

Headquarters U.S. Air Force

Fly – Fight – Win

Space Weather Workshop 2009



AF/A3O-W



U.S. AIR FORCE

Overview

- **Bottom Line Up Front**
- **Space Situational Awareness**
- **Space Weather Impacts**
- **Space Weather Roadmap / Initiatives**
- **Way Ahead**

National Partners working to provide timely & actionable space weather support for the warfighters and the Nation



Bottom Line Up Front

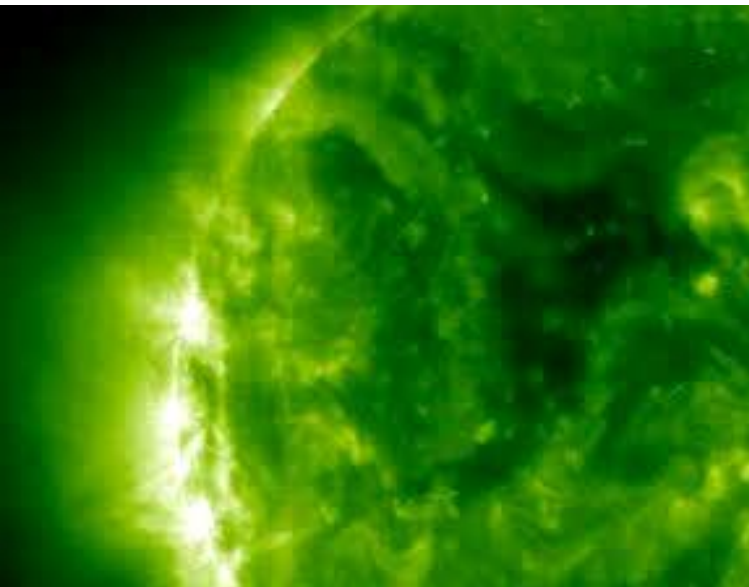
U.S. AIR FORCE

- **Space environment mission improvements to support SSA**
 - AFSPC and AF/A3O-S/W working in partnership to address needs across AFSPC SSA and AF Wx Weapon System (AFWWS)
 - AFSPC SSA: Space based sensors & Data exploitation (ISSA)
 - AFWWS: Ground-based sensors, models, net-centric database
 - Exploit data from existing infrastructure & national/international partners
 - Formalize space weather training and professional development
- **A3O-W published Space Wx Implementation Plan in Mar 08**
- **AFSPC, A3O-W, A3O-S, 14AF, AFWA, and National Partners concluded ICT to develop end-to-end implementation plan for way ahead ... Plan documented in SSA Interim Architecture**
- **OFCM leading interagency CSESMO (Committee for Space Environment Sensor Mitigation Options) effort for OSTP ... developing options for DMSP and ACE space sensors plus analysis/forecast model software**

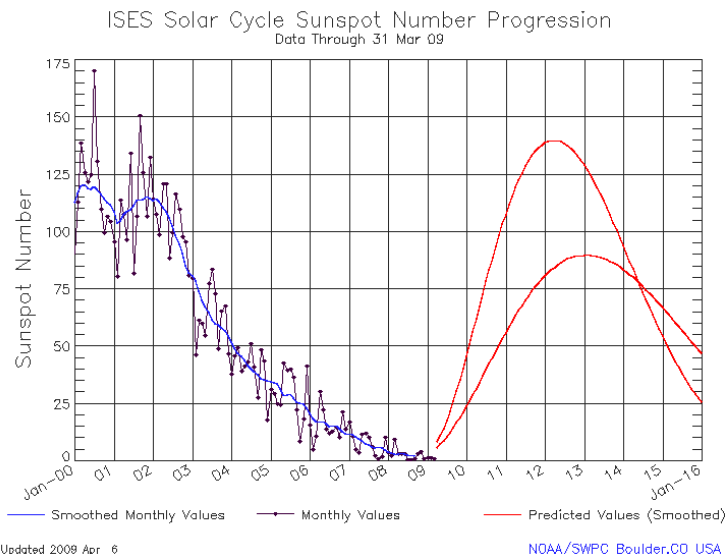


U.S. AIR FORCE

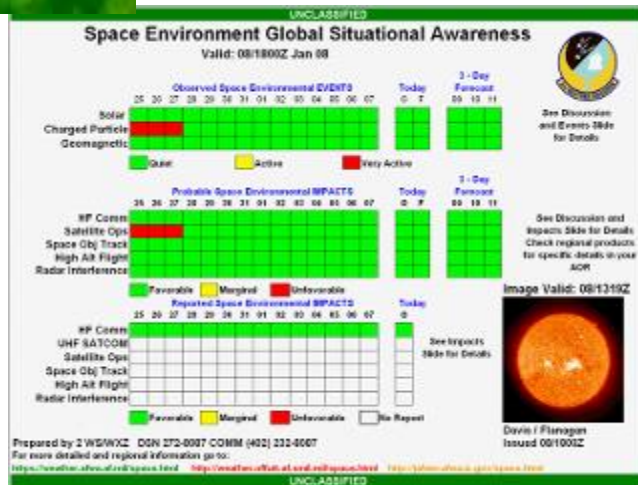
Space Weather Operations



**2 WS/WXZ
Space Wx
Product**



**Halloween storms
2003**



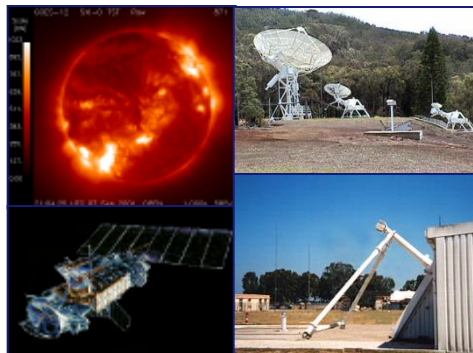
Solar Cycle 24



Space Weather Information Flow

U.S. AIR FORCE

*Environmental Inputs
(DoD, Civil, International)*



Observations
Requirements

Space /
Space Wx
Operators



Data Received



SWPC

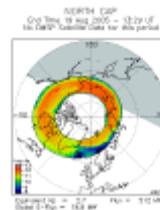
AFWA – weather data
ingest/analysis/prediction and
product flow to the warfighter!

Data & Products
Provided

AFWA: Space Wx
support provider

Teamwork

Tailored Products



2 WS
Space Weather Flight

Integrity - Service - Excellence



U.S. AIR FORCE

Space Weather Warfighter Impacts

X-Rays, EUV, Radio Bursts

- SATCOM Interference
- Radar Interference
- HF Radio Blackout
- Geolocation Errors
- Satellite Orbit Decay



Scintillation

- Degraded SATCOM
- Dual Frequency GPS Error
 - Positioning
 - Navigation
 - Timing



Proton Events

- High Altitude Radiation Hazards
- Spacecraft Damage
- Satellite Disorientation
- Launch Payload Failure
- False Sensor Readings
- Degraded HF Comm (high latitudes)



Geomagnetic Storms

- Spacecraft Charging and Drag
- Geolocation Errors
- Space Track Errors
- Launch Trajectory Errors
- Radar Interference
- Radio Propagation Anomalies
- Power Grid Failures





U.S. AIR FORCE

Current Status

■ **Space-Based Space Wx Sensors**

- **DMSF sunset program, NPOESS Nunn-McCurdy restructure de-manifested space environment sensors – follow on capability being worked by AFSPC to avoid gap in ~2016**
- **ACE (Advanced Composition Explorer) – replacement planning being worked as part of CSESMO for ~ 2016-2018**

■ **Ground-Based Space Wx Sensors ... Current sensors need replacement**

- **AFWA & SMC working RSTN SLEP (System Lifecycle Extension Program) and SOON modernization**
- **Using some R&D sensors (SCINDA & TEC) for ops – will continue to support**

■ **Space Environment Models**

- **AFWA w/ National Partners making progress ... increased \$s in FY08-15**
- **AFRL, NRL, NASA, NSF, and others R&D progressing, working funding for transition programs**

■ **System Effects Products**

- **AFSPC funding ops software capability; Additional R&D funding needed**



Space Wx Capability for SSA

Today & Circa 2017

U.S. AIR FORCE

Today's Space-Based and Ground-Based Measurement & Modeling Capabilities

1 DMSP
2 ACE/SOHO
3 GOES
4 GPS
5 DSP
6 NPOESS
7 C/NOFS
8 SOON
9. RSTN
10 DISS
11TEC
12 SCINDA
13 Geomag

Space Weather Parameter (% Space-based / Ground-based contribution)	Example Mission Supported	Observing Capability (Threshold SSA)	Forecasting Capability (Objective SSA)
Ionospheric Electrons (50%/50%) 1, 2, 7, 10, 11, 12, 13	Geolocation		
Ionospheric Disturbances (50%/50%) 1, 2, 7, 10, 11, 12, 13	Communications		
Energetic Particles (80%/20%) 1, 2, 3, 4, 5, 6, 7, 13	Satellite Ops		
Radiation & Disturbances (70%/30%) 1, 2, 3, 4, 5, 6, 7, 10, 11, 12, 13	Space Track		
Ionospheric Disturbances (50%/50%) 1, 2, 7, 10, 11, 12, 13	Navigation		

■ Good (>75%) ■ Moderate (50-75%) ■ Marginal (25-50%) ■ Little or None (0-25%)

Fund both Space-Based and Ground-Based Measurement & Modeling Capabilities

1 DMSP/SES*
2 ACE/SOHO FO
3 GOES
4 GPS
5 DSP
6 NPOESS
7 C/NOFS
8 ISOON/GONG
9 RSTN II
10 NEXION
11TEC
12 SCINDA
13 Geomag

Space Weather Parameter (% Space-based / Ground-based contribution)	Example Mission Supported	Observing Capability (Threshold SSA)	Forecasting Capability (Objective SSA)
Ionospheric Electrons (50%/50%) 1, 2, 7, 8, 9, 10, 11, 12, 13	Geolocation		
Ionospheric Disturbances (50%/50%) 1, 2, 7, 8, 9, 10, 11, 12, 13	Communications		
Energetic Particles (80%/20%) 1, 2, 3, 4, 5, 6, 7, 8, 9, 13	Satellite Ops		
Radiation & Disturbances (70%/30%) 1 - 13	Space Track		
Ionospheric Disturbances (50%/50%) 1, 2, 7, 8, 9, 10, 11, 12, 13	Navigation		

*SES– SSA Environment Sensing ... DMSP Space Wx Sensor Follow-on

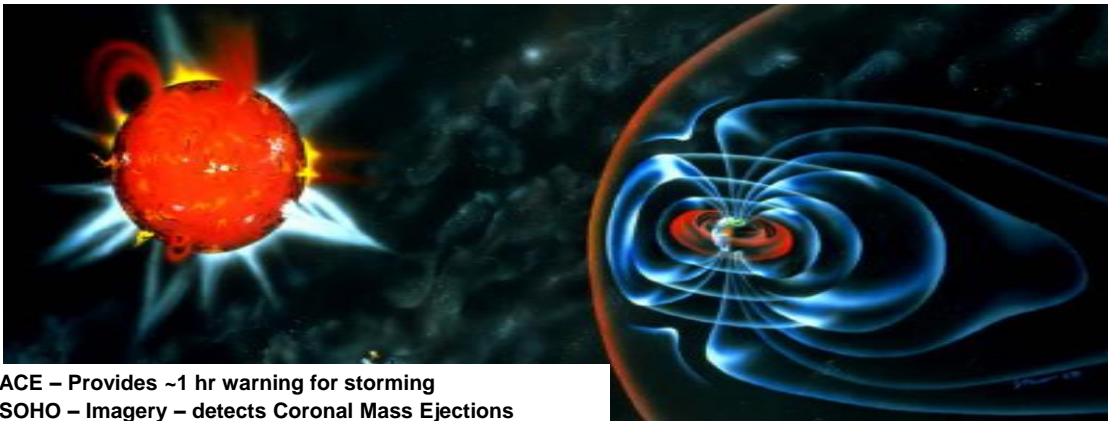
Integrity - Service - Excellence



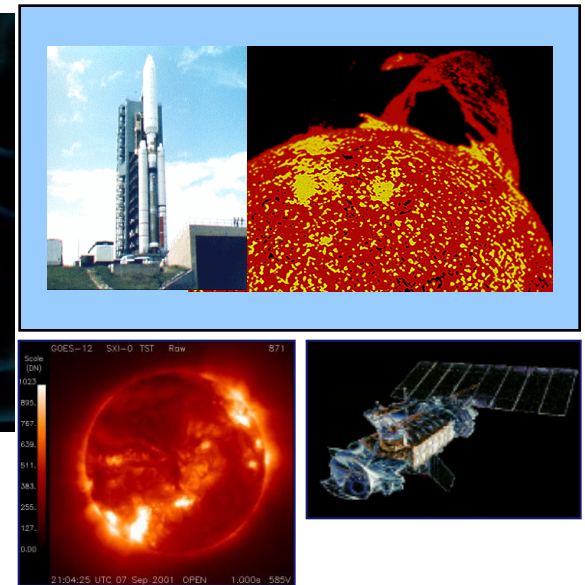
SSA: Space Weather Roadmap

U.S. AIR FORCE

- Improve analysis, forecasting, & effects capabilities ... FY08-17+
- Collaborate with U.S. & Allied government/civilian agencies to increase sensing capability & reduce costs ... NASA, NOAA, NSF, USGS, LANL, and others
- Modernize ground-based sensing capabilities ... FY08-17+
- Follow-on to DMSP space weather sensing capabilities ... FY12-17



ACE – Provides ~1 hr warning for storming
SOHO – Imagery – detects Coronal Mass Ejections
GOES – Energetic particles, X-Ray flux and X-Ray images
POES/DMSP – LEO space wx ionospheric sensors
SEON – Ground-based solar observatories
DISS – Ground-based ionospheric measurements
TEC – GPS-derived ionospheric measurements



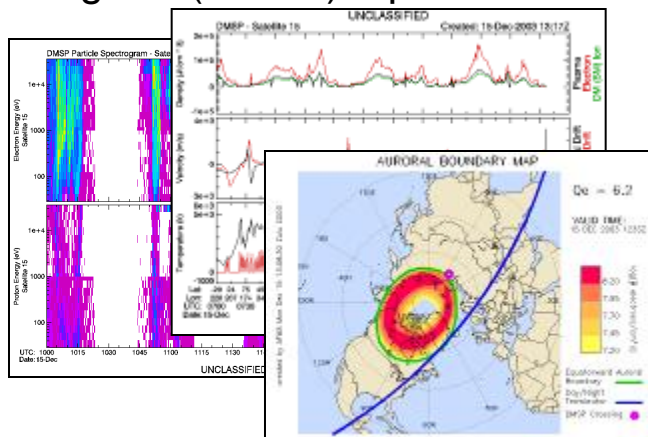
Integrity - Service - Excellence



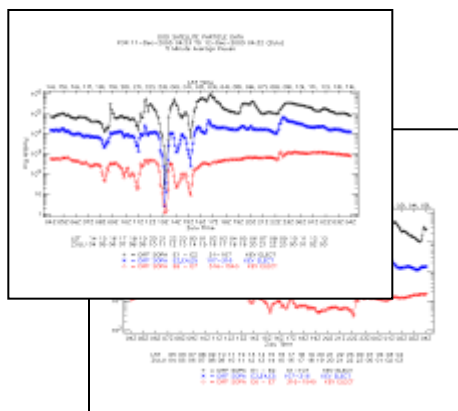
U.S. AIR FORCE

Space Weather Space-Based Sensing

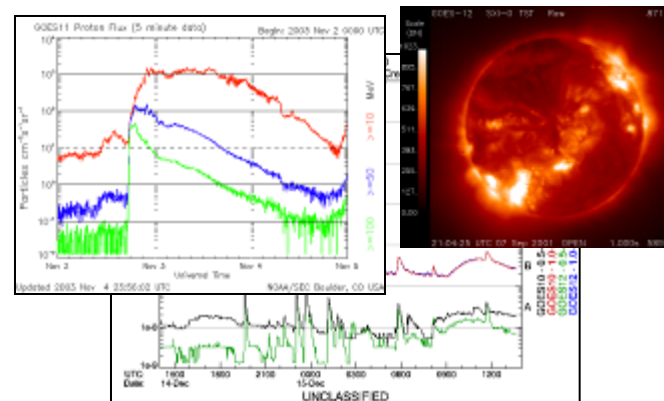
Defense Meteorological Satellite Program (DMSP) – particles/fields



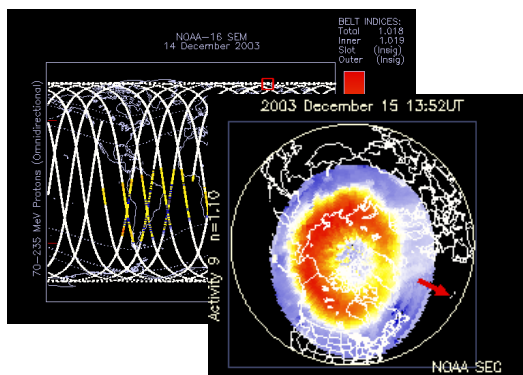
Defense Support Program (DSP) - particles



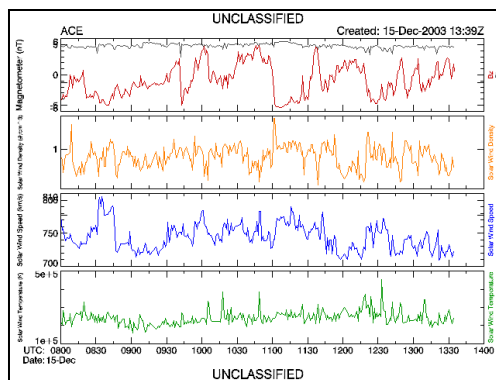
Geostationary Operational Environment Satellite (GOES) – X-ray, particles and fields



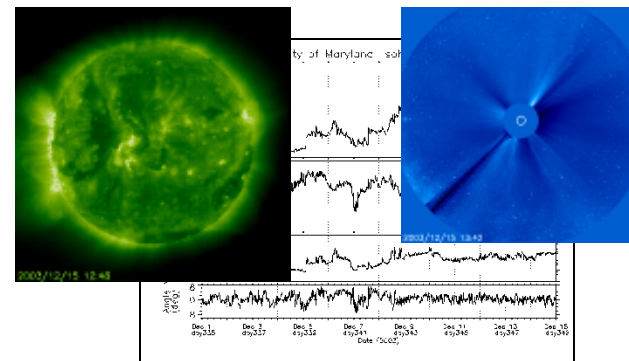
Polar-Orbiting Environmental Satellite (POES) - particles



Advanced Composition Explorer (ACE) – solar wind



Solar Heliospheric Observatory (SOHO) - solar wind/radiation



Integrity - Service - Excellence



Space-Based Sensor Options

U.S. AIR FORCE

NPOESS Mitigation

- **SSA Environmental Monitoring (SSAEM) proposed by AFSPC**
 - Looking to buy sensors for rides-of-opportunity
 - DoD identifying funding ... AFSPC leading requirements/concept development
- **Currently enhancing NPOESS space environment monitor (SEM-N)...**
METOP component of NPOESS may not fly SEM

Exploit current satellite systems space wx observing capabilities

- **GOES, GPS, and other satellites**
- **C/NOFS and COSMIC follow-on operations**

Advocacy to NOAA, NASA, etc.

- **Need partnerships to collect from the rest of the space domain**
- **Need ACE replacement ... OFCM/NOAA/NASA/DoD considering options for OSTP ... CSES MO**



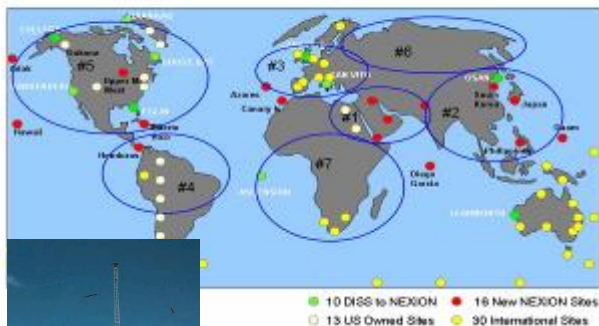
U.S. AIR FORCE

Space Weather Ground-Based Sensing Examples

AF and other agencies collect space weather data from ground-based sensors

- Sensors include SOON, RSTN, DISS, NEXION, USGS Magnetometer, SCINDA, TEC, and others
- Data from many government & non-government sources ... Data partnerships are crucial

All Sites



DISS





Ground Sensor Upgrades

U.S. AIR FORCE

Ground Based Space Wx Sensors (Ionosphere)

- Upgrading aging sensor hardware to meet requirements
 - Ionosphere sensor improvements (NEXION replaces DISS)
 - Leverage additional ionosondes fielded by NSF, NOAA, and international partners
- Continue to use NASA JPL Total Electron Content (TEC) data

Ground Based Space Wx Sensors (Solar Observing)

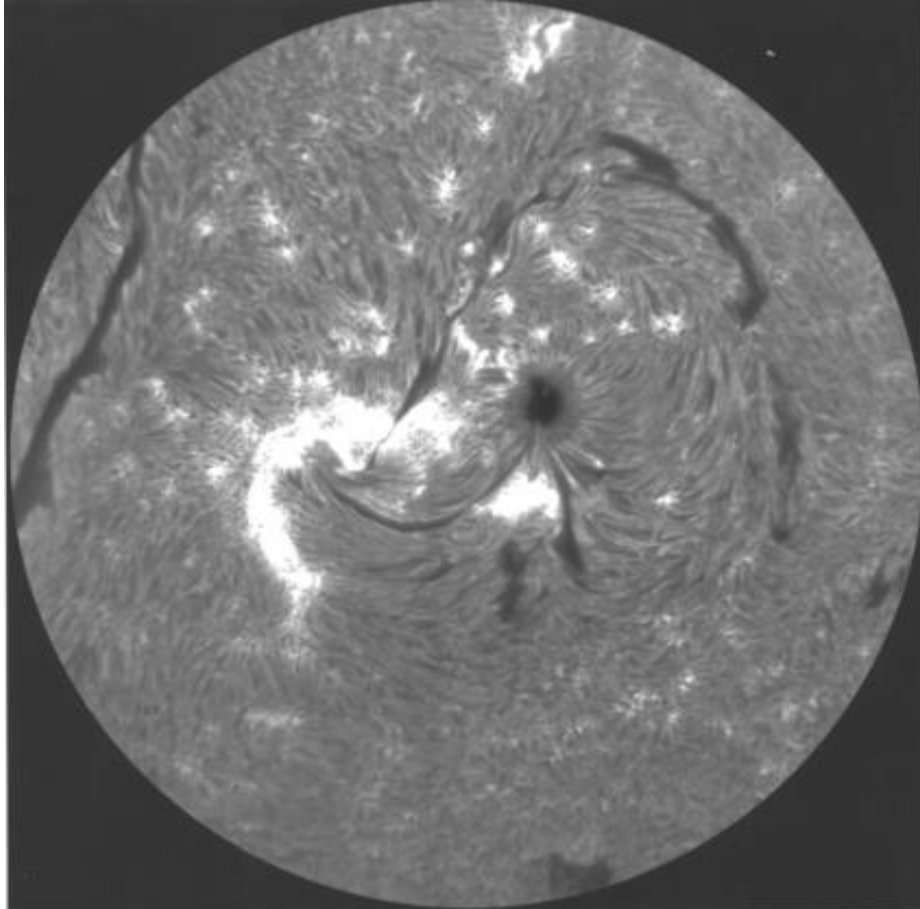
- Optical solar sensor upgrade (ISOON replaces SOON)
- Maintain radio solar sensors for solar max
 - Begin radio solar sensor R&D in FY09 (RSTN replacement)
- Collocate and automate solar observing sites
- Leverage NSF GONG to improve capabilities and reduce costs



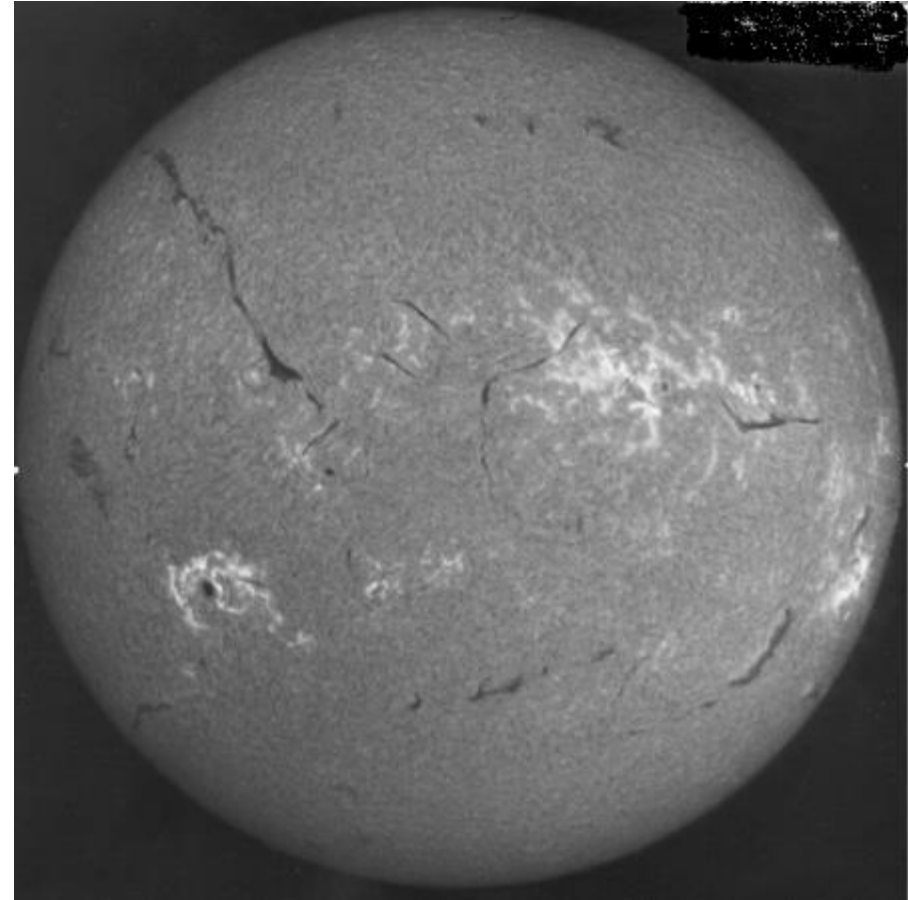
U.S. AIR FORCE

Improving Ground-based Obs Before Solar Max

ISOON



SOON



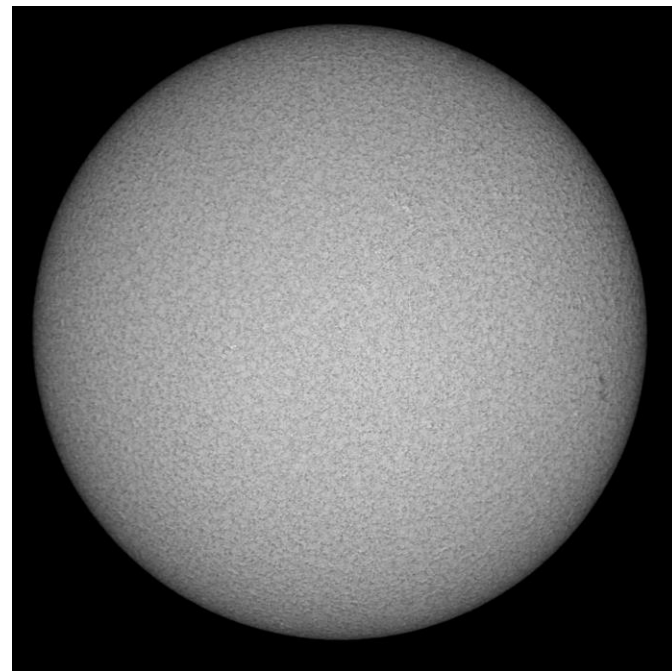
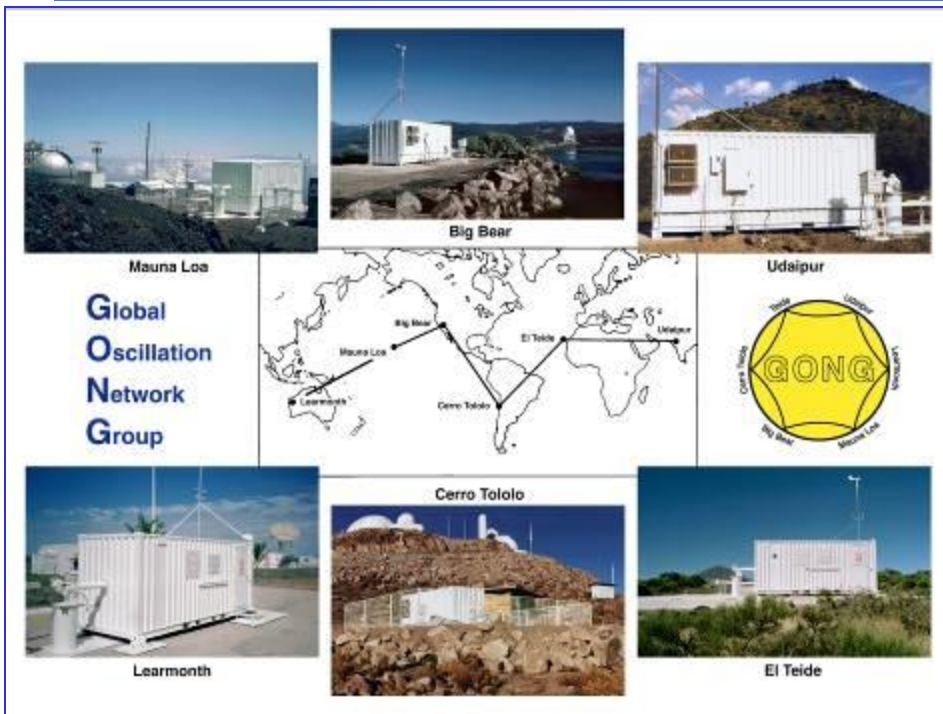
Note: Not the same date and time

Integrity - Service - Excellence



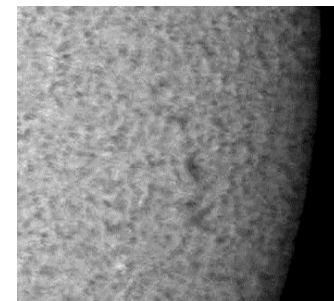
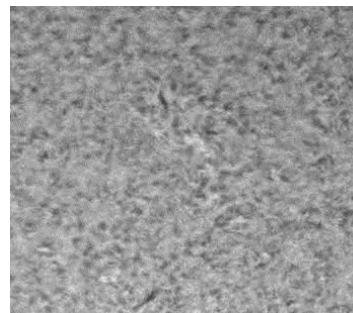
Ground-Based Space Wx Sensor Opportunities NSF

U.S. AIR FORCE



GONG

**Upgrade to provide H-alpha capability
... data products every minute**



Integrity - Service - Excellence



U.S. AIR FORCE

Modeling and Exploitation S/W Upgrades

Modeling/Exploitation

- **Additional investments accelerate space wx analysis, forecast & exploitation capabilities ... Directly enhances SSA for warfighters**
 - **Substantially increased investment in Space Weather Analysis and Forecast System (SWAFS)**
 - **AFSPC funding SSA Environmental Effects Fusion System (SEEFS) to provide JSpOC tool set to support ops assessments**
- **Investments provide Models, Apps, Graphics, Data Fusion, & Decision Aids to improve operational space weather support**

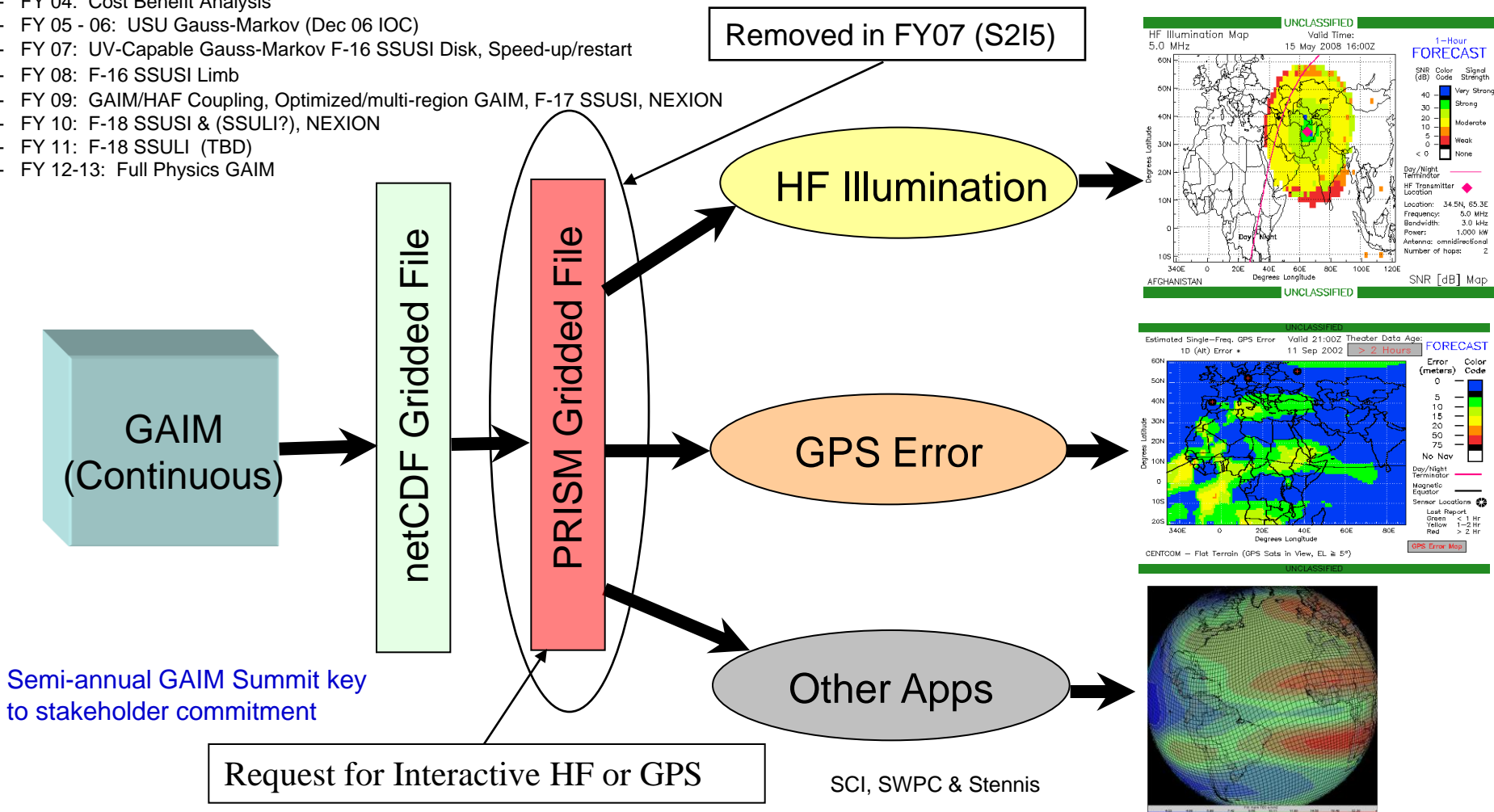


GAIM Plan & Deliverables

U.S. AIR FORCE

Global Assimilation of Ionospheric Measurements (GAIM) – 8-9 year effort

- FY 04: Cost Benefit Analysis
- FY 05 - 06: USU Gauss-Markov (Dec 06 IOC)
- FY 07: UV-Capable Gauss-Markov F-16 SSUSI Disk, Speed-up/restart
- FY 08: F-16 SSUSI Limb
- FY 09: GAIM/HAF Coupling, Optimized/multi-region GAIM, F-17 SSUSI, NEXION
- FY 10: F-18 SSUSI & (SSULI?), NEXION
- FY 11: F-18 SSULI (TBD)
- FY 12-13: Full Physics GAIM





Bottom Line

U.S. AIR FORCE

- **Accelerating actions to prepare for solar max ... and beyond**
- **OFCM, NOAA, NASA, DoD, and other National Partners working to determine way forward to support national space wx needs and SSA ... CSESMO and other efforts**
- **Increased investment in ground-based sensor, modeling and exploitation capabilities**
- **Must ensure AF space wx expertise available in future**

Working with National Partners to support National Space Wx needs

Headquarters U.S. Air Force

Integrity - Service - Excellence

Questions?



U.S. AIR FORCE



U.S. AIR FORCE

Space Wx Training & Personnel Initiatives

Space Weather Training

- **Formalize internal AFWA space weather training course – already available to outside agencies**
- **Continue to provide space weather overview during Weather initial skills training**

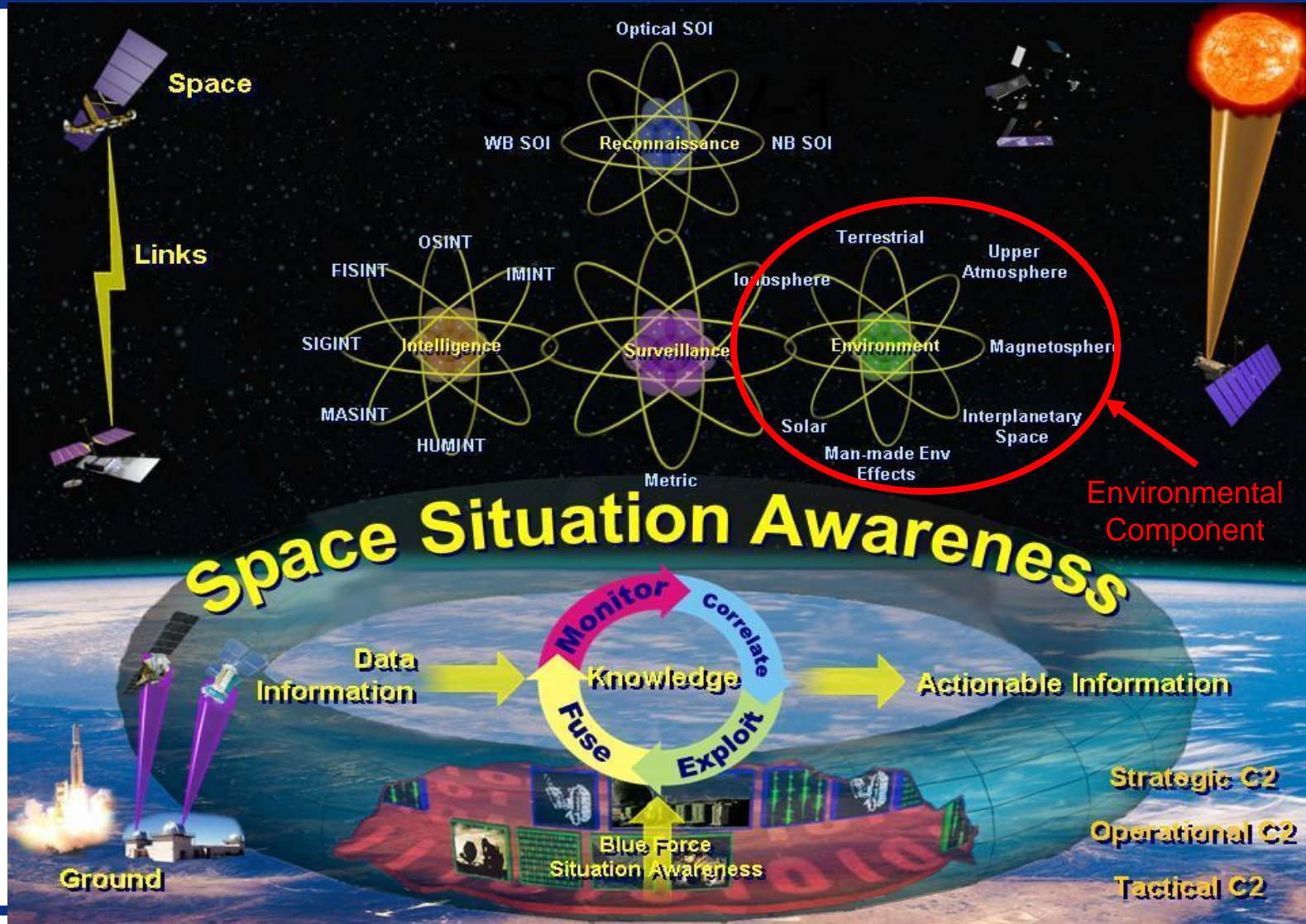
Personnel

- **Revitalizing Advance Academic Degree program for space weather modeling and exploitation**
- **Space weather officers/enlisted will now participate in AFSPC Space Professional Development**



U.S. AIR FORCE

Space Situational Awareness Operational View



Integrity - Service - Excellence



U.S. AIR FORCE

Mitigation of Impacts

■ Warnings

- Geomagnetic Activity
- Solar Event, Flare, Radio Burst
- Energetic Particle/Charging
- Short Wave Fade

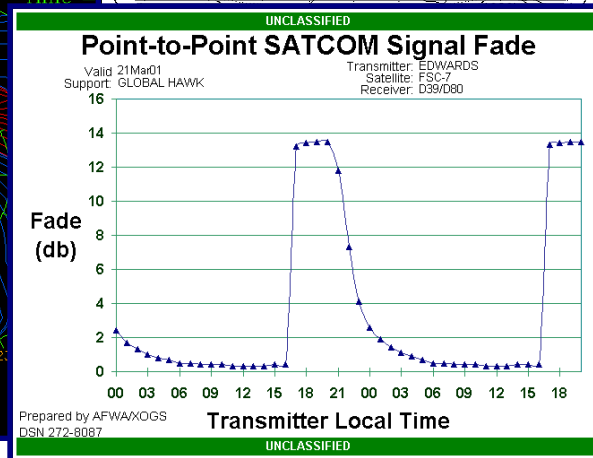
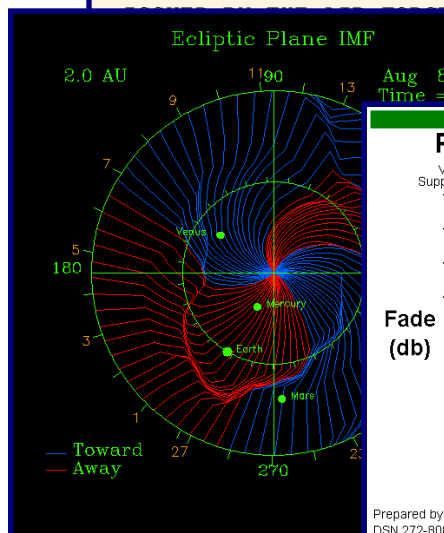
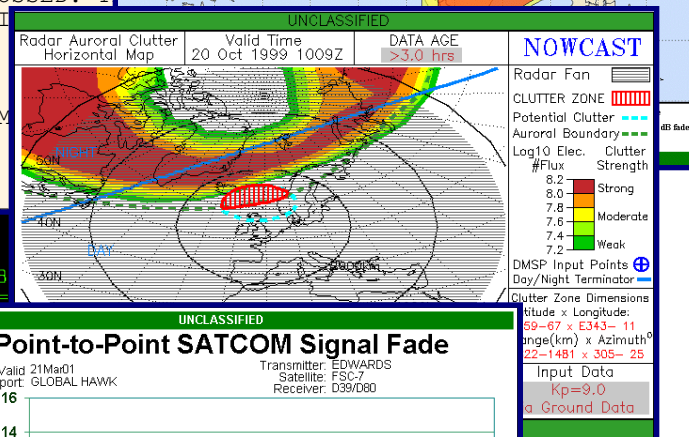
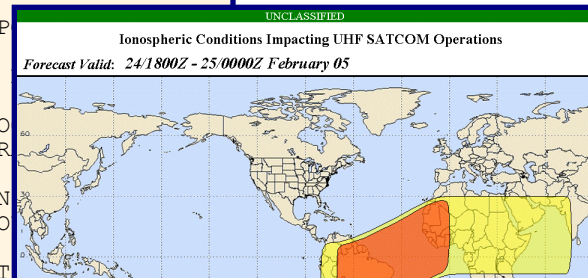
■ Specification & Forecast

- Ionosphere
- Magnetosphere
- Solar Wind

■ Products

- Radar Auroral Clutter
- HF Illumination
- GPS Error
- HF/UHF Point-to-Point
- Ap/F10 Forecast
- Anomaly Assessments
- UHF SATCOM Scintillation

WOXX56 KGWC 200802
SUBJECT: AFWA EVENT WARNING REP
0802Z 20 JAN 2005
PART A. SOLAR RADIATION DOSAGE
(UPDATE):
A SOLAR PROTON EVENT IS IN PRO
IS AN ESTIMATE OF THE MAXIMUM R
MILLIREMS BASED ON
THE GOES SPACECRAFT PROTON MON
WILL RECEIVE AN UPDATE EVERY HO
ONE OF THE
CATEGORIES BELOW IS CROSSED. T
RADIATION DOSE CALCULATI
MREMS.
CATEGORIES ARE:
GREEN = LESS THAN 10
YELLOW = 10 - 99 MREM
RED = 100 OR GREATER
PART B. N/A
PART C. REMARKS:





Space Wx Capability for SSA

Today

U.S. AIR FORCE

Today's Space-Based and Ground-Based Measurement & Modeling Capabilities

1 DMSP
2 ACE/SOHO
3 GOES
4 GPS
5 DSP
6 NPOESS
7 C/NOFS
8 SOON
9. RSTN
10 DISS
11TEC
12 SCINDA
13 Geomag

Space Weather Parameter (% Space-based / Ground-based contribution)	Example Mission Supported	Observing Capability (Threshold SSA)	Forecasting Capability (Objective SSA)
Ionospheric Electrons (50%/50%) 1, 2, 7, 10, 11, 12 ,13	Geolocation		
Ionospheric Disturbances (50%/50%) 1, 2, 7, 10, 11, 12 ,13	Communications		
Energetic Particles (80%/20%) 1, 2, 3, 4, 5, 6, 7, 13	Satellite Ops		
Radiation & Disturbances (70%/30%) 1, 2, 3, 4, 5, 6, 7, 10, 11, 12 ,13	Space Track		
Ionospheric Disturbances (50%/50%) 1, 2, 7, 10, 11, 12 ,13	Navigation		

■ Good (>75%)
 ■ Moderate (50-75%)
 ■ Marginal (25-50%)
 ■ Little or None (0-25%)



Space Wx Capability for SSA

Circa 2017

U.S. AIR FORCE

Do not fund Ground-Based or Space-Based Measurement & Modeling Capabilities

1 DMSP
2 ACE/SOHO
3 GOES
4 GPS
5 DSP
6 NPOESS
7 C/NOFS
8 SOON/GONG
9 RSTN
10 NEXION
11 TEC
12 SCINDA
13 Geomag

Space Weather Parameter (% Space-based / Ground-based contribution)	Example Mission Supported	Observing Capability (Threshold SSA)	Forecasting Capability (Objective SSA)
Ionospheric Electrons (50%/50%) 10, 11, 12 ,13	Geolocation		
Ionospheric Disturbances (50%/50%) 10, 11, 12 ,13	Communications		
Energetic Particles (80%/20%) 3, 4, 5, 6, 13	Satellite Ops		
Radiation & Disturbances (70%/30%) 3, 4, 5, 6, 10, 11, 12 ,13	Space Track		
Ionospheric Disturbances (50%/50%) 10, 11, 12 ,13	Navigation		

■ Good (>75%) ■ Moderate (50-75%) ■ Marginal (25-50%) ■ Little or None (0-25%)

Fund Ground-Based and not Space-Based Measurement & Modeling Capabilities

1 DMSP
2 ACE/SOHO
3 GOES
4 GPS
5 DSP
6 NPOESS
7 C/NOFS
8 ISOON/GONG
9 RSTN II
10 NEXION
11 TEC
12 SCINDA
13 Geomag

Space Weather Parameter (% Space-based / Ground-based contribution)	Example Mission Supported	Observing Capability (Threshold SSA)	Forecasting Capability (Objective SSA)
Ionospheric Electrons (50%/50%) 8, 9, 10, 11, 12, 13	Geolocation		
Ionospheric Disturbances (50%/50%) 8, 9, 10, 11, 12, 13	Communications		
Energetic Particles (80%/20%) 3, 4, 5, 6, 8, 9, 13	Satellite Ops		
Radiation & Disturbances (70%/30%) 3, 4, 5, 6, 8, 9, 10, 11, 12, 13	Space Track		
Ionospheric Disturbances (50%/50%) 8, 9, 10, 11, 12, 13	Navigation		



Space Wx Capability for SSA

Circa 2017

U.S. AIR FORCE

Fund Space-Based and not Ground-Based Measurement & Modeling Capabilities

1 DMSP/SES*
2 ACE/SOHO FO
3 GOES
4 GPS
5 DSP
6 NPOESS
7 C/NOFS
8 SOON/GONG
9 RSTN
10 NEXION
11 TEC
12 SCINDA
13 Geomag

Space Weather Parameter (% Space-based / Ground-based contribution)	Example Mission Supported	Observing Capability (Threshold SSA)	Forecasting Capability (Objective SSA)
Ionospheric Electrons (50%/50%) 1, 2, 7, 10, 11, 12, 13	Geolocation		
Ionospheric Disturbances (50%/50%) 1, 2, 7, 10, 11, 12, 13	Communications		
Energetic Particles (80%/20%) 1, 2, 3, 4, 5, 6, 7, 13	Satellite Ops		
Radiation & Disturbances (70%/30%) 1, 2, 3, 4, 5, 6, 7, 10, 11, 12, 13	Space Track		
Ionospheric Disturbances (50%/50%) 1, 2, 7, 10, 11, 12, 13	Navigation		

■ Good (>75%) ■ Moderate (50-75%) ■ Marginal (25-50%) ■ Little or None (0-25%)

Fund both Space-Based and Ground-Based Measurement & Modeling Capabilities

1 DMSP/SES*
2 ACE/SOHO FO
3 GOES
4 GPS
5 DSP
6 NPOESS
7 C/NOFS
8 ISOON/GONG
9 RSTN II
10 NEXION
11 TEC
12 SCINDA
13 Geomag

Space Weather Parameter (% Space-based / Ground-based contribution)	Example Mission Supported	Observing Capability (Threshold SSA)	Forecasting Capability (Objective SSA)
Ionospheric Electrons (50%/50%) 1, 2, 7, 8, 9, 10, 11, 12, 13	Geolocation		
Ionospheric Disturbances (50%/50%) 1, 2, 7, 8, 9, 10, 11, 12, 13	Communications		
Energetic Particles (80%/20%) 1, 2, 3, 4, 5, 6, 7, 8, 9, 13	Satellite Ops		
Radiation & Disturbances (70%/30%) 1 - 13	Space Track		
Ionospheric Disturbances (50%/50%) 1, 2, 7, 8, 9, 10, 11, 12, 13	Navigation		

*SES– SSA Environment Sensing ... DMSP Space Wx Sensor Follow-on