NOAA Satellite Science Week

GOES-R Space Weather
Operations to Research (O2R)

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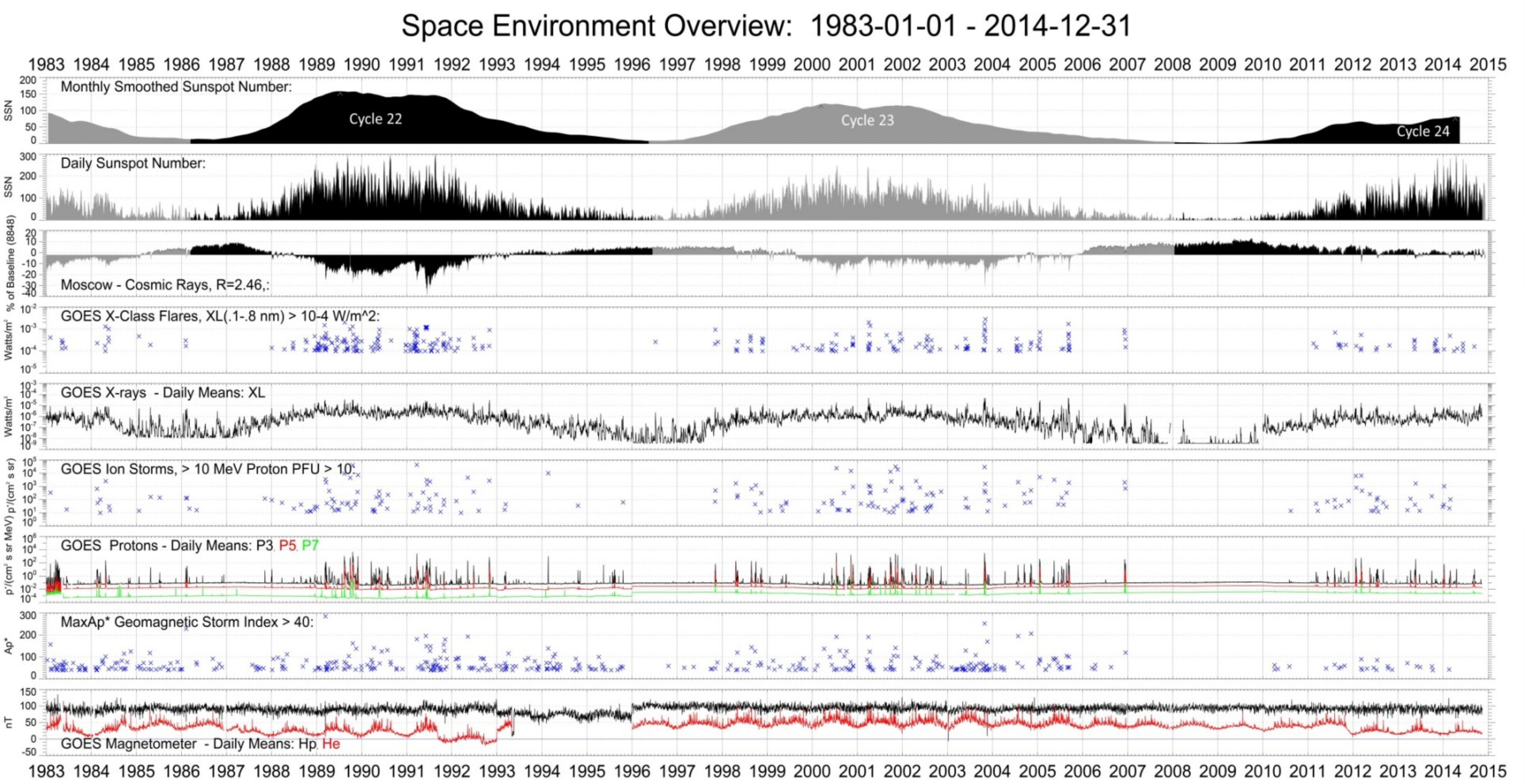
GOES-R Space Weather (SWx)

Maintaining a Long-term Record of Space Weather



	Start Date	Max Date	End Date	C-Class Flares	M-Class Flares	X-Class Flares	Ion Storms	Mag Storms Ap* > 40
Solar Cycle 22	1986-03	1989-07	1996-06	12,447	2,021	151	73	191
Solar Cycle 23	1996-06	2000-03	2008-01	13,102	1,437	126	92	158
Solar Cycle 24 *	2008-01	2014-04	TBD	5,288	488	35	32	25

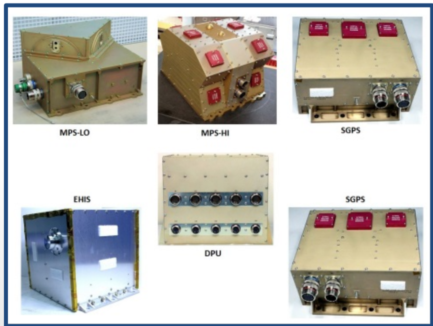
- We are far from the end of Solar Cycle 24 so these numbers should be considered a progress report rather than a final grade. Event totals are through November 2014.

GOES-R Space Weather (SWx)

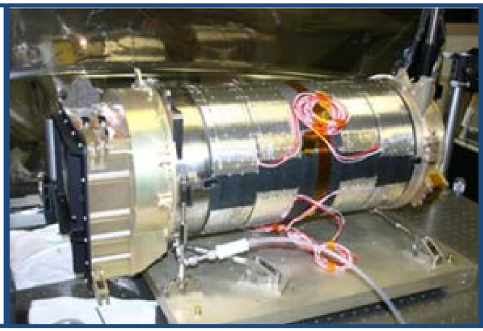
GOES-R Sensors Supporting O2R

GOES-R includes of a complement of in-situ particle/field and solar-viewing sensors providing a synoptic assessment of space weather.

SENSOR	IMPROVEMENT	SCIENCE APPLICATION
Space Environmental In-Situ Suite (SEISS)	Improved energy range / contamination rejection	Spacecraft charge models for electrostatic discharge
Solar Ultra-violet Imager (SUVI)	Multi-wavelength solar imagery	Surface features and thermal height profiles
EUV and X-Ray Irradiance Sensors (EXIS)	Improved accuracy and precision	Solar backgrounds/events impacting climate models
Magnetometer (MAG)	Gradiometer rejection of satellite generated fields	Geomagnetic field data with improved fidelity



SEISS



SUVI

EXIS

MAG

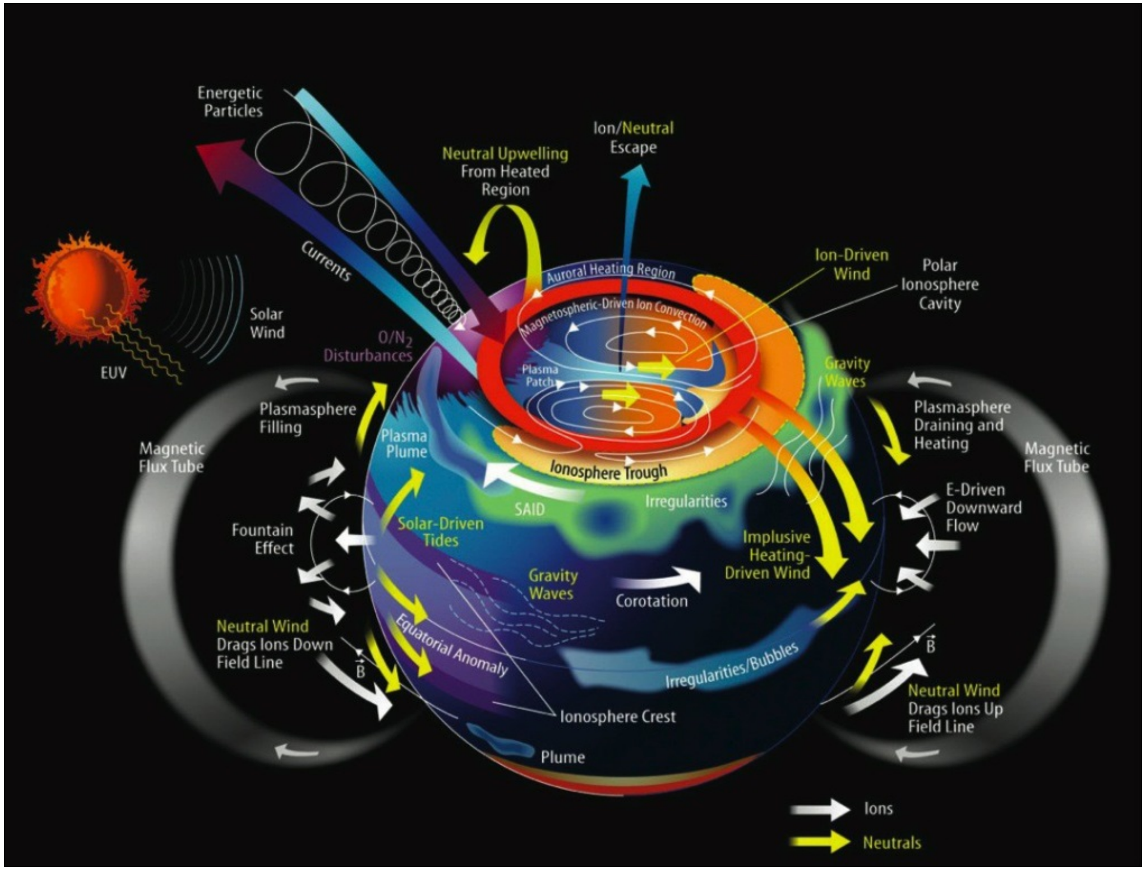
GOES-R Space Weather (SWx)

Why So Many Sensors?

This is what you see!

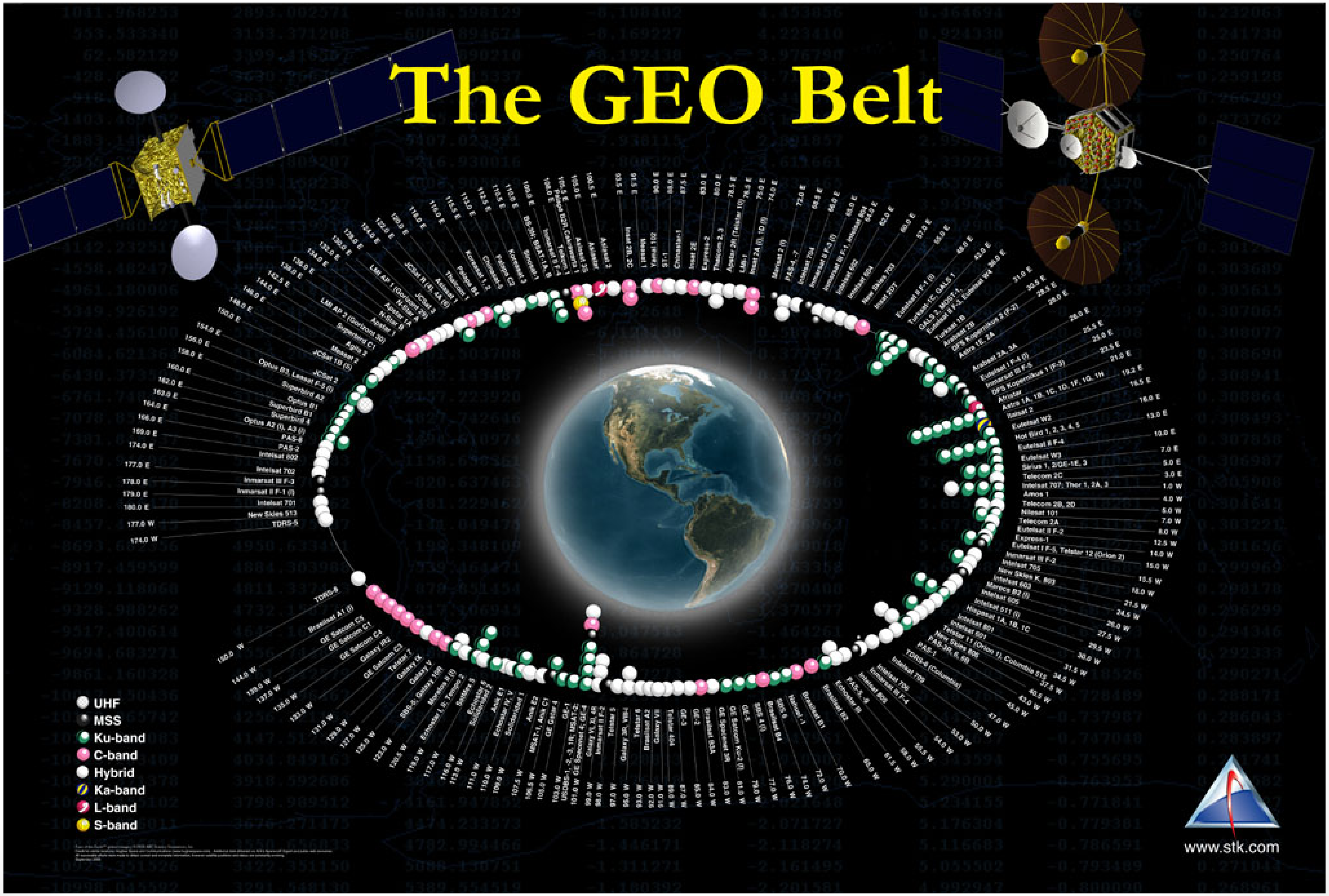
Why So Many Sensors?

This is what we see!



GOES-R Space Weather (SWx)

Protecting Space Assets – GEO is a Busy Place

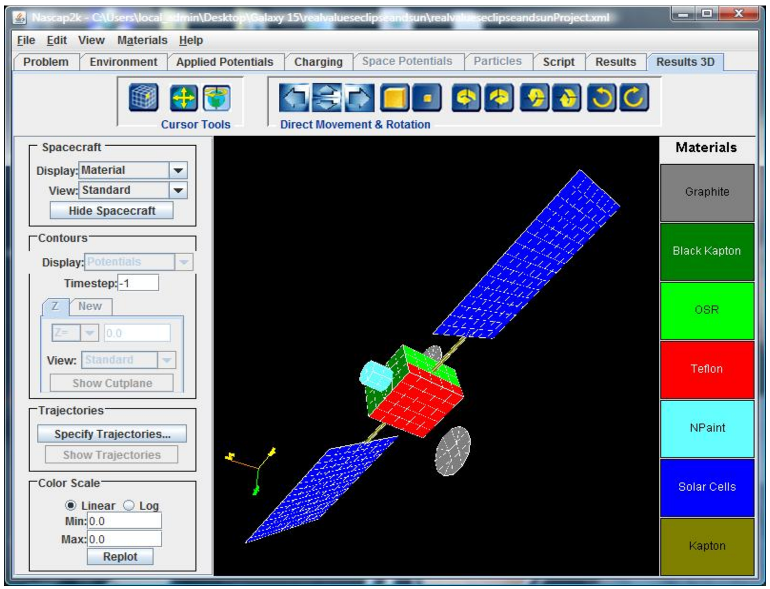


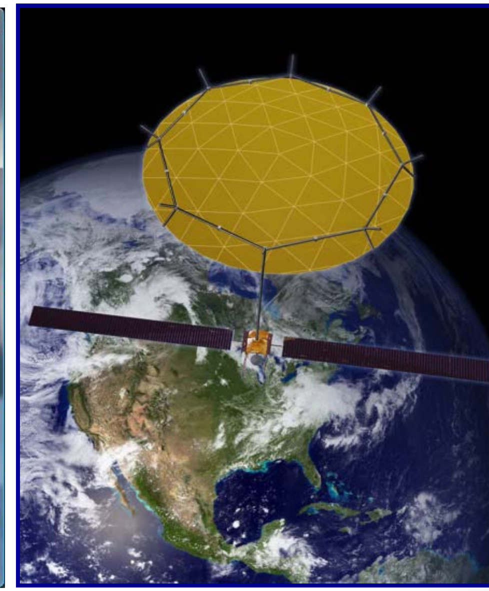
GOES-R Space Weather (SWx)

New Datasets for Spacecraft Charge Modeling

SEISS provides an improved in-site assessment of the local spacecraft charging environment.

- Extended low energy range for modeling surface charging
- Extended mass range for monitoring penetrating radiation



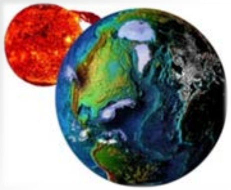


Example: Galaxy-15
Anomaly: 05 April 2010
Internal Charging/ESD
NGDC Report

GOES-R will provide new data to better serve the satellite charge modeling community

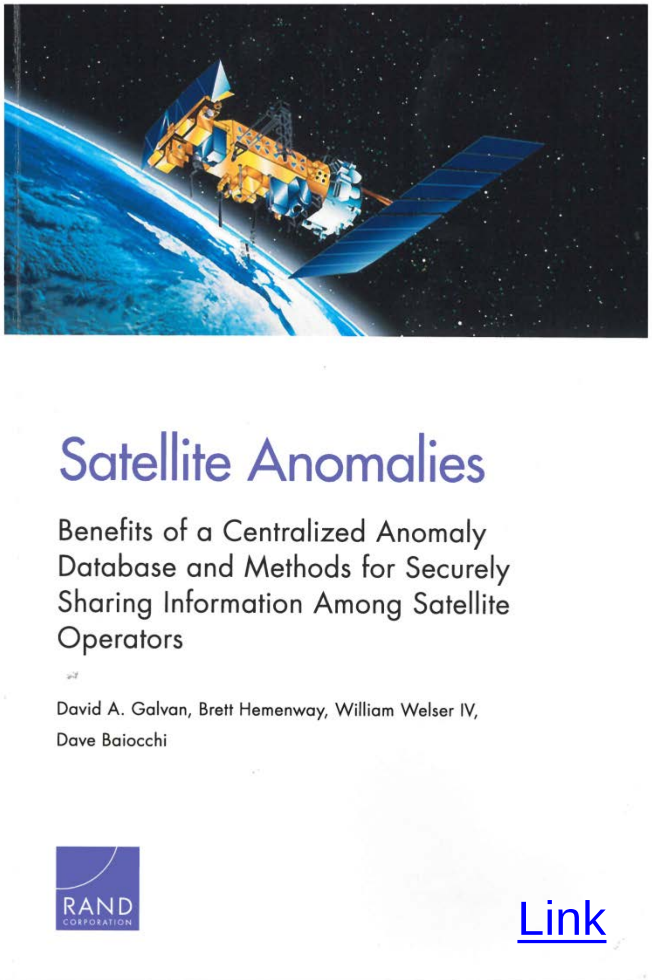
Example: SkyTerra-1
Anomaly: 07 March 2012
Single-Event Upset
NGDC Report

Reference: Ferguson, D.C., W.F. Denig and J.V. Rodriguez (2011), Plasma Conditions During the Galaxy 15 Anomaly and the Possibility of ESD from Subsurface Charging, 49th AIAA Aerospace Sciences Meeting, 04-07 Jan 2011, Orlando FL.



GOES-R Space Weather (SWx)

Cataloging Satellite Anomalies – Future Mission?



Link

Suggested Contents of an Anomaly Database

Description*	"Required"*	Reveals Identity (alone)	Reveals Identity (combined)
1. Date and Universal Time of anomaly	x	No	Yes
2. Fully specified spacecraft location during anomaly	x	Yes	Yes
3. Velocity or orbital elements at time of the anomaly	x	Yes	Yes
4. L-shell at time of anomaly		No	Depends
5. Magnetic Local Time of vehicle during anomaly		No	Depends
6. Eclipse state of the vehicle (full, penumbra, partial, none)		No	Depends
7. Vector to sun in spacecraft coordinates		No	Depends
8. Velocity vector of spacecraft in spacecraft coordinates		No	No
9. Initial guess at type of anomaly (SEU, discharge, TID)		No	No
10. Estimated confidence of that guess		No	No
11. Anomaly category (e.g., affected subsystem or type of disruption)		No	Depends
12. Vehicle identity (possibly anonymized)		Yes	Yes
13. Notes on recent operational states or changes (e.g., recent commands, attitude schemes)		Depends	Depends

NOTE: * Modified from O'Brien et al. (2011).

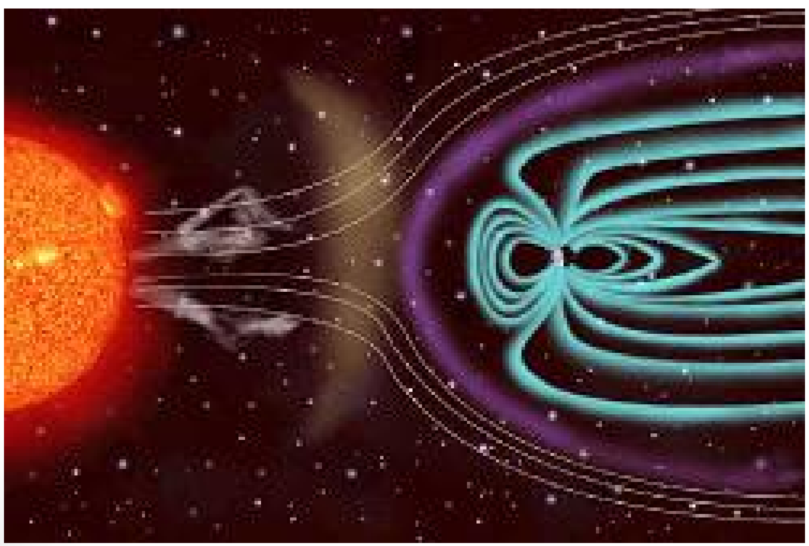
Reference: Denig, W.F., R.J. Redmon, J.V. Rodriguez and J.H. Allen (2014), Book Review: Satellite Anomalies: Benefits of a Centralized Anomaly Database and Methods for Securely Sharing Information Among Satellite Operators, Space Weather, 12, 528–529, doi:10.1002/2014SW001100.

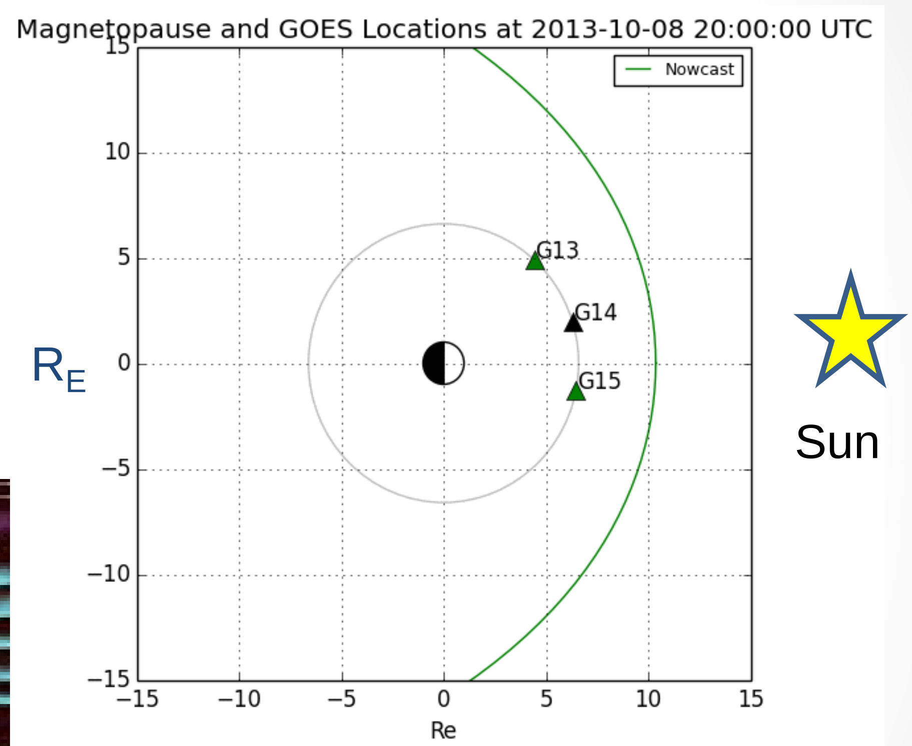
GOES-R Space Weather (SWx)

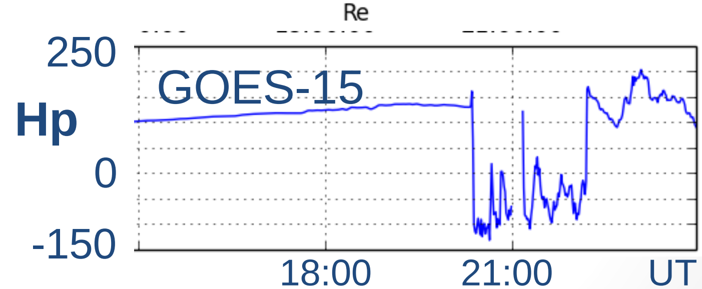
Monitoring the Occurrence of Solar Storms

During stronger space weather events the magnetopause location moves inside of the geostationary orbit.

At these time, satellites on the dayside are exposed to the interplanetary plasma conditions.







- ✓ Algorithm development supported by GOES-R Risk Reduction (GOES-RRR)
- ✓ Implementation support by the Satellite Product & Services Review Board (SPSRB) – [Link]

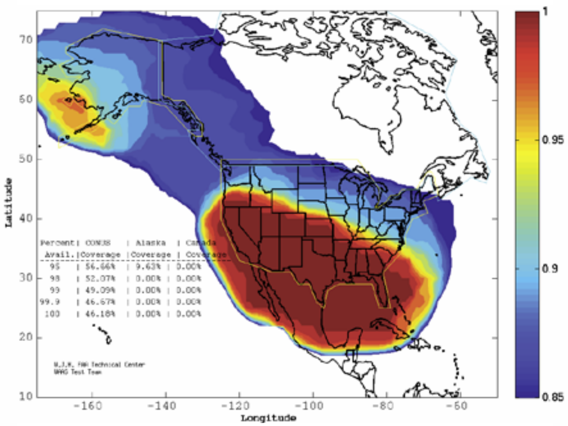
GOES-R Space Weather (SWx)

Monitoring the Performance of WAAS

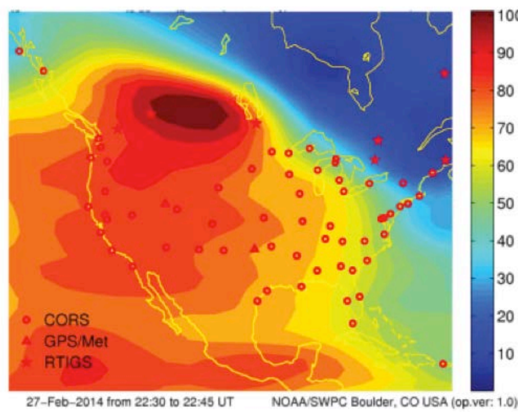
FAA Message to SWPC: "An Ionospheric Storm began on 2/27/14. The Satellite Operations Specialists were alerted at the WAAS O&M by a Significant Event 757 at 2120 Zulu. So far, LPV and LPV200 service has not been available in Eastern Alaska and Northeastern CONUS. At times, North Central CONUS and all of Alaska have lost LPV and LPV200 Service."

Storm Day

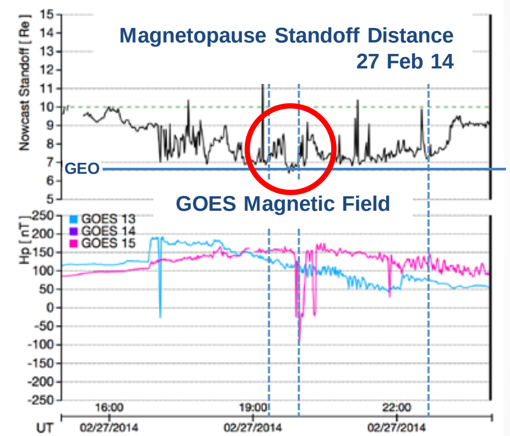
WAAS Coverage 27 February



TEC 27 February 22:30 UT

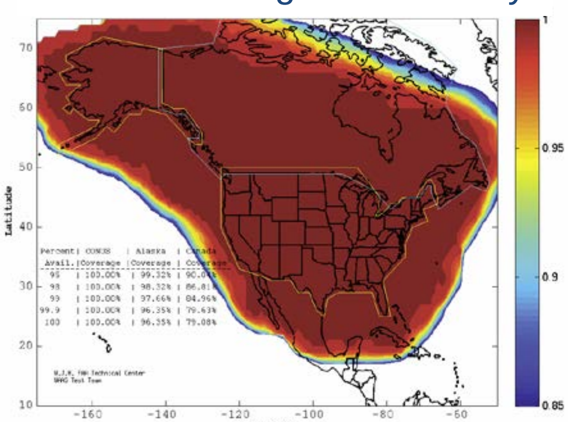


NGDC Magnetopause Crossing
27 Feb 14 – 17-24 UT

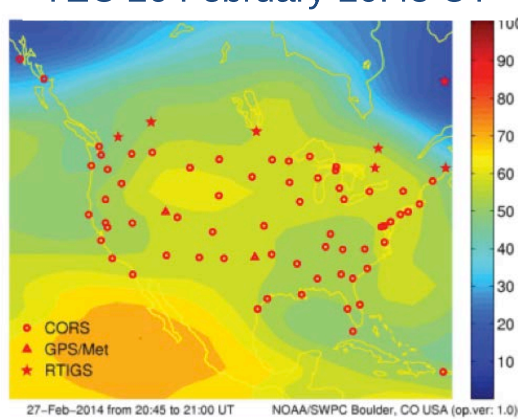


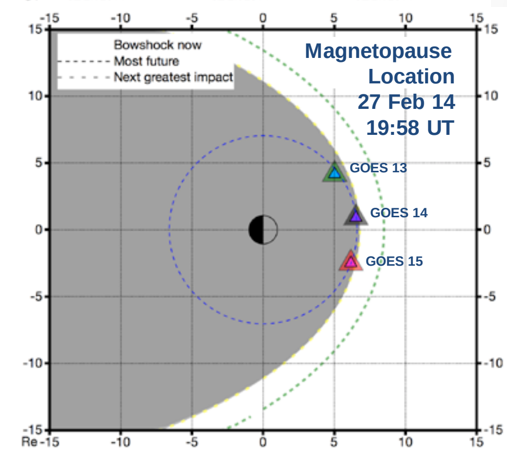
Reference Day

WAAS Coverage 26 February



TEC 26 February 20:45 UT



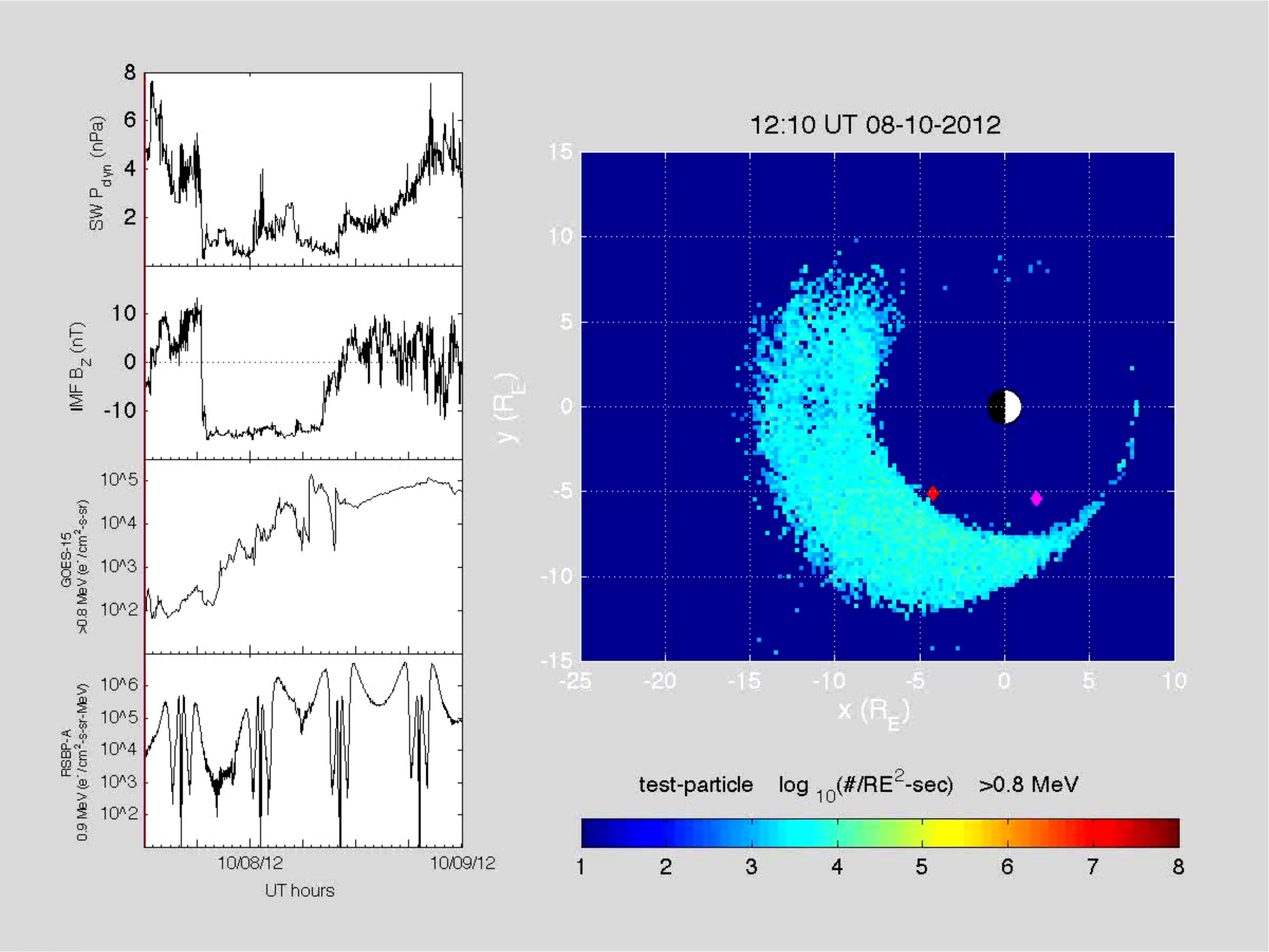


LPV - Lateral Precision with Vertical guidance

GOES-R Space Weather (SWx)

Repopulating the Magnetosphere

Rebuilding of Earth's outer radiation belt during 8-9 October 2012 geomagnetic storm



>0.8 MeV electron flux in equatorial plane in SM coordinates.

GOES-15 and RBSP-A spacecraft positions

[After Kress et al., GRL, 2014]

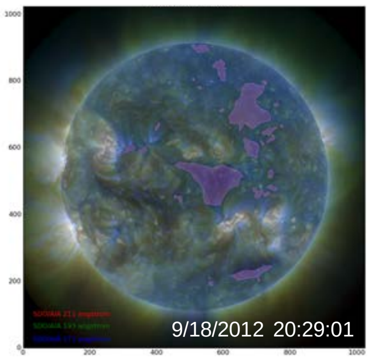
Kress, B. T., M. K. Hudson, and J. Paral (2014), Rebuilding of the Earth's outer electron belt during 8–10 October 2012, *Geophys. Res. Lett., 41*, 749–754, doi:10.1002/2013GL058588.

GOES-R Space Weather (SWx)

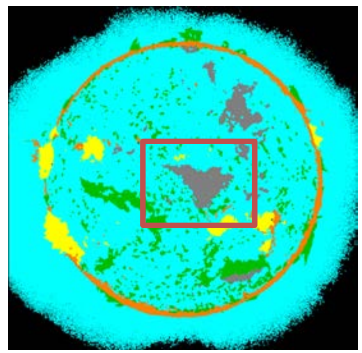
SUVI Classification of Solar Coronal Holes (CH)

SDO AIA solar images are used as proxy for SUVI. SUVI Thematic Maps (SUVI.19) and Coronal Hole Boundaries (SUVI.15) are L2+ SWx products.

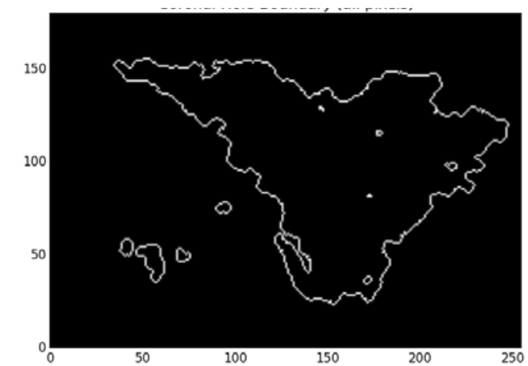
NASA/SDO as Proxy



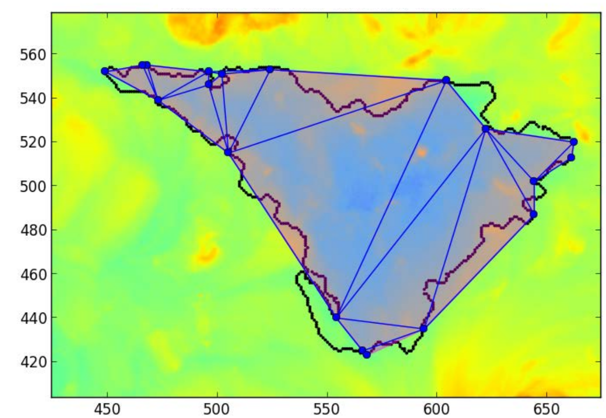
Thematic Map



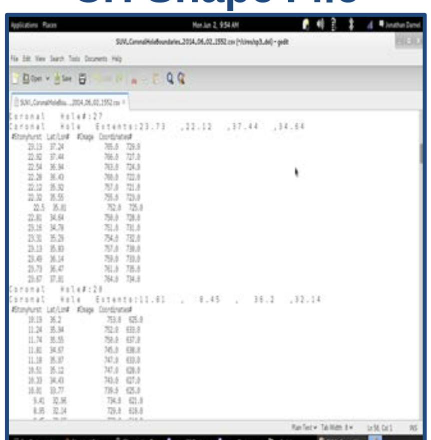
Coronal Hole Boundary



Finite Vertices



CH Shape File

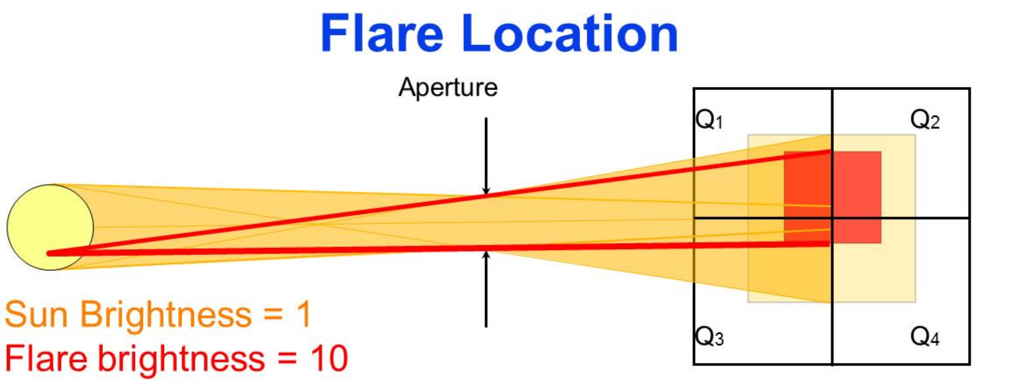


Coronal holes are regions of the corona where the magnetic field reaches out into space rather than looping back down onto the surface. Particles moving along those magnetic fields can leave the sun rather than being trapped near the surface. Recurring larger solar speeds originate within coronal holes.

GOES-R Space Weather (SWx)

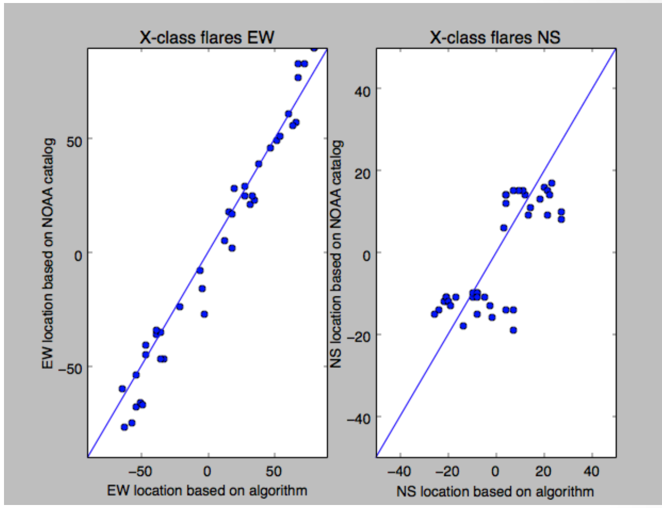
Exploiting New Capabilities for the EXIS/XRS

New quad-diode in XRS will provide solar flare locations



$$X=([Q_2 + Q_4]-[Q_1 + Q_3])/sum = ([(\tfrac{1}{4}+4)+(\tfrac{1}{4}+1)]-[(\tfrac{1}{4}+4)+(\tfrac{1}{4}+1)])/(1+10) = 0.00$$

$$Y=([Q_1 + Q_2]-[Q_3 + Q_4])/sum = ([(\tfrac{1}{4}+4)+(\tfrac{1}{4}+4)]-[(\tfrac{1}{4}+1)+(\tfrac{1}{4}+1)])/(1+10) = \mathbf{0.55}$$



Initial PLPT performance results using “quad-diode” proxy data from SXI compared to the NOAA flare catalog (5 arcminute requirement).

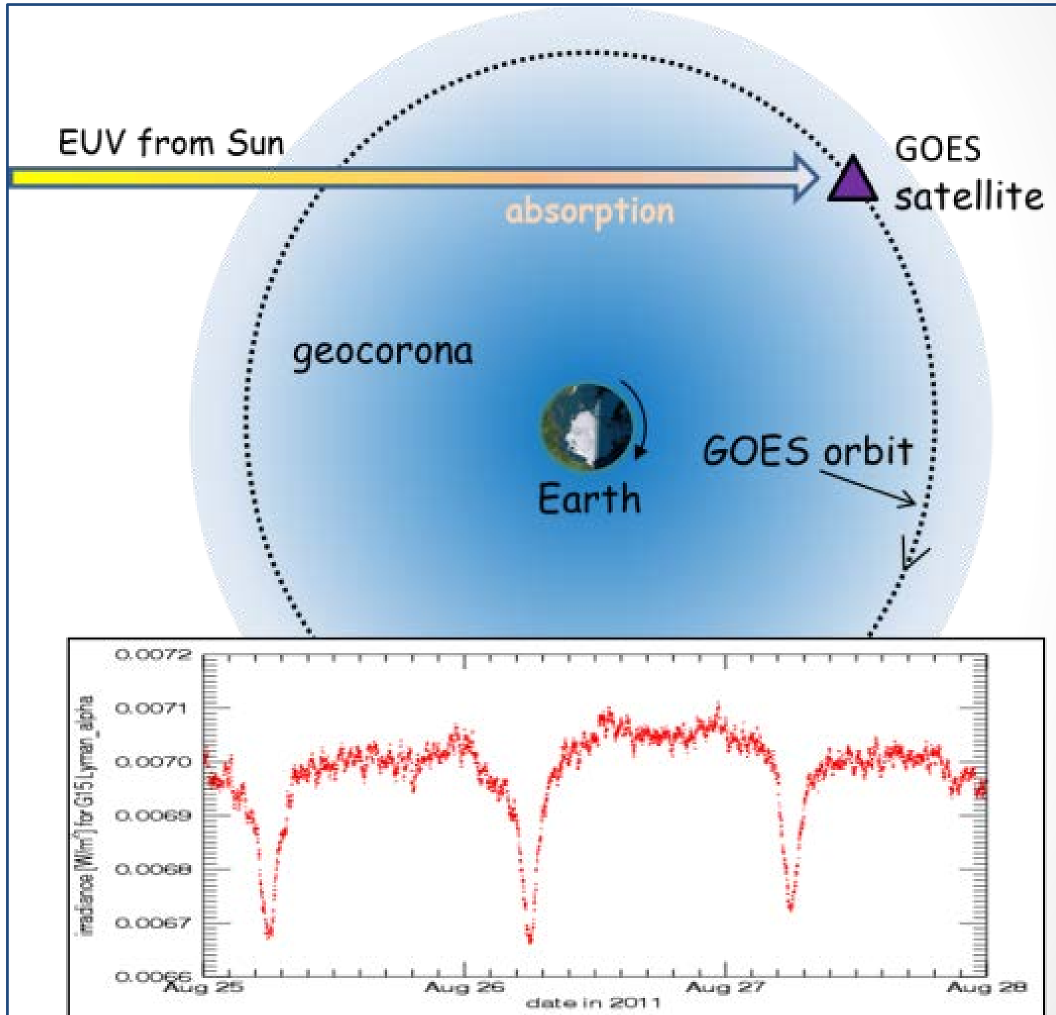
Classification	All flares	Good backgrounds
X-class flares	3.0±1.7 arcminutes	3.0±1.6 arcminutes
M-class flares	4.0±3.4 arcminutes	3.7±3.2 arcminutes
C-class flares	7.3±6.1 arcminutes	6.7±5.6 arcminutes

GOES-R Space Weather (SWx)

EUVS Continuous Monitoring of the Geocorona

Background: Use occultation technique to monitor the hydrogen geocorona at 121.6 nm (Lyman alpha) within the upper thermosphere. Atomic hydrogen in this region is a byproduct of hydrogen-containing species below such as methane and water vapor. Models have predicted 50-75% increases in upper atmospheric hydrogen as a consequence of a doubling of tropospheric concentrations of methane, a primary greenhouse gas.

GOES-R data will allow for establishment/continuation of a long-term (since 2006) record.



Funded as a University of Colorado/CIRES Innovative Research Project.

GOES-R Space Weather (SWx)

Parting Thoughts – Bill Denig

While the primary mission of GOES space environment sensors is to serve the needs of operational space weather community the data, nevertheless, contributes significantly to heliophysics (and related) research:

- Over 40 years of continuous space environmental data
  - ✓ SMS1&2 (7/74 – 4/76) /// GOES 1-15 (1/76 – present)
- GOES extensively used in peer-reviewed publications
  - ✓ 75 of 711 papers published in JGR-Blue in 2013
- Data available via NGDC (main site) and other sources
  - ✓ NGDC: http://www.ngdc.noaa.gov/stp/satellite/goes/
  - ✓ NASA CDA-Web: http://cdaweb.gsfc.nasa.gov/
  - ✓ VIRBO: http://virbo.org/