SuperMag are global coordinators in these areas
Ionosondes	
HF radars	e.g. SuperDARN
GNSS receivers	e.g. National networks, IGS is a global coordinator
Riometers	
Fabry-Perot interferometer	
Satellite accelerometers	
Neutron monitors	NMDB is a global consolidator in this area
Satellite particle and radiation monitors	
Satellite-based solar monitoring (optical and radio)	
Ground-based solar observations (optical and radio)	

C.3 International Organisations Survey (IO Survey)

International Organizations Survey

The United Nations (UN) Committee on the Peaceful Uses of Outer Space (COPUOS) Scientific and Technical Subcommittee (STSC) Expert Group on Space Weather requests International Organizations involved in space weather-related activities to complete a brief survey to aid in the generation of baseline data on the current state of space weather activities in International Organizations. The UN Expert Group on Space Weather will use these data to inform a report to be submitted to the STSC at its 58th session outlining the current state of space weather activities and providing recommendations for implementation of Long Term Sustainability (LTS) Guidelines specifically related to space weather, Guidelines B.6 "Share operational space weather data and forecasts" and B.7 "Develop space weather models and tools and collect established practices on the mitigation of space weather effects".

Background: COPUOS has recognized that space weather has the potential to significantly impact both space and ground-based critical infrastructure and identified it as international concern in the Guidelines for the Long-Term Sustainability of Outer Space Activities (A/AC.105/C.1/L.366), in particular B.6 and B.7, and the LTS 2.0 Working Group, and Thematic Priority 4: International Framework for Space Weather Services for UNISPACE+50 (A/AC.105/1171). A high-level goal of these initiatives is to promote communication between COPUOS Member States and relevant UN bodies and international organizations undertaking space weather observations, research or operational service activities to improve coordination and efficiency.

The LTS Guidelines underscore the need for continuous space-based and ground-based measurements and focused research efforts to improve modelling and forecasting capabilities of space weather events. Broad participation from international organizations involved in space weather-related activities helps Member States understand both the drivers and the impacts of space weather, thereby improving Member States' capacity to predict and mitigate severe space weather events. The LTS Guidelines further identify the need for Member States to understand their risks from adverse space weather and consider appropriate utilization of space weather services to mitigate these risks.

Survey

Question Title

* 1. I/we agree that data and information collected from this survey (which may include personal information such as names and contact details of individuals) will be shared and distributed amongst the UN Expert Group on Space Weather for the purposes outlined above towards fulfilling its mandate. I/we agree that I am authorised to provide this information for this purpose.

O Agree

O Don't agree

United Nations
Expert Group on Space Weather

2. Name of the international organization:

3. Name of point of contact for the purpose of this survey:

4. Email address of point of contact:

5. Type of the organization:

- Governmental Organization
- Non-governmental Organization
- Other (please specify)

6. Provide a link to your organization's public website:

7. Provide a list of the membership (e.g. countries, entities) of your organization (a link to a document or website with this information is acceptable):

8. Describe your organization's mandate for space weather activities:

9. Describe the origin of the space weather mandate (e.g. reference to resolution(s)/decision(s)):

10. Describe the type of space weather activities of your organization:

- research
- observations
- operational activities
- technical and regulatory framework

☐ socio-economic studies

☐ Other (please specify)

11. Describe your organization’s ongoing or planned contributions to facilitating Member States' implementation of the LTS Guidelines B.6 and/or B.7, be specific in your replies and if possible, refer to the relevant paragraphs of the two space weather related guidelines:

12. List any major shortcomings or gaps identified by your organization in the present system of international cooperation for space weather

a) service delivery:

b) observations:

c) science and modelling:

d) capacity building:

e) mitigation practices, procedures and standards:

13. Would your organization welcome assistance to improve international cooperation and coordination, and if so, in which of the areas listed under question 12 (e.g., service delivery, observations, research and modelling, capacity building, development of mitigating practices and standards for industry, product and data standards and formats etc.):

14. List any other suggestions identified by your organization for enhancing coordination of international space weather cooperation:

15. Any other issues you would like to bring to the attention of the UN Expert Group on Space Weather:

Appendix D. Respondents to Member State Survey 1 (Survey 1) and the International Organisation Survey (IO Survey)

D.1 Respondents to Member State Survey 1 (Survey 1; 40 responses received)

Algeria, Argentina, Austria, Australia, Belgium, Brazil, Canada, Czechia, Chile, Denmark, Ecuador, Finland, France, Germany, Indonesia, Kenya, Korea, Japan, Malaysia, Mauritius, Mexico, Mongolia, Netherlands, New Zealand, Norway, Pakistan, Paraguay, Peru, Philippines, Poland, Portugal, Saudi Arabia, Singapore, South Africa, Spain, Thailand, Ukraine, United Kingdom, United States

D.2 Respondents to International Organisations Survey (IO Survey; 24 responses received)

LAPAN
EMBRACE/INPE
Asia-Pacific Space Cooperation Organization (APSCO)
International Organization for Standardization (ISO)
International Union of Geodesy and Geophysics (IUGG)
Scientific Committee on Solar-Terrestrial Physics (SCOSTEP)
Asia-Oceania Space Weather Alliance (AOSWA)
International Association for the Advancement of Space Safety
Scientific Committee on Solar-Terrestrial Physics
International Space Environment Service; (Member of WDS)
International Association of Geomagnetism and Aeronomy (IAGA)
Asia-Pacific Space Cooperation Organization (APSCO)
Coordination Group for Meteorological Satellites
International Service of Geomagnetic indices (ISGI); Member of World Data System (WDS); Member of French Organisation for Applied Research in Space Weather (OFRAME)
Canadian Space Agency
World Meteorological Organization (WMO)
International Telecommunication Union (ITU)
Latin American Association of Space Geophysics (ALAGE in Spanish)
Secure World Foundation
INTERMAGNET (International Real-time Magnetic Observatory Network)
WDC - Sunspot Index and Long-term Solar Observations (SILSO); Member of WDS
International Civil Aviation Organization (ICAO)
World Data Center - Sunspot Index and Long-term Solar Observations (SILSO); Member of the World Data System (https://www.worlddatasystem.org/)
UNCTAD