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Executive Summary

The Space Weather Community Operations Workshop (SpWx COW) is designed as an open forum that allows participants to converse candidly about their experiences in Space Weather operations. The first conference took place in February 2011 at Utah State University in Logan, Utah and included representatives from six organizations: NOAA SWPC, SEC, UCB LASP, NASA, CCMC, SET SWD and USU SWC. Members of the community shared their experiences and made suggestions for improving processes.

The first event was such a success that a second workshop was planned for 2012. The Second Annual Space Weather Community Operations Workshop was held March 22-23, 2012 in Park City, Utah at the Newpark Resort. Four organizations sponsored the event: ACSWA, AIAA, AMS and USU SWC. Representatives from 11 organizations were present. The organizations represented were: AER, CCMC, CSPAR, EXPI, LASP, NOAA SWPC, RSI, SEC, SET, USGS and USU SWC. The meeting consisted of an open forum where organizational representatives shared their operational activities and answered questions from peers regarding those operations. Also, a large part of the workshop consisted of discussing lessons learned in Space Weather operations and mission assurance best practices that can be implemented by institutions performing Space Weather operations. These mission assurance best practices include reliability, maintainability, accessibility, dependability, safety and quality (RMAD SQ). The workshop also included three focused discussions, as follows:

1. CME forecast, ensemble modeling (CMEs, Dst)
2. Hi-lat energy inputs – Intermagnet, SuperMag, Boyle Index
3. Cloud Network: URL links, KMZ files, subscription lists, products/services/kiosks; team best practices, document as you go

This document is a recap of the lessons learned and best practices discussed at the meeting. It includes ideas and solutions mentioned and discussed by representatives of the 11 organizations who attended the 2012 workshop.
Sponsors

We’d like to express our thanks to our sponsors:

• The American Commercial Space Weather Association (ACSWA)
• The American Institute of Aeronautics and Astronautics (AIAA)
• The American Meteorological Society (AMS)
• The Utah State University Space Weather Center (USU SWC)
Workshop Objectives
The objective of the Space Weather Community Operations Workshop (SpWx COW) is to bring together commercial, agency and university Space Weather operational personnel in a two-day meeting to promote a robust data exchange capacity within the Space Weather enterprise. This data exchange focuses on sharing common operational problems and solutions, as well as working toward developing best practices that will eventually become standards for Space Weather operations.

Agenda

<table>
<thead>
<tr>
<th>Wed Mar 21</th>
<th>Time</th>
<th>Session</th>
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</thead>
<tbody>
<tr>
<td>18:00 – 19:00</td>
<td>Informal Welcome Reception</td>
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<tr>
<td>19:00 – 20:30</td>
<td>Dinner</td>
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<table>
<thead>
<tr>
<th>Thu Mar 22</th>
<th>Time</th>
<th>Session</th>
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<tbody>
<tr>
<td>06:30 – 06:40</td>
<td>Intro from Kent</td>
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<tr>
<td>06:30 – 10:10</td>
<td>Advances in Space Weather Operations - I (Agencies) (Meehan)</td>
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<tr>
<td>06:45 – 08:05</td>
<td>Mike Husler</td>
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<tr>
<td>09:05 – 09:25</td>
<td>Aleksandr Taktakisvili</td>
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<tr>
<td>09:25 – 09:45</td>
<td>JaSeok Shim</td>
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<tr>
<td>09:45 – 10:05</td>
<td>Jennifer Gannon</td>
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<tr>
<td>10:20 – 10:40</td>
<td>Chris Jeppesen</td>
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<tr>
<td>10:20 – 12:00</td>
<td>Advances in Space Weather Operations - II (University/Commercial) (Gardner)</td>
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<tr>
<td>10:40 – 11:00</td>
<td>Ramkumar Balasubramanian</td>
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<tr>
<td>11:00 – 12:00</td>
<td>Ludger Scherliess</td>
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<td>11:20 – 11:40</td>
<td>Rick Quinn</td>
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<td>11:40 – 12:00</td>
<td>Ghee Fry</td>
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<td>12:00 – 13:30</td>
<td>Lunch</td>
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<td>13:30 – 13:50</td>
<td>Don Rice</td>
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<td>13:30 – 15:10</td>
<td>Advances in Space Weather Operations - III (University/Commercial) (Hunsaker)</td>
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<tr>
<td>13:50 – 14:10</td>
<td>Vince Eccles</td>
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<td>14:10 – 14:30</td>
<td>Dave Bouwer</td>
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<td>14:30 – 14:50</td>
<td>David Hansen</td>
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<td>14:50 – 16:10</td>
<td>Jinni Meehan</td>
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<td>16:20 – 17:00</td>
<td>Developing Maintainable Operational Systems (Bouwer)</td>
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<tr>
<td>17:00 – 18:00</td>
<td>Social Hour</td>
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<tr>
<td>18:00 – 18:30</td>
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<th>Fri Mar 23</th>
<th>Time</th>
<th>Session</th>
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<tbody>
<tr>
<td>08:30 – 10:10</td>
<td>Creating Accessible Data Distribution Systems (Husler)</td>
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<tr>
<td>10:20 – 12:00</td>
<td>Ensuring Reliability in Operational Data Systems (Gannon)</td>
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<tr>
<td>12:00 – 13:30</td>
<td>Lunch</td>
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<tr>
<td>13:30 – 15:10</td>
<td>Building Dependable Data Networks (Eccles)</td>
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<tr>
<td>15:20 – 17:00</td>
<td>Operational Space Weather - Best Practices and Implementation (Tobiska)</td>
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Space Weather Lessons Learned

Don’t try to reinvent the wheel

The idea of “not reinventing the wheel” became the unofficial motto of SpWx COW, due to heavy focus on metadata, data reliability and the evolution of Space Weather operations throughout presentations given by attendees.

Metadata

Vince Eccles from Space Environment Corporation described metadata, saying that it is commonly referred to as “data about the data” or “content about the content.” He pointed out that often times data, programs, etc., are virtually unusable because information about what is being used does not accompany the data (e.g., basics such as column labels, missing value flags, responsible Institution/Point-of-contact, etc.). For example, in a table of data, are the columns specifically labeled? It often depends on the file type being labeled. Metadata in the form of headers and comments make parsing the data easier and, in turn, make the data more usable because the user knows what they are getting. A goal, then, is to encourage creators and updators of content to use metadata that is applicable to the content and the expected usage. When creating content, taking a few moments to provide descriptions about the data makes that content immensely more usable to an end user. Likewise, it is essential for those who maintain content to provide data about changes and fixes that they implement. Doing these simple things makes reinventing the wheel, or recreating content from scratch, often unnecessary. It also saves the end user a lot of headache in using a given piece content.

Data Reliability

Reliable data access is a necessity in the Space Weather operations community. There are many problems caused by unreliable data sources. Rick Quinn of AER described these problems. Included are failures to ingest data that can impact operations with possible effects on related products (domino effect):

- Allowing large gaps in a data set
- Failure to deliver core products
- No data, improper values loaded into delivery files

The causes of unreliable data sources can vary. Some causes are:
At a data center level
- Hardware and disk failures may occur
- Network connectivity problems (firewall, routing, etc.)
- Power Failures and unforeseen forces of nature

Data format changes
- Can occur with little to no notice
- Leads to parsing problems

Download site unavailability
- Internal data path changes – inability to locate remote data
- Disk problems can lead to missing data
- Frequent password changes – login failures requiring administrative action

Users have experienced unreliable source data when:
- sites routinely change format with little or no notice
- data is unavailable due to frequent data outages from disk or server failure
- stringent password policies require frequent updates

Because Space Weather products usually rely heavily on shared data, it is vital to ensure that data comes from reliable sources or is provided through reliable means. Data stream redundancy is important.
The Evolution of Space Weather Operations

Dave Bouwer of Space Environment Technologies presented an overview of the evolution of space weather centers over the past three decades, emphasizing how basic computer frameworks at isolated data centers have rapidly become interconnected in “Daisy Chains” with increasingly large and complicated data sets. While the complexity and volume of space weather products has increased dramatically, the end users require specific solutions – from computer-to-computer data exchanges, to smart phones and other appliances that can be used in the field. For example, a surveyor needs GPS uncertainties at a specific location using a smartphone; they do not need global TEC maps accompanying large binary data files.
Space Weather Operations Recommendations

Recommendations from the second annual SpWx COW have been split into six categories of **Mission Assurance Best Practices**: Reliability, Maintainability, Accessibility, Dependability, Safety and Quality.

**Mission Assurance Best Practices: Reliability**

In order to maintain reliable systems and data streams, redundancy is key. Creating several different channels, or streams, for data access makes systems more reliable by allowing data consumers multiple access points and relieving strain on systems. Levels of redundancy can be reached and maintained through several means. One means is already widely recognized: upgrading hardware and software system, clustering by adding more central processing unit (CPU) power, upgrading network communication systems, fail-over systems, mirrored or RAID disk systems, etc. These add power and speed to a system, creating faster access to data. A second method is through virtualization. This is done through creating and maintaining separate virtual “machines” within a stack or set of CPU’s. Virtualization provides a set amount of resources (RAM, CPU power, etc.) to a specific user. This allows for minimal downtime, as the virtual “machine” can be moved and backed up by the system administrator with little difficulty and with no negative effects. Virtualization also allows for seamless backups, system updates and failovers. Third, for failover systems, hot spares provide a safe, physical backup location, as it already runs as part of the system. Once a failure in the system is detected, the hot spare is activated, reducing mean-time recovery. Fourth, having physically redundant machines in separate geographical locations running identical software ensures that no single machine or facility failure will cause a data outage.

Third-party system monitoring through software such as Nagios, Big Brother, or other comparable maintenance tools, including homegrown monitoring webpages,
can be used to maintain an operational system and improve its reliability. These programs monitor internal websites and systems, providing alerts for systems, servers and applications, allowing administrators to quickly and efficiently repair any hiccups in the data stream. However, for automated space weather computer systems, other steps can be taken to reduce the impact of interrupted data services. One proposal by Dave Bouwer at SET is the use of a “Deadman” file or a performance monitor users or programs can monitor to ascertain the health of a data subsystem. A deadman file is created with every process, and until the file reports “All OK”, end users know to take mitigation measures.

Unreliable source data has a big impact on Space Weather products when downstream users are unable to ingest data. This can lead to large gaps occurring in data sets, causing a failure to deliver core products, and, in turn, can have a greater impact on related products. Similarly, problems with data parsing can create difficulty for providing products. This problem generally occurs when no data or improper data values are loaded into models, leading to inaccurate, or false, results. These results from unreliable source data are caused by a number of factors, i.e.: hardware and disk failure, network connectivity problems, power failure and other unseen forces of nature. Likewise, data formats (file types, etc.) can change with little notice, creating parsing problems.

In order to avoid these reliability issues, several steps can be taken to help prevent them. It should be noted that no system is impervious to reliability issues; the forces of nature often seem driven to cause problems, simply because they can. However, the following best practices can help prevent major problems. Creating and maintaining hardware redundancy will help improve reliability.

For hardware redundancy to be effective, backup systems must offload processing, maintain redundant disks for greater data availability, create SQL databases, which allow for pulling of specific missing data post-facto, and, finally, use standardized data formats that have been agreed upon by the community. These practices will help maintain reliable systems and will help prevent data loss and parsing problems.

**Mission Assurance Best Practices: Maintainability**

Maintaining systems for data processing and access can be difficult due to the complexity of the systems involved and potential reliability issues. In order to maintain
reliable systems, it is recommended that status reporting be done at the end of a program. This helps users avoid spending time tracking problems that don’t exist on their local system. Reporting can be done through methods like email, website posting, an automated Twitter account or an RSS feed. Whatever method is used, it must be consistent and follow standards that are already in place, as well as those that come out of the Space Weather community, use redundant systems and data streams and, most importantly, observe the trends of the end user and adapt accordingly.

Maintainability reaches beyond the system level though. It is important to create maintainable code. Such simple practices as consistent, intuitive file-naming conventions that are easy to understand, maintainable software, documentation (e.g., User guides, test plans, etc), and attention to other best practices in software development, are vital. Metadata about changes and important information about the code, e.g., version numbers, is necessary and beneficial to future users. The best practice here is to document as you go as this can migrate into a user’s guide for future users. Most importantly, if it isn’t broken, don’t fix it.

**Mission Assurance Best Practices: Accessibility**

Metadata plays a key role in accessibility. There are two types of metadata: Structural Metadata and Descriptive Metadata. Structural metadata is referred to as the “content of the content.” It is recommended that “#” should be used for comment lines, with “:” used for parsing out programming information and “;” used for IDL comment lines. This recommendation should be used with broadly approved formats, including FITS, XML and NetCDF.

When considering what to include in structural metadata, consider the Who, What, When, Where, Why, How and Whose.

- **Who:** The creator or author of the data; the institutional or organizational contact person; contact information for further information
- **What:** Acknowledge the source of the data to help users with traceability
- **When:** Time and date of file creation (UTC is recommended for all time tags)
- **Where:** Location of data (i.e.: URL); Where can one access the data? Where is it derived from? Where does it reside for access?
• Why: Purpose of the data, what’s its use? Audience can be producers or consumers of data; general description; identify intended uses; similar to XML comment tag

• How: Standards or methods used; program used to create the data; version numbers and dates of data and programs; names of programs created the code; enough information for the producer to recreate the data and provide traceability; description of the data

• Whose: Rights of usage; rules of the road, how to acknowledge the data, proprietary/ITAR/FAR/DFARS issues; warranty and licensing issues (pointers to these documents)

Considering these points will help in creating and developing meaningful metadata that will, in turn, benefit the end user. It is recommended to follow the current standards for metadata structure and use NetCDF, ISO and XML data definitions.

Descriptive metadata is also known as the “data about the data.” This metadata includes items like time stamps in the file for portability and describing the data, especially the geophysical units of the values being reported, goes a long way for helping the end user. Indicating analysis and source data dependencies, proper rules of usage and error estimates are proper for descriptive metadata in headers and/or readme files.

Customer responsiveness and latency play a role in accessibility. Customer responsiveness can give a feel for how accessibility of new products meets end user needs. Latency is customer-driven and can be seen as it takes minutes from spacecraft to dissemination.
Mission Assurance Best Practices: Dependability

When users rely on data and systems, dependability of data and systems become a main focus for data producers and maintainers. Producers and operators must have access to system level views because they provide a way to ensure a dependable system framework and determine most-likely and dynamic ranges of cases; this allows producers to set parameters and thresholds for operations. Producers must also consider customer desires for types of products (e.g., probabilistic vs. deterministic).

There are different programs and systems available to bolster dependability. ESWDS, a data portal provided by NOAA-SWPC, can provide: smaller data sets, security to trusted users, database access with lowest latency possible (compared to FTP or HTTP), users the choice of data preferred, alert logs in relational tables and traceability of data provisions. Java servlets provide similar benefits in accessing ESWDS data. The USGS Earthworm system also provides similar benefits to ESWDS. Earthworm includes TCP/IP between servers and “black box” push to outside users. From a security standpoint, users prefer to pull from Earthworm, while providers prefer to push as opening their firewall ports is a security issue in and of itself. Rsync, another available program, provides power, but security is an issue. Rsync, as a public protocol, is inherently weak to hacking. There is also ssh as a secure way to transfer and receive files and data. Finally, the cloud is an available system for dependable data transfer and receipt. The cloud could be used as a central data storage and distribution area. As there still exist considerable security concerns, the use of the cloud for data delivery is still evolving, but it has been proposed that a central Space Weather operational community cloud be set up with a common dashboard website pointing to data cross-linked to various Space Weather operational organizations.

A failover system can improve dependability by providing a redundant system that will take over in case the primary system fails. A failover system can provide contingency data and alternative data streams. Providing a failover system benefits the
end users and makes life easier for them, especially when used in conjunction with alerts systems for error reporting. This is the case, especially as systems are moving from human-managed manual systems to machine-managed automated systems.

Mission Assurance Best Practices: Safety and Quality

Safety and Quality of products go hand in hand. Since end users may rely on the quality of products for safety, products that deal with GPS must be quality products and they must contain a level of accuracy that ensure safe use. Quality of Space Weather products and data can be tested against several different challenges. Some of these challenges are GEM Metrics, CEDAR ETI, GEM-CEDAR (Dst) and SHINE. High quality products will help improve the safety of the same products, fostering a community perception of trustworthy space weather providers.