WORLD METEOROLOGICAL ORGANIZATION
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FOUR-YEAR PLAN FOR WMO ACTIVITIES RELATED TO SPACE WEATHER 2016-2019

DRAFT 2.1

9 June 2016

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1 INTRODUCTION

1.1 Purpose of this document

In response to the Sixteenth WMO Congress[1] and the sixty-sixth session of the WMO Executive Council (EC-66)[2], the present document defines a plan to be implemented in 2016-2019 to improve capabilities of WMO Members to deliver space weather services.

The activities under this plan are aligned with the WMO Strategic Plan; a working structure is designed to integrate space weather related efforts within core WMO Programmes, and an estimation is provided of the required resources and expected benefits.

As a result of this planned effort, space-based and ground-based space weather observing systems will be better coordinated; consistent, quality-assured space weather products will be available to all Members through WIS; and, in particular, space weather services for civil aviation will be addressed as required by the International Civil Aviation Organization (ICAO). The proposed high-level organization is expected to facilitate the effective coordination with initiatives external to WMO and to enable the long-term improvement of space weather service capabilities.

1.2 Definition of space weather

Space Weather is defined here as the physical and phenomenological state of the natural space environment including the sun and the interplanetary and planetary environments.

The associated discipline, “Meteorology of space” also commonly named “Space weather”, aims at observing, understanding and predicting the state of the Sun, of the interplanetary and planetary environments, their disturbances, and the potential impacts of these disturbances on biological and technological systems. .

1.3 Societal needs and trends of space weather services

There is an increasing societal demand for space weather services as a result of growing dependence on technologies impacted by space weather: air navigation on polar routes exposed to space weather events; fleet of satellites used operationally for telecommunication, broadcasting, observation or positioning; use of satellite-based navigation and timing signals that are affected by ionospheric disturbances; electric power grids that are exposed to geomagnetically induced currents with potentially disastrous cascading effects.

Emergency management agencies are developing procedures to manage the risks of severe space weather events as part of their overall risk management approach. Space weather services are regularly used today in a number of countries by the commercial airlines, the satellite industry, drilling and surveying operations, power grid operators, pipeline designers and users of satellite-based navigation systems. It is anticipated that this demand will expand with broader awareness of the impact of space weather events, increasing exposure of the society, and greater maturity of space weather products and services.

1.4 Need of international coordination of space weather related activities

The need to strengthen international coordination has been regularly stressed by international bodies involved in space weather such as the United Nations Committee on the Peaceful Uses of Outer Space (COPUOS) and the Space Weather Panel of the Committee on Space Research

[1] Sixteenth WMO Congress, Abridged Final Report, WMO-No. 1077, paragraph 3.7.11 and Annex IV
[2] Executive Council, sixty-sixth session, Abridged Final Report, paragraph 4.4.91

(COSPAR). Annex 1 provides an overview of the major international initiatives in this respect. None of them is currently addressing the end-to-end spectrum of activities needed for fully operational space weather services, but they represent a valuable resource that can be leveraged by WMO through appropriate partnerships.

For instance, numerous space-based and ground-based assets exist today that could be used to improve space weather services, but these assets are often not effectively coordinated, or easily available beyond the community which operates them. Observations are not systematically interoperable, shared in near-real time, and documented with metadata enabling their discovery and efficient use. There is no coordinated planning to avoid gaps on critical observations.

Alerts, warnings and forecasts must be communicated effectively to ensure consistent messages during extreme events and enable post-event verification and evaluation. Space weather services to aviation must be standardized, coordinated, evaluated and delivered along procedures to be agreed among ICAO and WMO.

In summary, operational coordination is the missing link between the international initiatives mentioned above and the fulfilment of user needs.

1.5 WMO ICTSW activities on space weather

The Inter-Programme Coordination Team on Space Weather (ICTSW)[3] initiated its activities in 2010 under the auspices of CBS and CAeM. As of April 2016 it involves experts from twenty-six WMO Members, and several international organizations: European Union, ICAO, the International Space Environment Service (ISES)[4], the International Telecommunications Union (ITU) and the Office of Outer Space Affairs (OOSA).

The initial achievements of ICTSW to-date include the formulation of observation requirements, the Statement of Guidance on space weather observation, the establishment of a Space Weather Product Portal, and the support to CAeM to review the ICAO concept of future space weather services to aviation. These results demonstrate the benefit that can be brought by WMO in this new area in providing a framework for cooperation and coordination, and building bridges between the space weather science community and the operational meteorological community. This role, played by WMO through ICTSW, has been acknowledged and encouraged by various international partners.

However, a number of challenges are still in front of us. Further mobilization of experts, sustained engagement of WMO Members to operate observing systems and share data, continued support by the Secretariat, would be required in order to achieve a breakthrough in the capability of WMO Members to provide and benefit from space weather services. A way forward to address these challenges is detailed in the present four-year plan.

1.6 WMO Members and space weather

Space weather exposure as described in Section 1.3 potentially affects all WMO Members, but the specific organization of responsibilities to address these issues may significantly differ among WMO Members. For several WMO Members[5] the mandate of the National Meteorological or Hydrological Service (NMHS) includes a space weather forecasting and warning responsibility, or at least an important building block of it such as ionospheric or geomagnetic observation.

[3] See: http://www.wmo.int/pages/prog/sat/spaceweather-ictsw_en.php
[4] International Space Environment Service: http://www.ises-spaceweather.org/
[5] Including Argentina, Australia, China, Finland, Russian Federation, Republic of Korea, United Kingdom, United States.

In many cases, however, space weather related activities are led by other national institutes which can be as diverse as a space agency, a solar observatory, a geomagnetic observatory, or a radio-communication agency. This is the case of most ICTSW members. In such cases, the Permanent Representative has nominated an expert from the relevant organization to contribute to this WMO activity. A cooperation framework may exist between the NMHS and the space weather organization, for instance when ground-based space weather observations are collocated with weather stations. In some cases, such cooperation was prompted by the opportunity to participate in ICTSW.

2 VISION OF WMO ACTIVITIES RELATED TO SPACE WEATHER

2.1 Coordination of space weather activities

Space weather phenomena are best monitored through coordinated efforts of multiple nations. They are triggered by events occurring on the Sun and in interplanetary space, are ranging from the global to the regional scale, are potentially affecting a global community and require extensive observation capabilities.

The global nature of WMO, as well as its intergovernmental status, its longstanding experience of operational coordination, its scientific basis, the potential synergy between meteorological and space weather related activities, the strong connection of WMO with the aeronautical sector through CAeM, and its engagement for the protection of life and property, are major assets enabling WMO to play a key role in this needed international coordination regarding space weather.

Considering, on one hand, the societal needs which are not fulfilled and, on the other hand, the strengths and capabilities of WMO, WMO undertakes international coordination of operational space weather monitoring and forecasting with a view to support the protection of life, property and critical infrastructures and the impacted economic activities. In providing a truly global and intergovernmental framework, WMO should enable international commitments and facilitate the establishment of a global framework for operational space weather services, for example in the context of the ICAO convention.

2.2 High-level goals

The following high-level goals are proposed for this activity:

- Promote the sustained availability, quality, and interoperability of the observations that are essential to support space weather warning and other services, while optimizing the overall cost of the observing system;
- Improve the collection, exchange and delivery of space weather data and information through open sharing, internationally agreed standards, and coordinated procedures taking advantage of the WMO Information System (WIS);
- Ensure that space weather analysis, modelling and forecasting methods allow the delivery of operational services on the best possible scientific basis; facilitate the transfer of technical and scientific advances from research to operations;
- Support the emergence and establishment of cost-effective and high-value services in identifying and addressing user requirements, focusing on the sectors where internationally coordinated responses are required, in coordination with aviation and other major application sectors, building on the Aeronautical Meteorology Programme (AeMP) and Public Weather Service (PWS) programme;

- Foster the production of high-quality end products and services by WMO Members, building on ISES centres and other examples of recognized services, in developing best practices, to improve the accuracy, reliability, interoperability, overall cost-efficiency of the provision of services;
- Improve the emergency warning procedures and global preparedness to space weather hazards in accordance with the WMO Strategy on Disaster Risk Reduction;
- Promote synergy between the space weather and the meteorological/climate communities and activities, and advance the understanding of space weather impacts on weather and climate processes;
- Support training and capacity-building, based on science and operational experience, to develop skills in the generation and interpretation of space weather products and services in order to allow WMO Members to utilize existing information in a meaningful way, build their own service capabilities, and facilitate user uptake of new products and services.

In pursuing the goals above it is recommended to:

- Build on the achievements of ICTSW and the momentum gained within this team;
- Establish actions for the next four-year period and update the working structure for WMO activities regarding space weather;
- Foster multi-disciplinary collaboration, noting the diversity of organizational schemes of space weather activities which in many countries are conducted outside the NMHS;
- Leverage national, regional or global initiatives and programmes, avoiding duplication but promoting instead complementary action through partnerships with internationally recognized UN or non-UN entities active in this area.

These activities must be underpinned by regular communication to raise awareness and understanding of the WMO community about space weather, report on the benefits of coordinated actions, provide external visibility and maintain a communication flow with external partners.

Furthermore, it is important to establish a high-level, effective coordination mechanism bridging the technical activities with the broader strategy and implementation of WMO Programmes.

3 ACTIVITIES

Key activities are described below, including their objectives, expected benefits, and possible challenges. These activities are structured in seven high-level functions related respectively to the Products and services level (3.1, 3.2, and 3.3), the System level (3.4, 3.5, and 3.6) and the Strategic level (3.7), as illustrated in Figure 1.

While this breakdown is intended to give a comprehensive view of the scope of activities to be addressed, a distinction is made between:

- Actions to be addressed in first priority, with expected deliverables within the four-year period, and with a target time frame for completion;

- Other actions that are either long-term actions for which the main outcome cannot be expected within the four-year period, or actions that will be addressed only if time and resources allow because they have a lower priority.

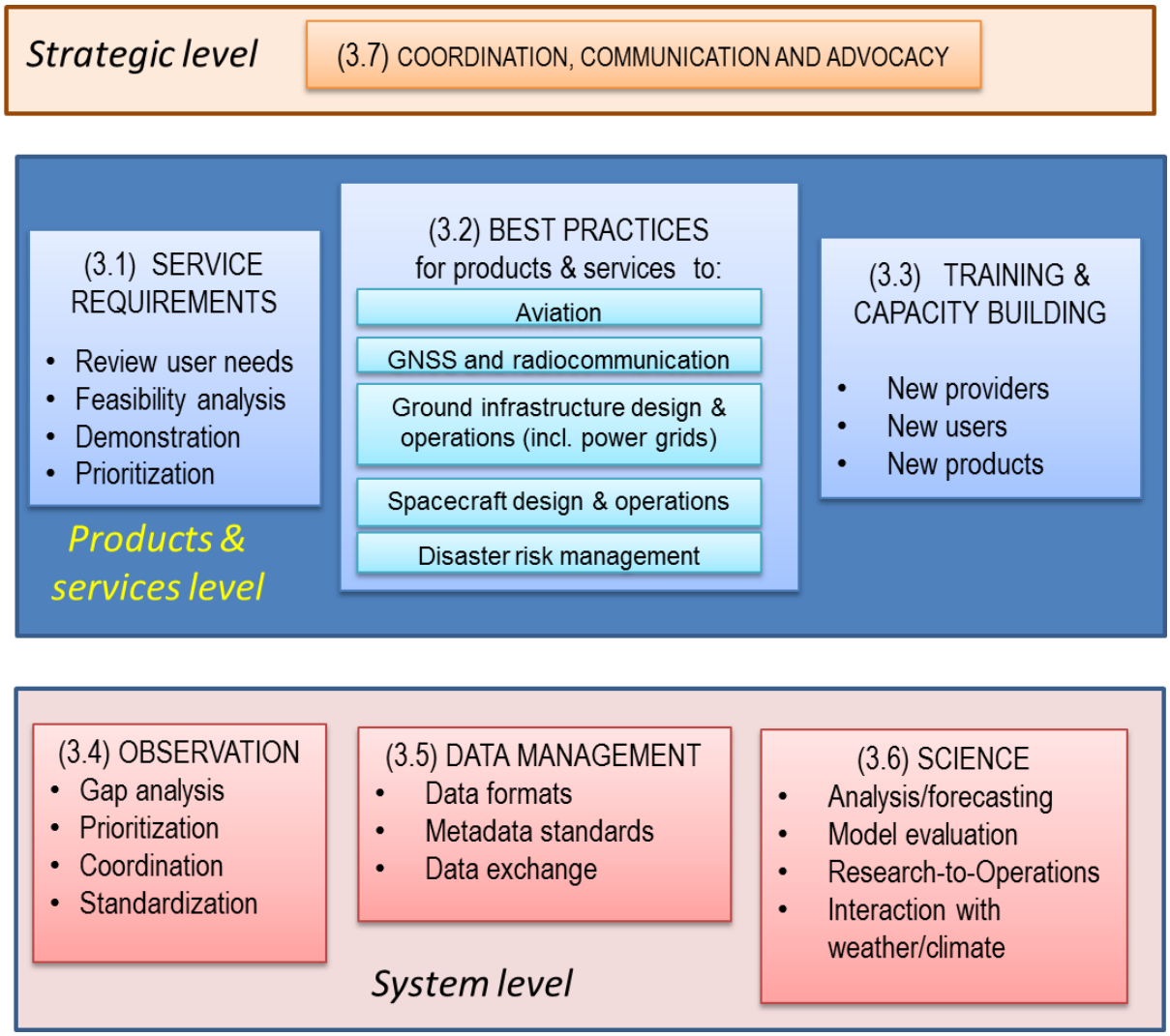

Figure 1: Schematic functional breakdown of the proposed key activities

3.1 Reviewing user requirements for space weather products and services, and priorities for coordinated responses

Goal: to support the emergence and establishment of cost-effective and high-value services in identifying and addressing user requirements, focusing on the sectors where internationally coordinated responses are required.

There are challenges, since space weather services haven't reached a level of maturity comparable with meteorological operations and potential users may not be aware of the capabilities of space weather services, and of how to use them. Demonstrations are needed to support the user-provider dialogue, helping users refine their requirements and providers to understand them, evaluate their feasibility, and specify a service responding effectively to these requirements. The specification of widely used end-products should be harmonized.

The requirements for products and services should be analysed in the following sectors:

- Aviation, where space weather services are being defined as part of Annex 3 of the ICAO Convention, and additional requirements are expressed by commercial airlines;
- Infrastructures impacted by geomagnetic disturbances, including the energy sector;
- Radio-communication, satellite radio-navigation and remote sensing radars;

- Spacecraft design, launch and operations;
- Disaster Risk Reduction (DRR) management;
- Other users' needs gathered and communicated e.g. by the NMHS.

First priority actions	Deliverable	Time frame
Support to WMO AeMP representation on the relevant ICAO working groups to review the feasibility of the draft requirements of ICAO for space weather services to aviation, and advise ICAO on the corresponding draft Standard And Recommended Practices (SARP)	ICAO requirement analysis ICAO SARP review	2016
Support to WMO AeMP representation on the relevant ICAO working groups to define the role, number, and required capabilities of future global and regional centres for the provision of space weather services to aviation	Roles, capabilities and target number of space weather service centres for ICAO	2016/2017
Survey of application sectors, other than aviation, where international coordination of services is required or desirable	List of priority services requiring international coordination	2017
Other actions (Long term or lower priority)	**Deliverable**	**Time frame**
Expand the Space Weather Product Portal to provide a representative sample of products for demonstration purposes and communicate on it	Additional products	2016-2019 (Continuous)
Investigate whether and how space weather impacts are addressed in national disaster risk reduction plans and the need for coordinated action	Survey on space weather element in national risk registers	2017
Analyse requirements for space weather services regarding radio-propagation in collaboration with ITU-R/SG-3 and ICG	Statement to ITU-R/SG-3, roadmap for development of such services	2018

3.2 Developing best practices for products and services

Goal: to foster the production of high-quality end products and services by WMO Members, building on the experience of ISES Regional Warning Centres or other recognized providers, in developing best practices to improve accuracy, reliability, interoperability, and overall cost-efficiency of provision of services; in particular, improve the emergency warning procedures and global preparedness to space weather hazards in accordance with the WMO strategy on Disaster Risk Reduction.

Best practices shall be defined in interaction with major users to best respond to the evolving needs of key socio-economic sectors and public safety. They should be based on scientific assessments and quality management principles (thus implying user focus).

First priority actions	Deliverable	Time frame
Establish real-time coordination and consultation	Consultation	2016/2017

mechanisms among warning centres for extreme events	procedure for extreme events	
Review the existing global and regional space weather event scales and develop an international, community agreed, scale or set of scales to characterize the severity of space weather events with a view to facilitate emergency procedures and verification activities	Community agreed space weather event scales	2017
Other actions (Long term or lower priority)	**Deliverable**	**Time frame**
Collaborate with CGMS to review the procedure for recording spacecraft anomalies attributed to space environment, including the archiving and utilization of this data	Agreed procedure spacecraft anomaly data	2016/2017
Develop best practices for space weather warning centres during extreme events, in collaboration with DRR programme	Guide on extreme space weather events	2018

3.3 Training and capacity-building, for new service providers and user uptake

Goal: Support training and capacity-building, based on science and operational experience, to develop skills in the generation and interpretation of space weather products and services, in order to allow WMO Members to utilize existing information in a meaningful way, build their own service capabilities, and facilitate user uptake of new products and services.

First priority actions	**Deliverable**	**Time frame**
Select existing training material and make it available on line through the Space Weather Product Portal	Training material on the Space Weather Product Portal	2016/2017
Identify target audiences, including NMHS meteorologists who wish to establish space weather service delivery within their organization, and training objectives	Schedule of training programme to support NMHS interest	2017
Conduct training sessions in coordination with the VLab and partner organizations, provide tutorial tools.	Completed training programme, feedback for training improvements	2018
Other actions (Long term or lower priority)	**Deliverable**	**Time frame**
Develop new educational material, in different languages and with content structured for different regional needs	Region-specific resources for space weather service improvement	>2019
Contribute to user information events to raise awareness of space weather impacts and of potential benefit of using space weather services	Co-sponsored events	2018

3.4 Coordinating ground- and space-based space weather observations

Goal: High-level coordination of satellite-based and ground-based observations to ensure the sustained availability, quality and interoperability of the observations that are essential to support space weather warning and other services, while optimizing the overall cost of the observing system.

This will be achieved through integration of space weather observing systems as component systems of WIGOS. It includes review of space-based and surface-based observations requirements, harmonization of sensor specifications, analysing priorities and monitoring plans to fill the gaps in space weather observation.

First priority actions	**Deliverable**	**Time frame**
Update the space weather observation requirements and the Statement of Guidance for space weather observation as part of the WMO RRR process	Requirements in OSCAR and updated SOG	2016/2017
List the key ground-based measurements to be performed on a routine operational basis, with required observation cycles	Initial list and specification of measurements	2017
List the space weather observatories performing the required measurements above (analogue to Vol. A)	List of observatories	2017
Develop observation metadata characterizing the measurements above	WIGOS metadata	2017/2018
Update the assessment of space-based capabilities for space weather observation in OSCAR/space as a support to gap analysis	OSCAR/Space update including gap analysis	2017
Dialogue with space agencies (including major agencies such as NASA, and international satellite coordination bodies such as CGMS) and relevant authorities, on actions needed to fill the gaps in space-based observation	Gap analysis communicated to major stakeholders in space observation	2017
Prepare initial addition to the WIGOS Manual	Draft update of WIGOS Manual	2018
Other actions (Long term or lower priority)	**Deliverable**	**Time frame**
Expand observing capabilities, communication infrastructure and procedures in order to fill the gaps in observation and improve data availability	Reduction of gaps	>2019
Expand the lists of measurements and observatories	Updated lists	>2019
Harmonize sensor specifications for energetic particle measurements and best practices for intercalibration and intercomparison of measurements	Specification guidelines, Intercomparison procedures	2018
Agree on quality standards for ground-based space weather observations (existing standards, or new provisions for inclusion into CIMO Guide if relevant)	Observation quality standards	>2019

3.5 Promoting and facilitating data management, standardization and exchange

Goal: to improve the collection, exchange and delivery of space weather data and information through open sharing, internationally agreed standards, and coordinated procedures taking advantage of the WMO Information System (WIS).

A major challenge is the stringent timeliness constraints of most space weather data.

First priority actions	**Deliverable**	**Time frame**
Identify list of essential data and products to be considered for routine exchange on the WIS, characterize them with appropriate discovery metadata, register and make them available in the WIS (with IPET-MDRD)	Set of space weather data and products discoverable and globally available, in near real-time in WIS	2016/2017
Register space weather service centres as Data Collection or Production Centre (DCPC) or National Centres (NC) in the WIS (with IPET-WISC)	Additional space weather service centres designated as DCPC or NC	2016/2017
Other actions (Long term or lower priority)	**Deliverable**	**Time frame**
Investigate the applicability and advantages of new formats, including e.g. RINEX/GTEX, for exchange of space weather data and products	Recommended format implementation	2017
Investigate the applicability and advantages of new protocols, such as the Common Alert Protocol (CAP)	Recommended protocol	2018

3.6 Evaluating space weather analysis and forecasting methods, promoting transition of mature research models to operations and synergy with climate/weather modelling

Goals:

- To ensure that space weather analysis, modelling and forecasting methods allow the delivery of operational services on the best possible scientific basis; facilitate the transfer of technical and scientific advances from research to operations;

- To promote synergy between the space weather and the meteorological/climate communities and activities and advance the understanding of space weather impacts on weather and climate processes.

This entails support to the development of operational, data-assimilative, predictive models, benefiting from advanced weather and climate prediction capabilities, and community initiatives for model coupling and evaluation. The dialogue between the research and operational space weather communities should be encouraged with a view to regularly assess methods and services potentially mature for operational use. The dialogue should also be encouraged between the space weather and the meteorological/climate communities.

First priority actions	Deliverable	Time frame
Share lessons-learned in the usage of space weather models in daily forecasting activities	Handbook for good practices in space weather forecasting	2017
Define skill scores and other verification techniques to assess the potential value of existing research models for user-oriented services	Objective evaluation of existing models	2018
Other actions (Long term or lower priority)	**Deliverable**	**Time frame**
Workshops on space weather impacts on Essential Climate Variables	Improved understanding of space weather–climate linkages	2017
Evaluate the benefit of whole atmosphere models (from the surface to the top of the thermosphere) used in conjunction with other space weather models	Impact evaluation of whole atmosphere models	2018
Workshop on data-assimilation capabilities for Sun-Earth system models to improve forecast skill	Guidelines for utilization of available data in numerical prediction models	2019

3.7 Coordinating the actions and ensuring a science-based, authoritative communication on operational space weather related activities in the United Nations system and beyond

It is important to establish a high-level, effective coordination mechanism bridging the technical activities with the broader strategy and implementation of WMO Programmes.

This must be underpinned by regular communication aiming to:

- Raise awareness and achieve understanding, by all Members, of the importance of space weather services and to seek feedback on success and limiting factors;
- Demonstrate the benefits of acting in coordination, for optimization of resources and higher reliability of space weather information;
- Provide visibility on WMO activities on space weather and maintain an information flow with external partners to ensure that efforts well supplement each other;
- Inform the society on the capabilities of space weather information and services as well as the limitations of these services in the state of the art.

While the COPUOS is an appropriate forum to communicate at the strategic level within the UN system, the dialogue with the space weather scientific and operational community and with key user groups is best achieved at targeted conferences. The annual “Space Weather Workshop” organized by the USA and the “European Space Weather Week” organized in Europe are the most active venues and host a number collocated events including discussion panels and user interaction. A comparable initiative is emerging in Asia, the Asia Oceania Space Weather Alliance (AOSWA).

First priority actions	Deliverable	Time frame
Keep COPUOS informed of the WMO plan for space weather and of the challenges requiring mobilization of effort beyond the WMO community	Reports	Annual
Report at the annual space weather workshops organized in the USA, in Europe, and in Asia	Presentations, or panel sessions	Annual
Identify cases demonstrating the benefit of space weather activities coordinated by WMO	Report on case studies	2017 - 2019
Provide the WMO Congress (Cg-18) with a draft plan for space weather activities beyond 2019 (e.g. within a Space Weather Watch programme)	Draft plan	2019
Other actions (Long term or lower priority)	**Deliverable**	**Time frame**
Coordinate with COSPAR on the interaction between this plan and the COSPAR roadmap implementation	Feedback	Annual
Address regional implementation of space weather services at Regional Association meetings or associated Technical Conferences	Presentation at RA meeting or Technical Conference	RA meetings

4 ORGANIZATION AND IMPLEMENTATION

4.1 Mapping of activities with WMO strategic priorities and activities

The table below summarizes the mapping of space weather activities with the seven key priorities of the WMO Strategic Plan 2016-2019 adopted in May 2015 by the Seventeenth WMO Congress.

Key priorities in the WMO Strategic Plan 2016-2019	Related activity in the space weather four-year plan
Improve the accuracy and effectiveness of impact-based forecasts and multi-hazard early warnings of high impact meteorological, hydrological and related environmental hazards from the tropics to the poles thereby contributing to international efforts on disaster risk reduction, resilience and prevention, in particular in response to the risks associated with increasing population exposure;	Improving global preparedness to space weather hazards, as requested by Cg-XVI, contributes to international efforts on disaster risk reduction, resilience and prevention.
Implement climate services under the Global Framework for Climate Services (GFCS) particularly for countries that lack them by: (i) establishing regional climate centres; (ii) identifying user requirements for climate	Interactions of space weather with terrestrial climate are a matter of investigation

products; (iii) developing the Climate Services Information System; (iv) advancing the sub-seasonal to seasonal prediction skill;	
Strengthen the global observing systems through full implementation of WIGOS and WIS for robust, standardized, integrated, accurate and quality assured relevant observations of the Earth system to support all WMO priorities and expected results;	Prepare the integration of space weather observations in WIGOS and WIS. This was requested by EC-LX, and is already well engaged with the active participation of the Space Weather Application Area in the Rolling Review of Requirements.
Improve the ability of NMHSs to provide sustainable high-quality services in support of safety, efficiency and regularity of air traffic management worldwide, with due account to environmental factors by: (i) accelerating the implementation of ICAO/WMO competency and qualification standards and quality management systems; (ii) addressing emerging requirements and challenges related to the 2013–2028 Global Air Navigation Plan, in particular concerning ICAO Block 1 Upgrades; and (iii) strengthening the sustainability and competitiveness of aeronautical meteorological service provision through improved cost recovery mechanisms and suitable business models for service delivery frameworks;	The emerging needs and challenges of space weather services to aviation are being addressed in priority in response to ICAO requirements
Improve operational meteorological and hydrological monitoring and prediction services in polar and high mountain regions and beyond by: (i) operationalizing the Global Cryosphere Watch; (ii) better understanding the implications of changes in these regions on the global weather and climate patterns; and (iii) advancing the polar prediction under the Global Integrated Polar Prediction System	As space weather events can be particularly acute in the Polar Regions because of the structure of the geomagnetic field, predicting geomagnetic and ionospheric disturbances and energetic particle impacts (sometimes visible in the form of aurorae) is important
Enhance the capacity of NMHSs to deliver on their mission by developing and improving competent human resource, technical and institutional capacities and infrastructure, particularly in developing and least developed countries and small island developing States	Capacity building towards the delivery of space weather services
Improve efficiency and effectiveness of WMO by adopting continuous improvement measures and recommendations based on a strategic review of WMO structures, operating arrangements and budgeting practices.	To ensure operational effectiveness, the proposed organisation would limit the standing working structure to one Inter-programme coordinating team linked to the relevant commissions, regional associations, partners and user representatives

WMO activities regarding space weather are led by the WMO Space Programme, which is a cross-cutting programme. As of 2015, these activities are already integrated into a number of WMO Programmes and projects as indicated below.

In the WIGOS perspective, space weather is fully integrated in the Rolling Review of Requirements (RRR). Space Weather is considered as a WMO "Application area" in the RRR process: space weather observation requirements have been defined and recorded in the OSCAR/Requirements[6] database; an assessment of the current gaps in our observing systems is documented in a Statement of Guidance; and a chapter and several actions are dedicated to space weather observation in the Implementation Plan for the Evolution of the Global Observing Systems (EGOS-IP)[7].

The *Instruments and Methods of Observation Programme (IMOP)* has just completed a new issue of the Guide on Instruments and Methods of Observation (CIMO Guide). Observation of space weather from space is addressed in its new Part III on Space-based observations.

The Steering Group on Radio Frequency Coordination (SG-RFC) has initiated consideration of frequency allocation issues for space weather observations in the microwave domain, based on inputs from ICTSW.

Regarding the WIS, a pilot project is underway within ICTSW and ISES to evaluate the use of the WIS for the exchange of space weather forecast products (geomagnetic activity, solar flares, and solar energetic particles).

Within the Aeronautical Meteorology Programme, ICTSW has supported the Aeronautical Meteorology Division in reviewing the ICAO Concept of Operations for space weather services to global air navigation and provided guidance on the future organization of an effective operational space weather service delivery coordinated by WMO. ICAO recognizes WMO, through ICTSW, as a source of technical advice on space weather matters. The continuing active participation of WMO will be essential as it is anticipated that Annex 3 of the ICAO Convention will make such space weather services for civil aviation mandatory as of 2018.

Space weather training is included in the training strategy of the WMO-CGMS Virtual Laboratory (VLab) for Education and Training in Satellite Meteorology, partnering with COSPAR.

4.2 Working structure

In order to address all the activity domains under this four-year plan, a pool of experts is needed in the following areas:

- Space weather basic systems, including issues related to observation techniques and networks, data management and exchange, data centres, and space climatology;
- Space weather science, including issues related to modelling, model evaluation and verification, interaction with climate, and transition from research to operations;
- Space weather applications, including requirements evaluation, the delivery of services, capacity building and user interaction.

The proposal aims at close integration into the existing structure of WMO technical commissions, strong linkage with relevant external partners, and increased involvement of space weather experts covering a broad range of expertise. It should also avoid a multiplication of teams with unnecessary overheads and reporting interfaces. It is thus proposed to replace the current ICTSW

[6] See: http://www.wmo-sat.info/oscar/applicationareas/view/25 .
[7] See chapter 7 in: http://www.wmo.int/pages/prog/www/OSY/Publications/EGOS-IP-2025/EGOS-IP-2025-en.pdf

by an Inter-Programme Team on Space Weather Information, Systems and Services (IPT-SWISS), who will pursue the work of ICTSW in close cooperation with the technical commissions, the space weather service provider community represented by ISES, and representatives of users.

IPT-SWISS shall coordinate the activities regarding space weather throughout technical commissions and regional associations. IPT-SWISS Members would include: space weather experts nominated by CBS, CAeM, and other relevant technical commissions such as the Commission for Instruments and Methods of Observation (CIMO), and the Commission for Atmospheric Sciences (CAS); points of contacts nominated by the regional associations; and a representative of ISES. Major partners and stake holders could be invited as Associate Members at no cost to WMO. IPT-SWISS would report in parallel to CBS and CAeM who would agree on a coordinated mechanism in order to provide joint oversight of IPT-SWISS. Draft Terms of Reference are contained in Annex 2.

IPT-SWISS will designate experts, among its members, to contribute to the relevant expert teams of the involved technical commissions. It would form ad-hoc task teams as appropriate, for topics requiring a specific expertise. In the context of a working arrangement with ISES discussed in 4.3, some of these ad hoc task teams could be jointly established with ISES and supported by ISES experts.

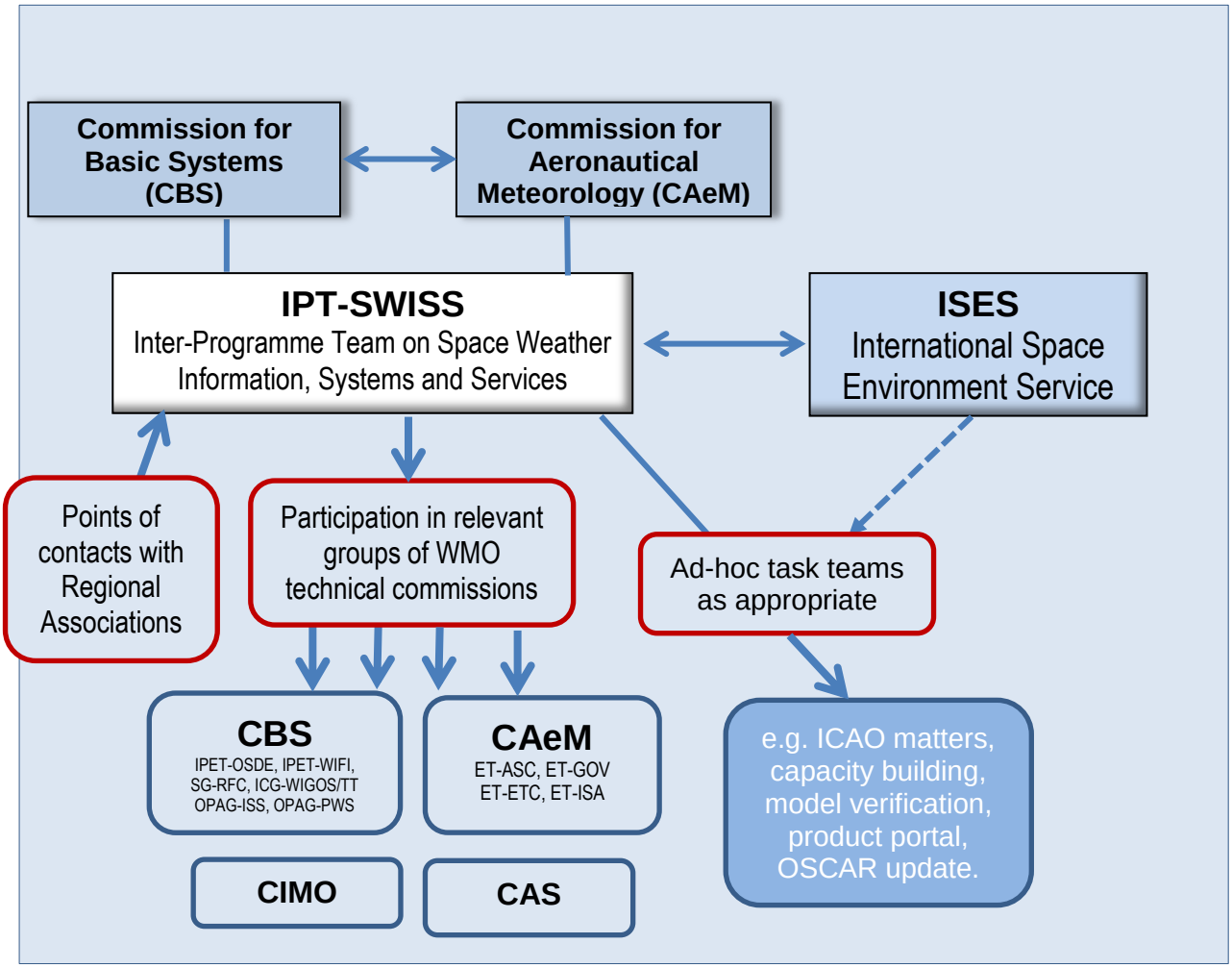

Figure 2: Proposed organization for space weather.

It is expected that, CAeM and CBS will consult each other via their presidents after EC-68 to proceed with a call for nominations for IPT-SWISS with a view to establish this team at the beginning of 2017. Work would be pursued by ICTSW until then. At the last meeting of ICTSW, tentatively in the 4th quarter 2016, the action plan will be updated taking into account the outcome of Congress, Executive Council and of CBS-CAeM consultations.

4.3 Partnership and user engagement

Partnership with ISES

A working arrangement has been established with ISES through an exchange of letters in order to formalize the collaboration with this organization which is the trigger and the enabler of WMO activity in space weather. Through this arrangement ISES and WMO state the intention to act in close cooperation with each other in order to facilitate the improvement and coordination of operational Space Weather services delivered by WMO Members and ISES Centres.

In particular, ISES and WMO will:

- Keep each other informed concerning all programmes of work, activities and publications on matters of common interest;
- Contribute to the specification of Space Weather services, in particular the services to be delivered in support to ICAO (through the appropriate bodies of CAeM), and to the

development of best practices, e.g. for emergency warnings;

- Advance the standardization of operational Space Weather observations, data management, products generation and dissemination, relying as appropriate on relevant international standards, such as WMO and/or ICSU standards;
- Raise public awareness on Space Weather and its impact, and support preparedness to Space Weather extreme events;
- Conduct joint surveys on needs of current and Space Weather services;
- Facilitate the transition of scientific knowledge on space weather into operational services to the society.

ISES and WMO will pursue these activities through joint technical meetings and workshops, and coordinated communications and outreach actions. The representatives of ISES and WMO will be invited to participate, without vote, in deliberations of the WMO Executive Council, or the ISES Annual Meetings respectively and, where appropriate, in their working groups on issues of mutual interest.

Other partners and user organizations

WMO and ISES will support initiatives bringing together space weather service providers, partners and key users: for instance, ITU, as well as the International Committee on GNSS (ICG)[8], or the North American Electric Reliability Corporation (NERC). Major partners or representatives of important potential or actual user communities could be invited to participate in IPT-SWISS as Associate Members.

As concerns ITU, it should be clarified that the relationship is two-fold:

- Since space weather disturbances in the ionosphere affect the propagation of radio-waves used in telecommunication and radio-navigation, ITU-R/SG-3[9] is potentially a proxy for these user communities;

- Since space weather observations partly rely on passive or active surface-based or space-based measurements in microwave frequency bands, which may require a frequency allocation and protection, the interests of the space weather community must be represented in ITU-R/SG-7[10], as part of the discussion on radio-frequency coordination, which is led in WMO by the CBS Steering Group on Radio-Frequency Coordination (SG-RFC). In November 2015, the World Radio-communication Conference (WRC) adopted Resolution 657 on spectrum needs and protection of space weather sensors which sets a way forward for space weather frequency requirements discussions at future WRC sessions, with a view to providing appropriate recognition and protection in the Radio Regulations without placing additional constraints on incumbent services.

4.4 Resources and benefits

This action plan is in continuity of the activity pursued with the current ICTSW, though with a significant expansion as necessary to move from a “demonstration stage” to an actual implementation enabling a breakthrough with tangible benefits in several applications.

Resources

[8] International Committee on GNSS: http://www.oosa.unvienna.org/oosa/fr/SAP/gnss/icg.html
[9] ITU-Radio-communication sector Study Group 3 on Radio-propagation
[10] ITU-Radio-communication sector Study Group 7 on Science services

The engagement of Members through their space weather experts and the support from the Secretariat, ideally at the level of one full-time person, are critical for the success of this plan. Given the tight situation of staff resources within the Secretariat, a minimum level of support could be achieved in supplementing the Secretariat staff with experts seconded by Members and external consultancy. With this assumption, the level of financial resources needed annually to cover the activities of the present four-year plan is estimated at CHF 240 000.

Table 1: Tentative estimation of the annual level of resources needed to support the plan

Type of expenditures	**Annual cost(CHF)**
Participation of qualified experts in one annual meeting of IPT-SWISS and related task teams	60 000
Participation of IPT-SWISS members in relevant bodies of WMO technical commissions	30 000
Liaison with external partners	20 000
Communication actions, development or translation of training material	20 000
One seminar	50 000
Consultancy and financial support to secondment of staff to supplement the Secretariat	60 000
Total	240 000

In accordance with the regular budget planned for the seventeenth financial period, it is assumed that the non-staff resources allocated to space weather activities in the regular budget (WMO Space Programme and possibly the Aeronautical Meteorology Programme) will remain marginal and need to be leveraged by extrabudgetary resources including:

- In-kind contributions from Members (for example, translation of training material, secondment of staff, or participation in meetings at no cost to WMO);
- Co-sponsoring of events (e.g. training seminar supported by COSPAR);
- Voluntary contributions to the Space Weather Trust Fund, as discussed by EC-66.

Table 2: Tentative breakdown of resources

Tentative indication of annual resources	**(CHF)**
Regular Budget (WMO Space Programme)	20 000
In-kind contributions	30 000
Co-sponsored events	30 000
Voluntary contributions to the Space Weather Trust Fund	160 000
Total	240 000

A tentative breakdown of annual resources is indicated in Table 2. It is anticipated that the WMO Members who are running a national space weather programme, would be the first inclined to contribute to the Space Weather Trust Fund, in view of the benefit of leveraging their national activities through data exchange, sharing best practices, and optimization of efforts, which could largely exceed the individual contribution from these Members.

Benefits

This activity plan is expected to provide significant benefits to the Members, in terms of more precise observations and improved reliability, accuracy, and timeliness of forecasts and warnings to their users. Once space weather services have reached a mature stage they can generate revenue to the information provider (e.g. cost recovery mechanism for the services required by ICAO, alert services to power grid, telecommunication or GNSS operators). The potential benefits derived from WMO space weather activities have been described in the report completed in 2008[11].

5 CONCLUSIONS

The early achievements of ICTSW in the sixteenth financial period (2012-2015) illustrate the broad field of activity that could benefit from WMO involvement in space weather, and demonstrate the capability of WMO to effectively facilitate a breakthrough in this area and play a recognized role in the international space weather community. Given the new requirements for space weather services to aviation and the emerging demand in other sectors, it is recommended that WMO engages more directly during the seventeenth financial period (2016-2019), and possibly beyond, to build up a sustainable basis for global, reliable, space weather service capabilities.

The present plan identifies a set of high-priority activities, which are considered necessary and feasible in the four-year time frame, and would lead to clear deliverables and tangible outcomes. Other desirable actions are identified and should be conducted as well if time and resources allow. It is furthermore suggested that the WMO Members who are currently the most advanced in that field engage technically, through their experts, and financially, through a modest contribution to the Space Weather Trust Fund, to take the lead in implementing the plan, thus demonstrating the benefits of this activity to other Members who may not be familiar with space weather yet.

The proposed activities are in line with several of the WMO strategic priorities for the seventeenth period.

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[11] The potential role of WMO in Space Weather, WMO, SP-5, TD-1482, 2008

ANNEX 1: Main International Initiatives in Space Weather

In the paragraphs below we briefly introduce the global initiatives focusing respectively on operational matters (ISES, CGMS, ICAO/IAVWOPSG), on policy (COPUOS), on research and education (COSPAR, ILWS, ISWI, SCOSTEP), and several regional initiatives.

ISES

ISES is, since 1962, a collaborative network of space weather service-providing organizations around the globe. Its aim is to improve and to coordinate operational space weather services. ISES members share data and forecasts and provide a broad range of services, including: forecasts, warnings, and alerts of solar, magnetospheric, and ionospheric conditions; space environment data; customer-focused event analyses; and long-range predictions of the solar cycle. ISES currently includes 16 Regional Warning Centers, four Associate Warning Centers, and one Collaborative Expert Center. ISES is a Network Member of the International Council for Science World Data System (ICSU-WDS) and collaborates closely with WMO.

CGMS

The Coordination Group for Meteorological Satellites (CGMS) is a technical coordination body of satellite operators focusing primarily on weather and climate satellite programmes in response to WMO requirements. In 2014, CGMS decided to include objectives related to space weather monitoring into its multi-year High-Level Priority Plan and agreed on Terms of Reference for CGMS Space Weather Activities. It is anticipated that CGMS will soon extend the scope of its activity towards space-based observation of space weather variables.

ICAO METP

The International Civil Aviation Organization (ICAO) is addressing space weather issues through its MET Panel (METP) Meteorological Information and Service Development Working Group (MISD). The MISD is developing a Concept of Operations and requirements for operational space weather services, in consultation with WMO, with a view to include such services in an amendment to Annex 3 of the ICAO Convention. The Conjoint WMO/CAeM-Met Divisional meeting in July 2014 has confirmed this objective, while considering that several issues required further consideration, including the definition of the roles, requirements, capabilities and overall number of global and regional forecasting centres, as well as their designation process, governance, cost recovery principles, competency standards and duration of mandate.

COPUOS

Since 2013, the Committee on Peaceful Uses of the Outer Space (COPUOS) of the United Nations General Assembly has started to address space weather issues within its Scientific and Technical Sub-Committee (STSC) in the context of the long-term sustainability of space assets and activities. It called for strengthening international coordination of efforts to monitor the space environment and welcomed the initial steps taken by WMO. An expert group on space weather was established in 2015.

Research and education: COSPAR, ILWS, ISWI, SCOSTEP

The Committee on Space Research (COSPAR) of the International Council for Science (ICSU) has a standing Space Weather Panel. Together with ILWS (described below), it has developed in 2014 a roadmap for improving the understanding of space weather processes and supporting the

development of space weather services[12]. The roadmap recommends actions pertaining to: (i) maintaining existing essential capabilities; (ii) developing modelling capability, research, or data infrastructure; and (iii) deploying new or additional instrumentation. The roadmap acknowledges WMO space weather activities.

Furthermore, a Memorandum of Understanding was signed in 2012 by WMO and COSPAR for establishing a partnership on training and capacity-building between the WMO-CGMS Virtual Laboratory for Education and Training in Satellite Meteorology (VLab) and COSPAR. COSPAR is funding space weather training events in developing countries in this framework.

International Living With a Star (ILWS) aims to stimulate space research to understand the governing processes of the connected Sun-Earth System as an integrated entity.

The *International Space Weather Initiative (ISWI)* was initiated by COPUOS to develop scientific insight on near-Earth space weather. ISWI is distributing ground-based monitoring instruments around the globe, hosting workshops and schools, and promoting joint research.

The *Scientific Committee on Solar Terrestrial Physics (SCOSTEP)* of ICSU runs international interdisciplinary scientific programmes and promotes solar-terrestrial physics.

There are scientific organizations involved in particular aspects, such as International Union of Radio-Science (URSI)[13], the International Astronomical Union (IAU)[14] or the International Association of Geomagnetism and Aeronomy (IAGA[15]).

Regional initiatives

The European Commission has supported several space weather related projects through the COST action framework (European Cooperation in Science and Technology)[16] and through the Seventh Framework Programme (FP7). This has led to establishing space weather data services such as SEPserver[17], ESPAS[18] , HELIO[19] and AFFECTS[20].

The European Space Agency (ESA) launched in 2009 a Space Situational Awareness (SSA) optional programme involving 14 of its Member States[21]. One of the three elements of the programme is dedicated to space weather and aims to implement space weather monitoring and information services in Europe to support spacecraft operations and other applications.

The Asia-Oceania Space Weather Alliance (AOSWA), currently involving organizations from 13 countries, was established in 2010 for encouraging cooperation and sharing information among institutes in Asia-Oceania region concerned with, and interested in space weather.

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[12] Understanding space weather to shield society: A global road map for 2015-2025 commissioned by COSPAR and ILWS, Schrijver, C. et al., Advances in Space Research,55 (2015), pp.2745-2807.
[13] International Union of Radio-Science : http://www.ursi.org/en/home.asp
[14] International Astronomical Union : http://www.iau.org
[15] International Association of Geomagnetism and Aeronomy : http://www.iugg.org/IAGA/
[16] COST 724 in 2003-2007, COST ES0803 in 2008-2012.
[17] http://www.sepserver.eu/sepserver/. This server contains data on Solar Energetic Particle events.
[18] http://www.espas-fp7.eu/. Near-Earth space data infrastructure for e-science.
[19] http://www.helio-vo.eu/. Heliophysics integrated laboratory.
[20] http://www.affects-fp7.eu/ . Advanced Forecast For Ensuring Communications Through Space.
[21] ESA/SSA participating countries include: Austria, Belgium, Czech Republic, Denmark, Finland, Germany, Italy, Luxembourg, Norway, Poland, Romania, Sweden, Switzerland, United Kingdom.

ANNEX 2: Draft Terms of Reference of IPT-SWISS

Scope

The responsibility of the Inter-Programme Team on Space Weather Information, Systems and Services (IPT-SWISS) is to coordinate space weather activities within the WMO Programmes, to maintain linkage with the constituent bodies and their relevant subsidiary groups, to maintain linkage with partner organizations, and to provide guidance to WMO Members. IPT-SWISS is established under Commission for Basic Systems (CBS) and the Commission for Aeronautical Meteorology (CAeM) who will provide joint oversight in consultation with each other via their presidents.

Main tasks

(a) Integration of Space Weather observations, through review of space- and surface-based observation requirements, harmonization of space-based sensor specifications, monitoring plans for Space Weather observations;

(b) Standardization and enhancement of Space Weather data exchange and delivery through the WMO Information System (WIS);

(c) Coordinating the development of SPW best practices for end-products and services, including e.g. quality assurance guidelines and emergency warning procedures, in collaboration with aviation and other major application sectors;

(d) Encouraging the dialogue between the research and operational space weather communities;

(e) Organization of capacity building, training and outreach activities towards WMO Members and space weather potential users;

(f) Provision of guidance to WMO Members and programmes on space weather matters, and conduct appropriate actions as requested by CBS and CAeM.

Composition

IPT-SWISS will be composed of members nominated by the relevant technical commissions, points of contacts nominated by the regional associations and associate members including representatives of ISES and other partners or major user applications.

IPT-SWISS members shall cover the various fields of expertise necessary to address space weather matters within WMO and will contribute to the relevant expert teams or other groups of WMO technical commissions including: Commission for Basic Systems (CBS)[22]; Commission for Aeronautical Meteorology (CAeM)[23]; Commission for Instruments and Methods of Observation (CIMO); Commission for Atmospheric Sciences (CAS).

IPT-SWISS will form ad hoc teams as appropriate focusing on topics requiring a particular field of expertise, for a particular time frame.

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[22] Such as the Inter-Programme Expert Teams on Observing System Design and Evolution (IPET-OSDE), on WIGOS Framework Implementation (IPET-WIFI), on Data Representation Maintenance Monitoring (IPET-DRMM), on Metadata and Data Representation Development (ET-MDRD), or the Steering group on Radio-Frequency Coordination (SG-RFC).

[23] Such as the Expert Team on Aviation, Science and Climate (ET-ASC), on Information & Services for Aviation (ET-ISA), on Education, Training and Competencies (ET-ETC).