Space Weather in Support of Aviation

Status of Progress

Presented to: Space Weather Workshop (SWW)

By: Steve Albersheim, FAA (ANG-C6)

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Federal Aviation Administration

Organization

- **Background**
- **Concept of Operations**
- **Performance Requirements**
- **Schedule**
- **Summary**

Background

- International Civil Aviation Organization:
  - Recognized Space Weather (SWx) as a hazard to Aviation
  - Need for global harmonization of services
  - Air Navigation Commission tasked the International Airways Volcano Watch Operations Group (IAVWOPSG) to develop set of draft *Operational Requirements for SWx*

Concept of Operations

- **Draft developed that identifies**
  - ➢ High-Level Operational Requirements
  - ➢ Functional Requirements

  - ➢ Performance Requirements
    - ✓Threshold values (Spring 2012)
    - ✓Complete draft requirements (June 2012)
    - ✓ICAO's IAWWOPSG adopt ConOps (March 2013) as SWx RoadMap

http://www2.icao.int/en/anb/met/iavwopsg/Pages/default.aspx

Concept Document Elements

- **Reduce Impact of Space Weather phenomena on Polar Route operations with the objective to:**
  - Improve “Detect & Forecasts Skills” for operational impact assessments
  - Develop and comply with ICAO guidance and recommendations
  - Lead establishment of Global Observations, Forecast and Dissemination methodology
  - Implement use NOAA Space Weather Scales for operational decisions
    - Intensity index and frequency of event occurrence
  - Integrate SWx information into global TFM Procedures

General Outline of ConOps

- **Purpose and scope**
- **User Needs**
- **Impacts: communications & navigation**
- **Types: Observation and Forecast**
- **Functional Requirements**
- **Providers of information**
- **Service: standardization of products and delivery**
- **Operational scenario**
- **Requirements: performance**

Performance Requirements

- Team to validate space weather functional and performance requirements
  - **Functional Requirements state what must be done**
    - **Observe Space Weather**
    - **Forecast Space Weather**
  - **Performance Requirements state how well it must be done**
    - **Observe Space Weather with an Accuracy of ± X**
    - **Forecast Space Weather with an Accuracy of ± Y**
- How team will validate the space functional & performance requirements:
  - **Review draft functional requirements to ensure all needed space weather types are included**
  - **Evaluate the performance values required for any changes to specific capability thresholds needed for 2016 implementation**
  - **Findings incorporated into draft ConOps**

Space Weather Performance Criteria for Observations and Forecasts

Impact	Space Weather Element + Fcst Lead Time	Accuracy	Observations and Forecast Threshold(s)	Operations Impact	Notes
Communications **Navigation**	**Solar Radiation Storm** **6 hours**	± 10 5% above median background	Levels S1 through S5 (particle flux units) **S3 level or > generally impacts operations**	Degraded HF in polar region Navigation position errors **Effects within few hours of event lasting for a day or more**	NOAA Space Weather Scale for Solar Radiation Storms S1 through S5
	Solar Geomagnetic Storm **6 hours**	± 10% ± 1 Kp index	Levels G1 through G5 (Kp index) **G3 level or > generally impacts operations**	Degraded Satellite Navigation and HF Communication **Effects in 18-96 hr range lasting hours to day(s)**	NOAA Space Weather Scale for Geomagnetic Storms G1 through G5
	Radio Blackout **6 hours**	± 10%	Levels R1 through R5 ($W \cdot m^2$) **R3 level or > generally impacts operations**	Wide spread HF outage immediately on sunlit side of earth **Lasting minutes to an hour**	NOAA Space Weather Scale for Radio Blackouts R1 through R5
Ionospheric Activity **N/A**	**Total Electron Content**	± 25%	N/A (No thresholds yet)	Communication/Navigation Impact **Daily variations**	Product in Map Format
	Amplitude Scintillation Index	± 0.1			
	Phase Scintillation Index	± 0.1			
	D-Region Absorption	± 5 MHz			

Space Weather Performance Criteria for Obs and Forecasts (Draft)

Impact	Space Weather Element	Verification*	Obs and Forecast Threshold(s)	Operations Impact	Notes
Communications **Navigation**	**Solar Radiation Storm**	7 days – 55% 3 days – 60% 30 hrs – 70% 12 hrs – 80% 6 hrs – 90% Obs – 95% (*2016)	Levels S1 through S5 (particle flux units) **S3 level or > generally impacts operations**	Degraded HF in polar region Navigation position errors **Effects within few hours of event lasting for a day or more**	NOAA Space Weather Scale for Solar Radiation Storms S1 through S5
	Solar Geomagnetic Storm		Levels G1 through G5 (Kp index) **G3 level or > generally impacts operations**	Degraded Satellite Navigation and HF Communication **Effects in 18-96 hr range lasting hours to day(s)**	NOAA Space Weather Scale for Geomagnetic Storms G1 through G5
	Radio Blackout (Solar Flares)		Levels R1 through R5 ($W \cdot m^2$) **R3 level or > generally impacts operations**	Wide spread HF outage immediately on sunlit side of earth **Lasting minutes to an hour**	NOAA Space Weather Scale for Radio Blackouts R1 through R5
	Ionospheric Activity (Obs)				
	Total Electrons	Obs - 95% (*2016)	N/A (No thresholds yet)	Communication/Navigation Impact **Daily variations**	Product in Map Format
	Amplitude/Phase Scintillation Indices				
	D-Region Absorption				

30-Hour Forecast Details

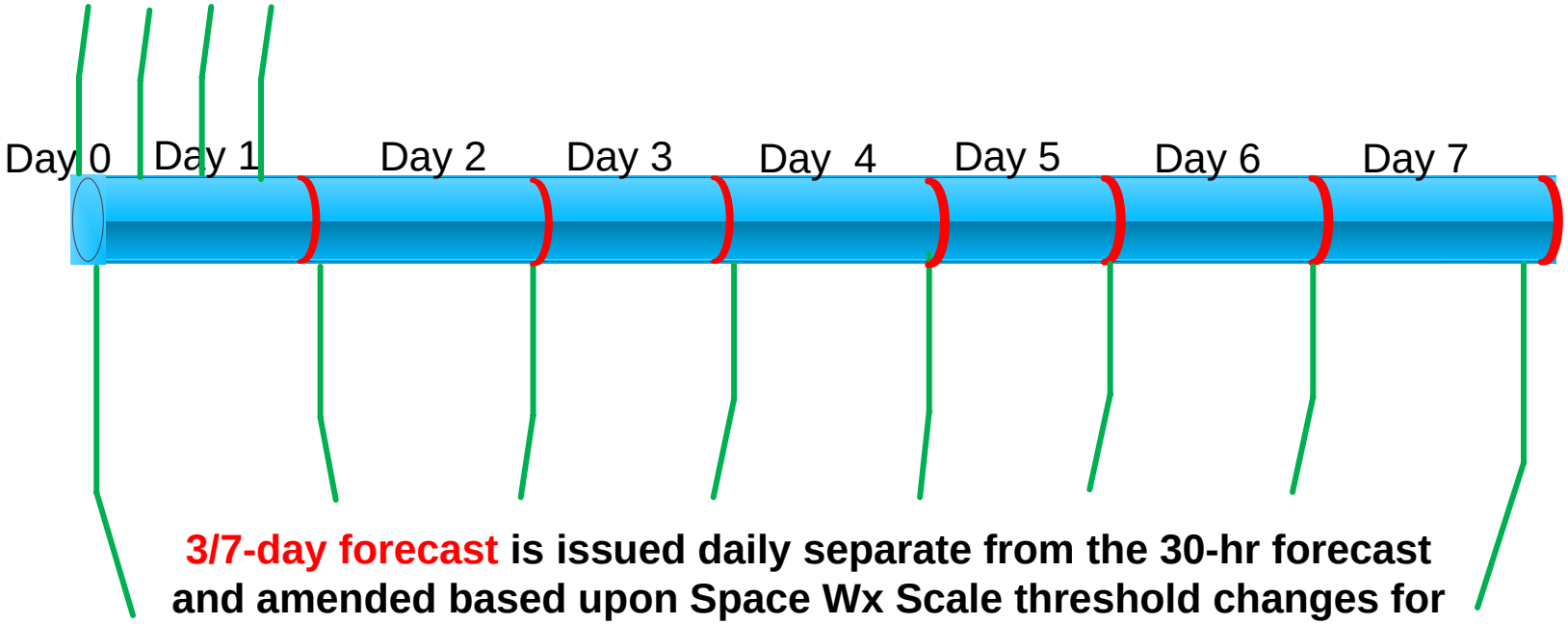
- **Issued every 6 hours (4 times per day out to 30 hours)**
  - TBD: NIL or Forecast changes in SWx Scales
  - Amendments based upon
    - ✓ Observation: Change in SWx Scales (*commonly associated with the SWPC use of the word "Alert")*
    - ✓ Forecast: Expected imminent change in SWx Scales - (*commonly associated with the SWPC use of the word "WARNING")*
    - ✓ Forecast: Potential changes in SWx Scales – (*commonly associated with the SWPC use of the word "WATCH")*

3/7-Day Forecast

- **Issued daily**
  - NIL or SWx Scale predictions (days 1-3) and general outlook (days 4-7)

Solution – Option X
Forecast Types and Update Rates

30-hr forecast issued every 6-hrs or 4 times/day and amended based upon Space Wx Scale threshold changes



3/7-day forecast is issued daily separate from the 30-hr forecast and amended based upon Space Wx Scale threshold changes for days 1,2, and 3

Issues

- **Items that still need to be resolved:**
  - Do the 30 hr & 3/7 day forecasts meet your operational requirements?
  - Does the 30-hr forecast only need to be issued when there's potential solar activity expected within the 30-hour period?
    - ✓ Is a NIL (no solar activity) 30-hr forecast needed 4 times at day?
  - Does a daily 3/7 day NIL (no solar storms) forecast meet your operational requirements?
  - Which NOAA Space Weather Scale values impact your operational decisions?
  - What Level of accuracy is acceptable for operational decisions?

- **Strawman has been proposed**

Schedule

- **2011: Draft ConOps**
- **2012: Develop initial set of Performance Requirements and Complete ConOps for presentation at IAVWOPSG March 2013**
  - Based Requirements (Current capabilities)
  - Gap analysis
- **2013: Validate Performance Requirements**
- **2014: Adopt ConOps + SWx SARP for ICAO/WMO Divisional Meeting**
- **2016: Implement SWx SARP**

Summary

- **Draft ConOps on ICAO Web page for comment**
- **Comments due by June 30, 2012**
- **FAA as rapporteur will review all comments received and report back to IAVWOPSG with recommendation on ConOps**
- **Adoption of ConOps targeted for ICAO/WMO Divisional Meeting in 2014**
- **SARPS for Annex 3 with Amd 77 in 2016**

Questions

NOAA Space Weather Storm Scale for Radiation Storm Events Solar Radiation Storms			Flux level of ≥ 10 MeV particles (ions)*	Number of events when flux level was met**
S 5	Extreme	Biological: unavoidable high radiation hazard to astronauts on EVA (extra-vehicular activity); passengers and crew in high-flying aircraft at high latitudes may be exposed to radiation risk. *** Satellite operations: satellites may be rendered useless, memory impacts can cause loss of control, may cause serious noise in image data, star-trackers may be unable to locate sources; permanent damage to solar panels possible. Other systems: complete blackout of HF (high frequency) communications possible through the polar regions, and position errors make navigation operations extremely difficult.	10^5	Fewer than 1 per cycle
S 4	Severe	Biological: unavoidable radiation hazard to astronauts on EVA; passengers and crew in high-flying aircraft at high latitudes may be exposed to radiation risk.*** Satellite operations: may experience memory device problems and noise on imaging systems; star-tracker problems may cause orientation problems, and solar panel efficiency can be degraded. Other systems: blackout of HF radio communications through the polar regions and increased navigation errors over several days are likely.	10^4	3 per cycle
S 3	Strong	Biological: radiation hazard avoidance recommended for astronauts on EVA; passengers and crew in high-flying aircraft at high latitudes may be exposed to radiation risk.*** Satellite operations: single-event upsets, noise in imaging systems, and slight reduction of efficiency in solar panel are likely. Other systems: degraded HF radio propagation through the polar regions and navigation position errors likely.	10^3	10 per cycle
S 2	Moderate	Biological: passengers and crew in high-flying aircraft at high latitudes may be exposed to elevated radiation risk.*** Satellite operations: infrequent single-event upsets possible. Other systems: effects on HF propagation through the polar regions, and navigation at polar cap locations possibly affected.	10^2	25 per cycle
S 1	Minor	Biological: none. Satellite operations: none. Other systems: minor impacts on HF radio in the polar regions.	10	50 per cycle