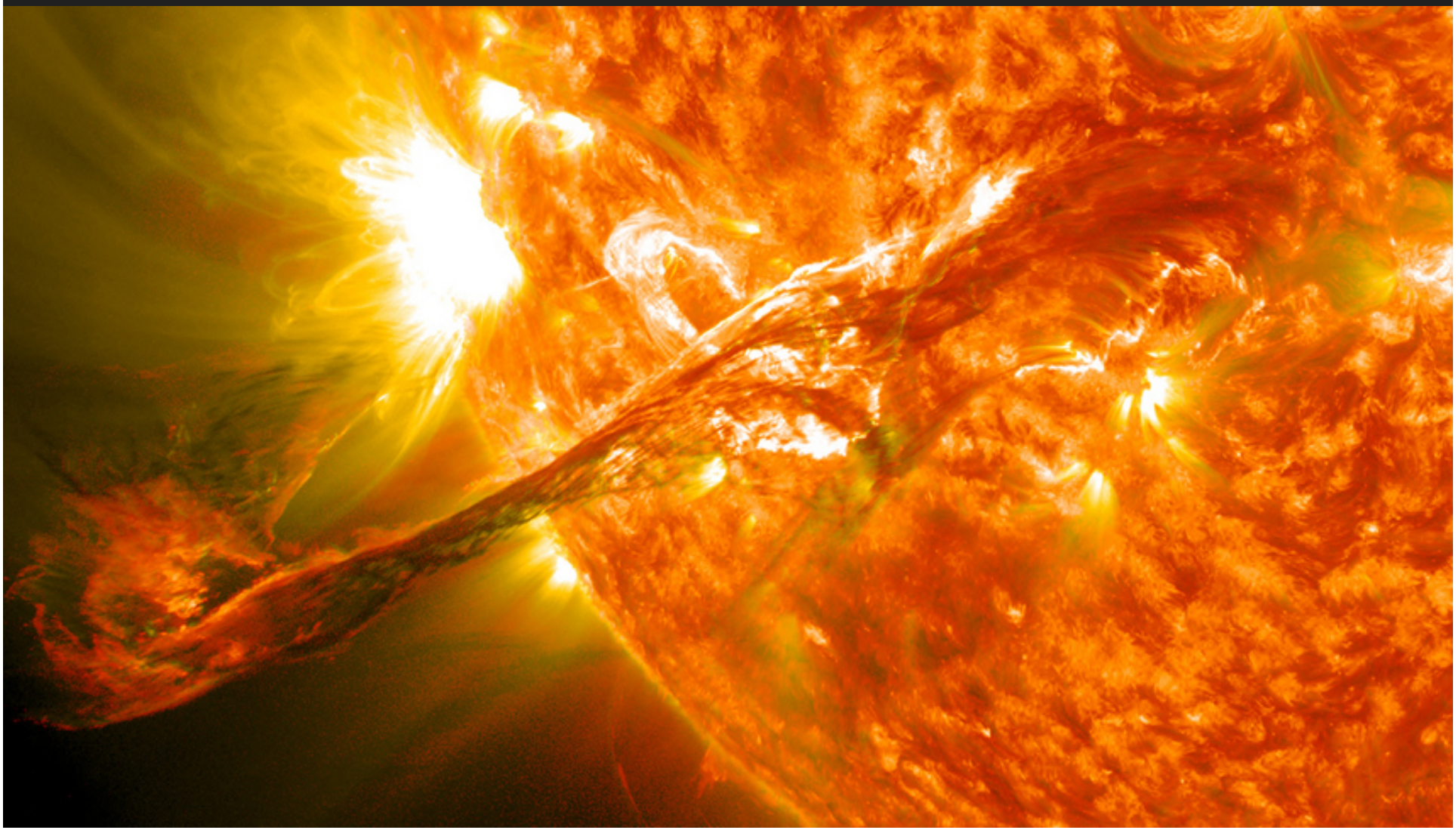
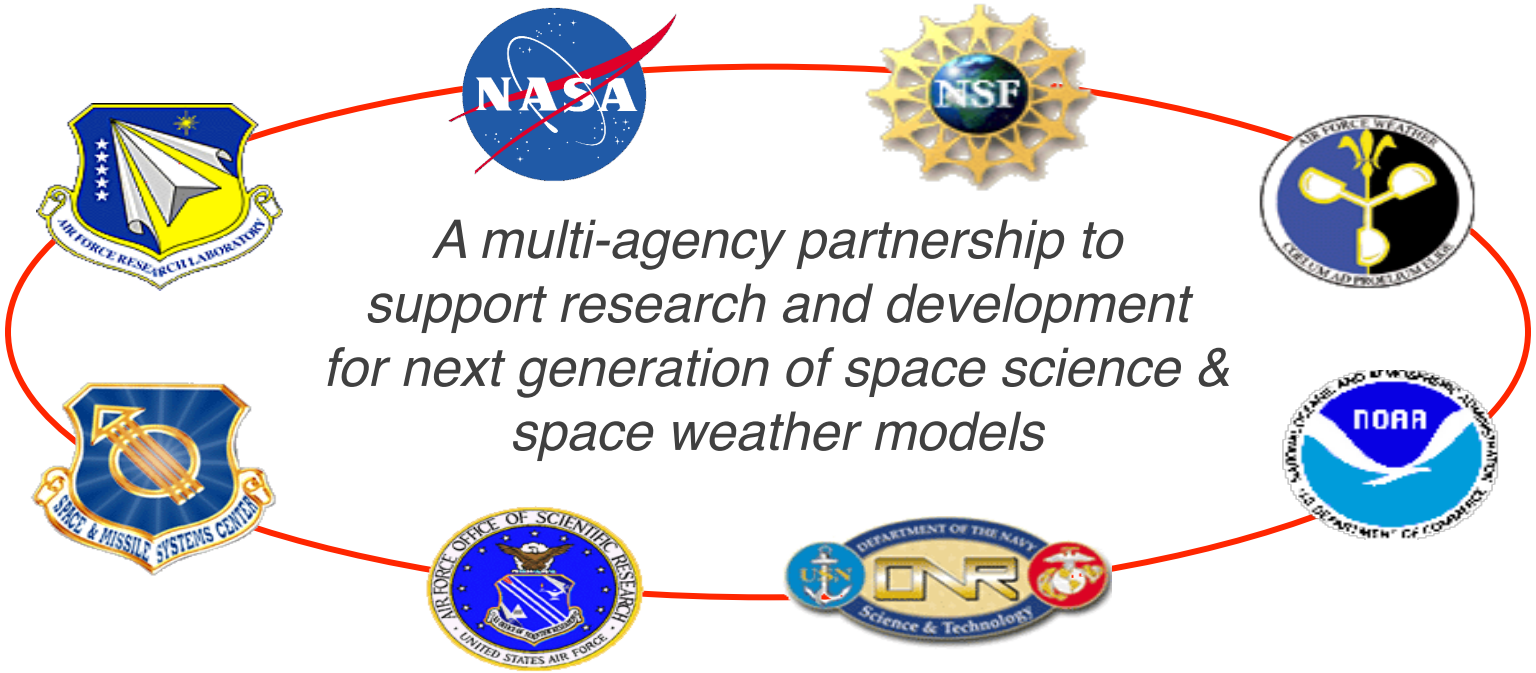

National Aeronautics and Space Administration
NASA
The Integrated Space Weather Analysis System
Marlo Maddox
SW REDI Bootcamp
June 2nd, 2015
NASA Goddard Space Flight Center
Greenbelt, MD
http://ccmc.gsfc.nasa.gov
HSD
Space Weather LAB
www.nasa.gov

How Do You Quickly Determine Past, Present, & Expected Space Weather Impacts?

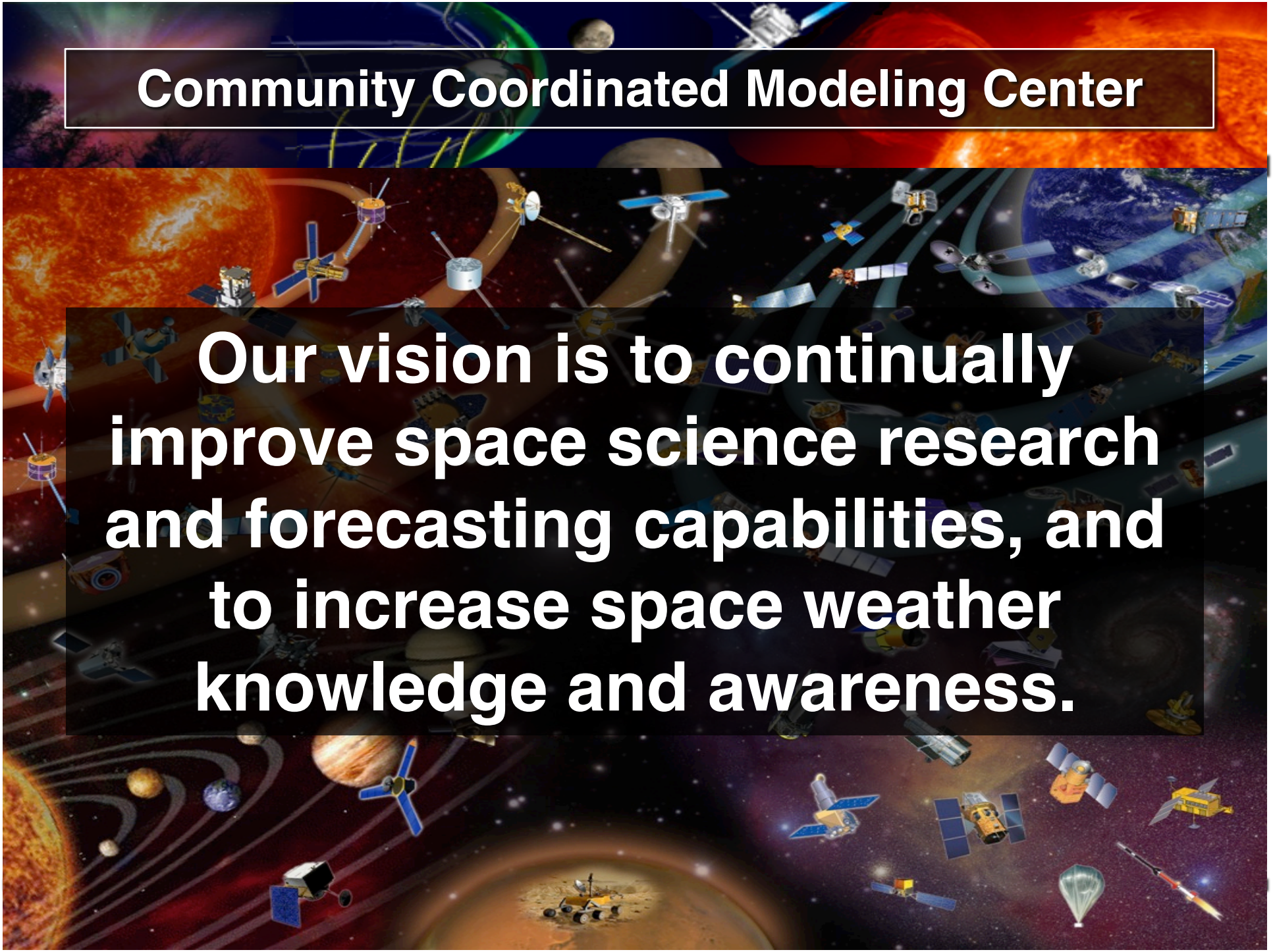


Community Coordinated Modeling Center



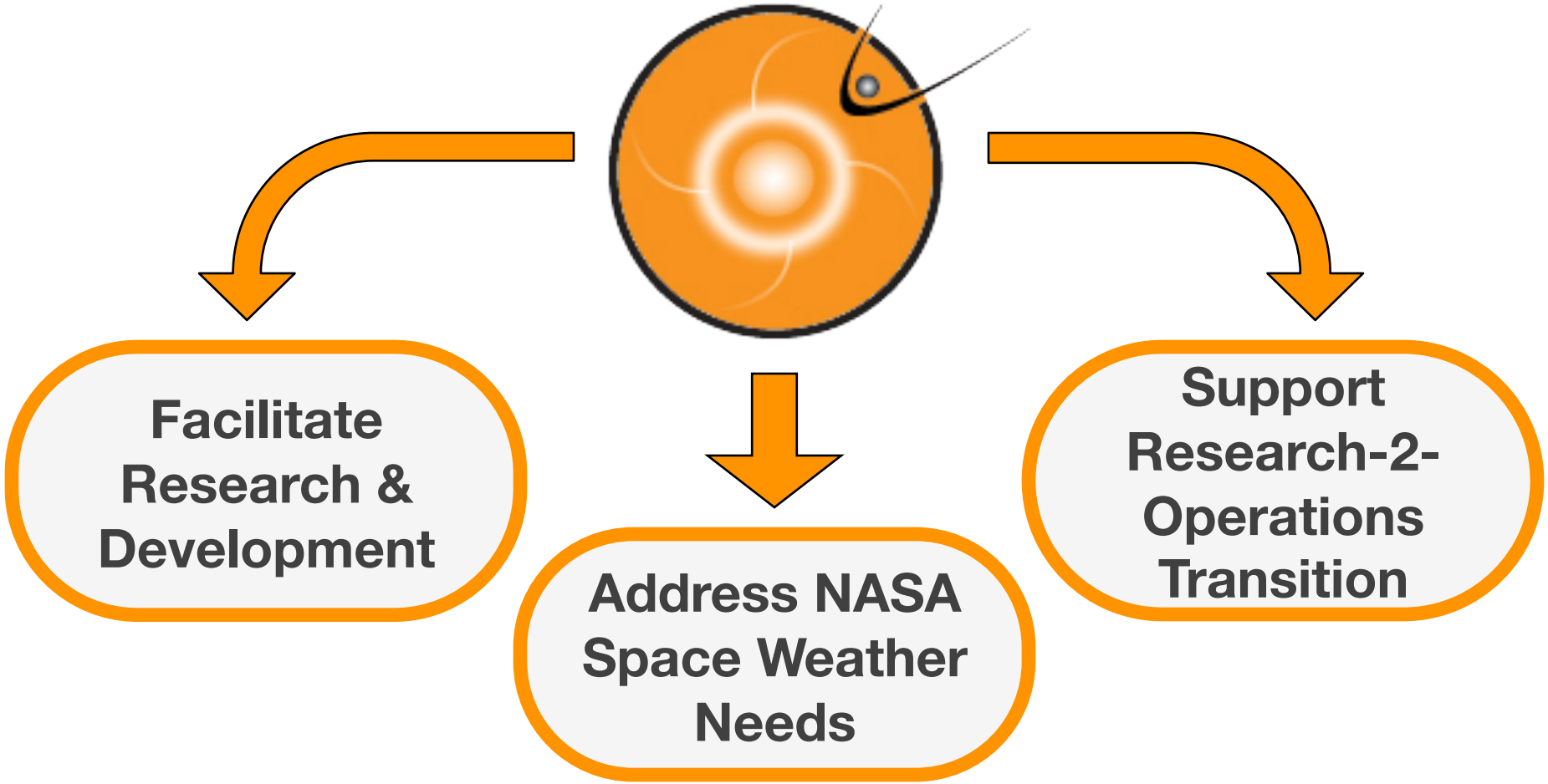
- Established in 2000 as an essential element of the National Space Weather Program
- Designed to be a long-term & flexible solution to the Research-to-Operations (R2O) transition problem.

Community Coordinated Modeling Center



Our vision is to continually improve space science research and forecasting capabilities, and to increase space weather knowledge and awareness.

CCMC Goals



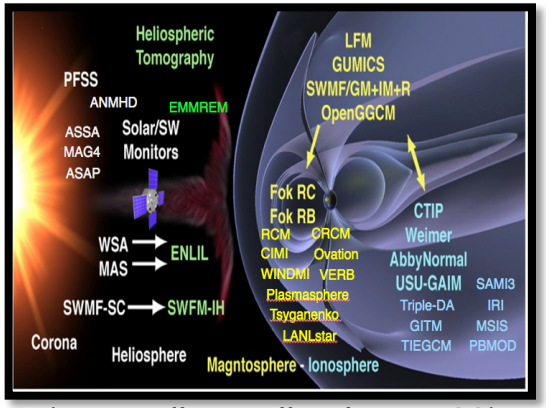
Core CCMC Partners: International Research Community, Model Owners, NASA Engineers and Mission Specialists, Operational Space Weather agencies (NOAA, DoD, UK Met Office).

CCMC Assets & Services:
Comprehensive Collection Of Space Weather Models

Corona **Heliosphere** **Magnetosphere** Inner Magnetosphere **Ionosphere/ Thermosphere**

CCMC Assets & Services

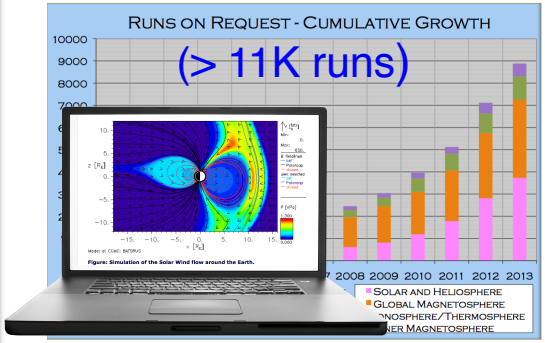
Models



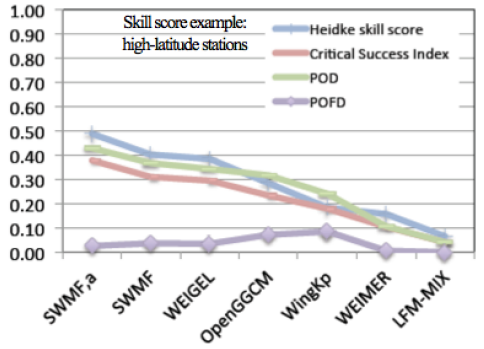
(expanding collection: > 60)

Simulation

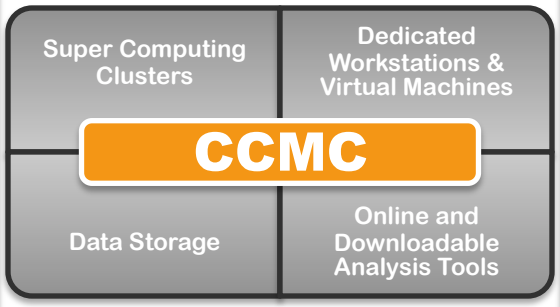
Services



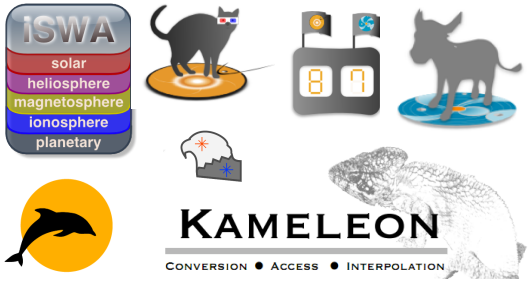
Assessment, Metrics, & Validation



Computational Infrastructure



Multi-Purpose Tools, Systems, Databases



Hands-on Education

Computational Resources

Community Coordinated Modeling Center

Super Computing Clusters

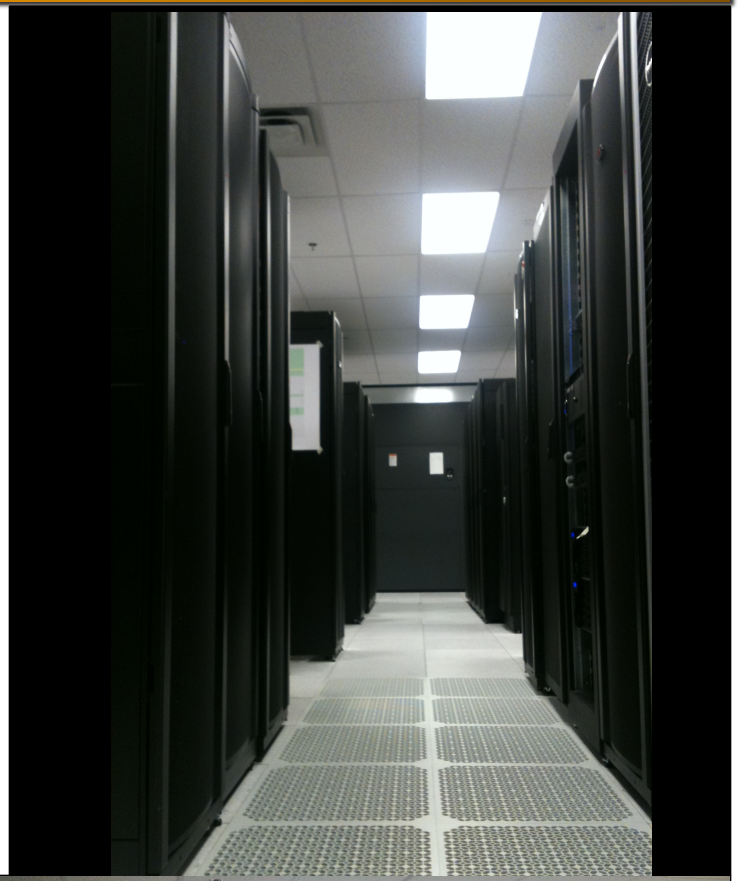
(2400 CPU's)

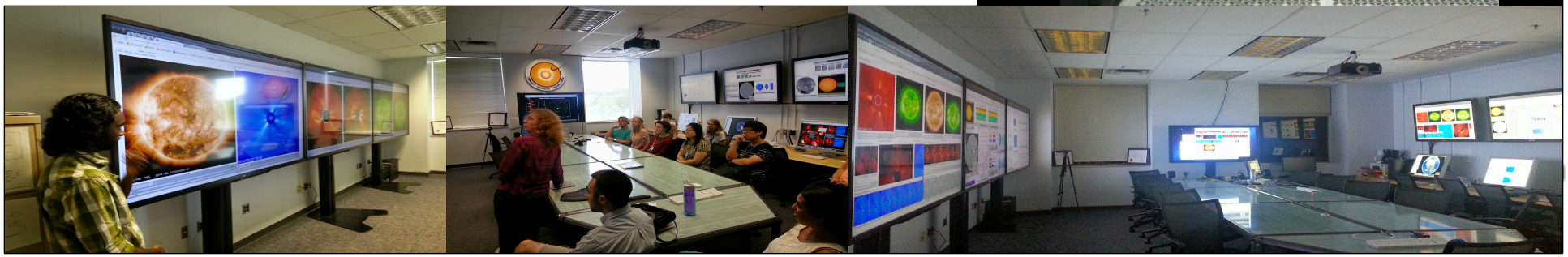
Dedicated Workstations

CCMC

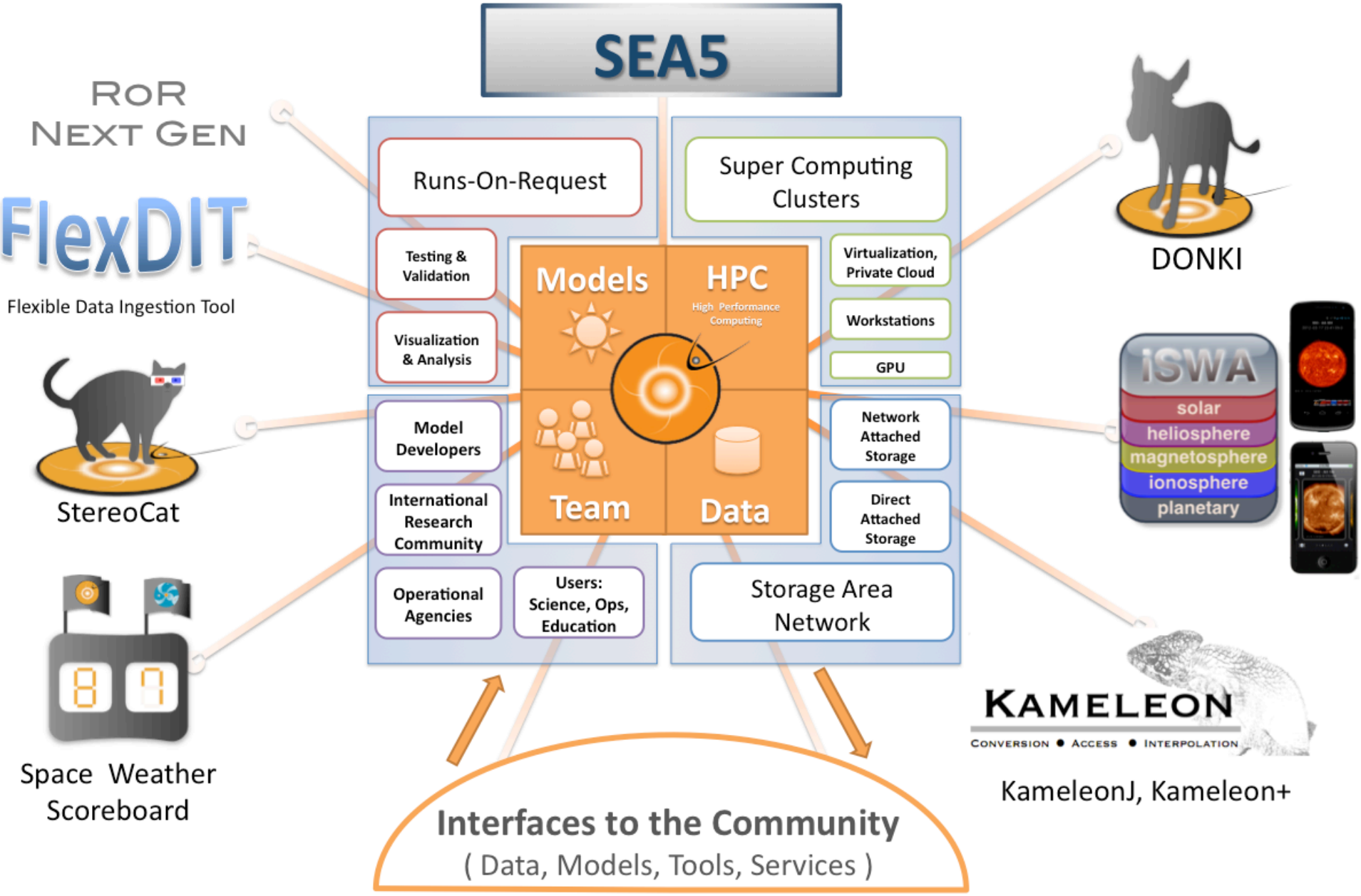
.8 Peta-Byte of Data Storage

Online and Downloadable Analysis Tools





CCMC Infrastructure, Tools, & Services



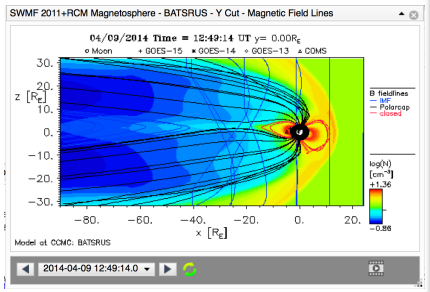
Technical Challenges

- Model ingestion, implementation, versioning
- Managing data streams: model input, model output, observational data (especially real-time & near-real-time streams)
- Maintaining Dedicated Computational Infrastructure
- Networking and Storage
- Maintaining A Perpetual Online Data Archive
- Disparate Data Formats & Metadata
- Advanced Scientific Visualization
- Decision Supporting/Actionable Space Weather Displays
- Data Discovery
- Data Dissemination

CCMC Tools, Systems, & Databases

for Research, Analysis, Metrics & Validation, Forecasting

Continuous Real-time Simulations



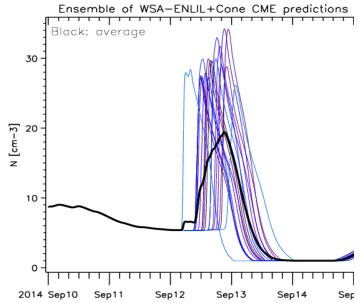
Event-Triggered Real-time Simulations

1-Click

Input Parameters Generation Tools

StereoCAT

Ensemble Simulations



iNtegrated Space Weather Analysis System

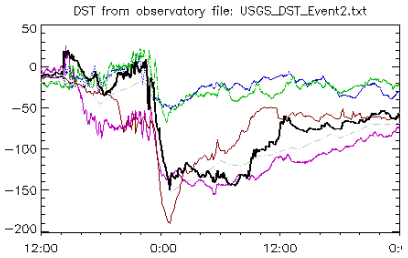
Databases:

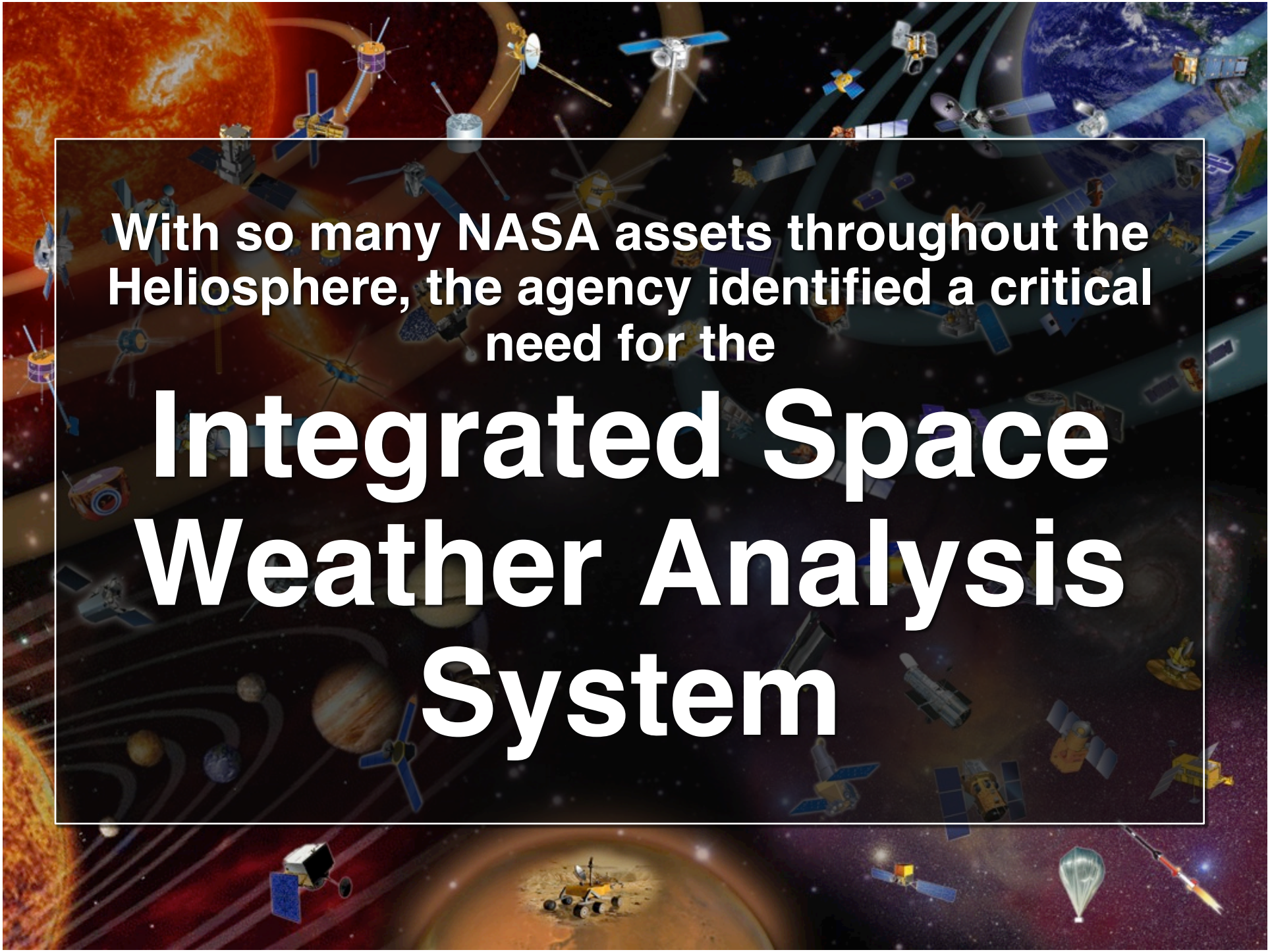
Run Results, Events, Impacts interpretations

DONKI

Forecasting Methods ScoreBoards

M&V Suite to Trace Model Improvements




With so many NASA assets throughout the Heliosphere, the agency identified a critical need for the
Integrated Space Weather Analysis System

iSWA Project Overview

OCE Technical Excellence Initiative Project

- Partnership between NASA HQ OCE, SWL, CCMC, & AETD
- Address technical challenges in acquiring space weather environment information
- Began March 2008
- Version 1.0 deployed November 2009

Fundamental Challenges To Be Addressed

- Existing space weather resources are diverse and scattered
- Data accessibility
- Accurate real time now-casting & forecasting of the space environment
- Historical space weather impact analysis

Initial Requirements Gathering

- GSFC SSMO, JSFC SRAG

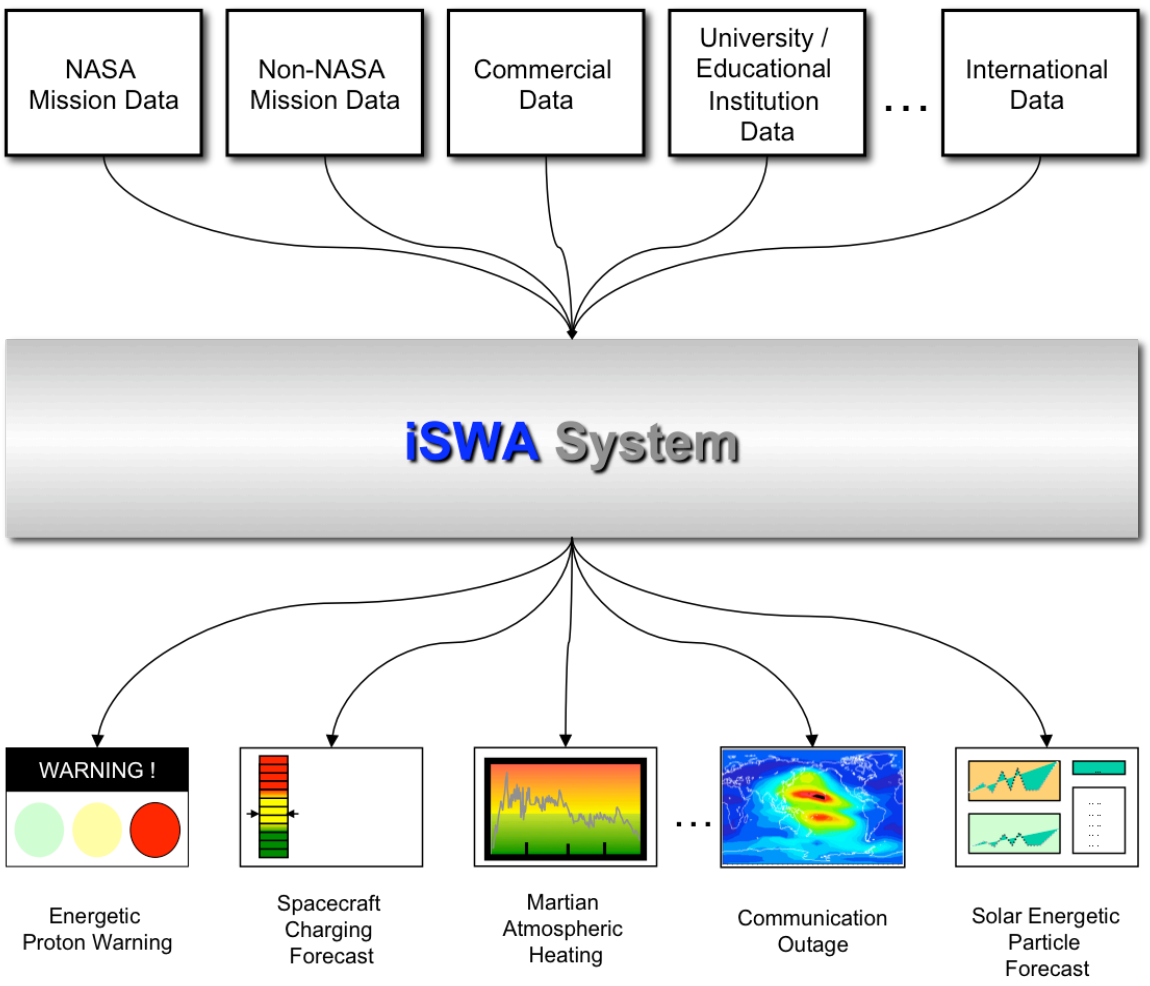
Refined Requirements

- Space Weather Workshops for NASA Robotic Missions

iSWA Solution & Deliverables

1. Acquire, ingest, and produce NASA relevant space weather information
2. Utilize both observational and simulation/model data
3. Produce and provide real-time data streams
4. Categorize and archive data for historical impact analysis
5. Provide customizable and highly configurable displays
6. Disseminate through the most widely deployed and accessible interface – the web

iNTEGRATED SPACE WEATHER ANALYSIS SYSTEM



Highly diverse and distributed space weather data consisting of the latest observational data along with the most advanced space weather model simulation output.

iSWA system collects data from a large and evolving list of sources. Data is sorted, characterized, and processed into 'mission decision supporting' products in response to individual user queries.

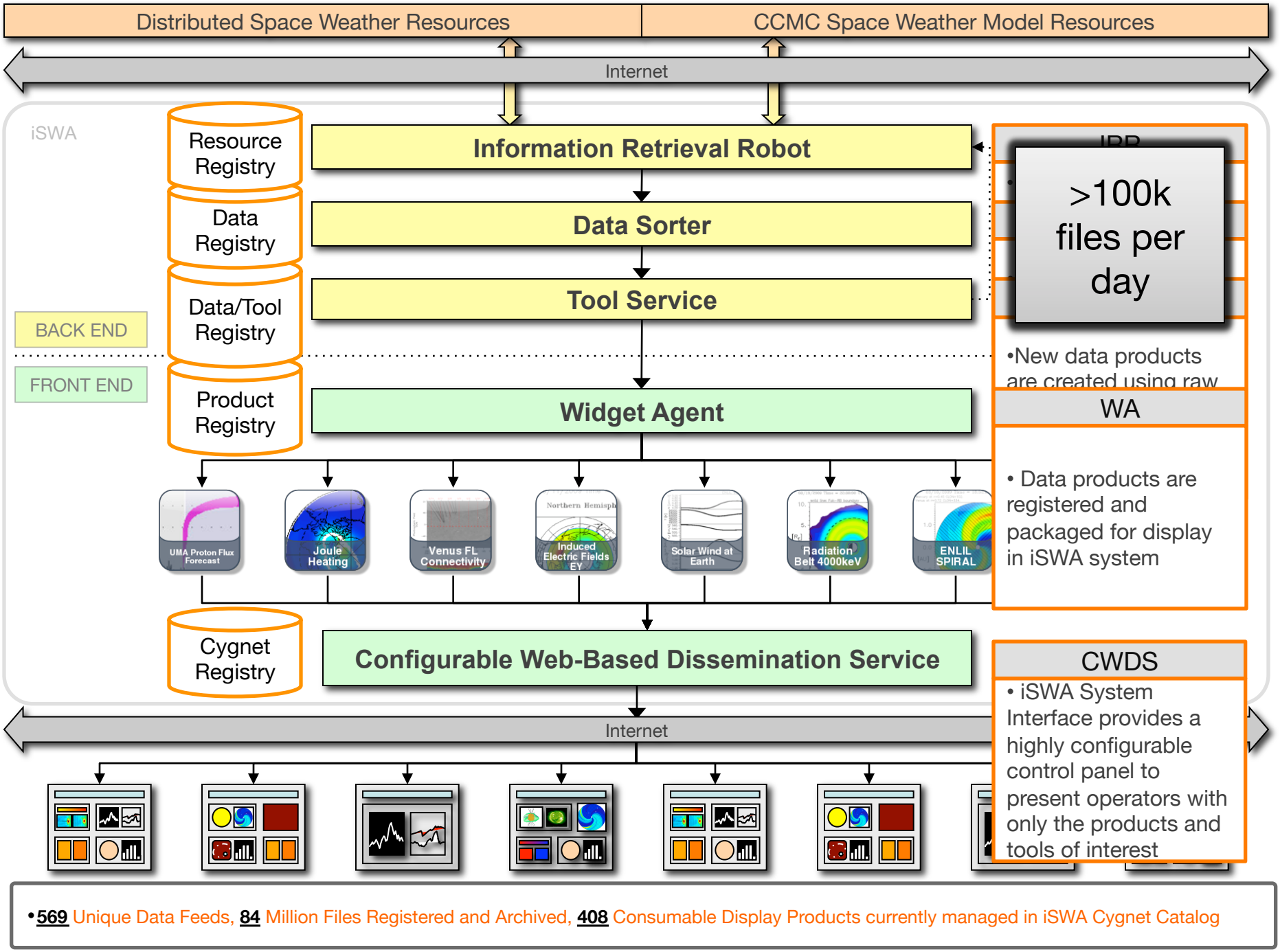
iSWA generates and provides a user-configurable display panel that can be accessed from a standard web browser. The end user can then customize their display to focus on specific products of interest.

iNTEGRATED SPACE WEATHER ANALYSIS SYSTEM

Data Management Challenges

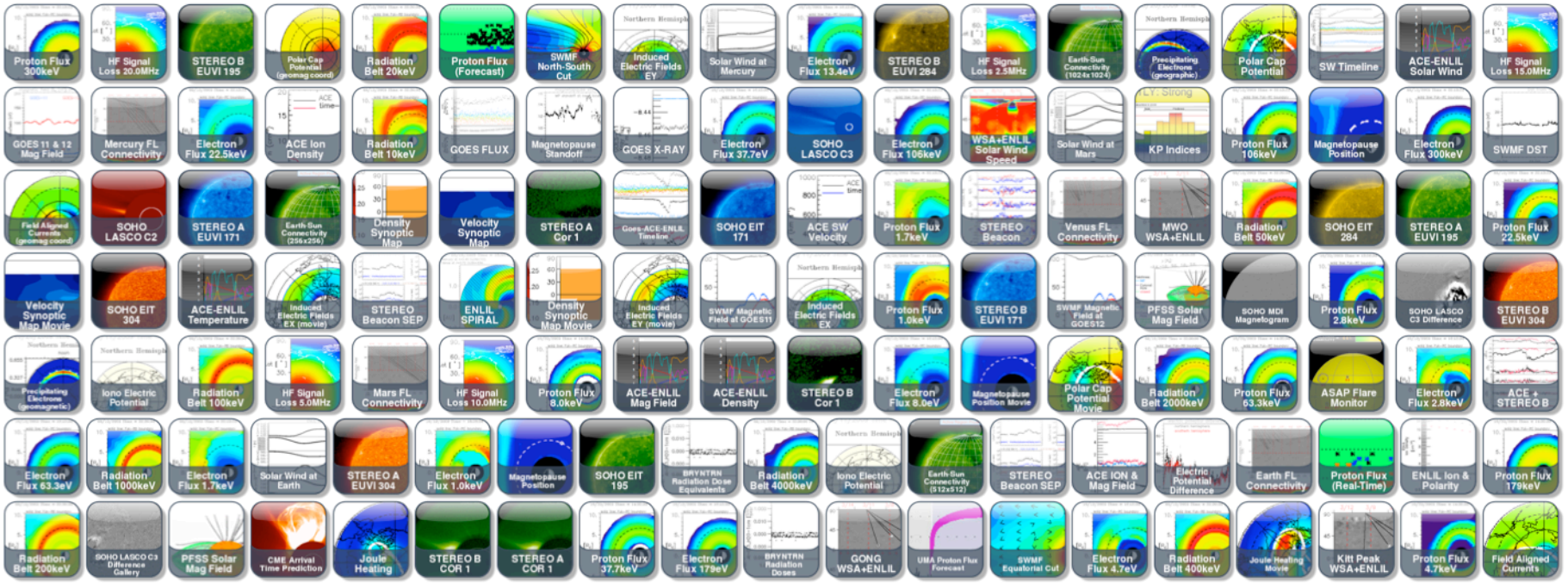
- Ingesting data streams from a variety of sources with varying:
  - Transfer Methods (push and pull)
  - Levels of availability
  - Access Protocols (http, ftp, scp, mv)
  - Naming Conventions
  - Update Intervals (efficient polling for new data)
  - Date & Time Stamp Formats i.e.

  [`2011-01-01_212500`] or [`2011-1-1_212500`] or [`20100101_212500`] or [`2011_001_212500`] or [`2010_Jan_01_212500`] or [`latest`] or…
- Sorting, Archiving, and Management
  - Persistent storage (file system or database)
  - Cataloging, How to keep track of what is where
  - Scalability, Additional storage
- Changes (urls, names, formats, extensions, etc.)


Distributed Space Weather Resources
CCMC Space Weather Model Resources
Internet
iSWA
Resource Registry
Data Registry
Data/Tool Registry
Product Registry
Information Retrieval Robot
Data Sorter
Tool Service
BACK END
FRONT END
Widget Agent
>100k files per day
•New data products are created using raw
WA
• Data products are registered and packaged for display in iSWA system
UMA Proton Flux Forecast
Joule Heating
Venus FL Connectivity
Induced Electric Fields EY
Solar Wind at Earth
Radiation Belt 4000keV
ENLIL SPIRAL
Cygnet Registry
Configurable Web-Based Dissemination Service
CWDS
• iSWA System Interface provides a highly configurable control panel to present operators with only the products and tools of interest
Internet
•569 Unique Data Feeds, 84 Million Files Registered and Archived, 408 Consumable Display Products currently managed in iSWA Cygnet Catalog

Innovative Dissemination

ISWA has ~300 products including modeling results and comprehensive sets of observational data.



Web-based. User configurable. Available world-wide.
One-stop shop for state-of-the-art information!
http://iswa.gsfc.nasa.gov

iSWA Design Highlights

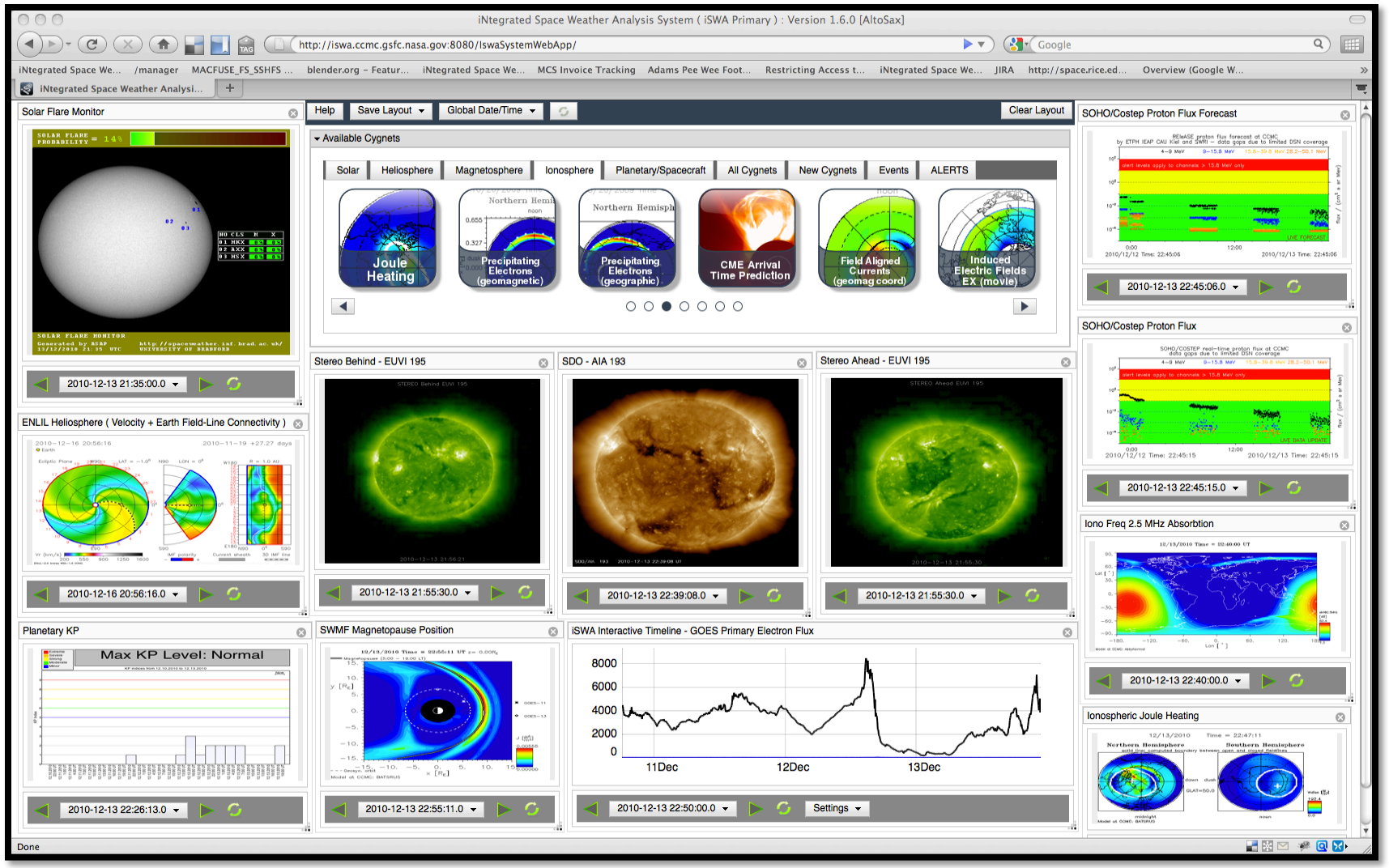
BACK END

- **Comprehensive data model that drives the system**
  - Minimizes need for actual code modifications
  - Allows rapid additions and modifications to data feeds and display products
- **Every granule of data is registered, cataloged, and archived**
  - Access data products for any available time period
  - Generate new tools and functionality using multiple existing data products

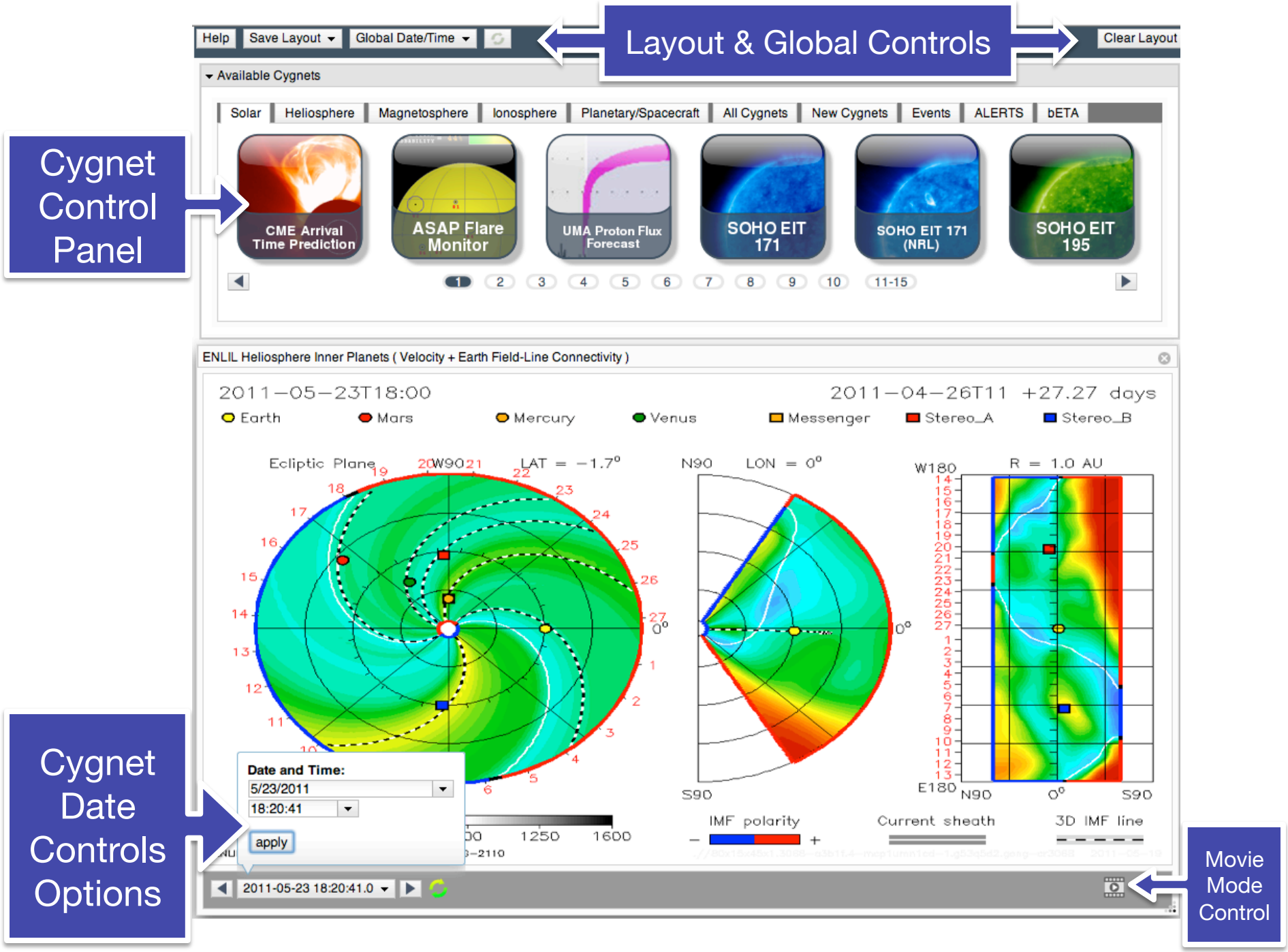
FRONT END

- **Consistent Interface with uniquely identifiable product icons**
- **Customizable layout**
  - automatically saved on browser exit
  - can be bookmarked and shared
- **Auto updating products and tools**
- **Individual and global date search functionality for historical impact analysis**
- ~~**Detailed descriptions for data products**~~

Unprecedented Access to Space Weather Information



http://iSWA.ccmc.gsfc.nasa.gov

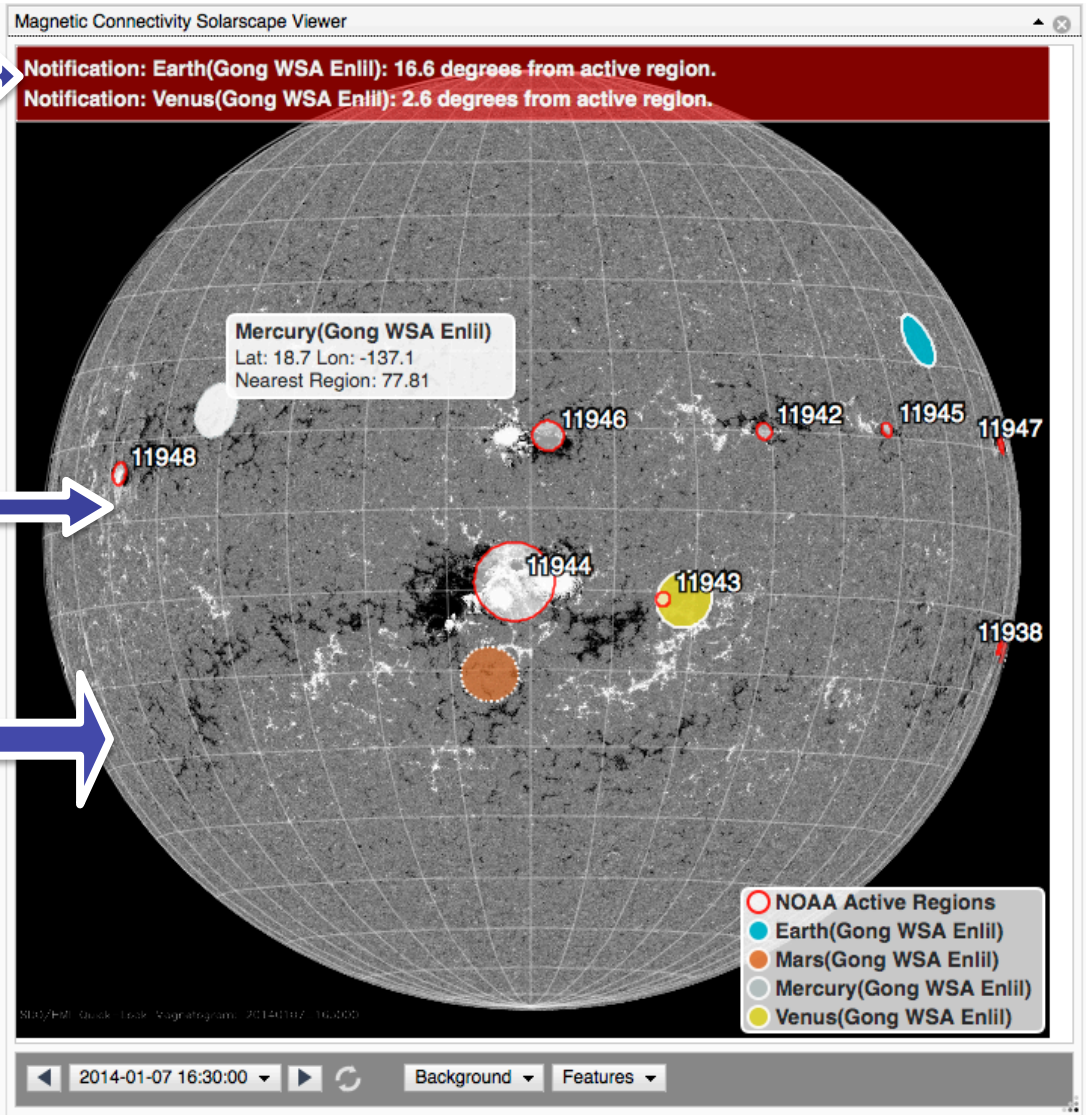

Layout & Global Controls
Cygnet Control Panel
Cygnet Date Controls Options
Movie Mode Control
Help
Save Layout
Global Date/Time
Clear Layout
Available Cygnets
Solar
Heliosphere
Magnetosphere
Ionosphere
Planetary/Spacecraft
All Cygnets
New Cygnets
Events
ALERTS
bETA
CME Arrival Time Prediction
ASAP Flare Monitor
UMA Proton Flux Forecast
SOHO EIT 171
SOHO EIT 171 (NRL)
SOHO EIT 195
1 2 3 4 5 6 7 8 9 10 11-15
ENLIL Heliosphere Inner Planets (Velocity + Earth Field-Line Connectivity)
2011-05-23T18:00
2011-04-26T11 +27.27 days
Earth
Mars
Mercury
Venus
Messenger
Stereo_A
Stereo_B
Ecliptic Plane
LAT = −1.7°
N90
LON = 0°
W180
R = 1.0 AU
S90
E180
IMF polarity
Current sheath
3D IMF line
Date and Time:
5/23/2011
18:20:41
apply
2011-05-23 18:20:41.0

Dynamically Generated & Interactive Products: Solarscape

Alerts/
Notifications

User Selectable Features
(MAG4, NOAA Active Regions,
CCMC Magnetic Connectivity)

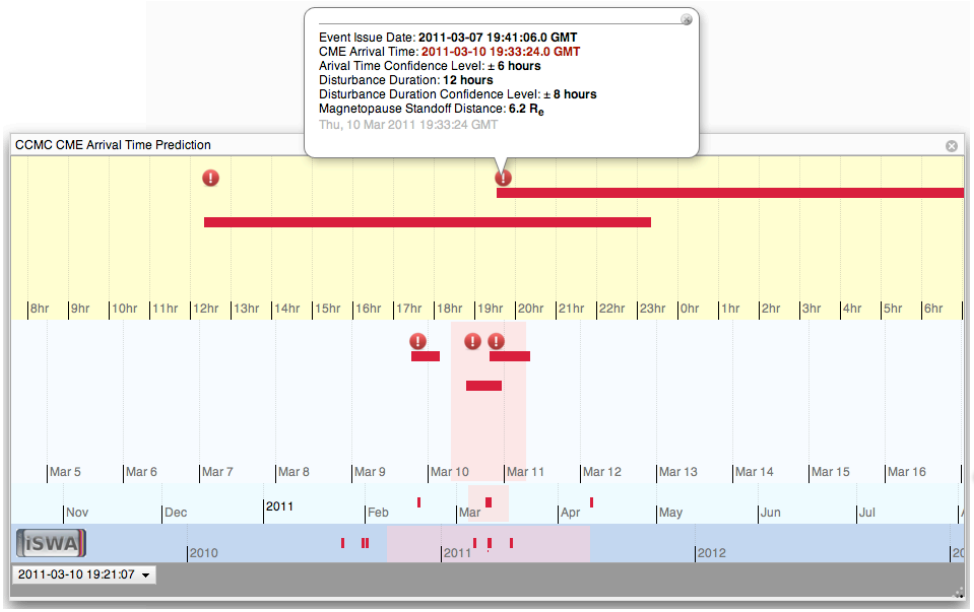
User Selectable Background
(SDO , Generic Grid)



Dynamic Product with User Selectable Features From Several Sources

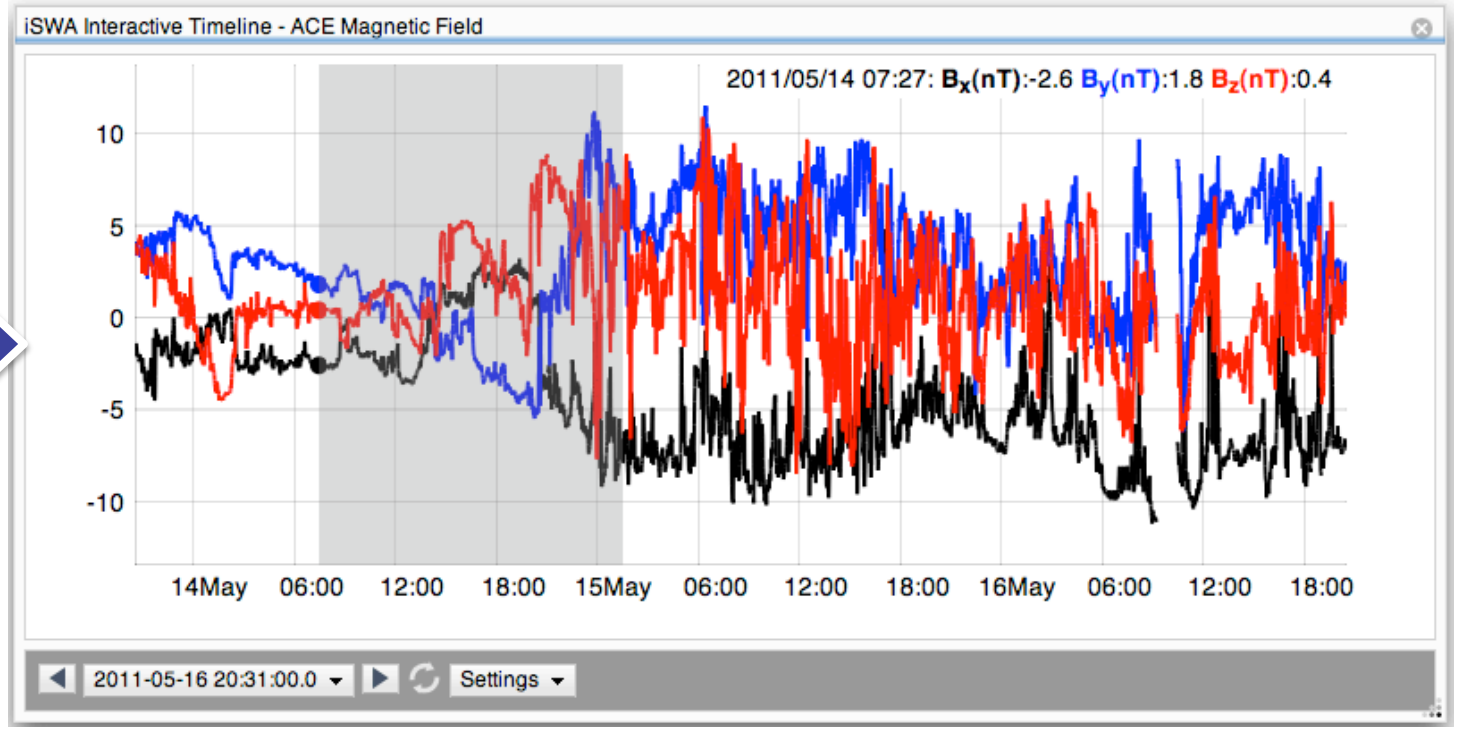
iSWA

Interactive Timelines

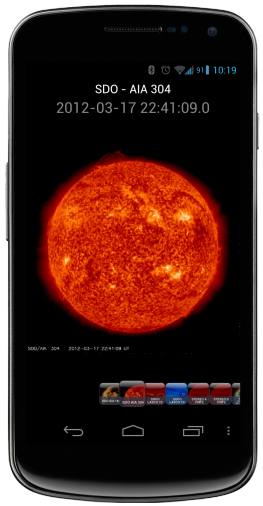


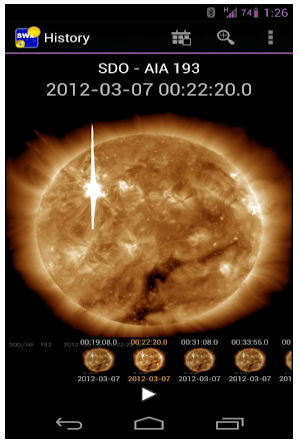
Interactive CME alert tool with chronological record of SWx Center issued CME time of arrival predictions

Interactive timeline tool with pan, zoom, mouse-over, and quantity toggling functionality



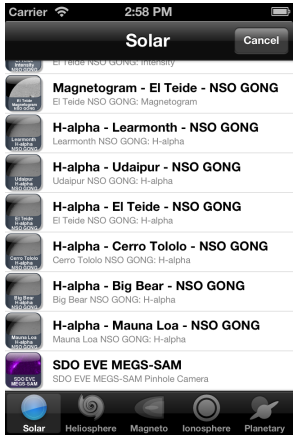
Mobile Access Powered by iSWA

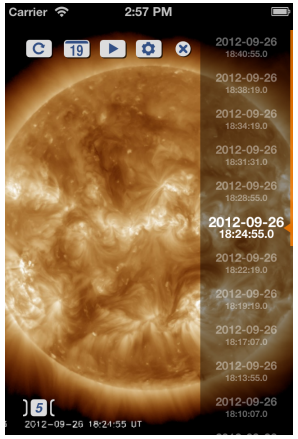




Android Front-End to iSWA

- History Mode
- Movie Mode
- >50k Downloads
- Available in Google Play Store





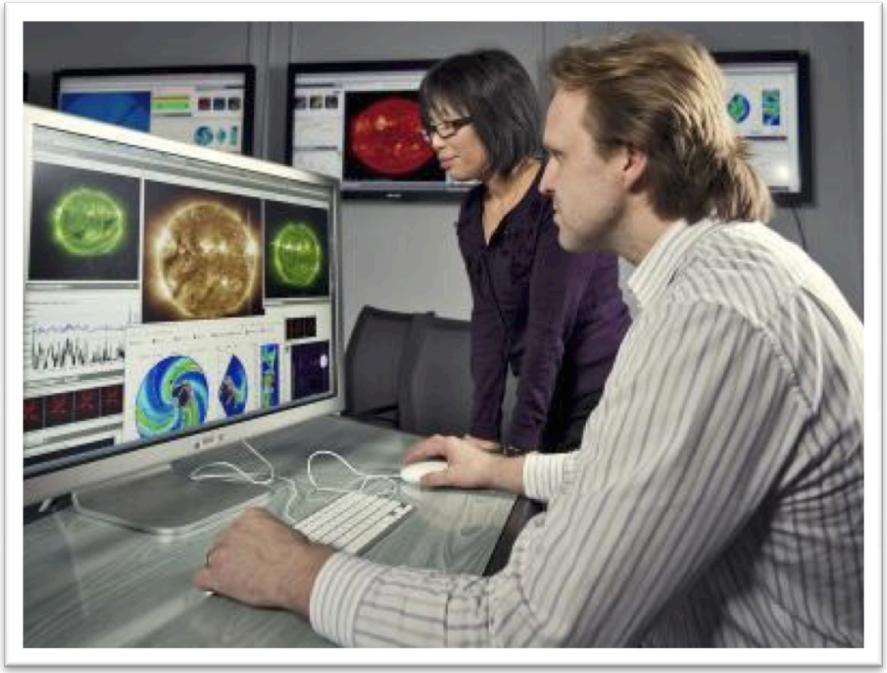
IOS Front-End to iSWA

- >100k Downloads
- Available in App Store

Services for NASA Robotic Missions Powered by iSWA

1. Providing assistance in spacecraft anomaly resolution by assessing whether space weather has any role in causing the observed anomaly/ anomalies.

2. Sending out weekly space weather reports/ summaries to NASA mission operators, NASA officials and involved personnel.



Services for NASA Robotic Missions Powered by iSWA

3. Sending out timely space weather info/forecasts regarding adverse conditions throughout the solar system, such as significant CME events, elevated radiation levels, etc.

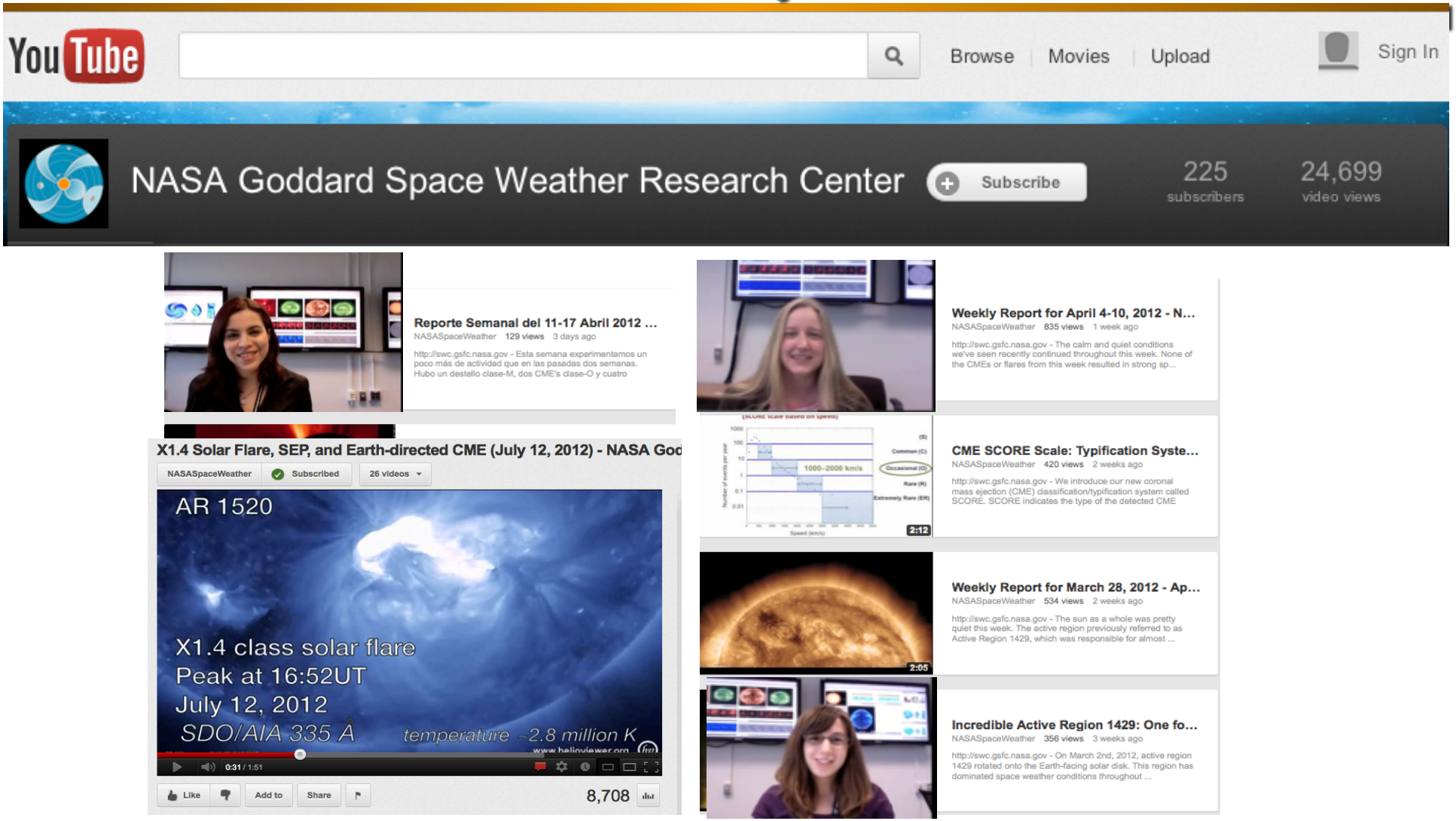
4. Providing general space weather support for NASA customers.

Education And Training Powered by iSWA

Arranged by NASA IV&V Educator Resource Center
High school teachers from West Virginia

Y. Zheng

Training Young Scientists & Educating the Public Powered by iSWA

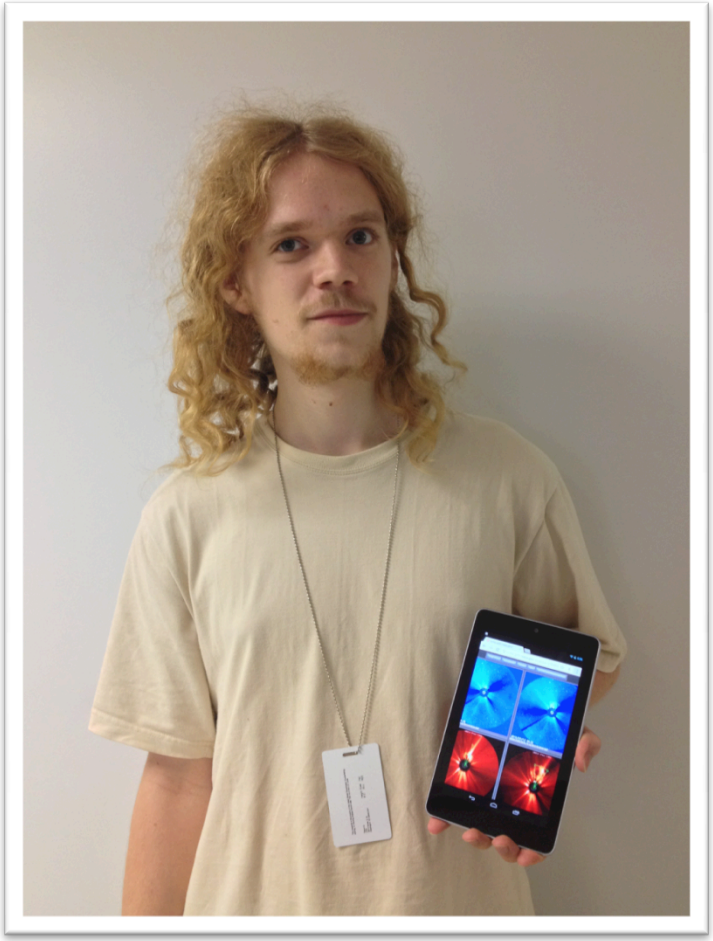


C. Black, D. Berrios, L. Mays, J. Collado-Vega, R. Evans

Undergraduate Computer Science Interns SW Research Analysis Tool Development Powered by iSWA

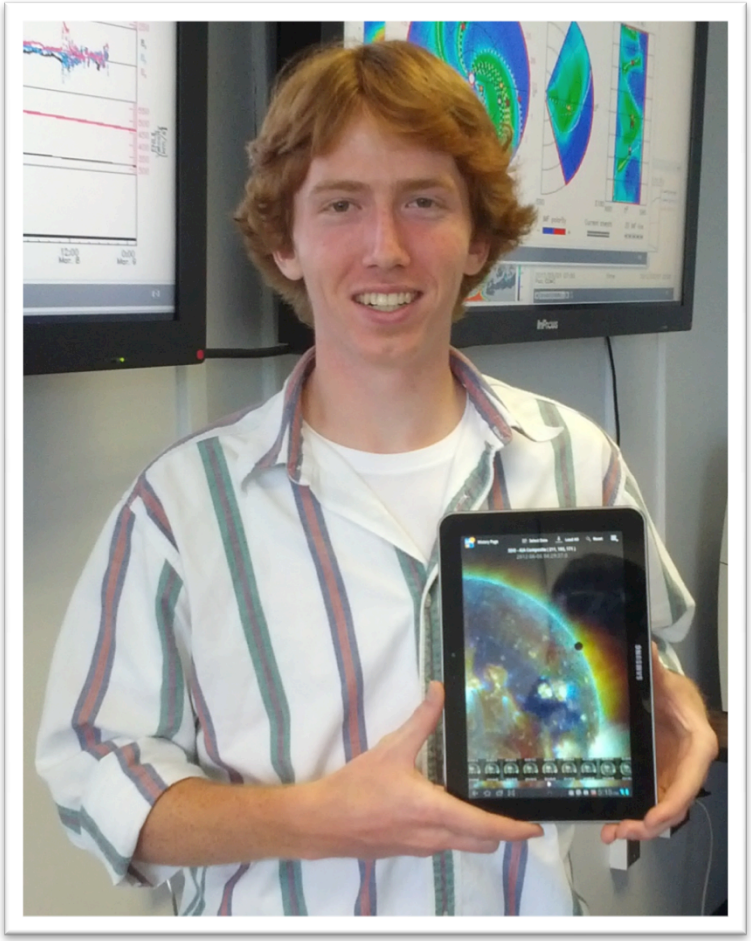
Jack LaSota

Web-based CME Analysis Tool



Justin Boblitt

Android iSWA App



CME Tool Link Sample Analysis Link iTunes Link Android Link

iSWA Impact

NASA

- iSWA provides a new capability to quickly assess **past**, **present**, and **expected** space weather effects.
  - Mission operators have a resource to assist in both anomaly resolution as well as potential space weather impacts.
- iSWA has helped enable the Space Weather Laboratory to establish a new **Space Weather Center** service **providing alerts**, anomaly reports, and weekly space weather summaries based on iSWA tools and products.

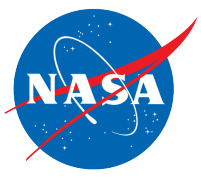
External Agencies

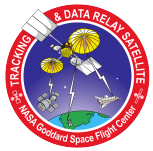
- Air Force Space Weather Agency can **monitor the iSWA system 24x7 for CME eruptions** and notify the CCMC as soon as an event is detected. A notification triggers a CME Cone Model calculation at CCMC that **estimates the CME arrival time, duration, and expected impact on earth**.
- iSWA has enabled numerous collaborations with data, model, and product developers/providers who want their tools to be available in iSWA.

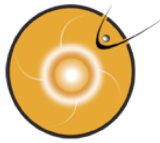
Science, Education, and Public Outreach

- Researchers, universities, and “citizen scientists” have access to a comprehensive suite of real-time and historical space environment data products.

Who Uses iSWA?












Present /In-Progress Users

- NASA GSFC (SSMO)
- NASA MSFC (ISS)
- NASA JSC (SRAG)
- NASA LRC (CALIPSO)
- AI Solutions/GSFC Conjunction Assessment Risk Analysis Team
- UK Met Office
- Air Force Weather Agency
- Air Force Institute Of Technology
- Electric Power Research Institute
- Belgium Institute Of Technology
- Space Research Institute, Russia IKI RAN
- Korea Meteorological Administration
- Space Environment Technologies
- Heliophysics Summer School
- CISM Summer School
- CCMC Research & Event Studies
- Space Science Programs (CUA, Michigan, GMU, Embry-Riddle, UCLA, ITU, AFIT, BU)
- Korea Astronomy and Space Science Institute (KASI)
- Department Of Homeland Security
- Federal Aviation Administration
- Power Grid Community (NERC, EPRI)
- NASA TDRSS
- Japan Aerospace Exploration Agency
- American Museum Of Natural History

Potential Users

- Any agency, entity, or individual with space weather requirements and/or interests
- Extended educational use (training, K-12, higher education)
- Extended research use (case studies, correlation studies, historical events, general space weather research)

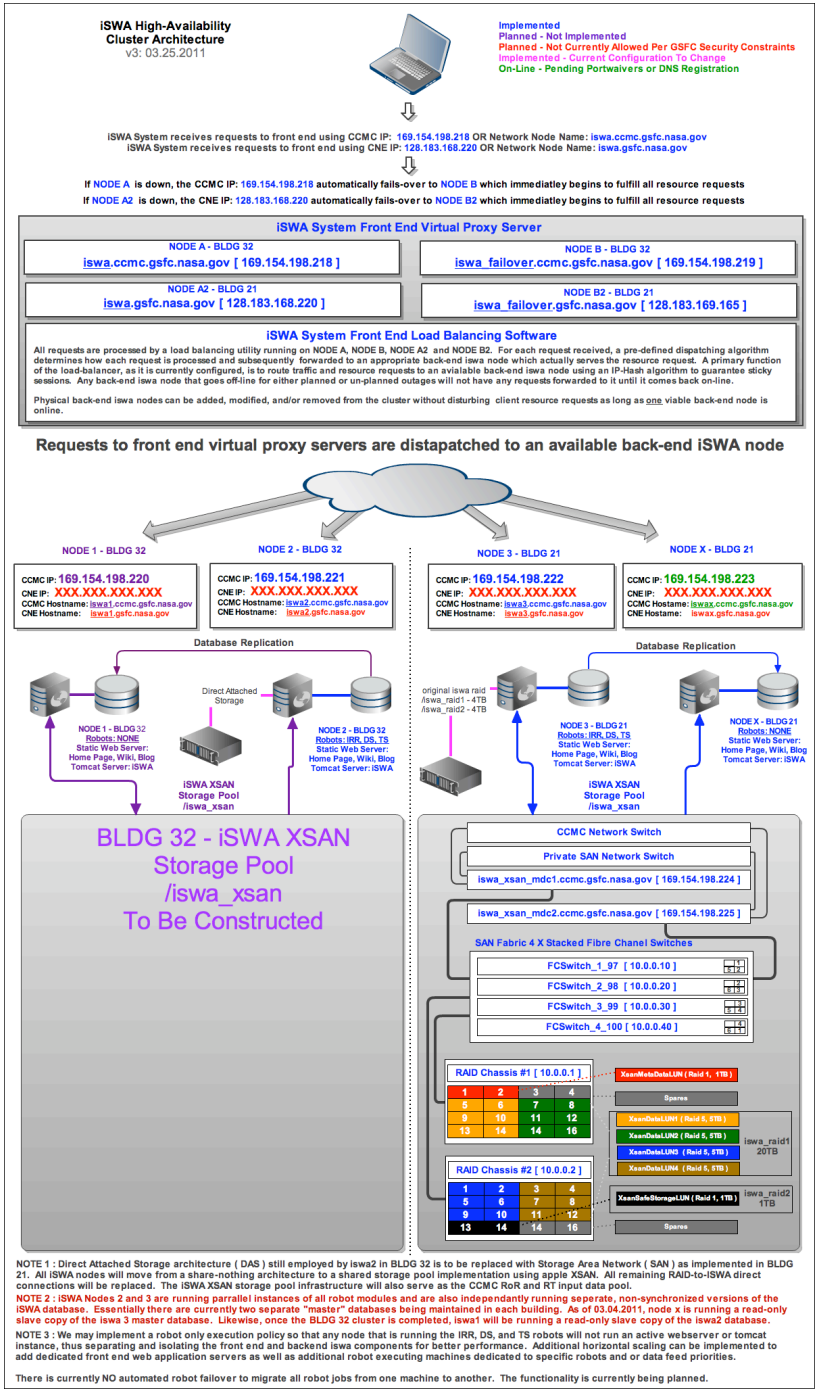
iSWA software can be applied to any agency, group, or project with general data ingestion, storage, management, display, & dissemination needs….

- "instant ground system" for other NASA projects
- turn-key software system for commercial and/or educational data management and dissemination
- customizable interface for existing data archives and sets

High Availability Architecture

- IP failover
- Load Balancing proxy/virtual proxy front end servers
- Database Replication
- Data Tree Replication/Mirroring
- Multi-site backups systems (multi-building in our case)
- Redundant Storage Fabrics
- Software-Monitoring Software (health, performance)
- ~~Network Failover with Dual Homing~~ (not allowed per gsfc security)

iSWA HA
Before & After



iSWA Cluster Design

Load Balancing/IP Failover Layer

- 4 proxy servers/load balancers
- automated IP failover

Back-End Processing Layer

- 4+ independent workstations
- Independent Databases (synchronized)
- Enterprise Java, Tomcat, Apache, MySQL
- Custom Software for data collection and processing modules

Data Storage Layer

- 24TB Expandable SAN Storage System
- Redundant metadata controllers
- 4 x 20 Port Stacked Fibre Chanel Switches
- SAN Fabric utilizes mesh topology

iSWA High-Availability Cluster Architecture

v3: 03.25.2011

Implemented
Planned - Not Implemented
Planned - Not Currently Allowed Per GSFC Security Constraints
Implemented - Current Configuration To Change
On-Line - Pending Portwaivers or DNS Registration

iSWA System receives requests to front end using CCMC IP: 169.154.198.218 OR Network Node Name: iswa.ccmc.gsfc.nasa.gov
iSWA System receives requests to front end using CNE IP: 128.183.168.220 OR Network Node Name: iswa.gsfc.nasa.gov

If NODE A is down, the CCMC IP: 169.154.198.218 automatically fails-over to NODE B which immediatley begins to fulfill all resource requests

If NODE A2 is down, the CNE IP: 128.183.168.220 automatically fails-over to NODE B2 which immediatley begins to fulfill all resource requests

iSWA System Front End Virtual Proxy Server

NODE A - BLDG 32
iswa.ccmc.gsfc.nasa.gov [169.154.198.218]

NODE B - BLDG 32
iswa_failover.ccmc.gsfc.nasa.gov [169.154.198.219]

NODE A2 - BLDG 21
iswa.gsfc.nasa.gov [128.183.168.220]

NODE B2 - BLDG 21
iswa_failover.gsfc.nasa.gov [128.183.169.165]

iSWA System Front End Load Balancing Software

All requests are processed by a load balancing utility running on NODE A, NODE B, NODE A2 and NODE B2. For each request received, a pre-defined dispatching algorithm determines how each request is processed and subsequently forwarded to an appropriate back-end iswa node which actually serves the resource request. A primary function of the load-balancer, as it is currently configured, is to route traffic and resource requests to an avialable back-end iswa node using an IP-Hash algorithm to guarantee sticky sessions. Any back-end iswa node that goes off-line for either planned or un-planned outages will not have any requests forwarded to it until it comes back on-line.

Physical back-end iswa nodes can be added, modified, and/or removed from the cluster without disturbing client resource requests as long as one viable back-end node is online.

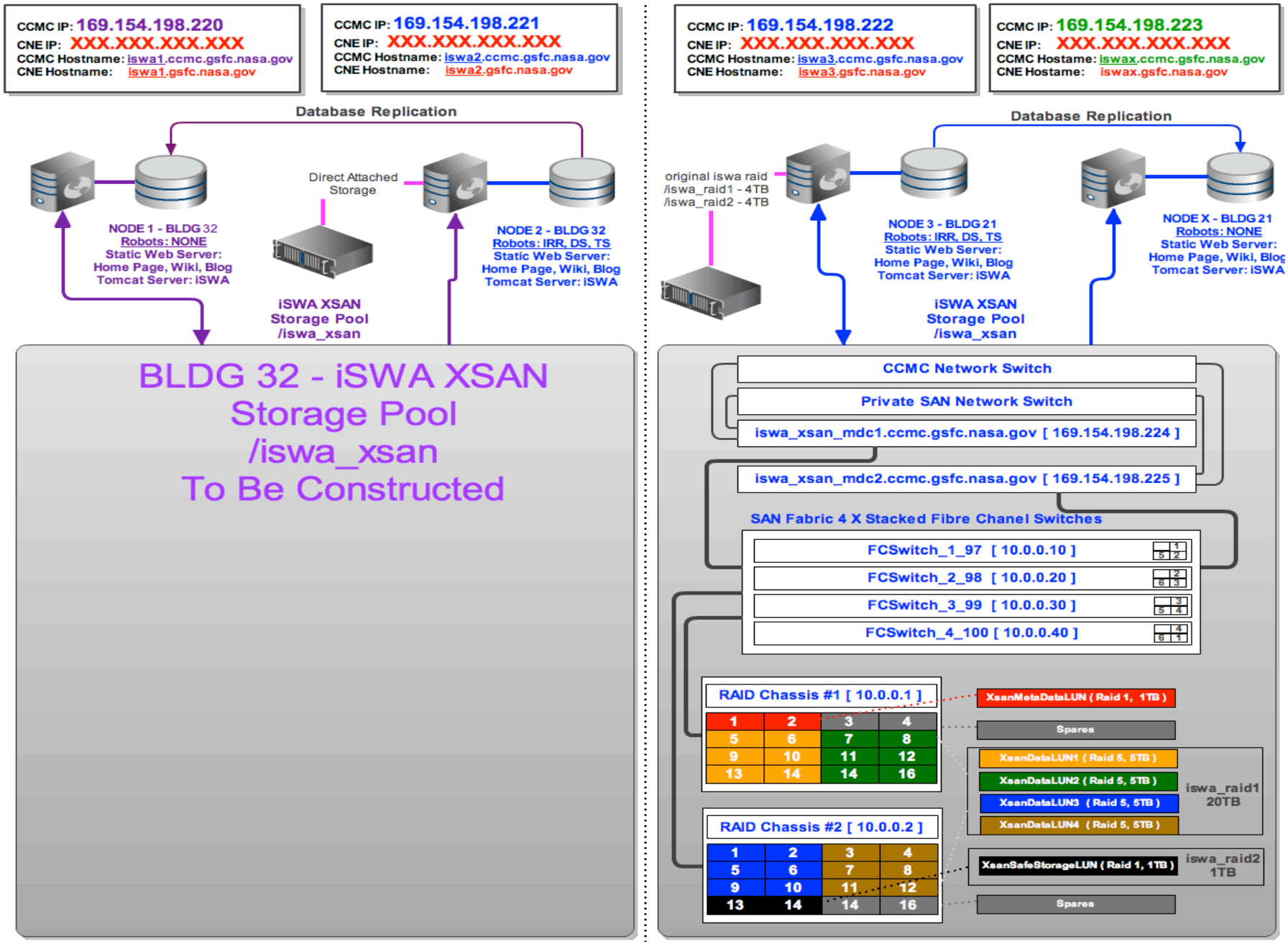
Requests to front end virtual proxy servers are distapatched to an available back-end iSWA node

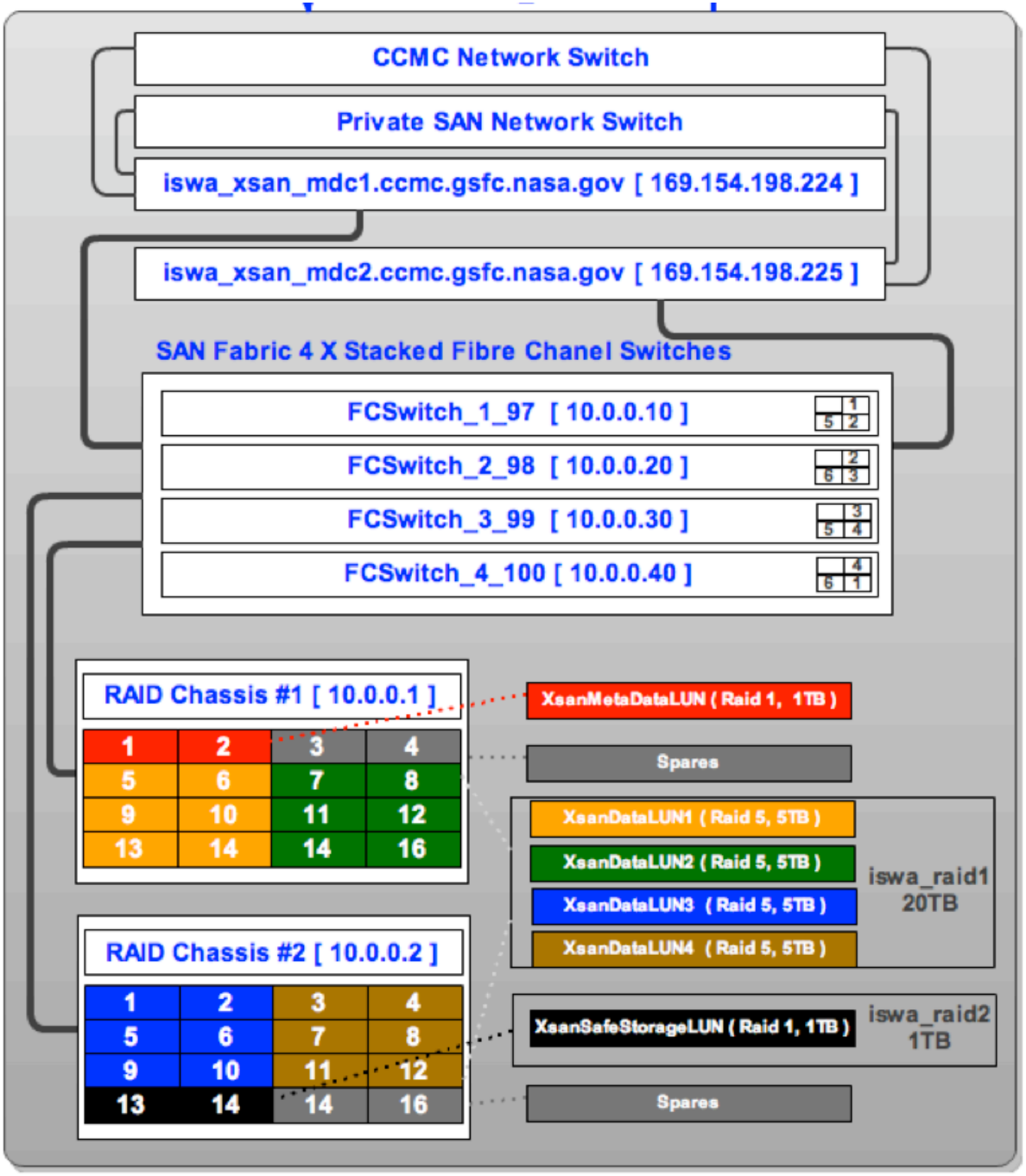
NODE 1 - BLDG 32
CCMC IP: 169.154.198.220
CNE IP: XXX.XXX.XXX.XXX
CCMC Hostname: iswa1.ccmc.gsfc.nasa.gov
CNE Hostname: iswa1.gsfc.nasa.gov

NODE 2 - BLDG 32
CCMC IP: 169.154.198.221
CNE IP: XXX.XXX.XXX.XXX
CCMC Hostname: iswa2.ccmc.gsfc.nasa.gov
CNE Hostname: iswa2.gsfc.nasa.gov

NODE 3 - BLDG 21
CCMC IP: 169.154.198.222
CNE IP: XXX.XXX.XXX.XXX
CCMC Hostname: iswa3.ccmc.gsfc.nasa.gov
CNE Hostname: iswa3.gsfc.nasa.gov

NODE X - BLDG 21
CCMC IP: 169.154.198.223
CNE IP: XXX.XXX.XXX.XXX
CCMC Hostame: iswax.ccmc.gsfc.nasa.gov
CNE Hostame: iswax.gsfc.nasa.gov


CCMC IP: 169.154.198.220
CNE IP: XXX.XXX.XXX.XXX
CCMC Hostname: iswa1.ccmc.gsfc.nasa.gov
CNE Hostname: iswa1.gsfc.nasa.gov
CCMC IP: 169.154.198.221
CNE IP: XXX.XXX.XXX.XXX
CCMC Hostname: iswa2.ccmc.gsfc.nasa.gov
CNE Hostname: iswa2.gsfc.nasa.gov
CCMC IP: 169.154.198.222
CNE IP: XXX.XXX.XXX.XXX
CCMC Hostname: iswa3.ccmc.gsfc.nasa.gov
CNE Hostname: iswa3.gsfc.nasa.gov
CCMC IP: 169.154.198.223
CNE IP: XXX.XXX.XXX.XXX
CCMC Hostame: iswax.ccmc.gsfc.nasa.gov
CNE Hostame: iswax.gsfc.nasa.gov
Database Replication
Direct Attached Storage
NODE 1 - BLDG 32
Robots: NONE
Static Web Server:
Home Page, Wiki, Blog
Tomcat Server: ISWA
NODE 2 - BLDG 32
Robots: IRR, DS, TS
Static Web Server:
Home Page, Wiki, Blog
Tomcat Server: iSWA
iSWA XSAN
Storage Pool
/iswa_xsan
BLDG 32 - iSWA XSAN
Storage Pool
/iswa_xsan
To Be Constructed
Database Replication
original iswa raid
/iswa_raid1 - 4TB
/iswa_raid2 - 4TB
NODE 3 - BLDG 21
Robots: IRR, DS, TS
Static Web Server:
Home Page, Wiki, Blog
Tomcat Server: iSWA
NODE X - BLDG 21
Robots: NONE
Static Web Server:
Home Page, Wiki, Blog
Tomcat Server: iSWA
iSWA XSAN
Storage Pool
/iswa_xsan
CCMC Network Switch
Private SAN Network Switch
iswa_xsan_mdc1.ccmc.gsfc.nasa.gov [169.154.198.224]
iswa_xsan_mdc2.ccmc.gsfc.nasa.gov [169.154.198.225]
SAN Fabric 4 X Stacked Fibre Chanel Switches
FCSwitch_1_97 [10.0.0.10]
FCSwitch_2_98 [10.0.0.20]
FCSwitch_3_99 [10.0.0.30]
FCSwitch_4_100 [10.0.0.40]
RAID Chassis #1 [10.0.0.1]
1 2 3 4
5 6 7 8
9 10 11 12
13 14 14 16
RAID Chassis #2 [10.0.0.2]
1 2 3 4
5 6 7 8
9 10 11 12
13 14 14 16
XsanMetaDataLUN (Raid 1, 1TB)
Spares
XsanDataLUN1 (Raid 5, 5TB)
XsanDataLUN2 (Raid 5, 5TB)
XsanDataLUN3 (Raid 5, 5TB)
XsanDataLUN4 (Raid 5, 5TB)
iswa_raid1
20TB
XsanSafeStorageLUN (Raid 1, 1TB)
iswa_raid2
1TB
Spares

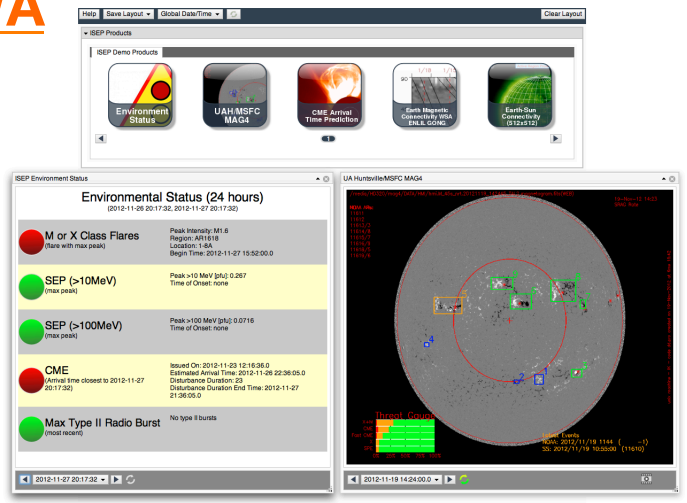

CCMC Network Switch
Private SAN Network Switch
iswa_xsan_mdc1.ccmc.gsfc.nasa.gov [169.154.198.224]
iswa_xsan_mdc2.ccmc.gsfc.nasa.gov [169.154.198.225]
SAN Fabric 4 X Stacked Fibre Chanel Switches
FCSwitch_1_97 [10.0.0.10]
FCSwitch_2_98 [10.0.0.20]
FCSwitch_3_99 [10.0.0.30]
FCSwitch_4_100 [10.0.0.40]
RAID Chassis #1 [10.0.0.1]
RAID Chassis #2 [10.0.0.2]
XsanMetaDataLUN (Raid 1, 1TB)
Spares
XsanDataLUN1 (Raid 5, 5TB)
XsanDataLUN2 (Raid 5, 5TB)
XsanDataLUN3 (Raid 5, 5TB)
XsanDataLUN4 (Raid 5, 5TB)
iswa_raid1
20TB
XsanSafeStorageLUN (Raid 1, 1TB)
iswa_raid2
1TB
Spares

iSWA Updates/Activities

New Systems/Extensions Powered by iSWA

- Project specific implementations
- Full iSWA feature set, infrastructure
- customized cygnet/product catalog
- **I**ntegrated **S**olar **E**nergetic **P**roton Event

Alert Warning System – Advanced Radiation Project
(OCT Game Changing Office)



Expanded Numerical Database - FlexDIT

- New parameters
- Custom alerts
- Dynamically generated products
- Data streaming for external applications

Web Services

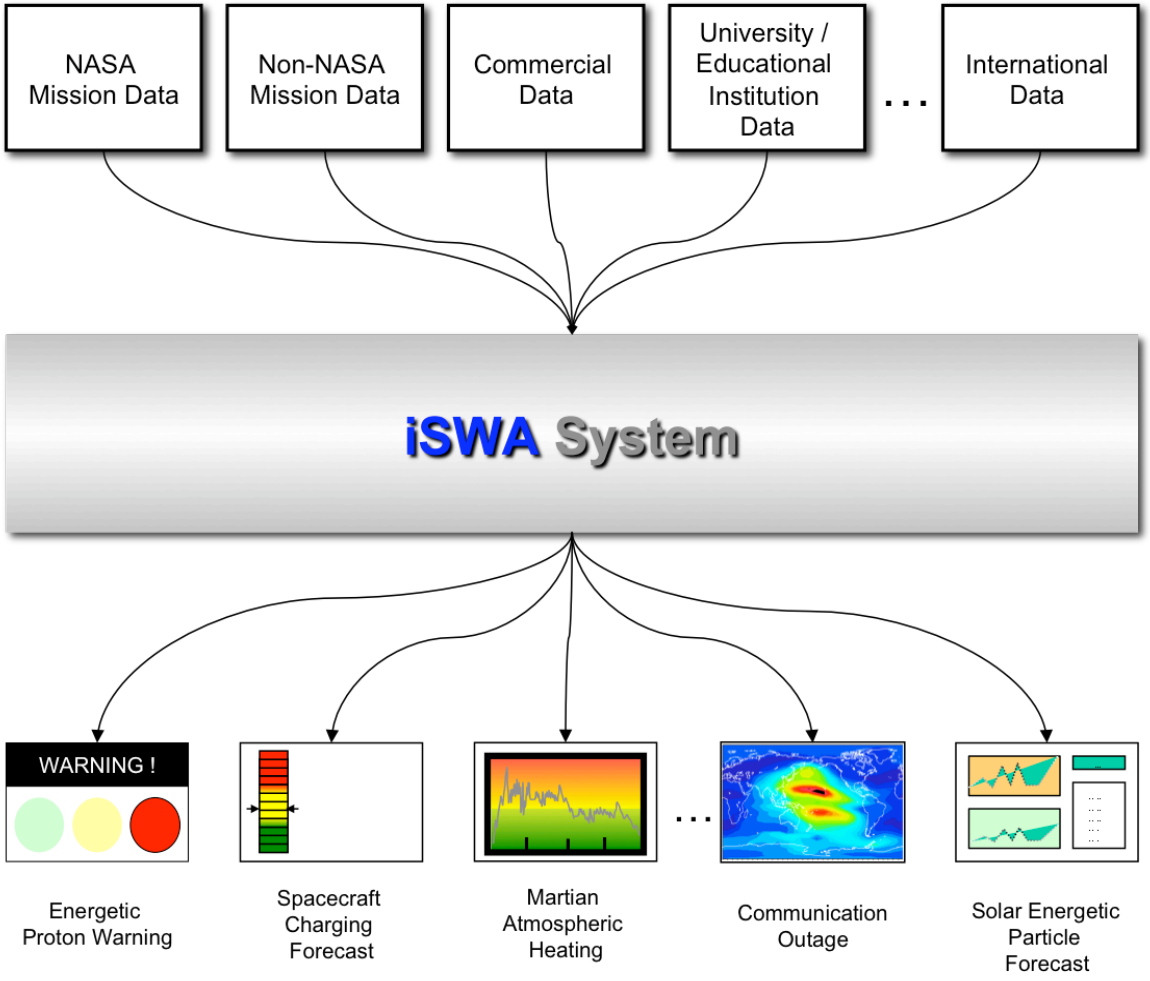
- Building web-based interfaces for machine-to-machine interaction
- Enabling external systems to query, access, and link to iSWA data

Space Weather Event Catalog and Event Linking – Linking to DONKI

- Building catalog of space weather event, forecaster-logs, alerts, etc.
- Establishing linkages, relationships, cause-and-effects between activities

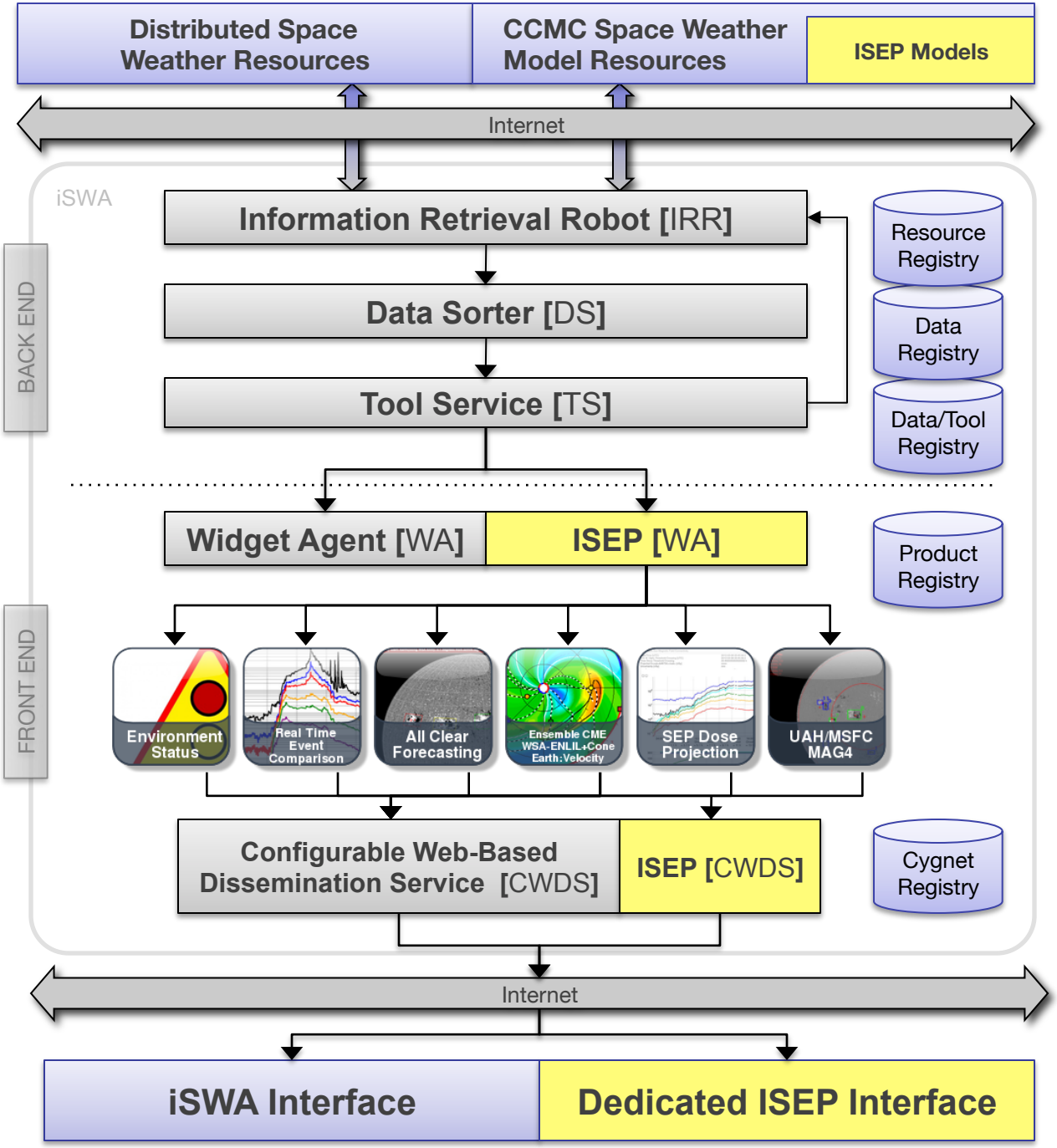
Integrated Solar Energetic Proton Event Alert Warning System

http://iSWA.gsfc.nasa.gov/ISEP



ISEP

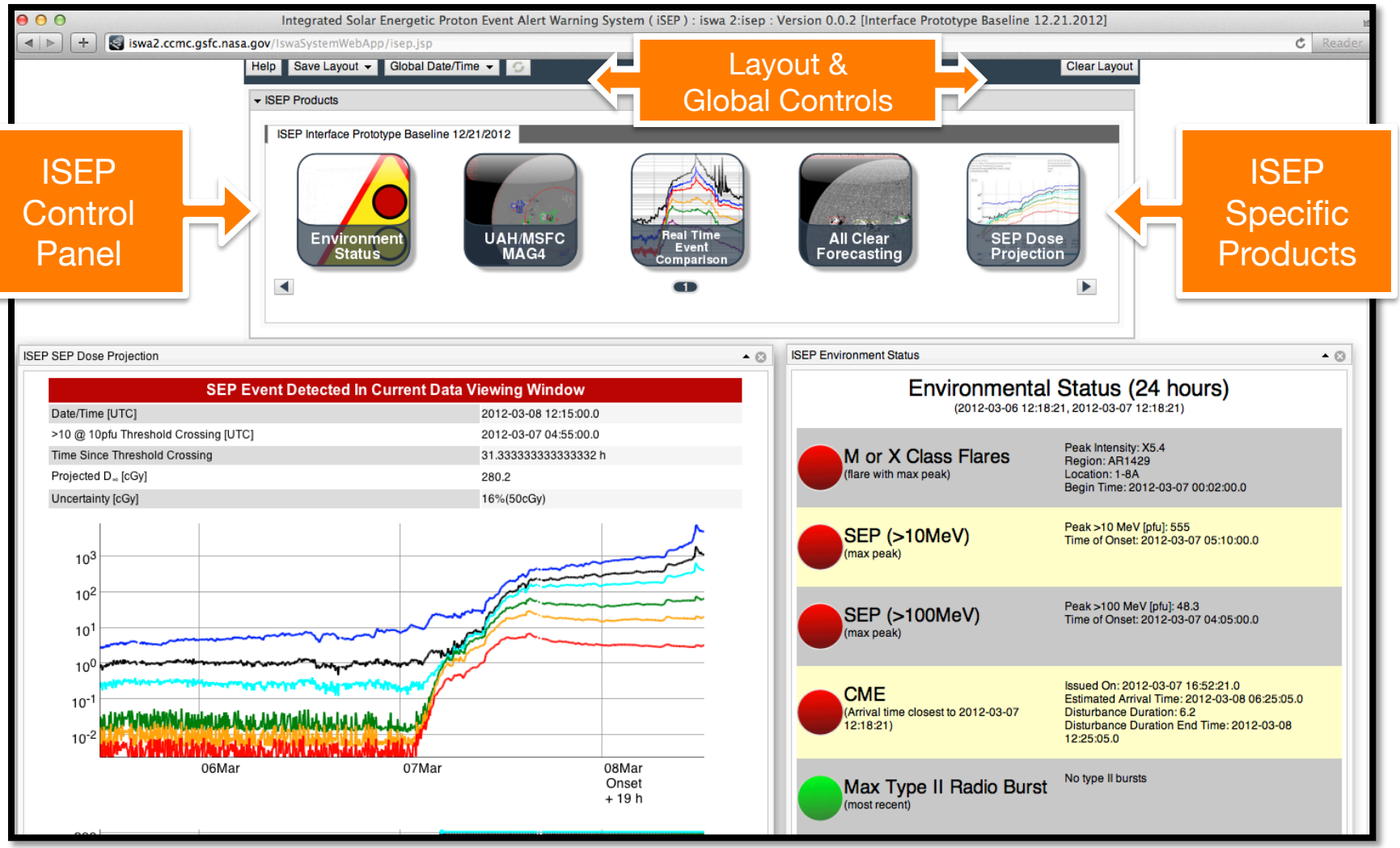
...flexible and robust decisional support tool for space weather



ISEP System

ISEP components are integrated into the iSWA system framework providing a solid development and operational platform. A modular architecture ensures new models, data, features, and functionality can be added to the system.

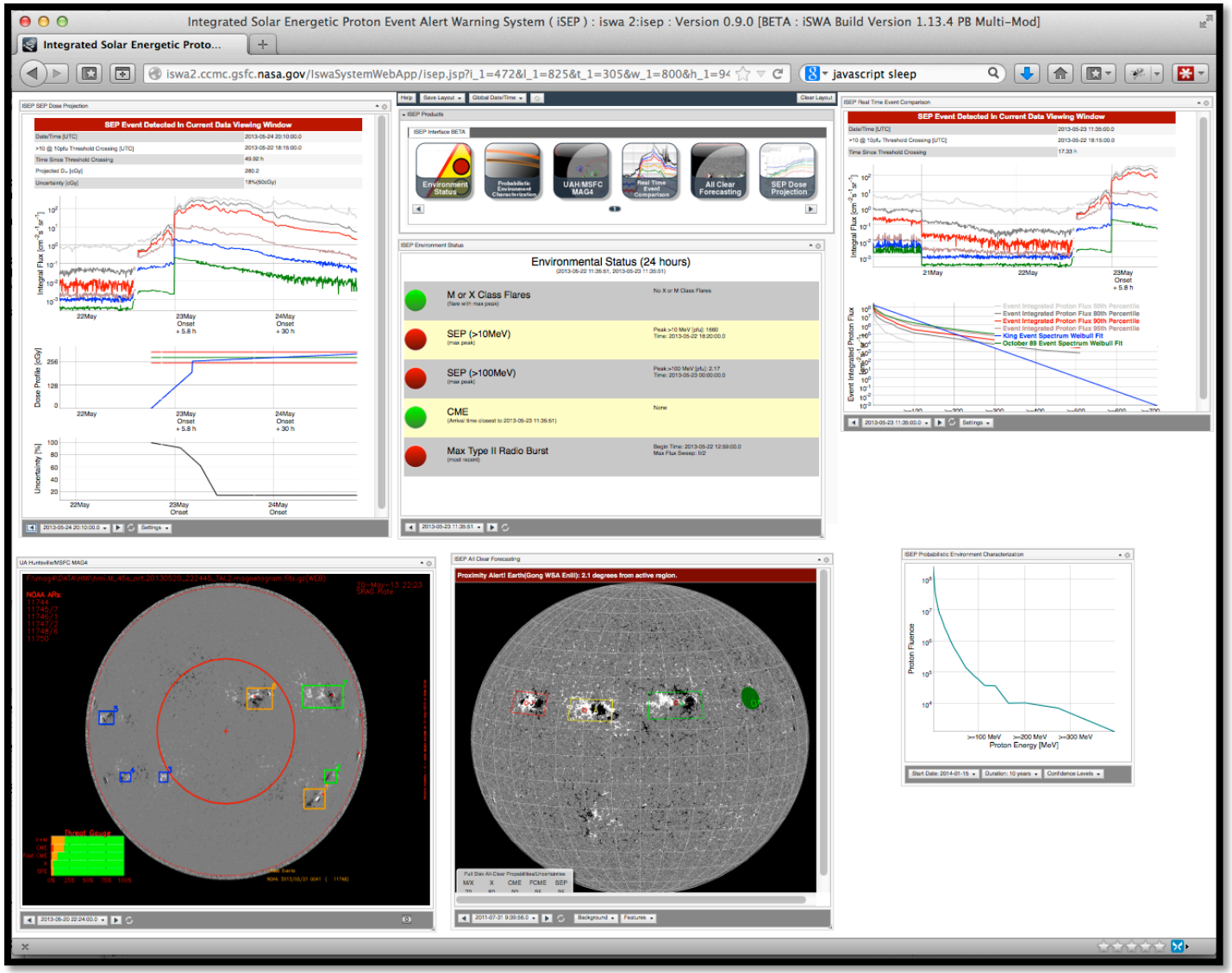
ISEP Interface Beta

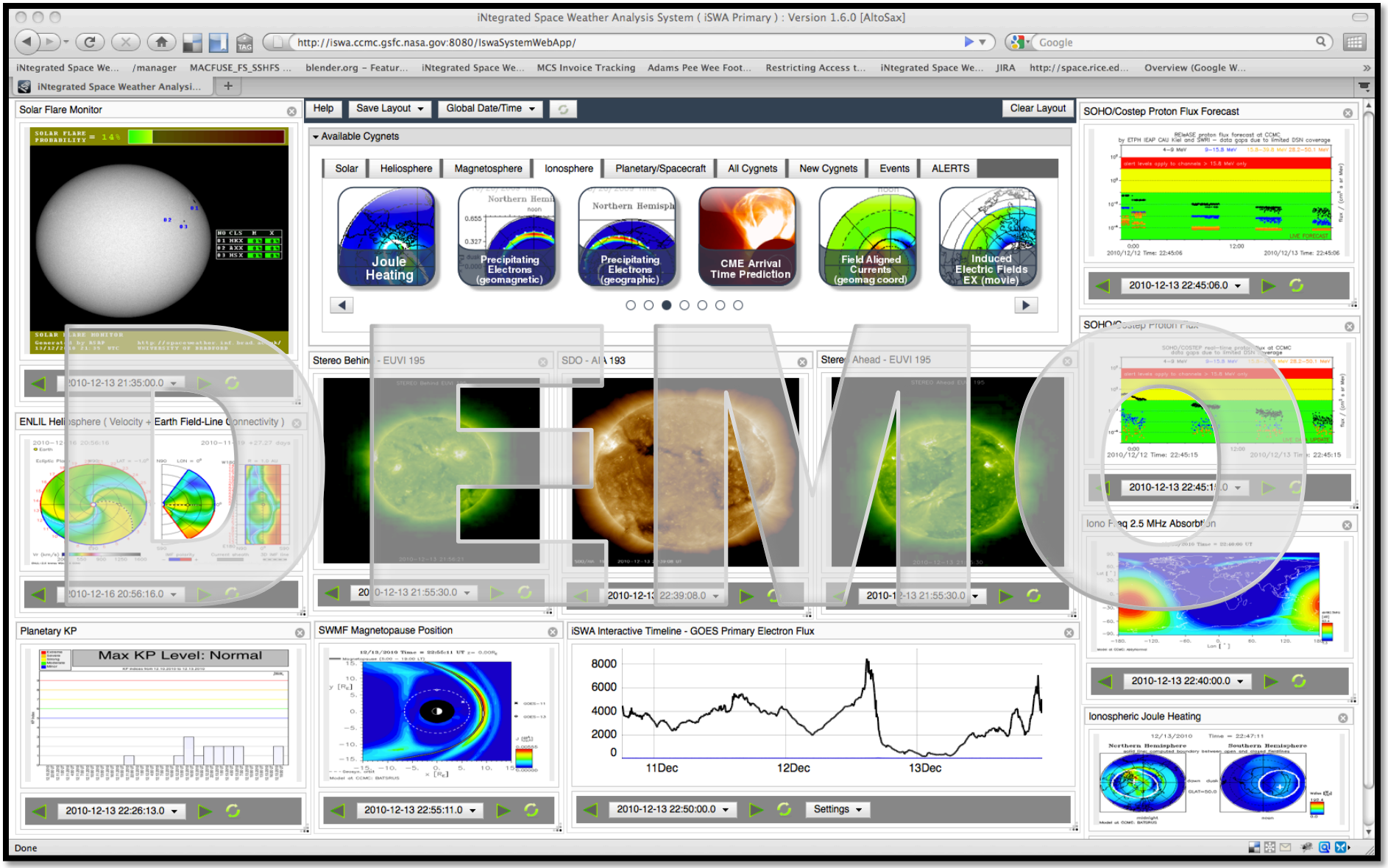


Customizable Products. Date Manipulation Controls. Save Layout Features.

Integrated Solar Energetic Proton Event Alert Warning System
http://iSWA.gsfc.nasa.gov/ISEP

● Real Time Info ● Interactive ● Web Accessible ● User Customizable ● Extensible





http://iSWA.ccmc.gsfc.nasa.gov