Welcome and Introduction to GOES-R

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The Next Generation of Geosynchronous Space Weather Measurements
Space Weather Workshop, Boulder, CO, April 13, 2015

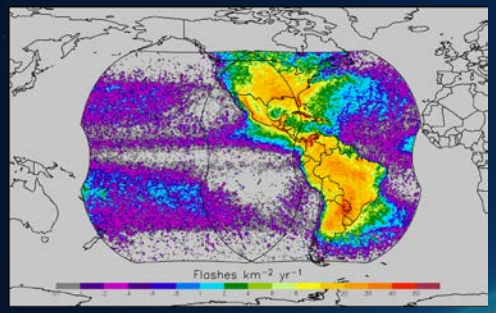
Outline

- GOES-R Mission Overview
- GOES-R Instruments
- Cal/Val and PLT/PLPT Timelines
- GOES-R Proving Ground
- Summary

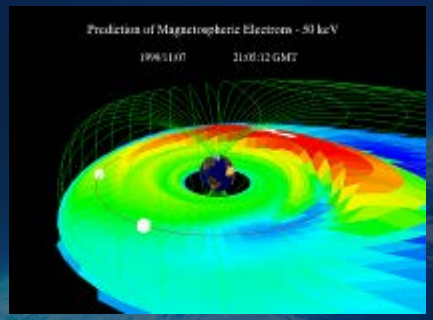
The GOES-R Mission

The GOES-R series will provide significant improvements in the detection and observations of meteorological phenomena that directly impact public safety, protection of property, and our Nation's economic health and prosperity

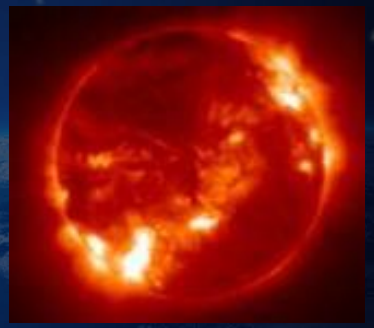
Visual & IR Imagery



Lightning Mapping



Space Weather Monitoring



Solar Imaging

- ✓ Improves hurricane track & intensity forecasts
- ✓ Increases thunderstorm & tornado warning lead time
- ✓ Improves aviation flight route planning
- ✓ Data for long-term climate variability studies
- ✓ Improves solar flare warnings for communications and navigation disruptions
- ✓ More accurate monitoring of energetic particles responsible for radiation hazards to humans and spacecraft
- ✓ Better monitoring of Coronal Mass Ejections to improve geomagnetic storm forecasting

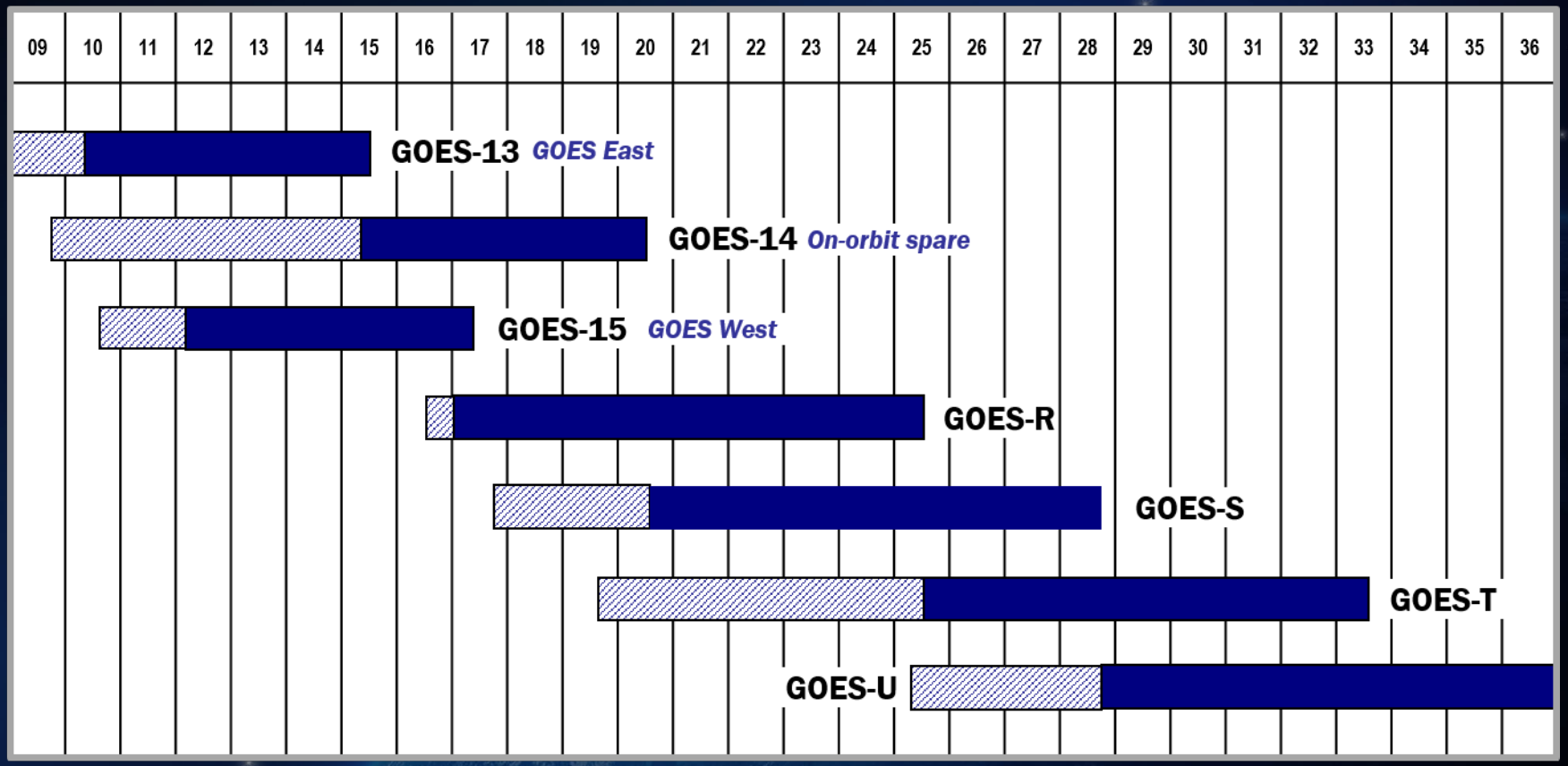
GOES-R Series Program Overview

Mission: Provide continuous imagery and atmospheric measurements of Earth's Western Hemisphere and space weather monitoring.

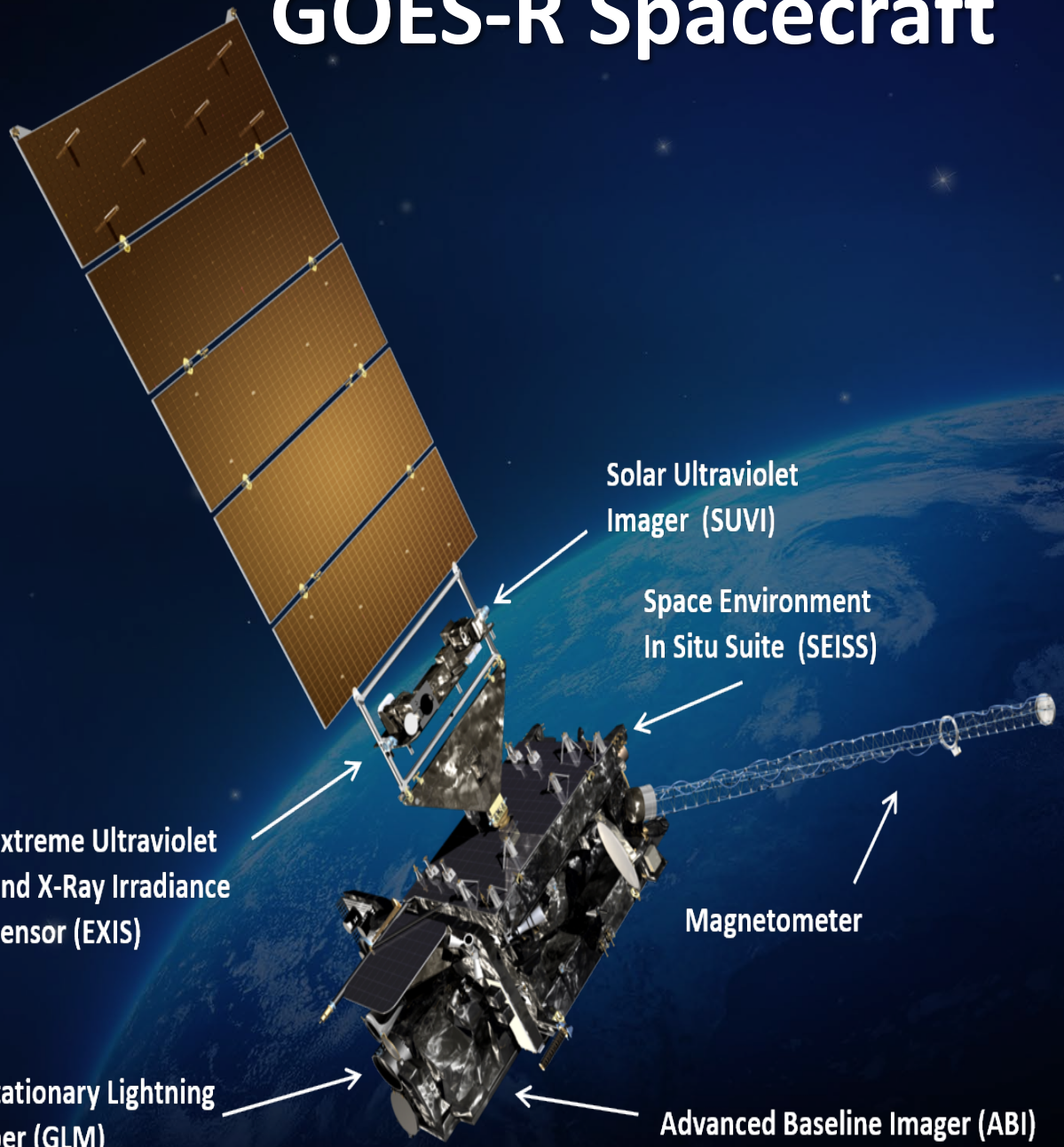
- **NOAA Responsibilities:**
  - Overall programmatic responsibility
  - Procurement of the Ground Segment
- **NASA Responsibilities:**
  - Procurement of the Space Segment
  - Systems Engineering lead
  - Safety and Mission Assurance lead
- **Joint mission between NASA and NOAA**
  - Builds upon successful GOES legacy program since the late 1970s

Host Center	**NASA Goddard Space Flight Center**
Program Architecture	**Four Satellites (GOES-R, S, T, U)**
Launch Readiness Dates	**GOES-R: March 2016** **GOES-S: 3Q FY 2017** **GOES-T: 3Q FY 2019** **GOES-U: 1Q FY 2025**
Program Operational Life	**FY 2017 – FY 2036**

Continuity of GOES Operational Satellite Program



GOES-R Spacecraft



GOES to GOES-R Comparison

	GOES I-M	GOES N-P	GOES R
Performance Capability			
Imaging			
Visible Resolution	1 km	1 km	0.5 km
IR Resolution	4-8 km	4-8 km N 4 km O/P	1-2 km
Full Disk Coverage Rate	30 min	30 min	5 min
# of Channels	5	5	16
Solar Monitoring	GOES-M only	Yes	Yes
Lightning Detection	No	No	Yes
Operate through Eclipse	No	Yes	Yes
Ground System Backup	Limited	Limited	Limited
Archive and Access	Limited	Limited	Yes
Raw Data Volume per spacecraft	2.6 Mbps	2.6 Mbps	75 Mbps

GOES-R Instruments

Earth Pointing

Visible & IR Imagery

Advanced Baseline Imager (ABI)

Exelis

Lightning Mapping

Geostationary Lightning Mapper (GLM)

Lockheed Martin Space Technology Advanced Research and Development Laboratories

In-Situ

Space Weather Monitoring

Space Environment in-Situ Sensor Suite (SEISS)

Assurance Technology Corp.

Magnetometer

Lockheed Martin with Macintyre Electronic Design Associates and ATK

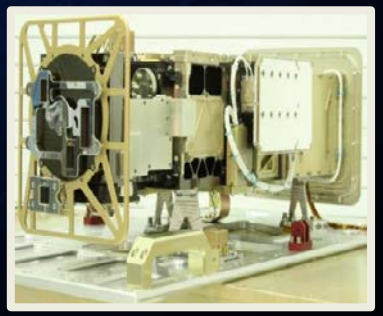
Sun Pointing

Solar Imaging

Solar Ultra-Violet Imager (SUVI)

Lockheed Martin Space Technology Advanced Research and Development Laboratories

Extreme Ultraviolet and X-ray Irradiance Sensors (EXIS)



University of Colorado Laboratory for Atmospheric and Space Physics

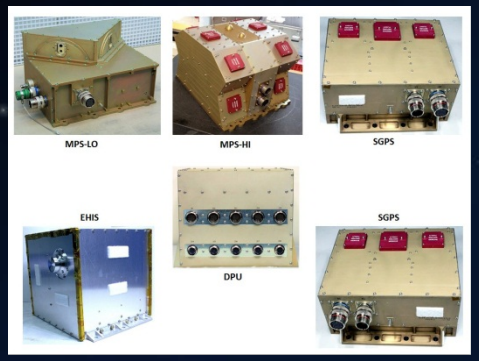
GOES-R vs. GOES N-P
Key Differences - Instruments

GOES N-P	GOES-R
Imager: 5 Channels 1.6 Mbs raw instrument data rate 1.0 km spatial resolution 26 min full disk Frame-by-frame commanding required via multiple daily schedules INR: Accomplished by precise image acquisition (control) Requires multiple INR uploads daily Lightning Mapper: None SXI: X-ray/EUV CCD 512x512 pixels, 5 arcsec/pixel resolution XRS: Ionization chamber design	**ABI** **16 Channels** **120Mbs raw instrument data rate** **0.5 km spatial resolution** **5 min full disk** **Autonomous sequences; no daily commanding** **INR: Accomplished by image post-processing (knowledge)** **Single ABI Target Star List uploaded daily** **GLM provides continuous full disk total lightning measurements** **SUVI: UV CCD 1280x2180 pixels, .28 arcsec/pixel resolution** **EXIS: Solid state detector design, higher dynamic range, adds flare location capability**

GOES-R, Generational improvement in instrument spatial, spectral and temporal resolution

Space Weather Instruments

Space Environment In Situ Suite (SEISS)

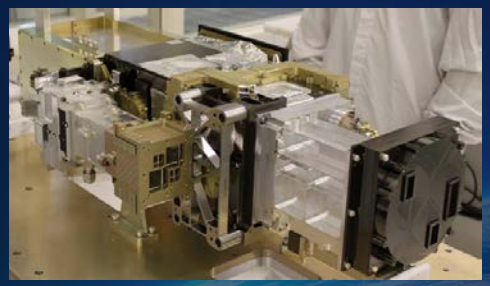


- Array of energetic particle sensors that will monitor the proton, electron and alpha particle fluxes
- Assess radiation hazard to astronauts and satellites
- Warn of high flux events, mitigating damage to radio communications and navigation systems

Magnetometer

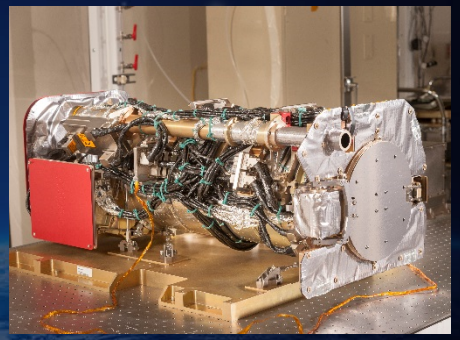
- Measures the magnitude and direction of the Earth's ambient magnetic field
- Provides map of the space environment that controls charged particle dynamics in the outer region of the magnetosphere
- Detection of magnetopause crossings, sudden storm commencements, and substorms

Extreme Ultraviolet and X-ray Irradiance Sensor (EXIS)



- The X-Ray Sensor (XRS) monitors solar flares that can disrupt communications and degrade navigational accuracy, affecting satellites, astronauts, high latitude airline passengers, and power grid performance.
- Extreme Ultraviolet Sensor (EUVS) monitors solar variations that directly affect satellite drag/tracking and ionospheric changes, which impact communications and navigation operations.

Solar Ultra-Violet Imager (SUVI)



- Locates coronal holes, flares and coronal mass ejection source regions
- Continuously images the sun in 6 extreme ultraviolet wavelengths to characterize active region complexity
- Will provide an early warning of possible impacts to the Earth environment and enable better forecasting of potentially disruptive events

Assembled GOES-R Spacecraft

GOES-R Products

Baseline Products

Advanced Baseline Imager (ABI)

- Aerosol Detection (Including Smoke and Dust)
- Aerosol Optical Depth (AOD)
- Clear Sky Masks
- Cloud and Moisture Imagery
- Cloud Optical Depth
- Cloud Particle Size Distribution
- Cloud Top Height
- Cloud Top Phase
- Cloud Top Pressure
- Cloud Top Temperature
- Derived Motion Winds
- Derived Stability Indices
- Downward Shortwave Radiation: Surface
- Fire/Hot Spot Characterization
- Hurricane Intensity Estimation
- Land Surface Temperature (Skin)
- Legacy Vertical Moisture Profile
- Legacy Vertical Temperature Profile
- Radiances
- Rainfall Rate/QPE
- Reflected Shortwave Radiation: TOA
- Sea Surface Temperature (Skin)
- Snow Cover
- Total Precipitable Water
- Volcanic Ash: Detection and Height

Geostationary Lightning Mapper (GLM)

- Lightning Detection: Events, Groups & Flashes

Space Environment In-Situ Suite (SEISS)

- Energetic Heavy Ions
- Magnetospheric Electrons & Protons: Low Energy
- Magnetospheric Electrons: Med & High Energy
- Magnetospheric Protons: Med & High Energy
- Solar and Galactic Protons

Magnetometer (MAG)

- Geomagnetic Field

Extreme Ultraviolet and X-ray Irradiance Suite (EXIS)

- Solar Flux: EUV
- Solar Flux: X-ray Irradiance

Solar Ultraviolet Imager (SUVI)

- Solar EUV Imagery

Future Capabilities

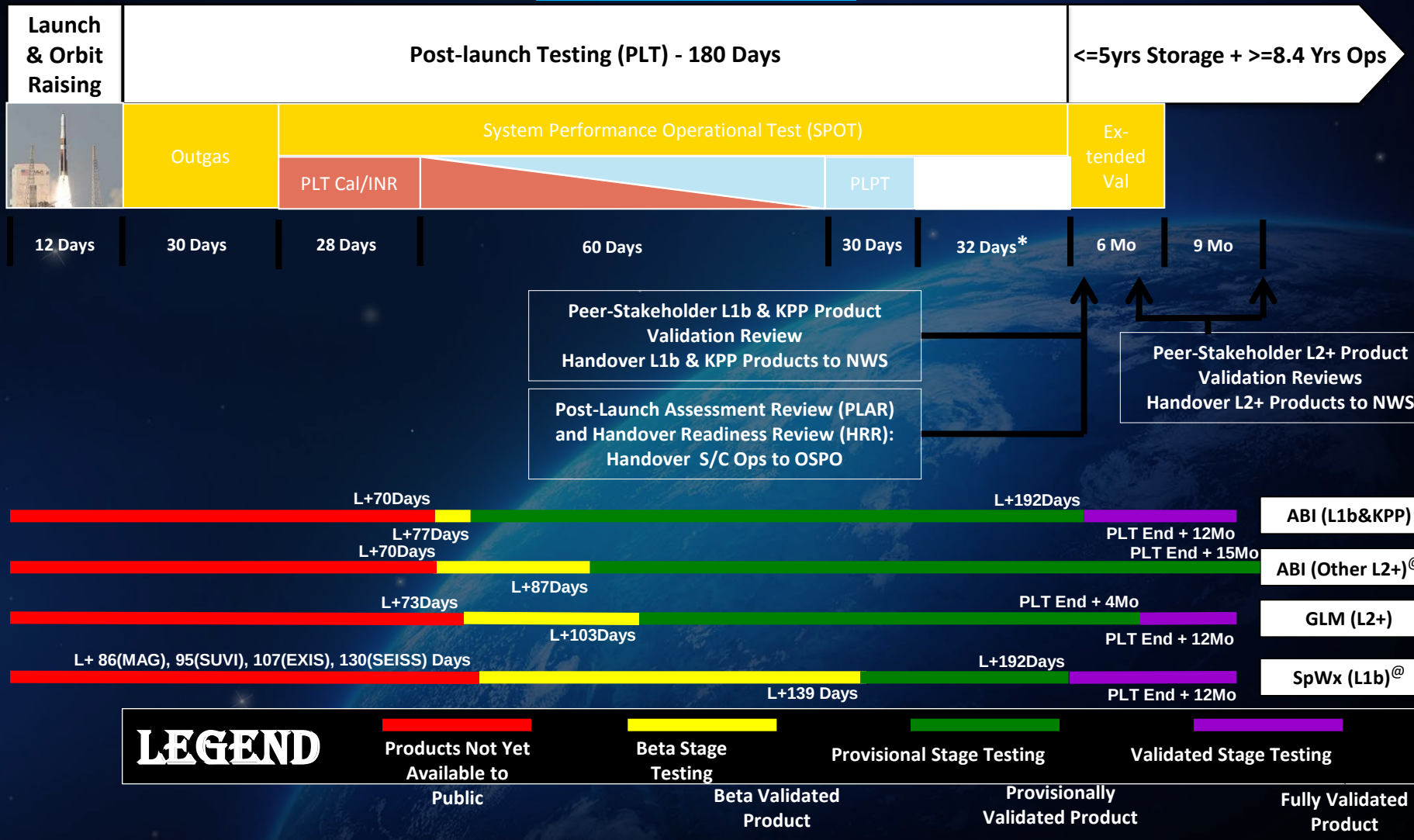
Advanced Baseline Imager (ABI)

- Absorbed Shortwave Radiation: Surface
- Aerosol Particle Size
- Aircraft Icing Threat
- Cloud Ice Water Path
- Cloud Layers/Heights
- Cloud Liquid Water
- Cloud Type
- Convective Initiation
- Currents
- Currents: Offshore
- Downward Longwave Radiation: Surface
- Enhanced “V”/Overshooting Top Detection
- Flood/Standing Water
- Ice Cover
- Low Cloud and Fog
- Ozone Total
- Probability of Rainfall
- Rainfall Potential
- Sea and Lake Ice: Age
- Sea and Lake Ice: Concentration
- Sea and Lake Ice: Motion
- Snow Depth (Over Plains)
- SO_2 Detection
- Surface Albedo
- Surface Emissivity
- Tropopause Folding Turbulence Prediction
- Upward Longwave Radiation: Surface
- Upward Longwave Radiation: TOA
- Vegetation Fraction: Green
- Vegetation Index
- Visibility

GOES-R System Architecture

Cal/Val and PLT/PLPT Timeline

PLT/PLPT at 89.5W



* Data blackout due to Storage Mode Ops and Station Change to 105W.

@ Maturity level may vary for each product, as product availability is driven by maturity of algorithm implementation, as well as, the existence of science phenomena and associated ground-truth data.

GOES-R Product (L1b and L2+) Validation Maturity Stage End States

Beta Validated	• Product is minimally validated, and may still contain significant errors (identified and unidentified). • Information/data from validation efforts can only be used to make initial qualitative and/or very limited quantitative assessments regarding product fitness-for-purpose. • Documentation of product performance and identified product performance anomalies, including recommended remediation strategies, exists.
Provisional Validated	• Product performance (L1b or L2+) has been demonstrated through analysis of a large, but still limited (i.e., not necessarily globally or seasonally representative) number of independent measurements obtained from selected locations, time periods, or field campaign efforts. • Product analyses are sufficient for qualitative, and limited quantitative, determination of product fitness-for-purpose. • Documentation of product performance, testing involving product fixes, identified product performance anomalies, including recommended remediation strategies, exists. • Product is ready for potential operational use (user decision) and for use in scientific publications after consulting product status documents.
Fully Validated	• Product performance has been demonstrated over a large and wide range of representative conditions (i.e., global, seasonal). • Comprehensive documentation of product performance exists that includes all known product anomalies and their recommended remediation strategies for a full range of retrieval conditions and severity level. • Product analyses are sufficient for full qualitative and quantitative determination of product fitness-for-purpose. • Product is ready for operational use based on documented validation findings and user feedback. • Product validation, quality assurance, and algorithm stewardship continue through the lifetime of the instrument.

PLT/PLPT Transition and Handover

- **Primary focus is "Day-one Readiness"** for GOES-R observatory post-launch tests and data post-launch product tests. This readiness includes: Planning of observatory and data product tests; Software analysis tool development and testing; Cal/Val Operational Concept development and rehearsals; and Core Ground Segment training for cal/val personnel using GS capabilities.

- **Pre-Launch:** L1b and L2+ algorithm implementation in the Ground Segment (GS) is verified by comparing data products produced by the GS with expected results provided by instrument vendors (L1b) and the Algorithm Working Group (ABI and GLM L2+)

- **Post-Launch:** The Post-Launch Testing period includes a traditional observatory checkout, but also contains a period of Post-Launch Product Tests (PLPTs) designed for limited product quality assessment before Spacecraft Handover (Launch + 6 mo). After Handover, a period of Extended Validation (Launch + 12 mo) is planned to enhance product science validation maturity.

- **At Spacecraft Handover:** the expectation is that all L1b products and Cloud & Moisture Imagery will be Provisionally Validated, while all other

GOES-R Satellite Proving Ground

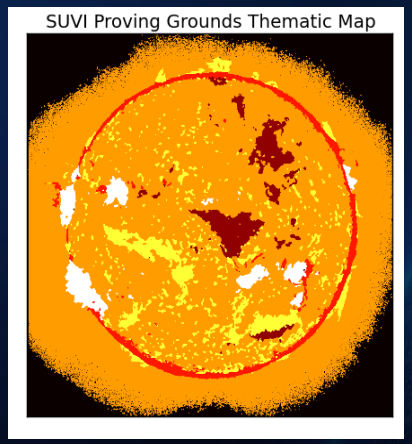
Making GOES-R test products available to forecasters, GOES-R level 2 products for research

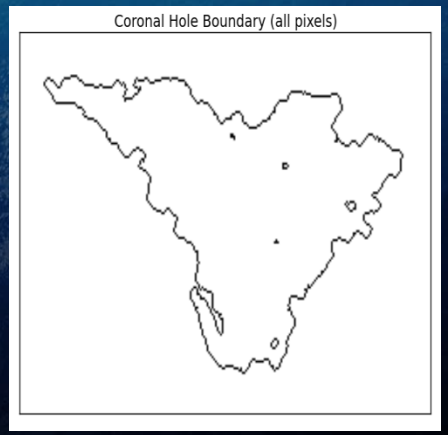
- Satellite liaisons (subject matter experts) at NWS National Centers
- Develop training for users
- Several GOES-R level 2 products are demonstrated in the GOES-R Proving Ground
- Examples can be found on the PG blogs and through the website www.goes-r.gov
- International projects

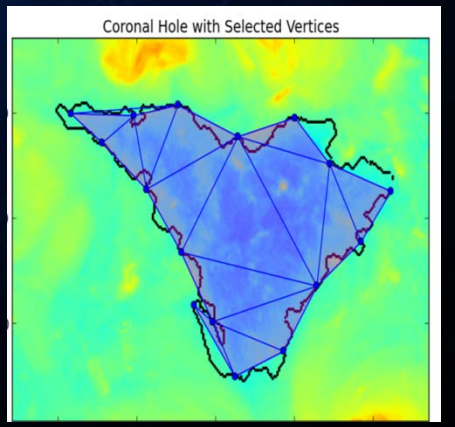
NOAA Hazardous Weather Testbed (HWT)

Space Weather Prediction Testbed: GOES-R Proving Ground

- Focuses on readiness of new capabilities and integration with National Weather Service (NWS) Advanced Weather Interactive Processing System (AWIPS) II Forecaster Workstation
- AWIPS II integration
- Thematic maps (multispectral pixel classifier) improvements
  - Assimilation of additional non-SUVI data (H-alpha images) in progress
  - Challenges with differing dynamic ranges and opacities (H-alpha vs. EUV)
- New product development based on Thematic Maps outputs
  - Bright regions – associated with solar active regions
  - Flare location – Solar eruptions seen as hottest & brightest of bright regions
  - Coronal Hole Boundaries – dark areas of strong, outflowing solar wind







Summary

GOES-R Series Follow-on

- In developing the observations requirements, what science measurements are required by forecasters and why
- What is the best vantage point- Geo, Leo, L1, other, for each in a holistic/comprehensive constellation
- Determine what science and measurements are best served from a GEO orbit. This information would be helpful to NOAA in determining what the multi-platform, multi-senor optimal integrated observing system for space weather forecasting should move towards.

GOES- R Additional Information

GOES-R web site

http://www.goes-r.gov

NOAA Satellite Services

http://www.ospo.noaa.gov/Services/

GOES-R FAQs

http://www.goes-r.gov/resources/faqs.html

GOES-R Rebroadcast (GRB), Product Users Guide, Downlink Specifications

http://www.goes-r.gov/users/grb.html

GOES-R Super Rapid Scan Experiment with GOES-14

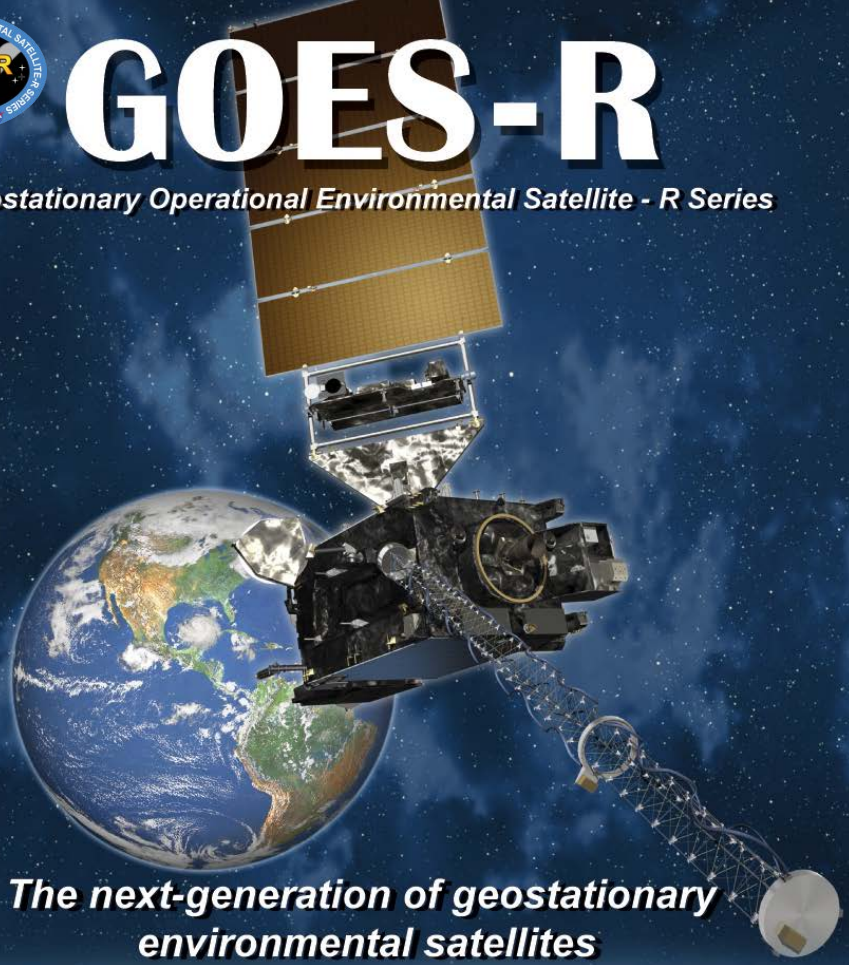
http://cimss.ssec.wisc.edu/goes/srsor2014/GOES-14_SRSOR.html

http://rammb.cira.colostate.edu/training/visit/blog/index.php/category/goes-r-proving-ground/


GOES-R
launches in
March
2016!

GOES-R

Geostationary Operational Environmental Satellite - R Series



The next-generation of geostationary environmental satellites

Advanced imaging for accurate forecasts

Real-time mapping of lightning activity

Improved monitoring of solar activity

Spacecraft image courtesy of Lockheed Martin

Thank you!

For more information visit www.goes-r.gov

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www.facebook.com/GOESRsatellite

https://www.youtube.com/user/NOAASatellites

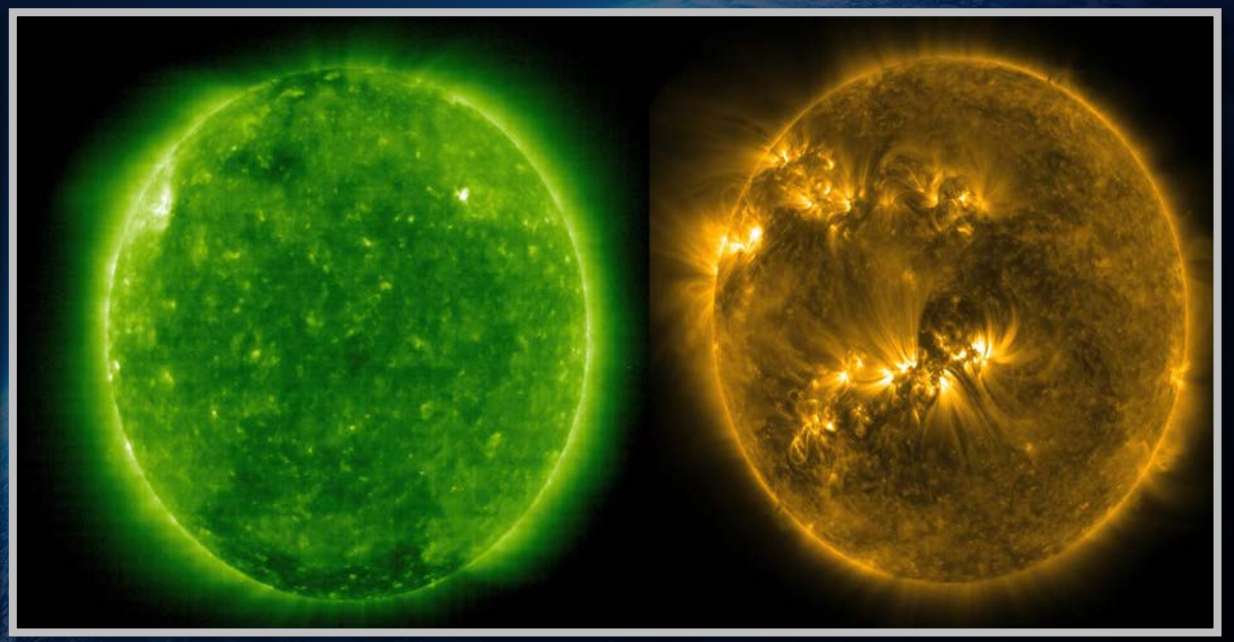
https://twitter.com/NOAASatellites

https://www.flickr.com/photos/noaasatellites/

Back-Up

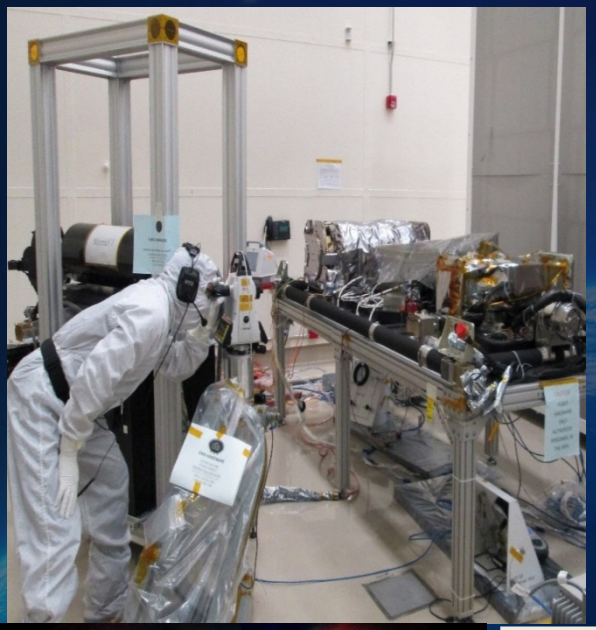
Solar Ultra-Violet Imager (SUVI)

- Improved detection of coronal holes, flares and coronal mass ejection source regions
- Improved geomagnetic storm forecasting
- Increased dynamic range, resolution, and sensitivity in monitoring solar x-ray flux

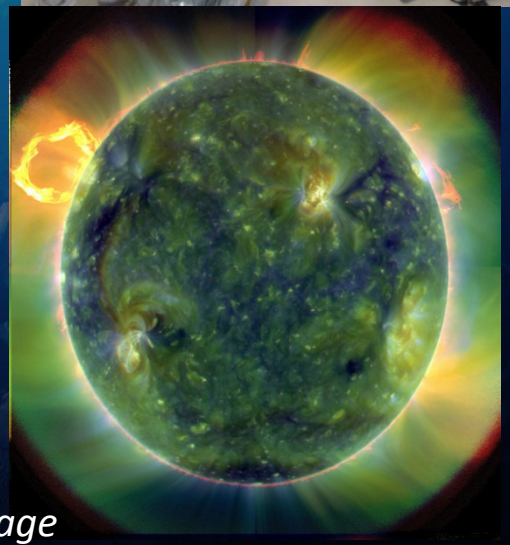


Extreme Ultraviolet and X-ray Irradiance Sensors (EXIS)

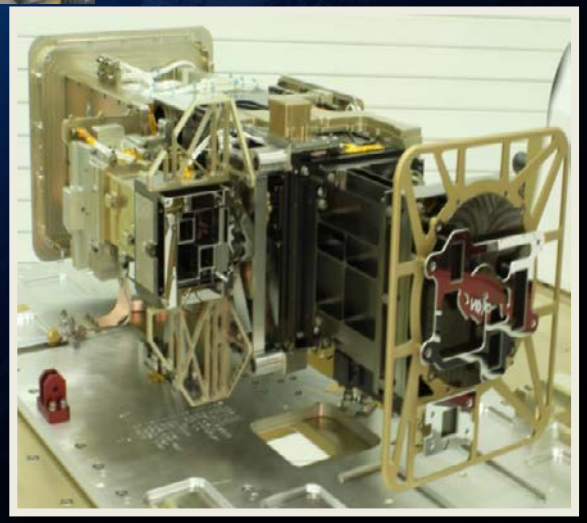
- EXIS has two sensors to measure solar radiation:
  - Extreme Ultraviolet Sensor (EUVS): monitors solar variations that affect satellite drag, and ionospheric changes impacting communication and navigation operations
  - X-Ray Sensor (XRS): detects the beginning, duration, and magnitude of solar X-ray flares
- EXIS provides improved solar flare warnings for communications and navigation disruption
- Provides input to models predicting severe impacts on satellites, astronauts, and airline passengers on polar routes, and provides input on possible impacts to power grid performance



Solar Flare

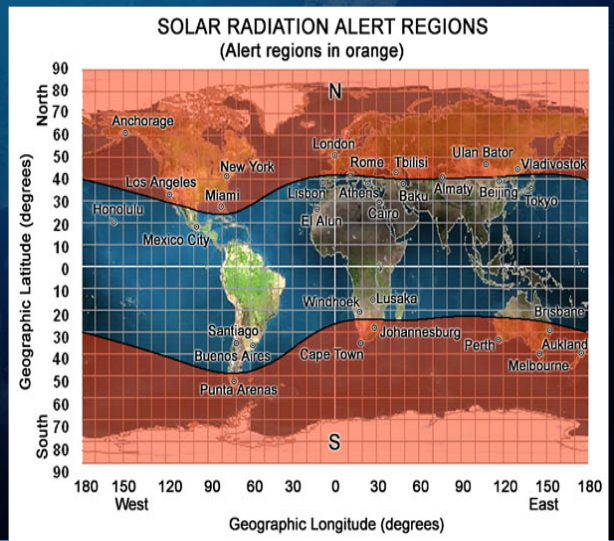


EUV Composite Solar Image



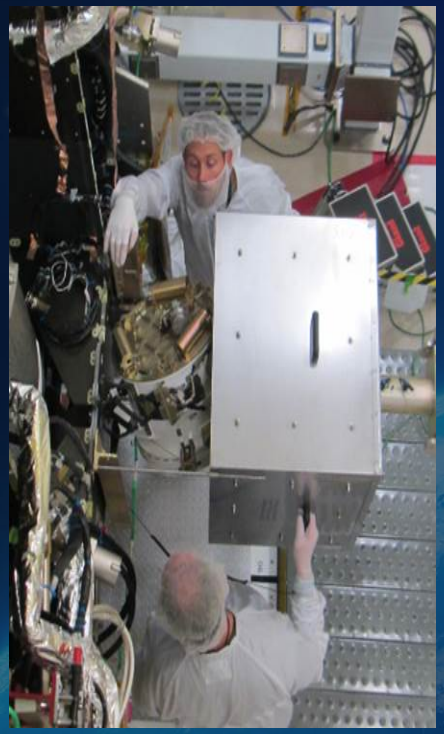
Space Environment in-Situ Sensor Suite (SEISS)

- SEISS consists of energetic particle sensors to monitor proton, electron and alpha particle fluxes to provide:
  - More accurate monitoring of energetic particles responsible for radiation hazards to humans and spacecraft
  - Better monitoring of low energy ionizing responsible for spacecraft charging
  - Improved warning of high flux events, mitigating damage to radio communication



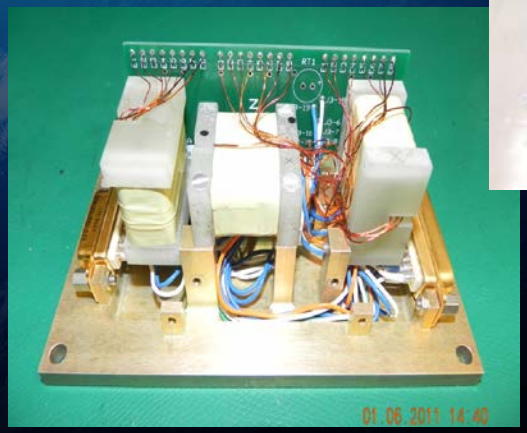
Magnetometer

- The magnetometer measures the magnitude and direction of Earth's ambient magnetic field
- Will provide the only operational measure of the impact of geomagnetic storms at geosynchronous orbit (key for interpreting solar radiation storm measurements by SEISS)
- Provides automated Magnetopause Crossing Detection and automated Sudden Impulse Detection



Magnetometer Installat

Magnetometer Boom



Magnetometer Sensor