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Notes on a Vision for the Global Space Weather Enterprise

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Abstract

Space weather phenomena impacts human civilization on a global scale and hence calls for a global approach to research, monitoring, and operational forecasting. The Global Space Weather Enterprise (GSWE) could be arranged along lines well established in existing international frameworks related to space exploration or to the use of space to benefit humanity. The Enterprise need not establish a new organization, but could evolve from existing international organizations. A GSWE employing open architectural concepts could be arranged to promote participation by all interested States regardless of current differences in science and technical capacity. Such an Enterprise would engender capacity building and burden sharing opportunities.

Keywords: Space weather; International cooperation; Global; Architecture

1. Introduction

Space weather is a natural area for international cooperation and collaboration (White House, 2010; Commission Europeenne, 2011). The variety of the phenomena, the terrestrial impacts, the observation and forecasting requirements, as well as the technical, intellectual, and monetary resources needed are inherently global. International collaboration in this area may well grow to interdependence and partnership. As a first step towards global harmonization of space weather monitoring, research, and operations, this document explores the concept of a Global Space Weather Enterprise.

This Vision document will advance cooperation between nations in space weather monitoring, research, and operations by articulating the desired Global Space Weather Enterprise. Such a Vision is valuable in many respects. First, it defines a system for space weather (SW) operational forecasting without limits imposed *a priori*. Second, it provides a mechanism for focusing the consideration and opinions of all interested parties. Third, it provides a means to establish metrics to assess achievement. Fourth, it provides a framing document contextualizing what is envisioned to be an ongoing dialogue and commitment to cooperative activities. Finally, it helps promote and define the endstate.

At present there are approximately 60 State or multi-State space actors. There are also over 70 members of the United Nations Committee on the Peaceful Uses of Outer Space, underscoring that States that are not space actors nonetheless use and in many cases are reliant upon space borne services (e.g. Head and Haubold, 2012). Hence the Vision anticipates and encourages roles for all interested parties. In addition, the Vision is focused on the operational considerations leading to the desired space weather operational service capability. The Vision also takes into account the role of fundamental research in enabling the technical capabilities required now and in the future for space weather services. Besides articulating a Vision, this document suggests a common strategic plan and possible implementation plans, to be carried out by the interested States.

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2. Vision

The space weather world envisioned here is characterized by unity of effort amongst the participating nations and international organizations. This means that governments and government agencies would be fully coordinated in their space weather research and operational activities. This level of coordination could be achieved through commitment to a common vision, a common set of research and operational goals, and a common, global, formal architecture frame work. With these coordinating tools in place, governments and international organizations would execute programs, missions, and other activities either singly or in cooperation with partners.

These activities could be coordinated via a formal international body, *e.g.* the World Meteorological Organization (WMO) or a formal coordination mechanism *e.g.*, the Inter-Agency Debris Coordination Committee (IADC). The coordinating body could be a new organization or could be a generated within the existing international institutional frameworks. The chief work of the coordinating body would be to:

1. Establish and maintain clear, robust, comprehensive communications between all parts of the global SW enterprise.
2. Facilitate a consensus amongst nations as to the required space weather observations and forecasts.
3. Establish and promote a formal ground and space-based architecture that when manifested, would meet the space weather forecasting needs of the international community.
4. Provide a mechanism whereby nations could coordinate their activities to avoid unnecessary duplication of effort while developing and maintaining a resilient forecasting capability, and
5. Aide implementation of national space weather strategies. Participation in the coordinating body would be voluntary and for mutual benefit.

The space weather world envisioned here is characterized by sustained observational capabilities that deliver the necessary data with the requisite reliability. The required global capacity for space weather observation and operational analysis is greater than that prevailing today. Existing capabilities should be built upon as part of the future monitoring campaign. The assets used to gather, transmit, and analyze space weather data are already international to some degree and will very likely remain so. To succeed therefore, the enterprise must build strong, multilateral, partnerships, with a final goal of implementing a truly international approach. Since the operational capabilities of tomorrow derive from the research of today, the enterprise should in particular encompass the transition from research to operations.

The space weather world envisioned is characterized by the right information being delivered at the right time to the right people (Table 1). The monitoring and forecasting system must be resilient with redundancy at key nodes. Regional forecast and warning centers will provide tailored information to their customer bases. An idealized, international space weather enterprise should be able to provide accurate forecasts to its customers with sufficient warning time for effective corrective action. The forecast areas include Global Navigation Satellite Systems (GNSS) signal availability and reliability, High-frequency (HF) communications availability and reliability, radiation flux in *cis*-lunar and interplanetary space, regionally resolved thermospheric density, and regionally resolved geomagnetic field characteristics. The White House Office and Science and Technology Policy has released a requirements document that could provide guidance in this area (National Space Weather Program Council, 2013).

2.1. Measurements required

The ideal space weather monitoring network will be composed of several terrestrial networks, several space assets, and the communications architecture required to deliver all required data to the user community. Terrestrial monitoring equipment could include devices to sound the ionosphere and magnetosphere and to monitor the sun at several wavelengths. The devices should be numerous enough and distributed geographically in order to permit regional forecasting. Space-based monitoring includes a broad range of devices deployed so as to monitor the sun and near earth space in order to provide the warning times required from the customer community. Space assets monitoring the radiation environment should be located so as to protect space infrastructure, *e.g.* the GEO belt. The networks should run continuously. The World Meteorological Organization's Inter-programme Coordination Team on Space Weather (see references)

Table 1
Notional warning times for representative customer groups. HSF = human space flight. S/C = spacecraft.

Phenomenon	Warning time (h)	Mitigation	Users
GNSS signal	8	Transfer to back-up systems	Defense, industry
HF communications	8	Re-routing aircraft	Defense, airlines
Cis-lunar radiation	2	Cancel EVA, seek shelter, safe modes	HSF, satellites
Interplanetary radiation	48	Safe modes	Exploration S/C
Thermospheric density	8	Update atmospheric models	Space control
Geomagnetic field	2	Grid protection	Electric utilities