

SWPC Customer Requirements

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User Requirement	Timeliness	Customer	Rationale
AVIATION			
Forecasts (text or graphics) of radiation storms (proton events) at energy levels that could create a radiation hazard for aircrew and passengers	6, 12, and 18 hours	Airlines	Forecasts need to be early enough to plan a crew change (for a stop in route) and/or flight-plan. 18 hours is best but a lesser lead time will still aid in the decision making
Space Weather Outlook: A text discussion on potential space weather impacts on aviation.	7-day outlook, updated daily	Aviation agencies Airlines	Identified by airlines as a very useful planning product
Nowcasts (text or graphic) of radiation storms (proton events) at energy levels that could create a radiation hazard for aircrew and passengers	Near real-time (<30 minutes)	Airlines	Will enable mitigation procedures to reduce dose during extreme radiation storms
Graphical forecast product to include intensity, onset and duration, and boundary of degraded communication areas for Polar routes	12 to 24-hours Updated every 6 hours	FAA NavCanada (Air Traffic Control) Airlines	Accurate predictions will help with route selection and management, emergency response, and other critical decision making processes at the control centers
Forecasts and specification of HF outage areas at low and middle latitudes	Any prediction capability of this impact is wanted.	Communications agencies	Communications agencies will enable back-up procedures when HF communication is unusable over the

	Probability forecasts are of limited use.	Airlines	oceans.
Geomagnetic Kp >10 MeV protons Current and Forecasts	Current and short term (hours) forecasts	FAA	The information is sent to FAA engineers across the U.S. and to FAA Senior management for the purposes of correlating space weather events with HF and VHF system problems that may have been unexplained.
TEC and ionospheric scintillation for GPS applications	TBD in developing NextGen requirements	FAA Airlines	Satellite navigation is a cornerstone of NextGen (i.e., ADS-B). This reliance on GPS/GNSS necessitates space weather products for the conditions that impact the accuracy and availability of GPS.
<i>Electric Utilities</i>			
Geoelectric Field Vector	6 hr. forecast, updated hourly	Various Power Companies	To know the key ingredient that plays into the GIC at selected points, is a critical parameter for the industry. To do this requires local dB/dt and geologic conductivities.
K-7 Geomagnetic Storm Warnings	Minutes to hours Operators want as much lead time as possible, but any lead time is considered useful	North America Electricity Reliability Corp. Midwest Independent System Operator Electricity Reliability Coordinators	The Midwest Independent System Operator receives the K-index forecast. If the index is K-7 or higher, MISO notifies all NERC reliability coordinators concerning the level and expected duration of the specific event. These forecasts are shared with all power system operating entities throughout North America so that those power systems that are particularly susceptible

			to this phenomenon can institute preventive procedures
Geomagnetic Storm Warnings/Watches	1-2 days >50% accuracy	Various Power Companies	Allows maintenance procedures that shut down some facilities to be rescheduled, thus maintaining the full reserve for emergency situations.
Geomagnetic Storm Warnings (K-5 through K-9)	2-3 hours >80% accuracy	Various Power Companies	Bring reserve or maintenance generation on line
Geomagnetic Storm Warnings (K-5 through K-9)	15-30 minutes >90% accuracy	Various Power Companies	Reduce loading: use more conservative margins
Geomagnetic Storm Warnings (K-5 through K-9)	5 minutes >99% accuracy	Various Power Companies	Desensitize SVAR device protective relay setting. These circuits are used in power grids to isolate problems that are unrelated to GICs but can also be tripped by a secondary reaction to GICs when the GIC magnitude is large but not in itself damaging.
Geomagnetic storm outlook	3-Day	Various Power Companies	Valuable tool for planning purposes
Real-time geomagnetic monitoring data for GIC confirmation.	Every 15 minutes	Various Power Companies	Real-time measurements from sensors located regionally would better assess the GIC threat for any given station
Graphical Products - Regional Auroral electrojet	Updating in real time	Various Power Companies	Improved determination of the electric fields produced during geomagnetic disturbances by including the effect of the structured source fields produced by the auroral electrojet
Graphical Forecast Products of real-time GIC flow throughout the power system	Updating in real time	Various Power Companies	Needed to determine the GIC distribution regionally across the system, and examination of factors affecting transformer saturation, harmonics that are produced and where they flow in the system.
Geo-alert status	As needed	Various Power Companies	Continual updating of geo-alert status so that power system operations can return to normal as soon as possible.

Spatially resolved forecasts of large <u>geomagnetically induced currents</u> , to allow mitigation measures to be taken	>1 hour (1-2 days preferred)	Various Power Companies	1-2 days warning is preferred since it allows rescheduling of generator and circuit downtime. However, useful mitigation can be taken based on warnings at shorter notice.
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GEOLOGICAL

Forecasts of perturbations in the geomagnetic field	>1 day	Geological prospectors Mining and drilling operations	Long lead time needed for planning surveys. Shorter warnings will ensure poor quality surveys are avoided. Some users request data 1-3 days in advance.
Post-event knowledge of perturbations in the geomagnetic field	<1 day	Geological prospectors and drilling industry	It is estimated that correction of magnetically oriented drilling requires a time-scale of about 1 day to prevent drilling errors becoming unacceptable.
Predictions of Ionospheric Scintillations and TEC	>1 day	Geophysical Surveyors	Precision GPS is a keystone for exploration geophysics, and there is a need to know a priori of conditions that affect accuracy and availability of GPS.

RADAR and COMM SYSTEMS

Forecasts of ionospheric disturbances leading to loss of range, degradation and outage of radio	> 1 day	RF systems (civil and military)	RF systems include radar and comms to and from spacecraft. Timeliness requirements depend strongly on the user. 1 day is taken as a typical time for
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communications e.g. fadeout, polar cap absorption and scintillation			alternative communications to be arranged.
Now-casts of ionospheric reflection properties for HF frequency selection	< 5 minutes	RF systems (civil and military)	Frequency selection to include density profile, not just f0F2. These data also give real-time information on over-the-horizon radar range and blind-spots.
Solar Radio Emissions 1400 – 5000 MHz Nowcasts and Forecasts	Minutes to hours	Radar installation and maintenance companies	Perform antenna installations Radar Calibrations Engineers need short-term forecasts when they begin calibrations

GNSS and NAVIGATIONAL APPLICATIONS

Now-casts of ionospheric total electron content	Nowcasts	GNSS location systems Radar systems. (civil and military) Drilling operations Surveying Navigation systems	Real-time data are needed for correction of GNSS positions. Trans-ionospheric radar systems are affected. Radio tracking of satellites and radio-location of emergency beacons are similarly affected.
Forecasts of ionospheric total electron content	>1 hour	GNSS location systems Radar systems. (civil and military) Drilling operations Surveying Navigation systems	Accurate predictions of a disturbed ionosphere will ensure GNSS systems users postpone or modify operations dependant on precision measurements
Geomagnetic Kp and Ap Forecasts	Hours to days	Surveying	Used for planning and scheduling work If activity is expected they consider rescheduling the survey so as to avoid erroneous survey results
Now-casts of ionospheric phase and amplitude scintillations	Nowcasts	Many – precision agriculture, precise surveying, NextGen...;	The future of GNSS brings more civil frequencies. BUT, those new frequencies only add value IF they can

		anything that requires multiple frequencies	all be received. Even under quiet conditions, multiple frequency techniques increase multipath error, so knowledge of the ionosphere is most important to optimize the value of the application.
Forecasts of ionospheric phase and amplitude scintillations	>1 hour, up to 1-2 days	See previous	Same as above.
SATELLITE OPERATIONS			
Forecasts of hazardous environments affecting operational satellite systems. Energetic particle events and geomagnetic storm conditions of varying intensities	>1-2 days	Satellite operators (civil and military)	Enables preventative measures to be accomplished and recovery procedures prepared. Spacecraft vulnerabilities vary.
Now-casts of hazardous environments affecting operational satellite systems. Energetic particle events and geomagnetic storm conditions of varying intensities	< 5 minutes	Satellite operators (civil and military)	Now-casts are useful since disturbed environments are often long lasting and it is often not too late to enable preventative measures to be taken and recovery procedures prepared, Spacecraft vulnerabilities vary.
Now-casts of atmospheric drag for LEO spacecraft	< 5 minutes	Satellite operators (civil and military) (and ballistic missile defense)	A LEO requirement only. Drag information is needed for orbit, re-entry and attitude perturbation calculations. In military use, LEO spacecraft orbit calculations are required as a part of ballistic missile defense.
F10	Current values	NASA	Essential in meeting the orbit

<p>Kp and Ap indices</p> <p>Forecasts and observations</p>	<p>Daily forecasts</p> <p>3-day forecasts</p> <p>27-day forecasts</p>		<p>determination accuracy requirements for NASA missions, where they routinely determine the orbit to within 20 meters, while the predicted values allow for accurate orbit predictions that are required for mission planning and scheduling.</p>
<p>Localized environmental assessments at given satellite orbits</p>	<p>Real-time</p>	<p>All satellite agencies</p>	<p>Critical need for anomaly assessments</p>
<p>Post-event information on environments affecting operational satellite systems, e.g. radiation and charging environment</p>	<p>< 1 day</p>	<p>Satellite operators (civil and military) and Insurance and financial services</p>	<p>Post-knowledge is considered valuable for diagnosis of anomalies.</p>
<p>Prediction and specification of >10 MeV proton flux</p>	<p>Two days before launch to four minutes before launch.</p>	<p>Integrated Flight Test launch (IFT) vehicles (IFT13 and 14 vehicles)</p>	<p>>10 MeV proton flux must be less than 10 pfu for launch</p>
<p>Prediction and specification of >50 MeV protons</p>	<p>Two days before launch to four minutes before launch.</p>	<p>Satellite launch companies</p>	<p>Launch teams are concerned with the possibility of a proton event causing single-word multiple upsets in the rocket control circuitry during launch. The warning provides situational awareness for spacecraft launch operations. They will monitor the proton flux closely and they will hold the launch if they see more than 100 PFU at > 50 MeV. Warnings of severe events more than 1 day ahead would allow a planned launch delay.</p>

NASA and DEEP SPACE OPERATIONS

Onset time for a SEP event 30 MeV up to 100-200 MeV	10 to 12 hour forecast prior to a likely event	NASA International space agencies Commercial space providers	Higher confidence in exposure forecast Greater mission schedule assurance
Predict time of arrival and magnitude of shock- enhanced peak 30 MeV up to 100-200 MeV	At Event on-set	NASA International space agencies Commercial space providers	Higher confidence in exposure forecast Implementation of more flexible flight rules Reduced period of uncertainty Greater EVA scheduling flexibility
Predictions of the temporal evolution profile of the SEP event at selected energies with associated probabilities.	6 to 8 hour forecast of magnitude and spectral slope after event on-set	NASA International space agencies Commercial space providers	Higher confidence in exposure forecast Implementation of more flexible flight rules Reduced period of uncertainty Greater EVA scheduling flexibility
Rolling forecast as SPE progresses	Every 3-4 hours	NASA International space agencies Commercial space providers	Higher confidence in exposure forecast Implementation of more flexible flight rules Reduced period of uncertainty Greater EVA scheduling flexibility

Peak flux and intensity profile from the actual event at the selected energies in real time.	Hours to one day	NASA International space agencies Commercial space providers	Higher confidence in exposure forecast Implementation of more flexible flight rules Reduced period of uncertainty Greater EVA scheduling flexibility
Reliable forecasts of no solar activity of interest—i.e., all-clear forecasts. 95% Accuracy Avoid 95% of SPEs	3 – 7 Day	NASA International space agencies Commercial space providers	Higher confidence in exposure forecast Greater EVA scheduling flexibility Greater mission schedule assurance
An all-clear forecast following a major SEP event or geomagnetic storm so that normal operations can be resumed. (Reliability TBD)	As Needed	NASA International space agencies Commercial space providers	Higher confidence in exposure forecast Greater EVA scheduling flexibility Greater mission schedule assurance
The anisotropy in the particle velocity distribution	TBD	NASA International space agencies Commercial space providers	
Geomagnetic storm levels	TBD	NASA Shuttle/ISS	Cutoff latitudes

International Space Station & Shuttle Avionics

Command & Data Handling, Comm & Track, Environment & Life Support, Power, Robotics, Thermal Control

<p>Prediction and specification of differential energy particle spectra as a function of time inside / outside magnetosphere</p> <ul style="list-style-type: none"> • ion species (z=1 to 28) (spectra for selected elements would be acceptable - helium, protons, oxygen, iron) • energy (10 to 2000 MeV/n) 	TBD	<p>ISS</p> <p>Shuttle</p> <p>Mars Missions</p>	<p>>400 equipment items susceptible to Single Event Latch-up (it is recommended these be powered down during a large proton event)</p> <p>Space Station needs time to prepare to shut down equipment</p>
<p>Prediction and Specification of geomagnetic field– Geomagnetic index (Kp) - onset and progression</p>	TBD	<p>Boeing</p> <p>ISS Partners</p>	<p>Situational Awareness and anomaly assessment on ISS</p>
<p>Alerts and Warnings of 50 PFU at > 100 MeV</p> <p>(Accuracy TBD)</p>	TBD	<p>Boeing</p> <p>ISS Partners</p>	<p>ISS</p> <p>Shutdown the robotic arm to prevent electronics damage.</p>
<p>Alerts and Warnings 100 pfu at > 100 MeV</p>	TBD	<p>Boeing</p> <p>ISS Partners</p>	<p>Alert the flight team in Mission Control. The Flight Team will start to evaluate a plan to shutdown equipment to prevent damage to electronics.</p>
<p>Alerts and Warnings 200 pfu > 100 MeV</p>	TBD	<p>Boeing</p> <p>ISS Partners</p>	<p>Implemented plan to shutdown equipment to prevent damage to electronics.</p>

