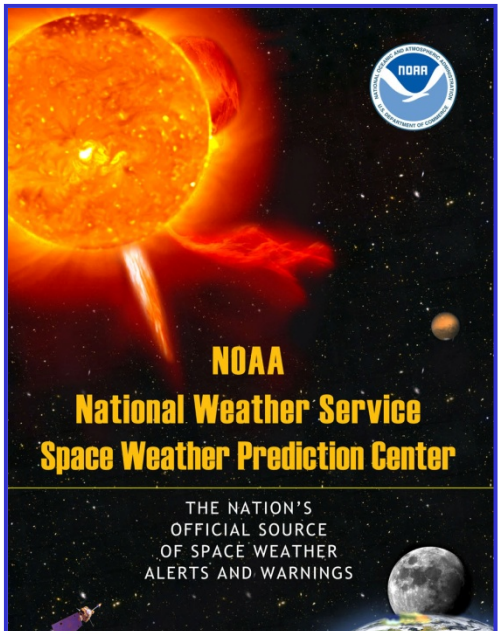
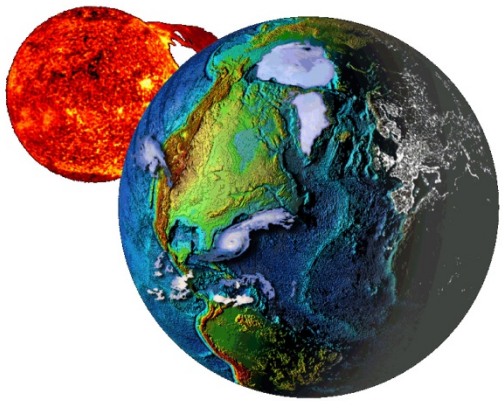
NOAA SWPC Needs
Space Weather Operations Support





Outline:

- Customer Motivation (selected examples)
- Solar Wind Forecast Model (WSA-Enlil Model Transition Status)
- Geospace Model(s) (Future plans)
- CCMC Partnership

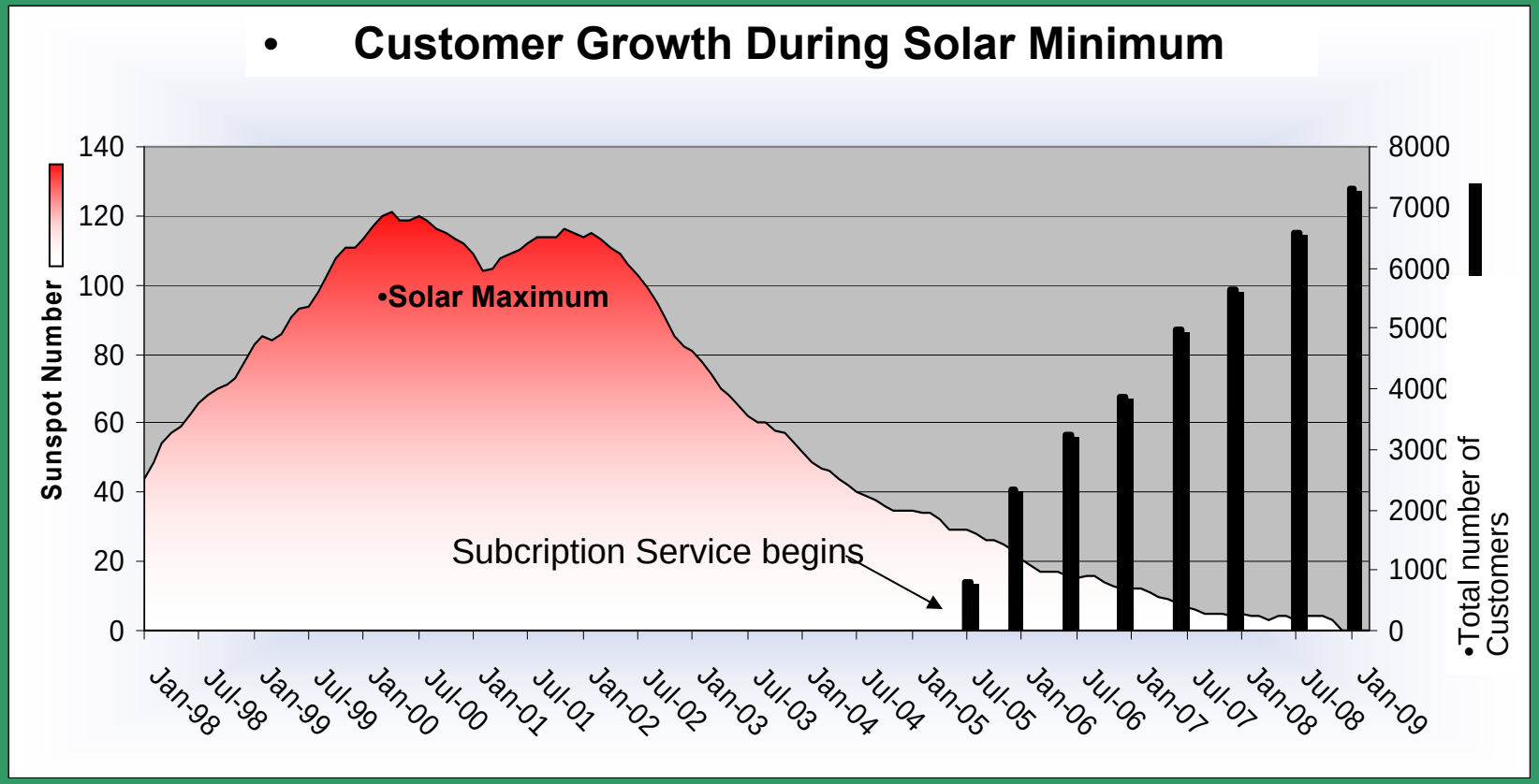
Acknowledgments: Baker, Biesecker, Bogdan, Codrescu, Green, Kunches, Millward, Murtagh, Pizzo

Howard J Singer - NOAA Space Weather Prediction Center
The 5th CCMC Community Workshop
Key Largo, Florida January 28, 2010

Safeguarding Our Nation's Advanced Technologies

SWPC Product Subscription Service

1,695 New Subscription Customers in 2008

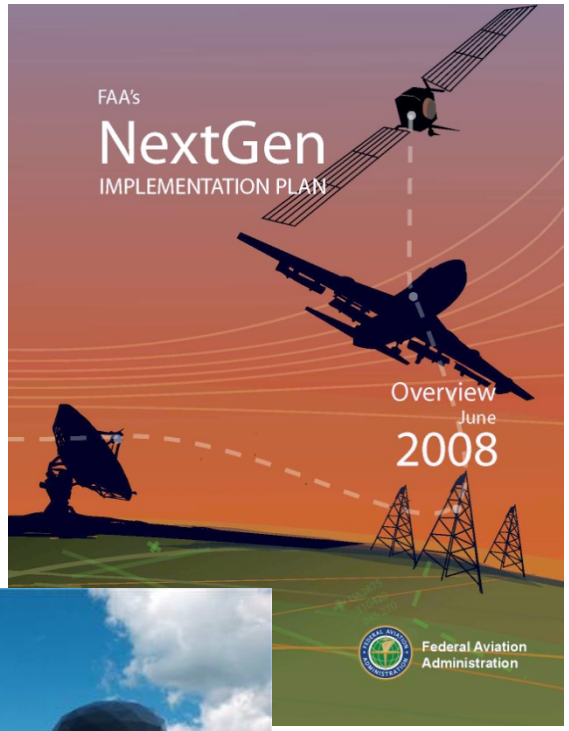


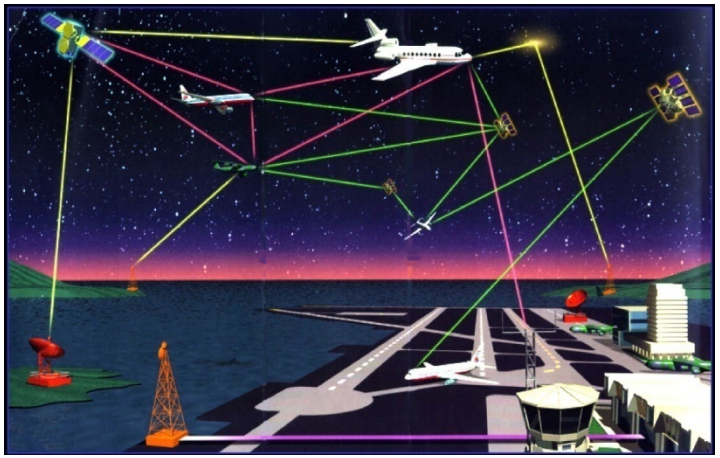
USSTRATCOM	Inmarsat	FEMA	Boeing	FAA
White House Communications Agency	L-3 Communications	Florida Division of Emergency Mgnt.	British Petroleum America	Bonneville Power Administration
Washington St. Dept of Transportation	Caterpillar, Inc.	Alaskan Airlines	United Launch Alliance	Salem and Hope Creek Nuclear Stations

Example of Registrants in 2008

Next Generation Air Transportation System 2012-2025

- Aviation takes a big leap
- NextGen has a heavy reliance on navigation, communication & radiation issues
- Huge challenge ahead for our space weather models and observations!





Space Weather Requirements in NextGen

- Space Weather Prediction Center actively engaged in the NextGen Environmental Information (EI) Team

- Detailed Space Weather Performance Requirements for both Observations and Forecasts are being defined

•Examples

"The NextGen shall determine regions of the globe affected by geomagnetic storm activity with a horizontal accuracy of plus or minus 80 km"

"The NextGen shall forecast the regions of high energy (> 10 MeV) solar radiation with a vertical accuracy of plus or minus 4,000 feet"

Federal Aviation Administration

Preliminary Performance Requirements (pPR)

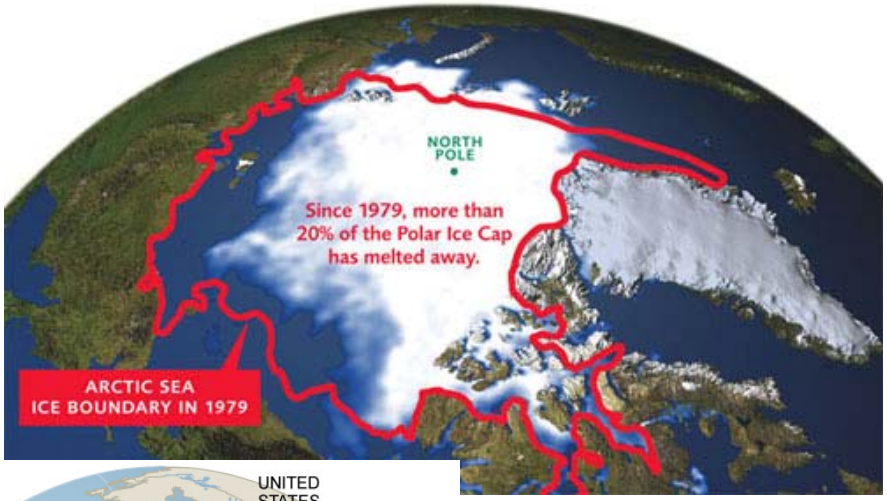
Developed for the Next Generation Air Transportation System (NextGen)

Concept and Requirements Definition (CRD) Phase

NextGen Four-Dimensional Weather Single Authoritative Source (4-D Wx SAS)

Initial Draft - Version 0.1a2c

High-Latitude Geophysical Exploration, Navigation and Communication



A Shortcut Across The Top of the World

The Northeast Passage, across the Arctic Ocean, provides a shorter alternative for cargo vessels travelling between Europe and Asia than using the Suez Canal. It is shorter than the Panama Canal route for some voyages between the North American west coast and Europe.

LENGTH OF A VOYAGE TO ROTTERDAM FROM:

YOKOHAMA, JAPAN
12,894 miles via Suez Canal,
8,452 miles via Northeast Passage

SHANGHAI, CHINA
12,107 miles via Suez Canal,
9,297 miles via Northeast Passage

VANCOUVER, CANADA
10,262 miles via Panama Canal,
8,038 miles via Northeast Passage

Electrical Power Grid…

- **The grid is becoming increasingly vulnerable to space weather events** *Future Directions in Satellite-derived Weather and Climate Information for the Electric Energy Industry – Workshop Report Jun 2004*

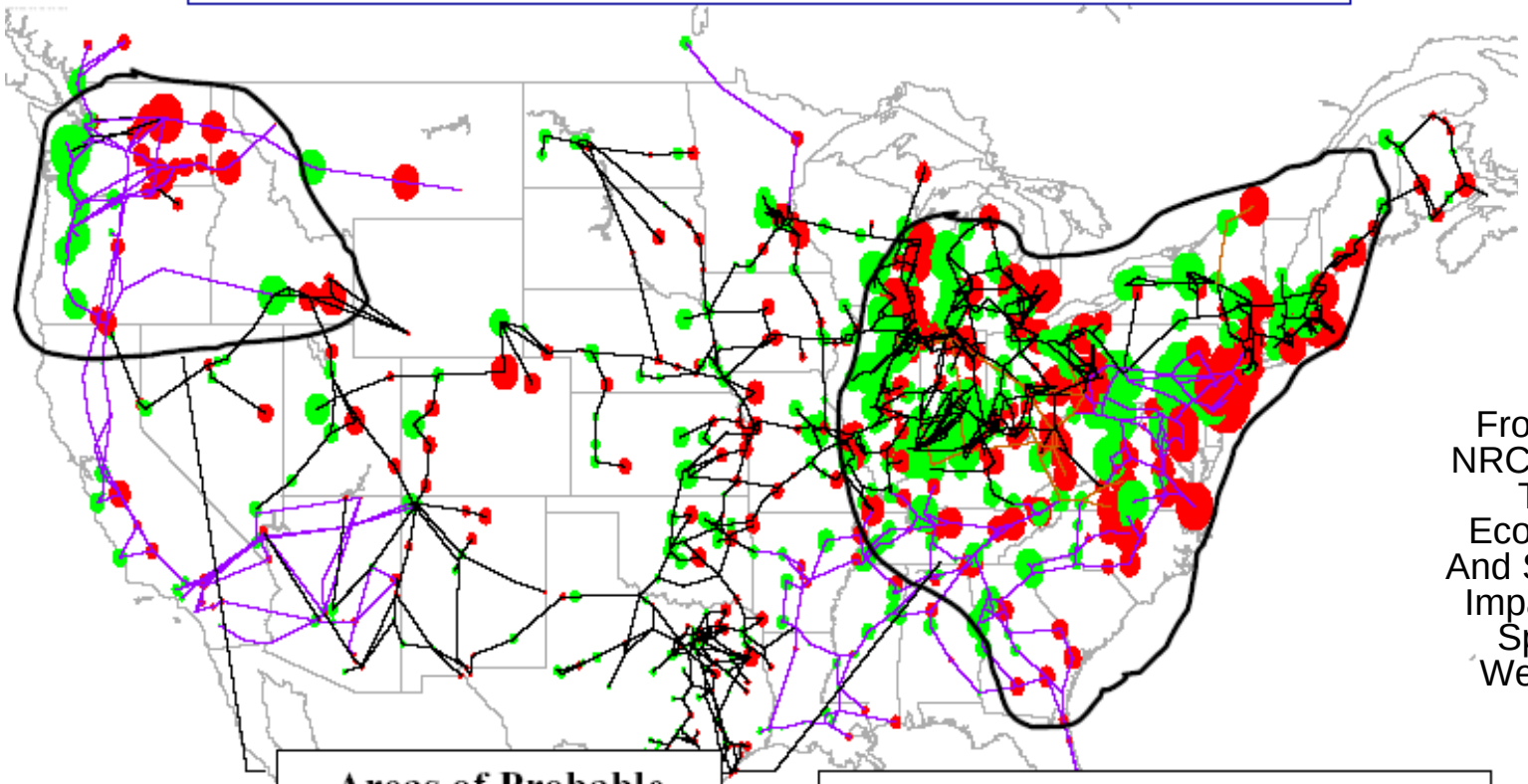
- **"…blackouts could exceed even that of the very large blackout that occurred in August 14, 2003. And there is no part of the U.S. power grid that is immune to this… we could impact over 100 million population in the worst case scenario."** John Kappenman - before U.S. House Subcommittee on Environment, Technology & Standards Subcommittee Hearing on *"What is Space Weather and Who Should Forecast It?"*

From the NRC report: The Economic And Societal Impacts of Space Weather

Regional Power Grid Disruptions

Severe Electrojet Disturbance Scenario

Power System Disturbance and Outage Scenario of Unprecedented Scale



Areas of Probable Power System Collapse

Impacted Regions involve population of >130 Million

From the NRC report: The Economic And Societal Impacts of Space Weather

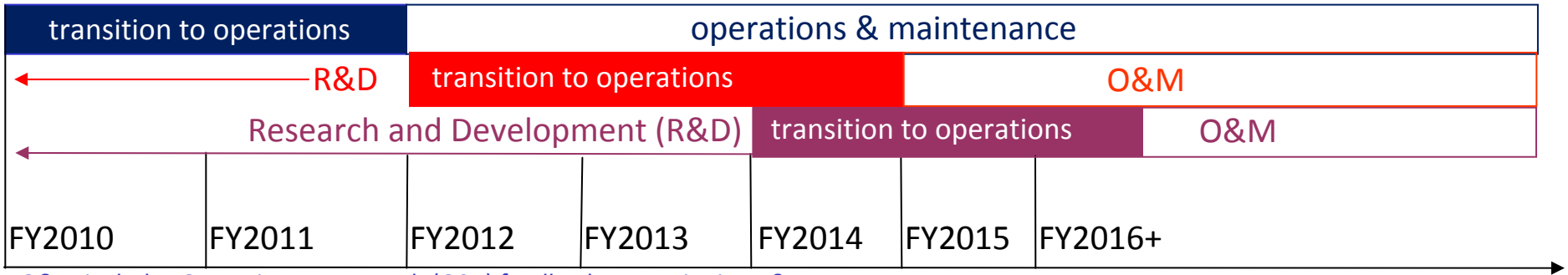
Planned Improvements

- *The proposed way forward to develop improved space weather models to maximize solar wind and CME data for extended forecast and warnings*

- **Solar Wind Disturbance Propagation Model**
  - Geomagnetic storm predictions go from ~1 hour to 18hr - 4 days

- **Geospace Response Model**
  - Will replace limited value global predictions with actionable regional forecasts and warnings

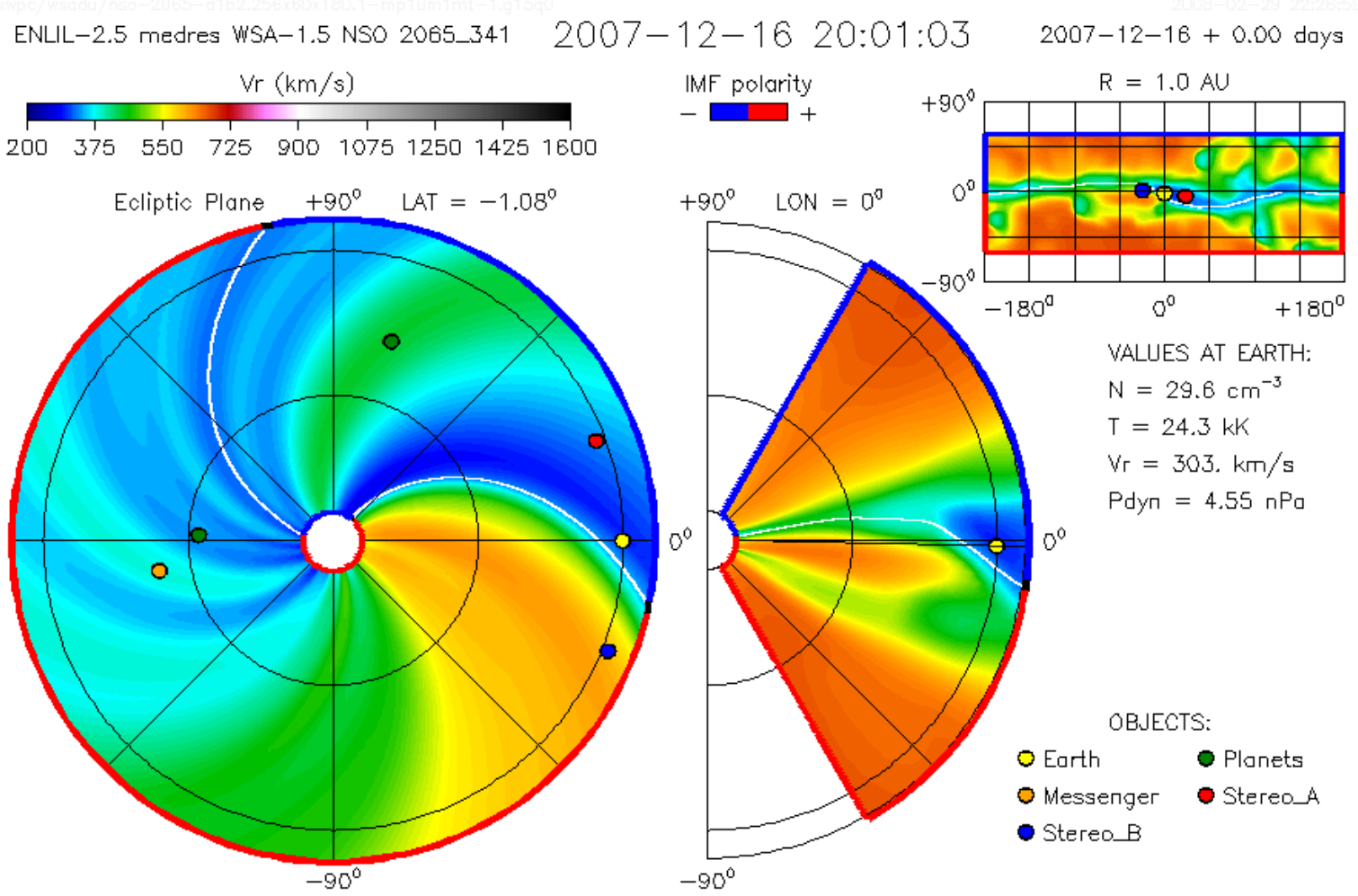
- **Energetic Particle Transport Model**
  - Model to predict radiation storm peak intensity, timing, and spectrum; no models currently exist!



- O&M includes Operation to Research (O2R) feedback to continuing R&D

WSA-Enlil

(SWPC Test Product now providing forecast guidance)

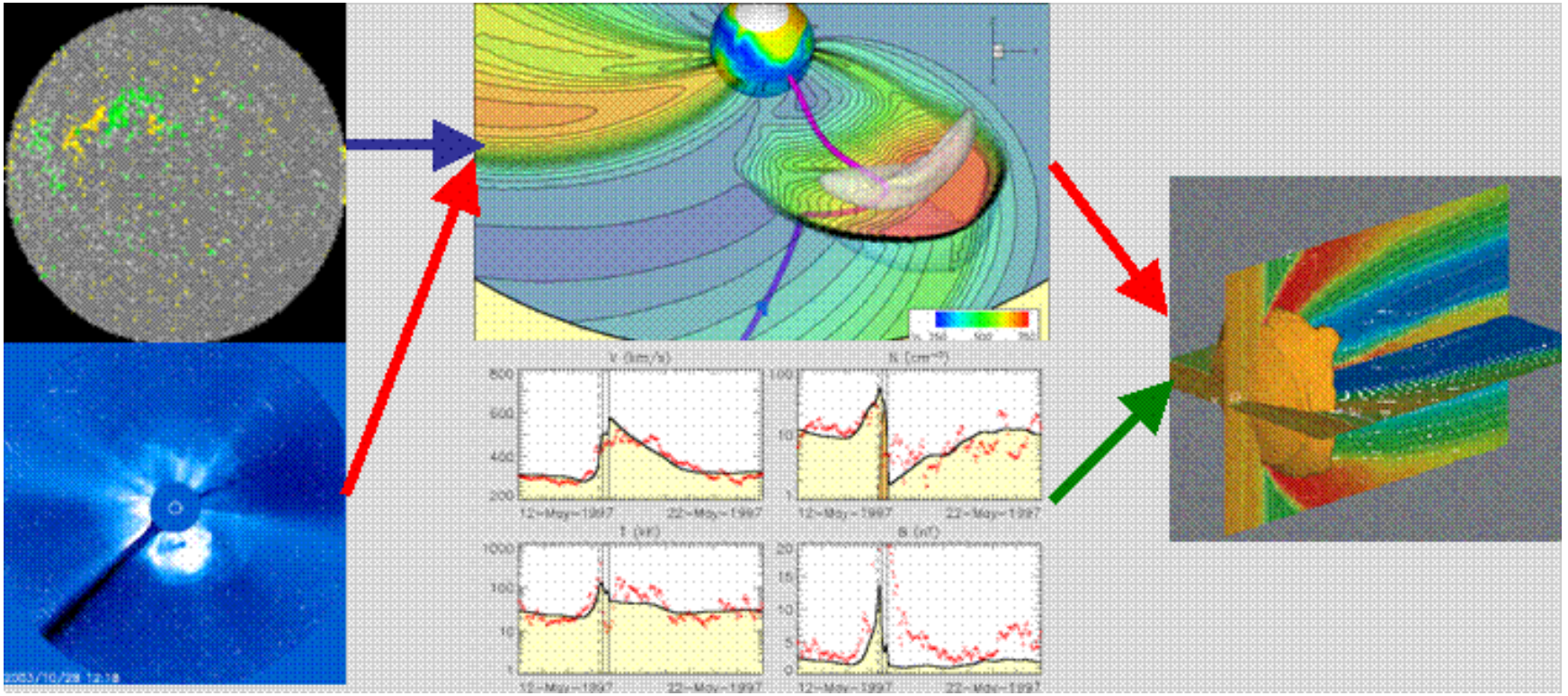


ambient only, no CME

D. Odstrcil and N. Arge

Solar Wind Forecast Model

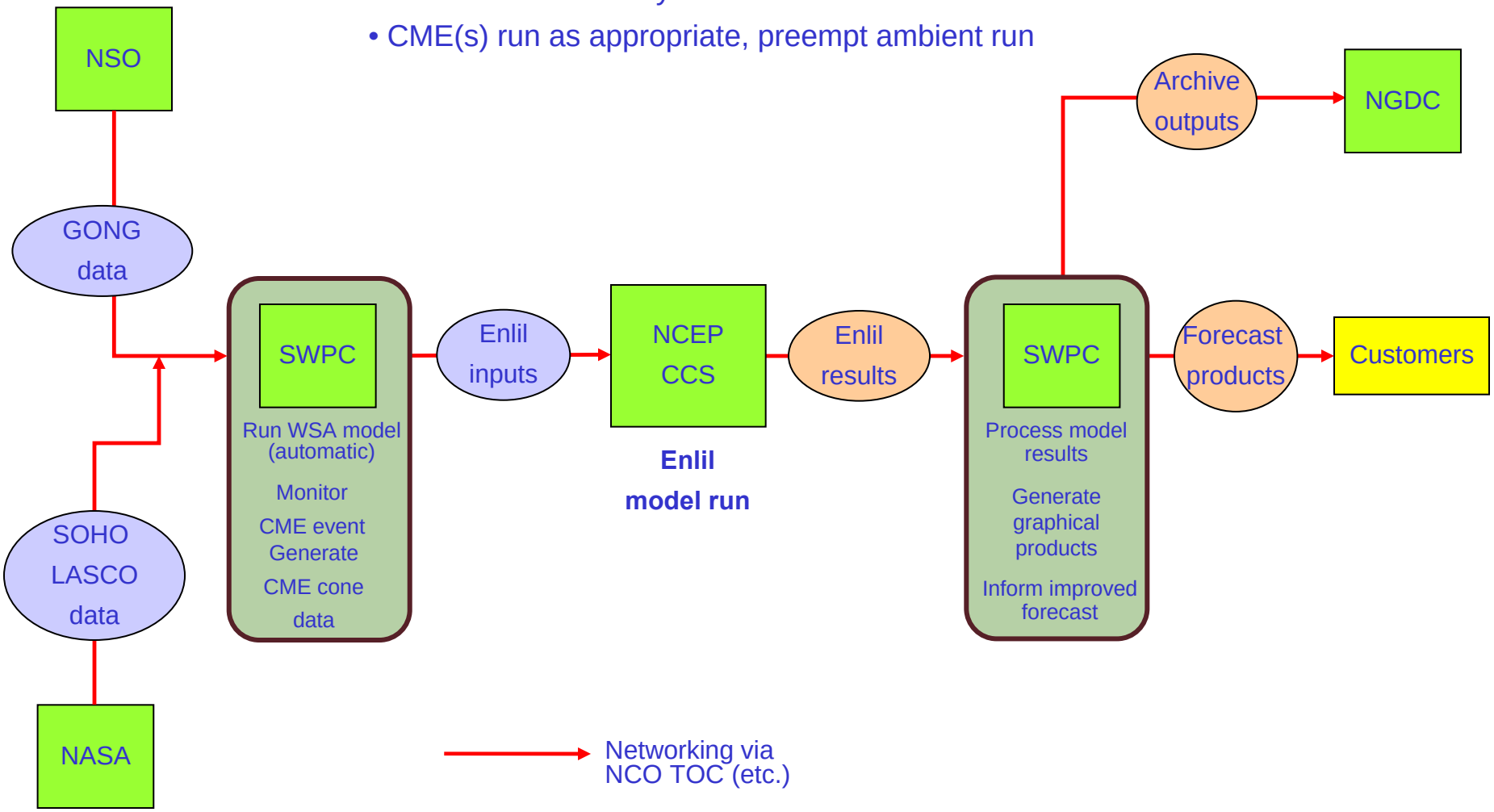
(WSA - Enlil background and CME Disturbance Cone)



- Partnership: NOAA SWPC, CU CIRES and LASP, NSF/CISM, NWS EMC and NCO, AFWA, AFRL, NASA/ESA, NASA CCMC, NCAR, NSO, NRL…
- FY 10 NOAA SWPC expects adjustment to base funds for transition (waiting on final numbers)

WSA-Enlil CONOPS

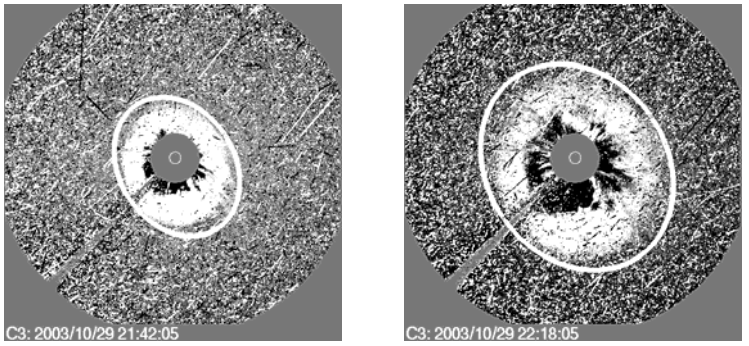
- Ambient run 4x / day
- CME(s) run as appropriate, preempt ambient run

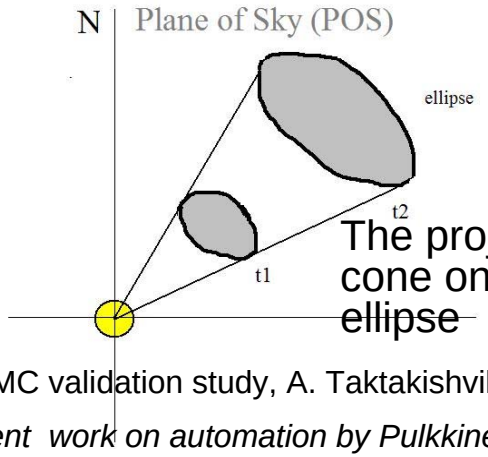


Cone Model for Halo CME

- CCMC implemented cone model (based on work of Zhao, Xie and coworkers) and provided to SWPC
- SWPC building operational tool in cooperation with CCMC and NRL
- Continued model validation and discussions with CCMC on implementation for operations is essential

LASCO/C3 coronograph running difference images

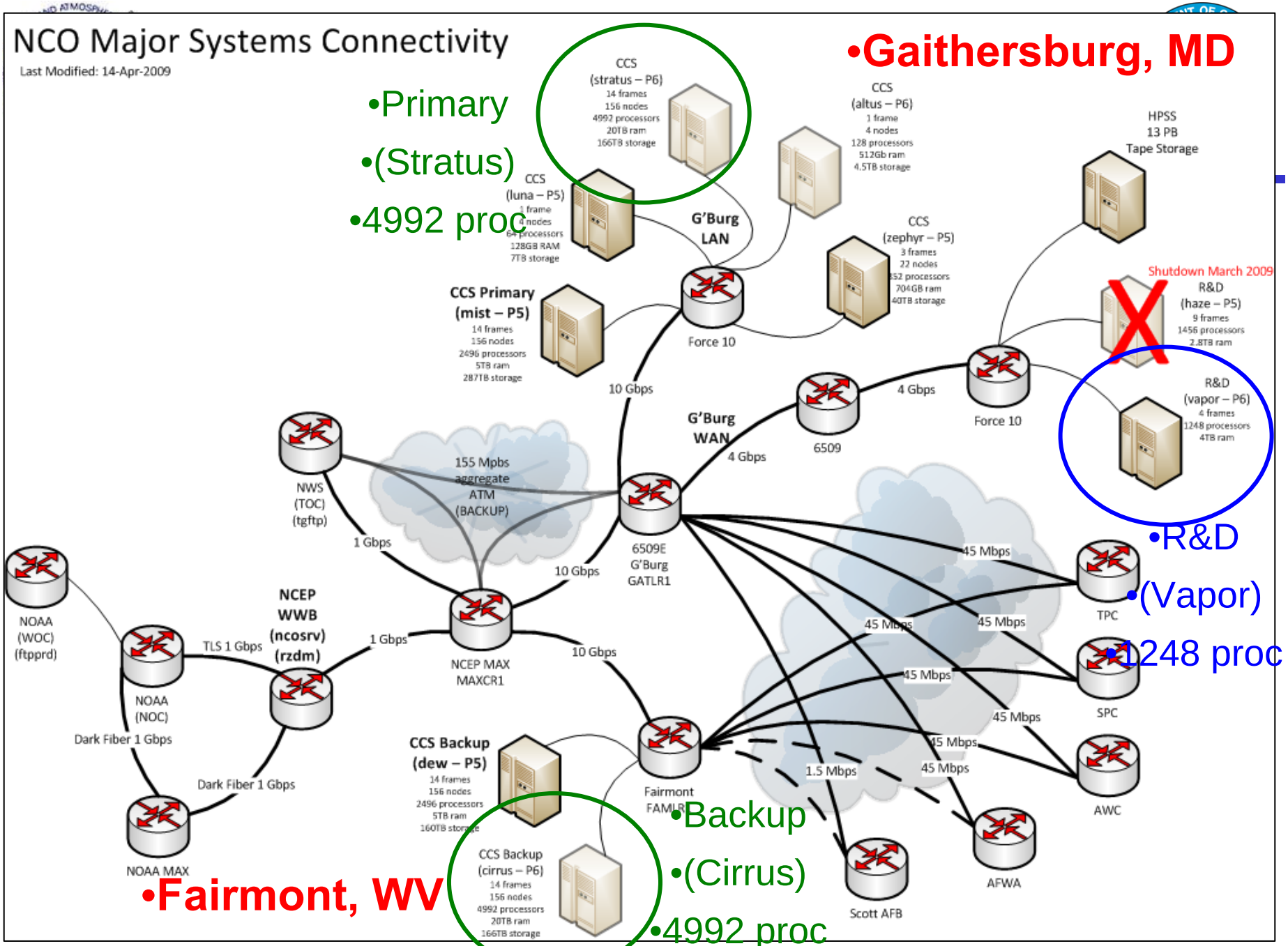




The projection of the cone on the POS is an ellipse

From CCMC validation study, A. Taktakishvili, *et al, 2009*

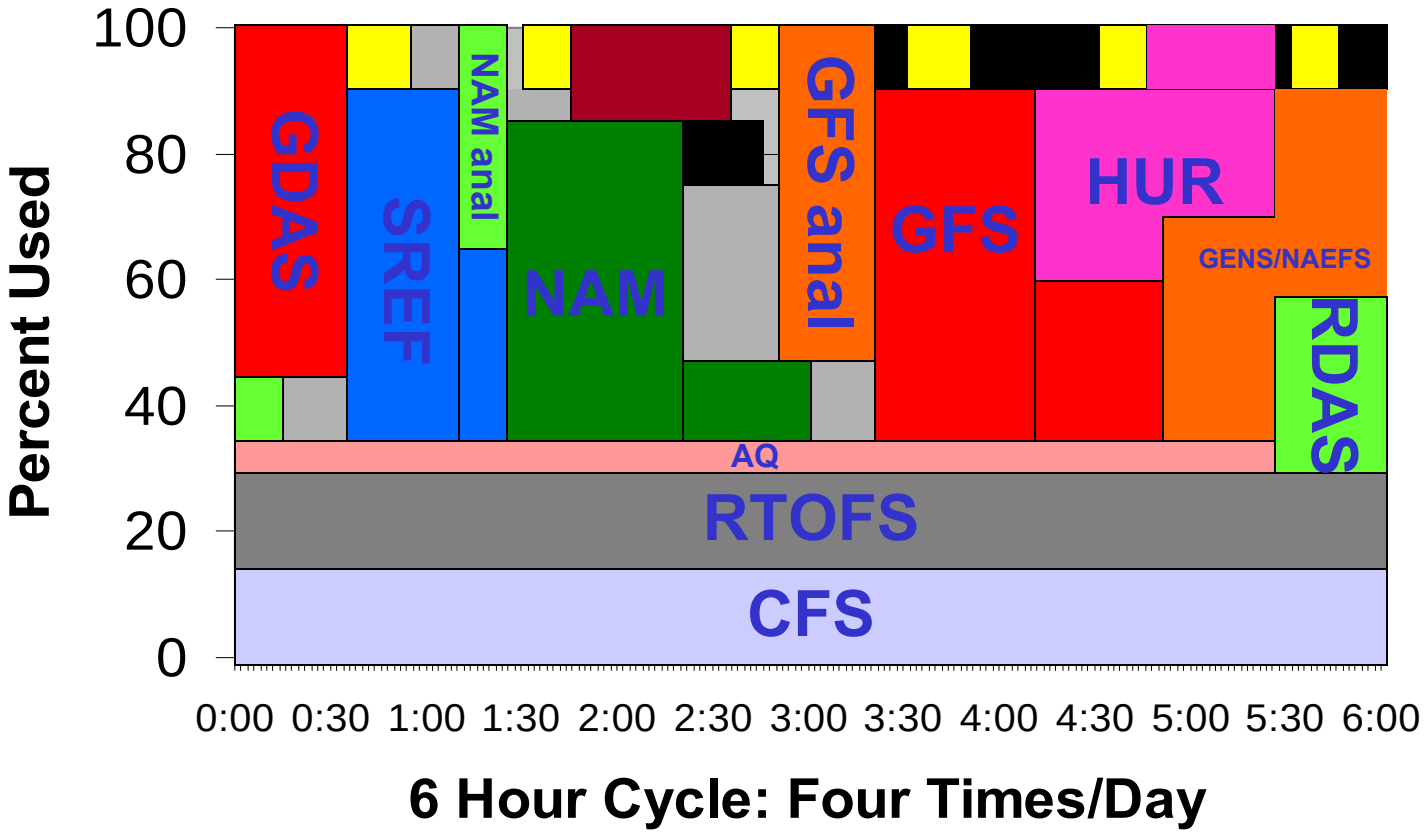
(Also recent work on automation by Pulkkinen et al. 2010)


NCO Major Systems Connectivity
Last Modified: 14-Apr-2009
•Gaithersburg, MD
•Primary
•(Stratus)
•4992 proc
CCS
(stratus – P6)
14 frames
156 nodes
4992 processors
20TB ram
166TB storage
CCS
(altus – P6)
1 frame
4 nodes
128 processors
512Gb ram
4.5TB storage
HPSS
13 PB
Tape Storage
CCS
(luna – P5)
1 frame
4 nodes
64 processors
128GB RAM
7TB storage
G'Burg
LAN
CCS
(zephyr – P5)
3 frames
22 nodes
352 processors
704GB ram
40TB storage
Shutdown March 2009
R&D
(haze – P5)
9 frames
1456 processors
2.8TB ram
CCS Primary
(mist – P5)
14 frames
156 nodes
2496 processors
5TB ram
287TB storage
Force 10
10 Gbps
4 Gbps
6509
Force 10
G'Burg
WAN
4 Gbps
R&D
(vapor – P6)
4 frames
1248 processors
4TB ram
•R&D
•(Vapor)
•1248 proc
NWS
(TOC)
(tgftp)
155 Mpbs
aggregate
ATM
(BACKUP)
1 Gbps
10 Gbps
6509E
G'Burg
GATLR1
45 Mbps
TPC
45 Mbps
45 Mbps
SPC
45 Mbps
45 Mbps
45 Mbps
AWC
NOAA
(WOC)
(ftpprd)
NCEP
WWB
(ncosrv)
(rzdm)
TLS 1 Gbps
1 Gbps
NCEP MAX
MAXCR1
10 Gbps
NOAA
(NOC)
Dark Fiber 1 Gbps
Dark Fiber 1 Gbps
NOAA MAX
CCS Backup
(dew – P5)
14 frames
156 nodes
2496 processors
5TB ram
160TB storage
Fairmont
FAMLR
1.5 Mbps
45 Mbps
AFWA
Scott AFB
•Backup
•(Cirrus)
•4992 proc
CCS Backup
(cirrus – P6)
14 frames
156 nodes
4992 processors
20TB ram
166TB storage
•Fairmont, WV

NCEP Production Suite

Weather, Ocean, Land & Climate Forecast Systems

Current - 2009



Computational Details

- Running on NCEP “Vapor” machine (IBM Power 6)
- 32 processors (1 node): parallel MPI
- Medium resolution (2deg) mode (512 * 60 * 180)
- Runtime ~ 30 minutes
- Output data ~ 12 Gb
- Startup: input today’s global maps and let relax for 12 days to remove transients, resulting in fixed co-rotating solution that can be used for today to 5-day predictions

Planned Improvements

- ***The proposed way forward to develop improved space weather models to maximize solar wind and CME data for extended forecast and warnings***

- **Solar Wind Disturbance Propagation Model**
  - **Geomagnetic storm predictions go from ~1 hour to 18hr - 4 days**

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  - **Will replace limited value global predictions with actionable regional forecasts and warnings**

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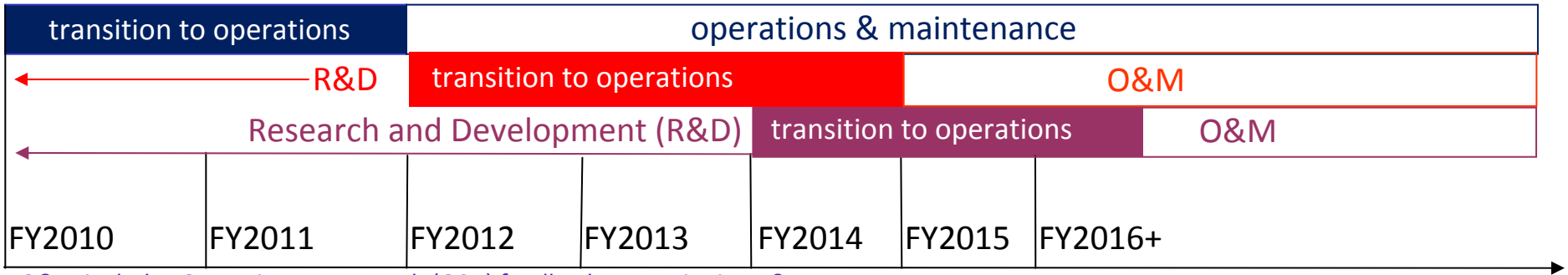

•O&M includes Operation to Research (O2R) feedback to continuing R&D

Electric Power Grid

NORTH AMERICAN ELECTRIC RELIABILITY COUNCIL

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Geomagnetic Disturbance Phenomenon

- The Space Environmental 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)

Electric Power Companies Take Actions to Mitigate Geomagnetic Storm Impacts

	© ISO New England Inc. 2003	Procedure: Implement Solar Magnetic Disturbance Remedial Action
	Process Name: Implement Emergency Operations	
	Procedure Number: RTMKTS.0120.0050	Revision Number: 6
	Procedure Owner: Steve Weaver	Effec 2005
	Approved By: VP Operations	Revi 1, 20

1. Discontinue maintenance work and service high voltage transmission line long lines out of service.
2. Maintain system voltages within ac range to protect against voltage swing
3. Review the availability of the Chest Orrington capacitor banks to respond deterioration if necessary.
4. Adjust the loading on Phase 1 or Ph Sound Cable and Highgate HVdc ties t 40% to 90% range of nominal rating of
5. Reduce the loading…

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

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

SWPC 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

SWPC Customer Requirements – One Example Used to Establish Metrics that Represent Needs

ELECTRIC UTILITIES

User Requirement	Timeliness	Customer	Rationale
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. 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 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

SWPC Customer Requirements – Example (con't)

ELECTRIC UTILITIES (con't)			
User Requirement	**Timeliness**	**Customer**	**Rationale**
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 geomagnetically induced currents, 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.
GEOPHYSICAL OPERATIONS			
Forecasts of perturbations in the geomagnetic field	>1 day	Geophysical surveyors 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	Geophysical surveyors and drilling industry	It is estimated that correction of magnetically oriented drilling requires a time-scale of about 1 day to prevent drilling errors from becoming unacceptable.

Complete Customer Requirements document at: http://www.swpc.noaa.gov under customer services

Operational Metrics for Geospace Models – Status

- Goal: Validation of Geospace prediction models to determine which model or models should begin transition to operations process beginning about 2012.
- Focus: Models that can predict regional geomagnetic activity
- Timeline: About 12 months
- First Steps: CCMC leads evaluation; Build on GEM Storm Challenge; Establish partnerships; Decide on metrics; Conduct evaluation
- Metric Selection Workshop: Monday April 26, in Boulder, preceding Space Weather Workshop (April 27-30). Discussing and determining the metrics that can be used to select models that can meet operational needs.

Recent Activity and Next Steps

- 4/09 SWPC sends CCMC recommendations for performance measures and metrics to assess models for predicting regional geomagnetic disturbances
- 6/09 Validation of Geospace Models, and issues regarding validation, circulated to community
- 6/09 GEM summer meeting presentation on operational metrics
- 6/09 GEM lunch meeting with model developers and other interested members of the community results in valuable advice (focused options, need for clearly defined user metrics, capturing extreme events, community participation, model robustness limits choice of model parameters, models will likely have different performance strengths, feedback to research…)
- 6/09 SWPC Geomagnetic Activity Products document prepared
- 9/09 Meeting of opportunity with CCMC (Kuznetsova, Pulkkinen, and Singer) to discuss metrics, including "threshold" metrics
- 12/09 AGU meeting: Antti Pulkkinen reports on his new "threshold" metrics and further discussion to establish next steps, Singer presentation
- 1/10 CCMC Workshop: this presentation and community discussion
- 4/10 Geospace Model Validation Workshop at SWPC with model developers, agencies… to finalize metrics, selection of events, and other details

- All of these discussions are leading to developing appropriate metrics for validation of geospace models for operational purposes

The Process for Establishing Operational Metrics

- Derived from operational needs and customer requirements
- But, also needs model developer participation
  - For example: an operational metric might be specification of the dB/dt disturbance amplitude at a particular location and time; but the developer might suggest a metric that specifies the magnetic field at geosynchronous orbit. The later may indicate the quality of the former, but isn't a product for the user.
- Metrics must be defined by operational needs but tuned by working with developers
- Scientific models contribute to operations (R2O), and metric studies will identify where model improvements are needed (O2R)

Geomagnetic Disturbance Model Performance Measures / Issues

Set Up:

- Choice of events or intervals for model performance comparisons
  - E.g. Storms caused by CME's, by corotating interaction regions
- Use of Level 2 data or real-time data that includes gaps and other data quality issues
- Method of propagation from of L1 data to the magnetopause
- Choice of selectable model parameters: e.g. conductivities, spatial and temporal resolution

Performance Measures:

- Ground-based ΔB variations compared to ground magnetometer chain observations
- Skill scores: using either mean values or persistence as the standard model for comparison; comparisons for individual stations, as well as for overall average and averages for different longitude sectors and latitudes
- Performance during the course of a storm from pre-storm, to main phase, to recovery phase, and how models perform in general for different activity levels

Geomagnetic Disturbance Model Performance Measures / Issues

Performance Measures (con't)

- Improvements over current products: demonstrate that the regional model skill provides improved value over the global Kp prediction from the Costello or Wing models
- Utility Metrics: Determine how well models succeed at detecting the timing, amplitude and duration of an event (e.g. large magnetic perturbation) in a long time series of data.
  - Questions need to be examined such as how many hits, false alarms and missed events occur and the various statistical properties that can be determined from accumulation of this information. As shown in Pulkkinen et al. (2007) this sort of examination can be performed on a long run of data to look for various event thresholds. Events can be defined with different amplitude thresholds and time windows and then plots can be made showing properties such as the ratio of hits to misses for different model runs.

Other Issues:

- Intellectual property agreements, publishing metrics and results, pathways to operations (CCMC, AFRL, universities, laboratories…)

Summary

- SWPC values the continuing support and expertise provided by the CCMC
- CCMC is:
  - key for an independent validation of models available for transition to operations
  - a testbed for tools that can be used by forecasters
  - an important interface between model developers, the research community, and operational organizations and a,
  - forum for bringing together model developers, researchers, operations personnel, and agencies