

Space Weather

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Outline

About space weather, including a very little physics

Customers

Aviation

GPS users

Electric grids

Satellite operations

National Space Exploration Program

National security

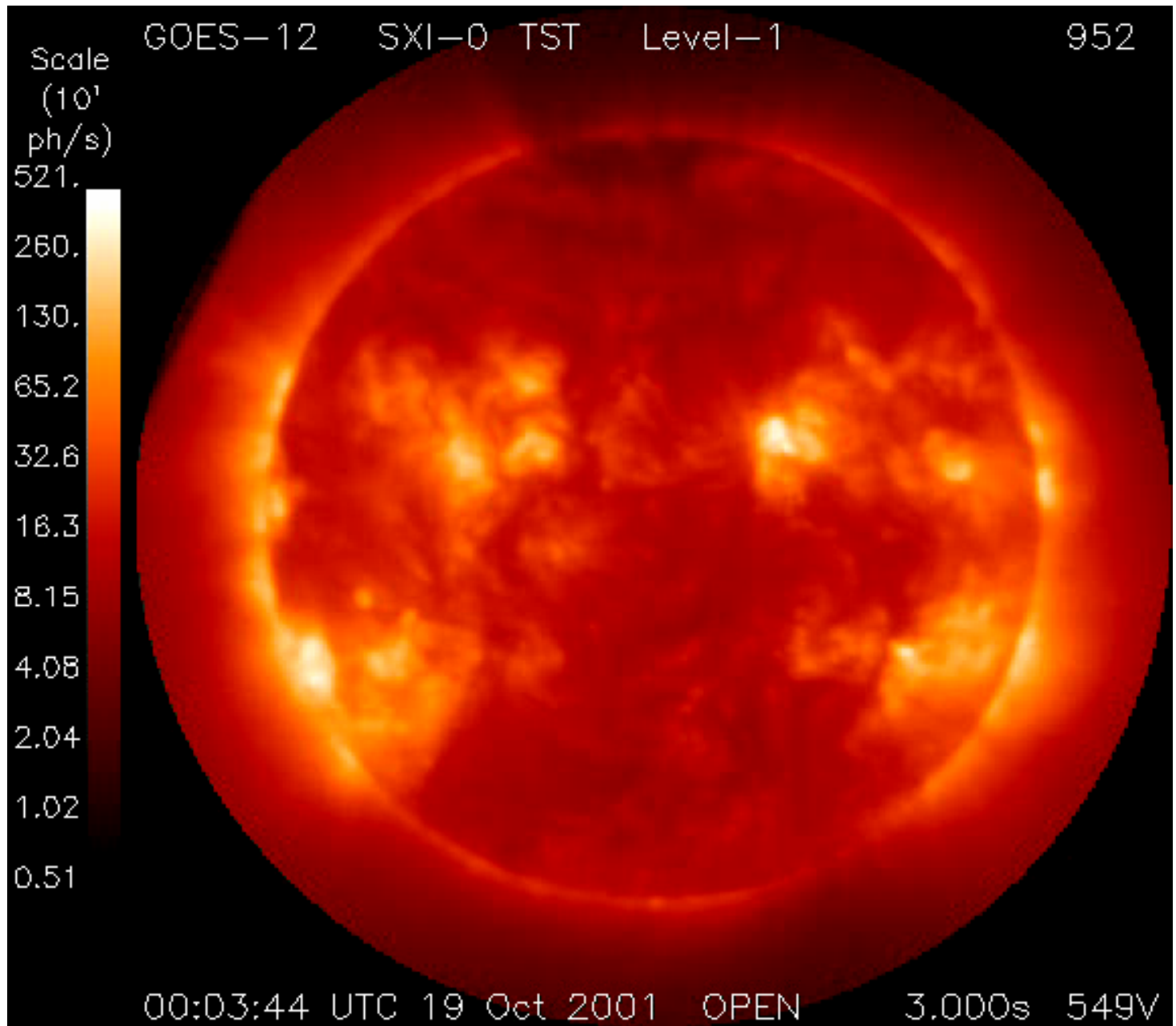
Conclusions

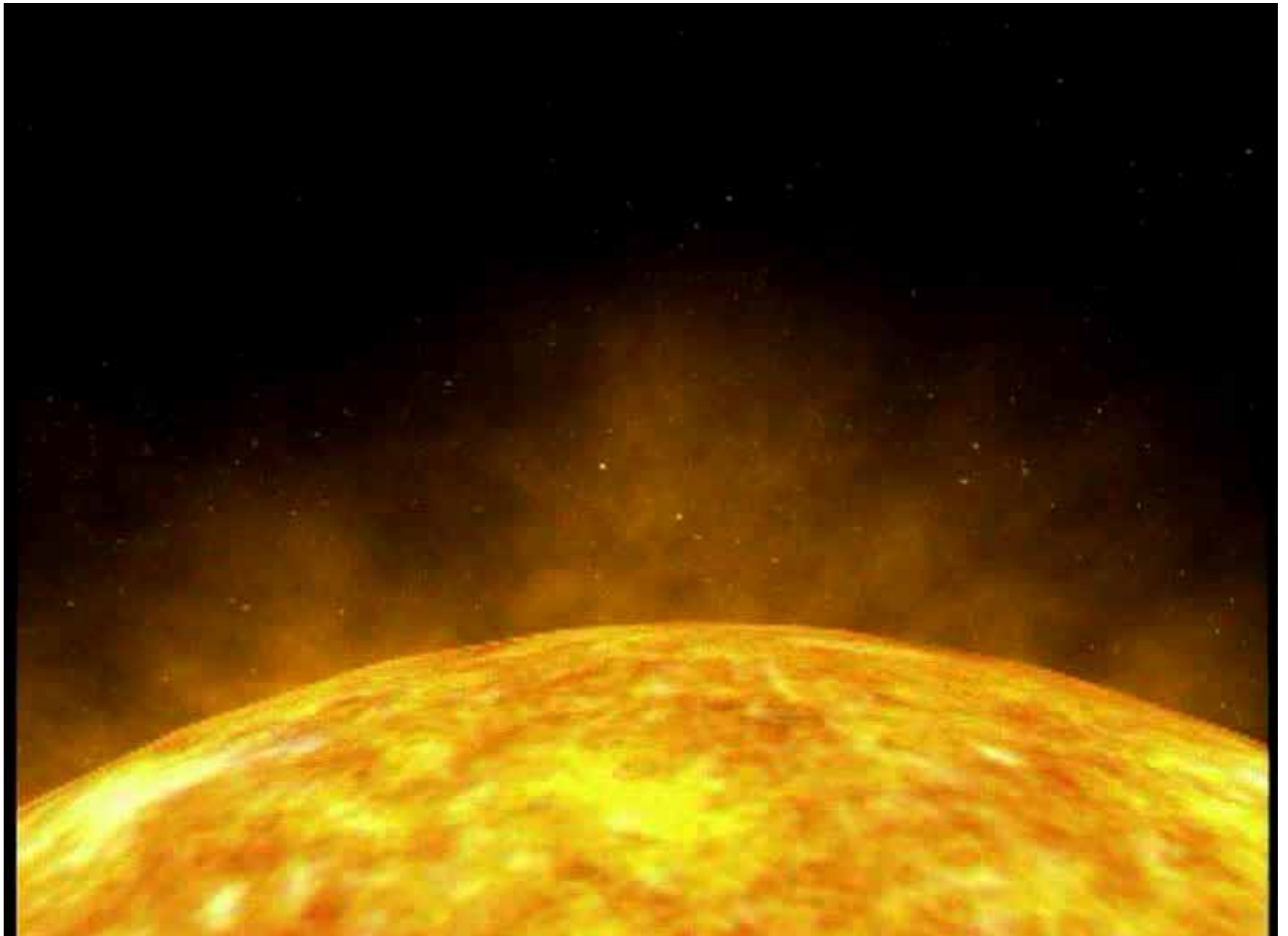
NWS Space Weather Mission

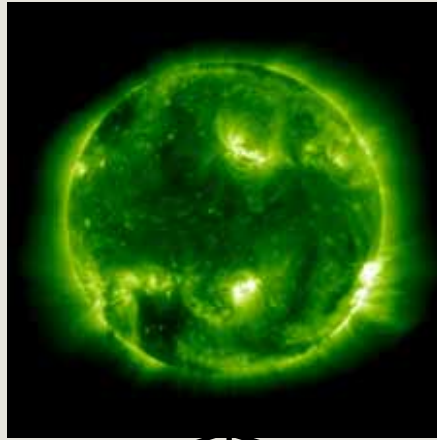


The objectives of the National Weather Service Space Weather Service Program are to provide space weather forecast information and services to the Nation for protection of life and property, and to develop new products and services to meet the needs of users of space weather information and services.









Solar Flare

(Electromagnetic Radiation)

ARRIVAL: 8 min

DURATION: 1-2 HOURS

EFFECTS

- HF RADIO BLACKOUT
- SATCOM INTERFERENCE
- RADAR INTERFERENCE
- GPS LOSS OF LOCK

Radiation Storm

(High Energy Charged Particles)

ARRIVAL: 15 MIN TO FEW HOURS

DURATION: DAYS

EFFECTS

- HIGH-LATITUDE HF RADIO BLACKOUT
- SATELLITE ANOMALIES
- RADIATION EXPOSURE
- AVIONICS GLITCHES

Geomagnetic Storm

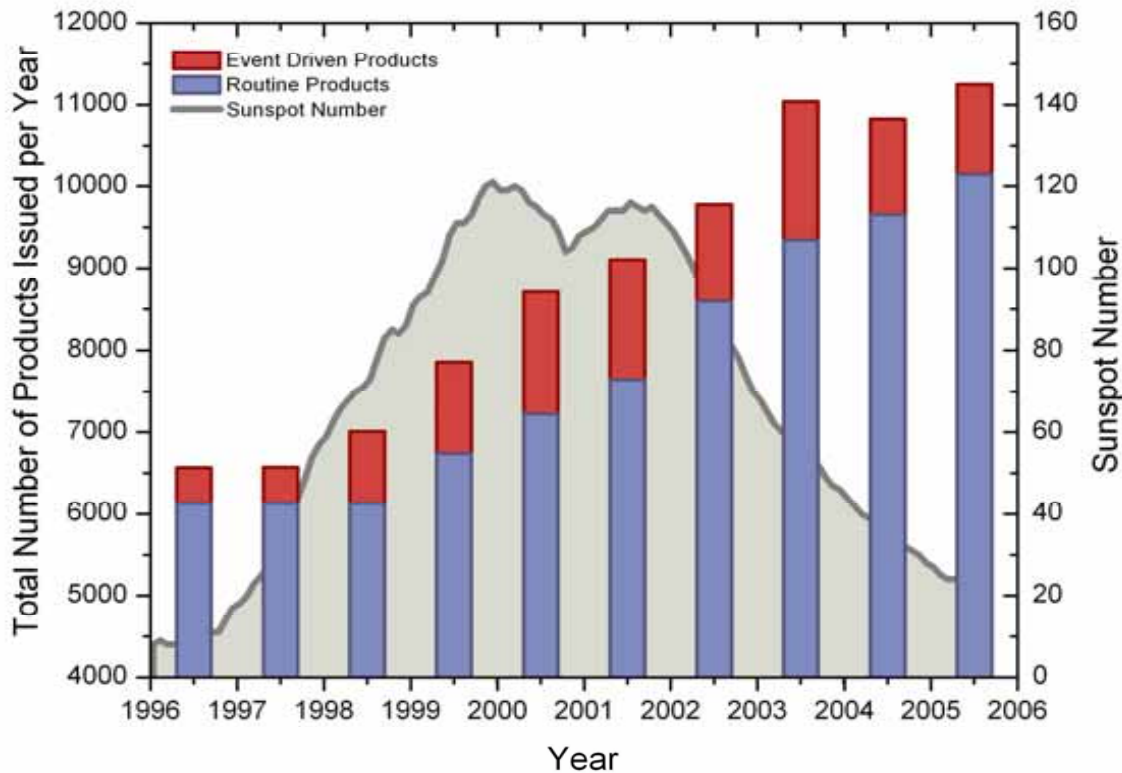
(Coronal Mass Ejection)

ARRIVAL: 1-4 DAYS

DURATION: DAYS

EFFECTS

- HF RADIO BLACKOUT
- POWER GRID PROBLEMS
- SATELLITE ANOMALIES
- RADAR INTERFERENCE
- GPS ERRORS



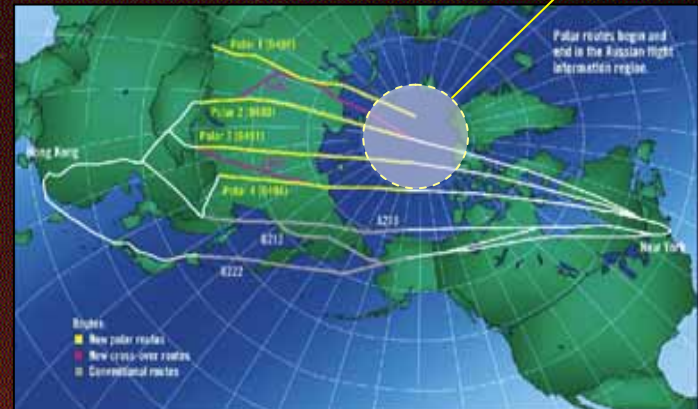
- **The demand for space weather products is increasing regardless of stage of solar cycle**
- **Strong solar storms impacting critical technology infrastructure occur every year of the solar cycle**

Space Weather Impacts on Polar Routes

Communications

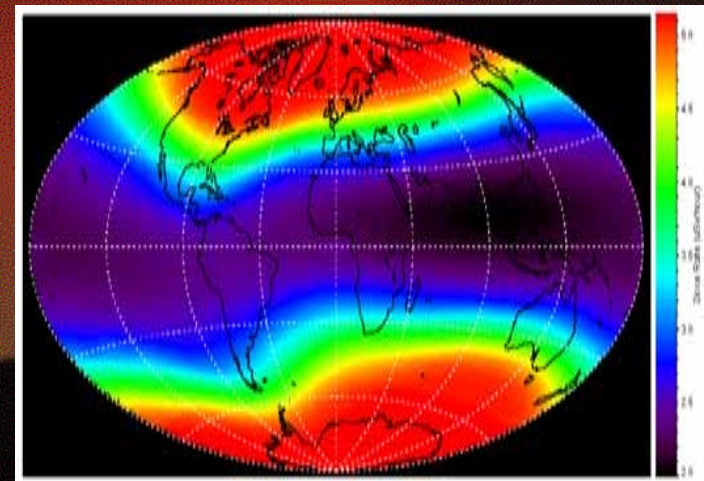
- SatCom and VHF communications are unavailable over the Pole
- Polar flights rely on HF (3 – 30 MHz) as the primary means of communication inside the 82 degree circle
- Solar radiation storms can result in a prolonged (days) periods of HF blackout

HF Communication only



Radiation Exposure

- Exposure levels are very small. Two sources:
 - Galactic Cosmic Rays (always present and inescapable)
 - Solar Radiation Storms occur sporadically (significant exposure increases are rare, but do occur).
- Airlines have introduced restrictions on polar route due to this increased radiation



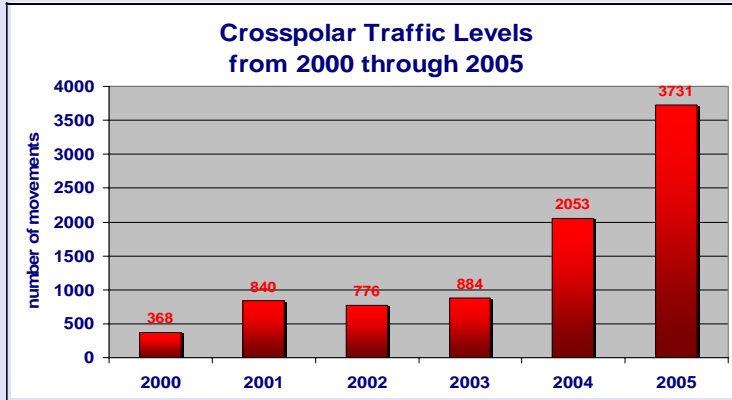
SEC Customers - Aviation Groups



Aviation companies, big and small, rely on NOAA space weather products...

Aer Lingus	Boeing / Flight Test	Northwest Airlines
Association of Flight Attendants	British Airways	Oslo Lufthavn AS
Air Canada	Bushmail	PrivateSky
Air China	Cathay Pacific Airway	Qantas Airways
Air Europa	CBAir, LLC	Ravenware Aviation
Aeroflex Inc.	Colegio de Pilotos de Aviacion	Raytheon Aircraft Co.
Air Line Pilots Association (ALPA)	Continental Airlines	UPS
Air New Zealand	Emirates	SkyWest Airlines
Air Routing International	FedEx	Sun Country airlines
AirMed Inc.	German ALPA	Sundt air (Norway)
Airservices Australia	Icelandic ALPA	Swales Aerospace
Alaska Airlines	Irish Aviation Authority	United Airlines
Allied Pilots Association	Jet Aviation Business Jets	Argentina ALPA
Japan Airlines	Korean Air	ARINC
American Airlines	Lufthansa	Era Helicopters
Turkish Airlines	Delta Airlines	NetJets
American Trans Air (ATA)	Lufthansa Cargo	North American Airlines

Aviation Growth...



NAVCANADA

Polar Route Passenger Movement				
	2004	2009	2014	2019
Capacity	228k	384k	972k	1.7mil
Avg. Annual Growth Rate		13.9%	20.4%	12.7%

Courtesy - Transport Canada

By June, 2007, ten major airlines, including six U.S. carriers, were flying polar routes.

Polar routes will grow at above average growth rates stimulated by:

- Availability of modern aircraft with a 6,000 to 9,000 mile range
- Further development of the polar route system due to burgeoning economies in China and India.

Space weather identified as the #1 concern for Polar Operations

Growing Space Weather Needs

Integration of Space Weather Into NGATS

- More Efficiency
- More Capacity
- More Profitable



GPS Customers



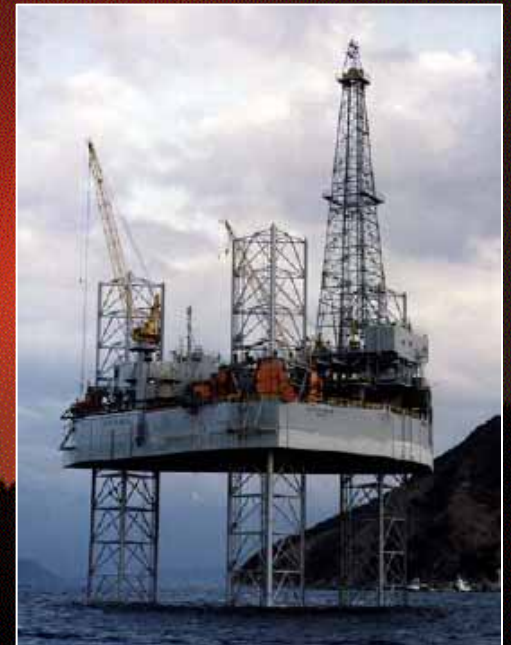
- Deep-sea drilling operations
- Surveying companies - land surveying, topographic work, and property boundary analysis
- FAA navigation systems
- Various DoD operations
 - Aircraft operations, weapon systems
- Mining operation
- Highway construction
- Farming
 - Pinpoint locations where changes in watering, fertilization or weed control are necessary



Drilling and Survey Operations

Geomagnetic warnings and alerts uses:

- Critical when DGPS high accuracy solutions are required by surveyors
- Dynamic Positioning (DP) operators will cease operations or resort to back-up options
- GPS anomaly assessments
- International oilfield services companies issue "technical alerts" to their surveying and drilling staff for solar storms



SEC Customers – Drilling/Surveying

GPS customers represent the fastest growing user base for space weather products

AE & E Trucking, Etc., LLC	Geoconsultants, Inc.	Planning Consultants, Inc.
AEI-CASE Engineering	GeoLogic Solutions, Inc.	Portland Natural Gas
Airmag Surveys	GlobalSantaFe Drilling Co.	Sanborn Mapping
Associated Engineers, Inc	GRW Aerial Surveys, Inc.	Raymac Surveys
Athens Group (oil & gas)	Halcyon Exploration Company	Schlumberger Drill & Measure
Baker Hughes (drilling)	J. D. Barnes Ltd. (survey)	Seelye
Banks Engineering	Johnson Engineering	SP Surveys
Barr Engineering Co.	Jones, Wood & Gentry, inc	Sutherland
Black Hawk County Engineer	KCI TECHNOLOGIES	Teledyne Brown Engineering
Carver County Survey Office	NC Geodetic Survey	The Boeing Company/GPS Ops
Christopher B Burke Eng Ltd.	Nexen Inc. (oil)	The Keith Companies, Inc
Clarida Engineering Co.	NOVA Engineering & Consulting	The Troyer Group
DGR Consultants	NYS Professional Engineer	Transocean Drilling
Diamond Offshore Drilling, Inc.	Old Dominion Freight Lines	Unintech Engineers
DMG	Olson Trucking	Vickrey & Associates, Inc.
Eastern Topographics	Oxy (oil & gas)	Westerngeco/Schlumberger
Excel Geophysics	Pape-Dawson Engineering	Winzler & Kelly Engineers
Fugro Chance	PGS Onshore	Zonge Engineering

Electric Power Grid

NORTH AMERICAN ELECTRIC RELIABILITY COUNCIL

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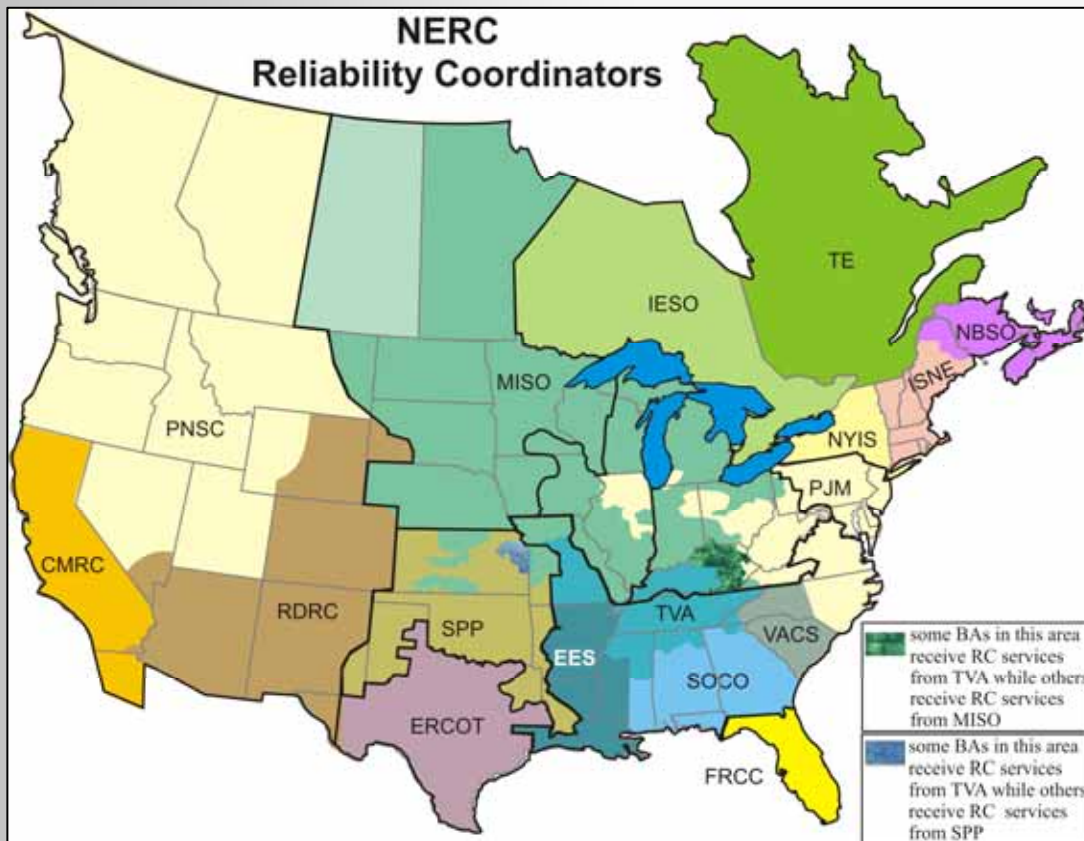
Geomagnetic Disturbance Phenomenon

The Space Environment Center provides NERC and its reliability coordinators with forecasts of geomagnetic disturbance activity.

The Midwest Independent System Operator (MISO) receives the K index forecast from NOAA. 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 the United States and Canada so that those power systems that are particularly susceptible to the impacts of this phenomenon can institute preventive operating procedures.

From the North American Electric Reliability Council (NERC)

NERC reliability coordinators distribute geomagnetic storm messages to all power systems entities throughout the USA and Canada



- Pacific Northwest Reliability Coordinator
- California Mexico Reliability Coordinator
- Entergy
- ERCOT ISO
- Florida Power & Light
- Hydro Quebec, TransEnergie
- Ontario - Independent Electricity System
- SO New England Inc.
- Midwest ISO
- New Brunswick System Operator
- Rocky Desert Reliability Coordinator
- New York Independent System Operator
- PJM Interconnection
- Southern Company Services, Inc
- Southwest Power Pool
- Tennessee Valley Authority
- VACAR-South

Electric power companies take actions to mitigate geomagnetic storm impacts



© ISO New England Inc.
2003

Process Name: Implement
Emergency Operations

Procedure Number:
RTMKTS.0120.0050

Procedure Owner: Steve
Weaver

Approved By: VP Operations

Procedure: Implement
Solar Magnetic
Disturbance Remedial
Action

Revision Number: 6

1. Discontinue maintenance work and restore our transmission lines. Avoid taking long lines out of service.
2. Maintain system voltages within acceptable operating voltage swings.
3. Review the availability of the Chester SVC and respond to voltage deterioration if necessary.
4. Adjust the loading on Phase 1 or Phase II, the Highgate HVdc ties to be within the 40% to 90% range.
5. Reduce the loading...

U.S. Nuclear Regulatory Commission Power Reactor Status Report for October 30, 2003

<i>Unit</i>	<i>Power</i>	<i>Reason or Comment</i>
<i>Hope Creek 1</i>	<i>80</i>	<i>REDUCED POWER DUE TO SOLAR MAGNETIC DISTURBANCES</i>
<i>Salem 1</i>	<i>80</i>	<i>REDUCED POWER DUE TO SOLAR MAGNETIC DISTURBANCES</i>
<i>Braidwood 2</i>	<i>90</i>	<i>COASTDOWN TO REFUELING OUTAGE REVIEWING SYSTEM PLANNING OPERATING GUIDE FOR SOLAR FLARE RESPONSE</i>
<i>Arkansas Nuclear 1</i>	<i>100</i>	<i>HOLDING OFF ON SWITCHYARD MAINTENANCE FOR SOLAR FLARE</i>
<i>Palo Verde 1</i>	<i>98</i>	<i>T-HOT LIMITED TAKING EXTRA READINGS ON PLANT COMPUTE DUE TO SOLAR FLARE</i>
<i>Comanche Peak 1</i>	<i>100</i>	<i>CANCELLED D/G SURVEILLANCE DUE TO SOLAR FLARE RESPONSE</i>

SEC Customers – Power Grid

Allegheny Power	EnvaPower	NYS Professional Engineer
Ameren Corporation	FirstEnergy	Ohio Valley Electric Corporation
Bechtel Nevada	Fugro Chance Inc.	PJM Interconnections LLC
Bonneville Power Administration	ISO New England Inc.	PSEG Nuclear LLC
Cannon Technologies, Inc.	LADWP	Puget Sound Energy
Central Maine Power Co.	Maine Public Service Company	Soreq NRC
Cinergy	Maine Public Utilities Cmsn.	SUNBURST Group
Cleco Power LLC	Manitoba Hydro	Swedish Geological Survey
Dayton Power & Light Co.	Metatech Corporation	Texas-New Mexico Power
DOE Western Area Power Admin.	N E Arizona Energy Servs Co	Transmission Engr.
Dominion Nuclear CT	Nathaniel Energy Corporation	Transpower
Dominion Virginia Power	NB Power	Transpower NZ Ltd
DTE Energy	New Brunswick Power	US NRC
Electric REsearch, Inc.	New York Independent System O	We Energies
Elk Valley Coal	New York Power Authority	Western Area Power Admin.
Entergy Corp.	New York State Power Authority	Northeast Utilities

Satellite Industry



Solar storm warnings and alerts uses:

- Instruments and/or spacecraft turned off or safed
- Maneuver planning
- Anomaly assessments
- Orbit determination accuracy
- Increased spacecraft and instrument monitoring for health and safety during solar storms

“The SEC provides an invaluable and essential service to space operators” – Director of DG Space Operations – 22 March 2006

Actions taken by Satellite Operators

- October 2003 – NASA's Earth Sciences Mission Office directed all instruments on five spacecraft be turned off or safed due to Level 5 storm prediction.
- “We use [space weather] products extensively to plan and/or react in powering off vulnerable subsystems in orbit when the solar flares (Protons) reach a certain level.” - JPL Flight Operations Team (April 2006)

Manned Space Flight

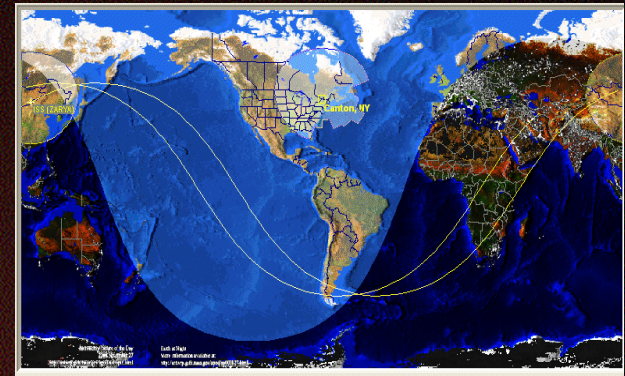
- Shuttle missions and EVAs require particular attention. Note: The EVA-1 hr briefing is the last opportunity to abort an EVA due to space weather. (>30 MeV events are primary concern)

NASA SRAG will report to Mission Control when:

- >K6 observed (1 observed period after decay)
- >M5 observed
- Protons (All >100 MeV events).

- Electron belt enhancements can delay or postpone an EVA.

NASA ISS: 50 pfu at > 100 MeV - shutdown the robotic arm
100 pfu at > 100 MeV - alert Mission Control. The Flight Team will start to evaluate a plan to shutdown equipment to prevent damage to electronics.
200 pfu > 100 MeV - plan is implemented



Space Commercial Transportation...

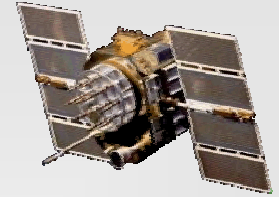


SpaceShipOne

- **Virgin Galactic – tourism flights in 2009**
- **Futron's Space Tourism Market Study: 15,000 passengers and Revenues in excess of \$1 billion per year by 2021**
- **Space tourism scenario by 2030 suggests 5 million passengers into space per year** (CNN Science & Space Friday, September 24, 2004)
- **The Commercial Space Launch Amendments Act of 2004**
 - FAA define medical requirements for passengers
 - **Space Weather will be included**



National Security Concerns



Our military and National Intelligence Community rely on alerts and warnings of space weather storms:

- **High-frequency and Satellite communications**
- **Precision Navigation and Timing users (GPS users)**
- **Radar operations**
- **High-altitude operations**
- **Space operations**



Advance warnings of solar storms - *“enables space operators to take proactive courses of action protecting 47 satellites that provide strategic and tactical space effects for the warfighter.* – MGen William Shelton, Commander, 14AF, Vandenberg AFB, CA, April 2006

Conclusion

Our ever-growing dependence on space-based technology will result in an increasing need for space weather services.

The health of this Nation's technological infrastructure will depend heavily on our understanding of the space environment and our ability to predict hazardous space weather storms.