



# Deep Space Climate Observatory (DSCOVR)

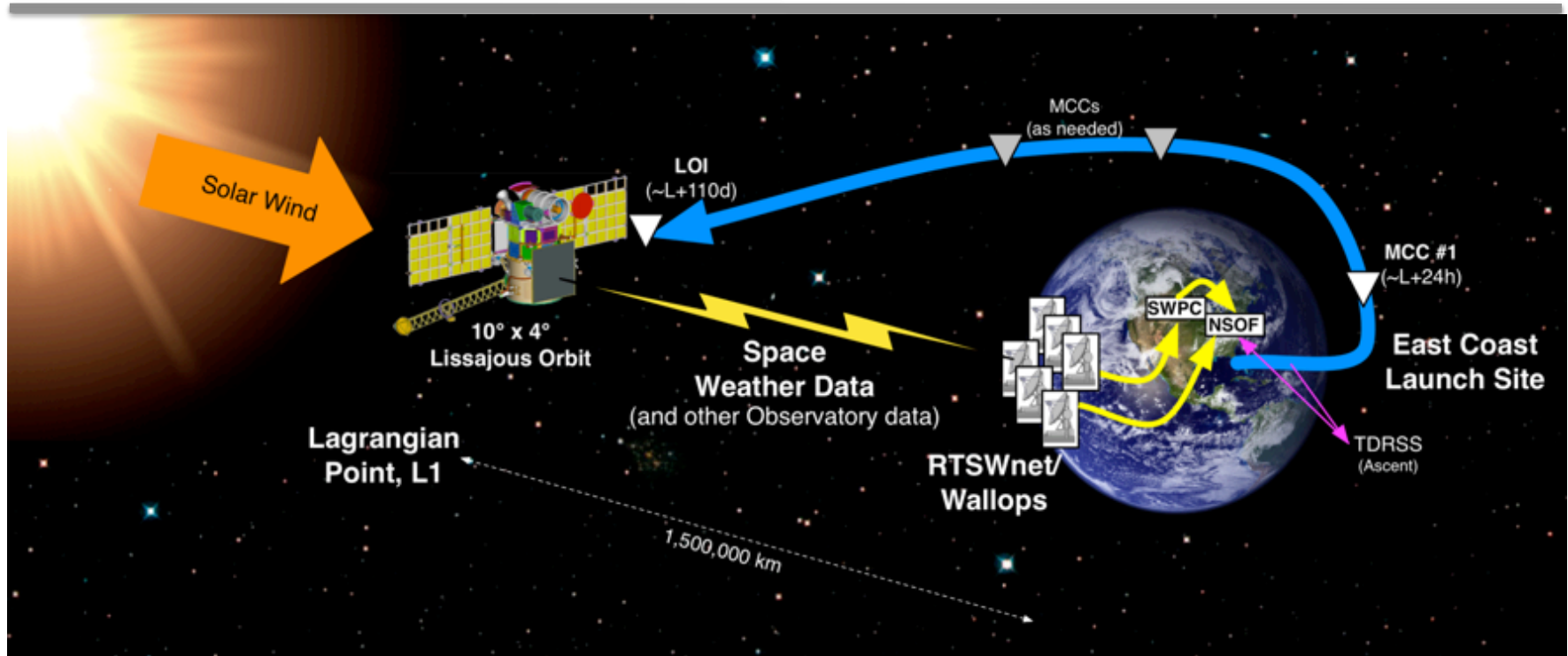
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6<sup>th</sup> NASA Space Weather &  
Robotic Mission Operations  
Workshop

September 17-18, 2014



# DSCOVR Mission Overview



## Mission Objectives:

- Primary science objective of the DSCOVR mission is to provide solar wind thermal plasma and magnetic field measurements to enable space weather forecasting by NOAA
- Secondary science objectives are to image the Sun lit disk of Earth in 10 spectral bands with a spatial resolution of 25 km or better, to determine ozone, aerosol, cloud cover, cloud height, vegetation, and leaf area indices and to measure the Earth reflected irradiance in the wavelength range of 0.2 - 100 microns

Category II, Risk Class D

## Instruments:

- Fluxgate Magnetometer
- Faraday Cup
- Electron Spectrometer
- Earth Polychromatic Imaging Camera (EPIC)
- NIST Advanced Radiometer (NISTAR)
- Pulse Height Analyzer (PHA)



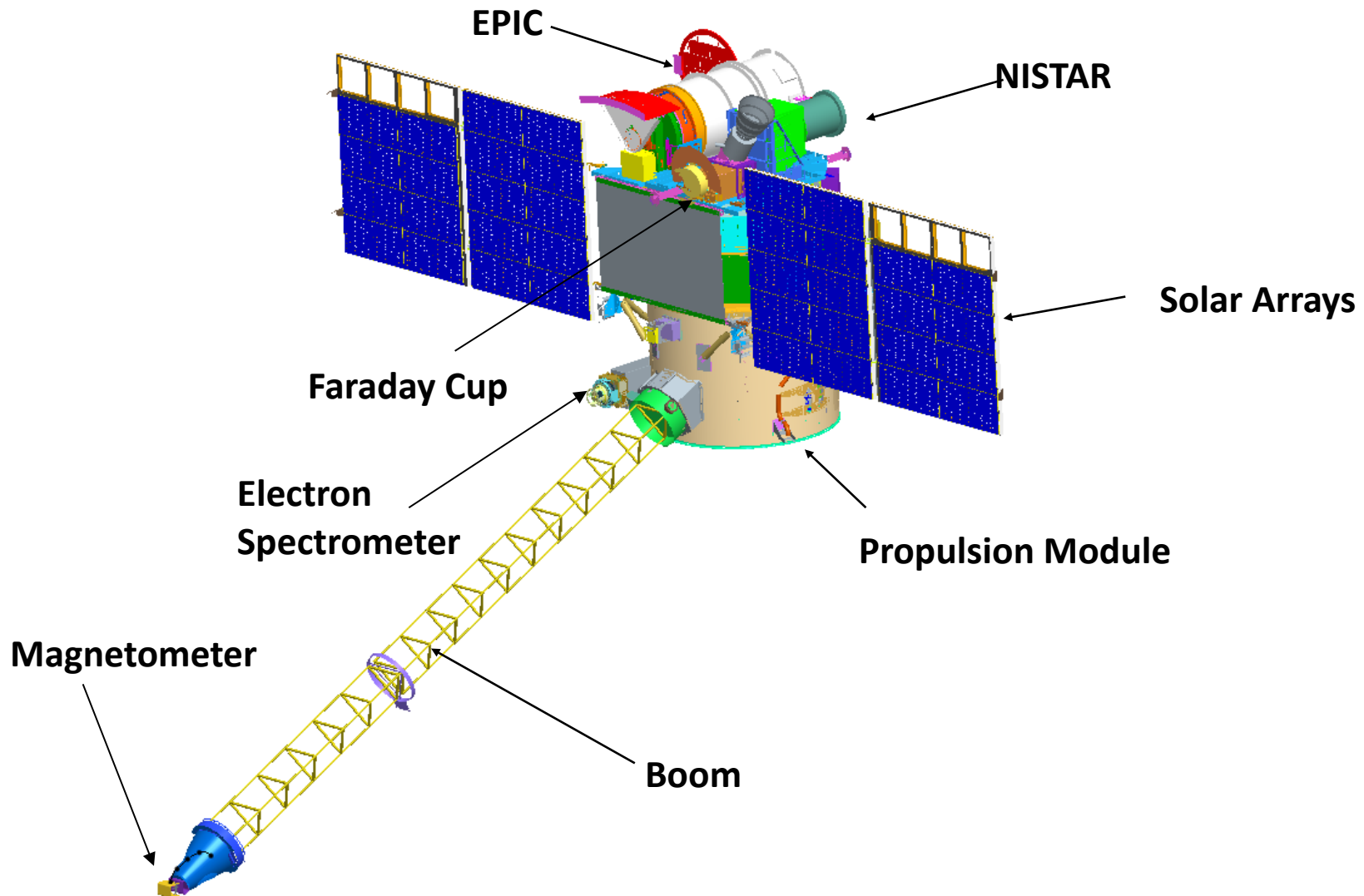
# DSCOVR History



- Triana Observatory fully integrated and environmental testing completed
- Placed in “Stable Suspension” in November 2001
- Observatory stored in GSFC B29 clean room
- GSFC Restart Study, June 2007
- GSFC Serotine Report, January 2009
  - Performed abbreviated aliveness test
  - Delivered cost and schedule estimate
- Refurbishment of EPIC & NISTAR 2009
  - NASA Earth Science Division funded
  - NISTAR tested & recalibrated
  - EPIC corrected ghosting, replaced CCU DC/DC converters
    - Tested & recalibrated
- NOAA issued startup funds in 2011 & 2012
  - Funds initial project planning activities via planning phase Inter-Agency Agreement
- Baseline Review held June 2012
- NOAA/NASA DSCOVR Implementation Inter-Agency Agreement signed July 2012
- NASA Science Mission Directorate Earth Science Division funds EPIC and NISTAR integration, test and operations Feb 2013

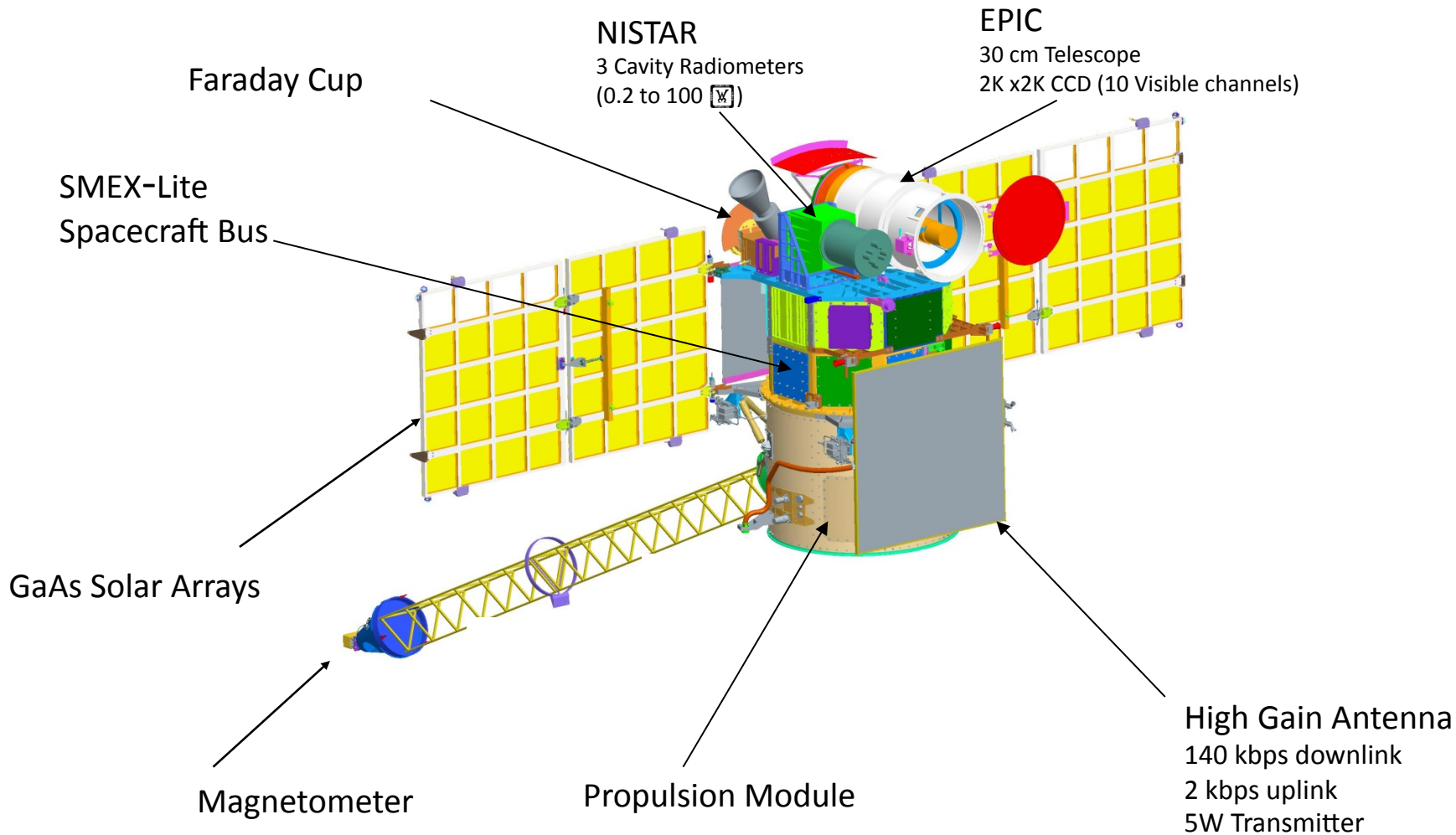


# Sunward Side of the Spacecraft





# Earthward Side of the Spacecraft





# Level 1 Science Requirements



Threshold science requirements of the DSCOVR mission that enables real-time space weather forecasting are:

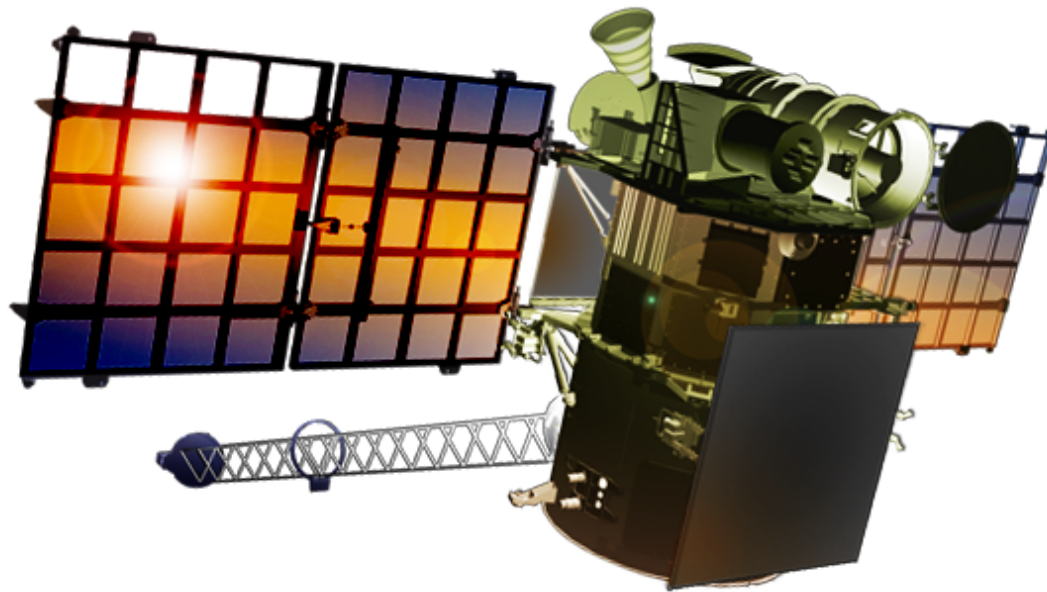
- Measure the interplanetary vector magnetic fields in the range of 0 – 100 nT with an absolute accuracy of  $\pm 1$  nT
- Measure the bulk velocity of the proton component of the thermal solar wind in the range of 200 – 1250 km/s with a 20% accuracy.
- Measure the density of the proton component of the thermal solar wind in the range of 1 – 100 particles/cm<sup>3</sup> with a 20% accuracy.
- Measure the temperature of the proton component of the thermal solar wind in the range of 40,000 – 2,000,000 Kelvin with 50% accuracy
- Measure the above parameters with a cadence of 1 sample per minute or better
- Deliver the above measurements with a system latency of no more than 5 minutes
  - The latency is measured as the time of instrument measurement to the time the data are processed to Level 2 and stored on a SWPC server



## Mission Success Criteria



- The DSCOVR mission is successful if it provides measurements of solar wind conditions impacting Earth that result in “Minor” or greater geomagnetic storms as defined by the NOAA Space Weather Scale for Geomagnetic Storms (G1 or greater) 96% of the storm time periods during normal spacecraft operations, for a period of at least 12 months after spacecraft checkout

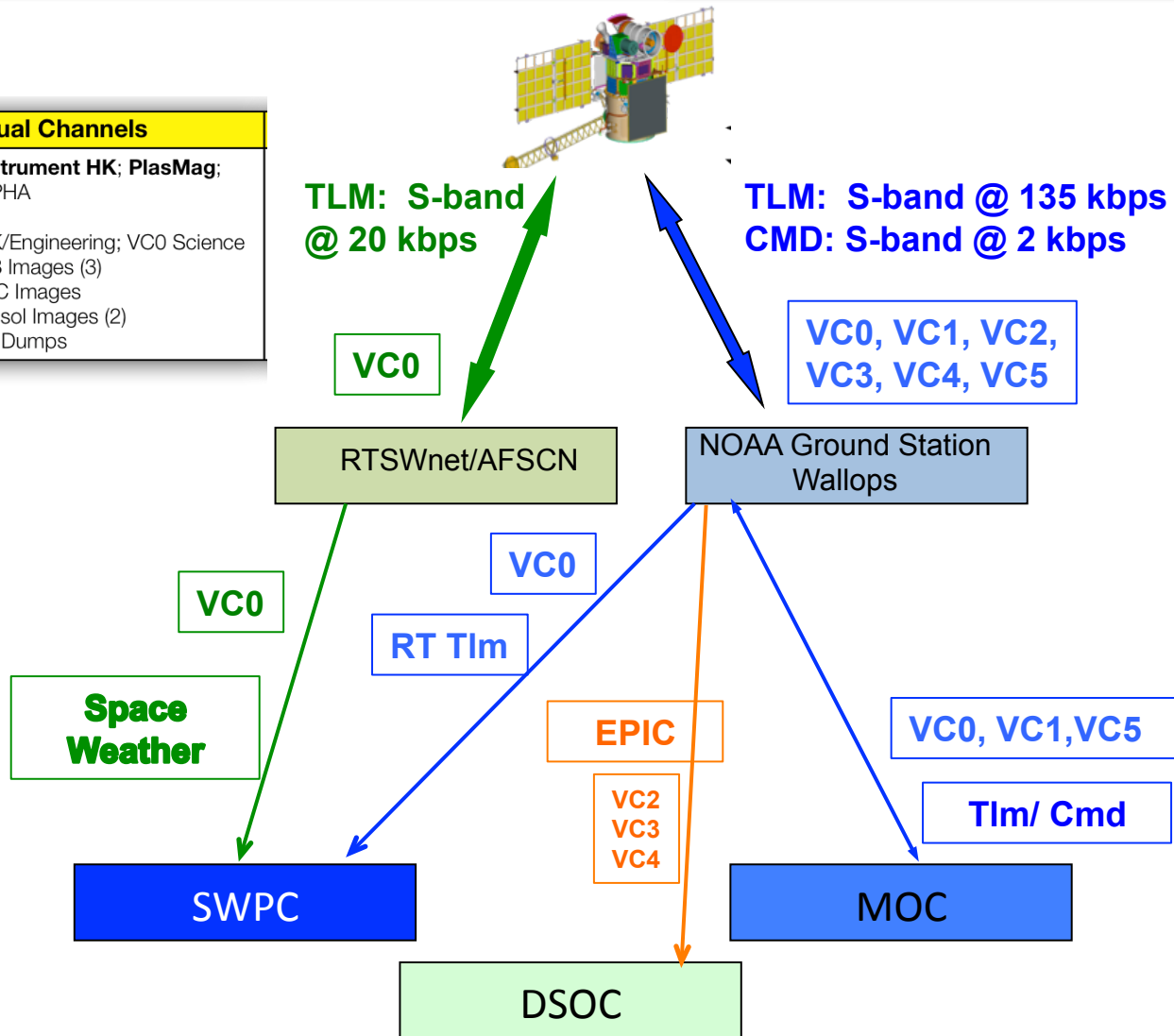




# Space/Ground Communications Normal Operations



Virtual Channels
VC0: <b>S/C &amp; Instrument HK; PlasMag; NISTAR, PHA</b>
VC1: Stored HK/Engineering; VC0 Science
VC2: EPIC RGB Images (3)
VC3: Other EPIC Images
VC4: EPIC Aerosol Images (2)
VC5: S/C Table Dumps







# DSCOVR Launch



- DSCOVR will be launched on a SpaceX Falcon 9 v1.1 launch vehicle
- NET launch is January 13, 2015
- NOAA handover ~150 days after launch

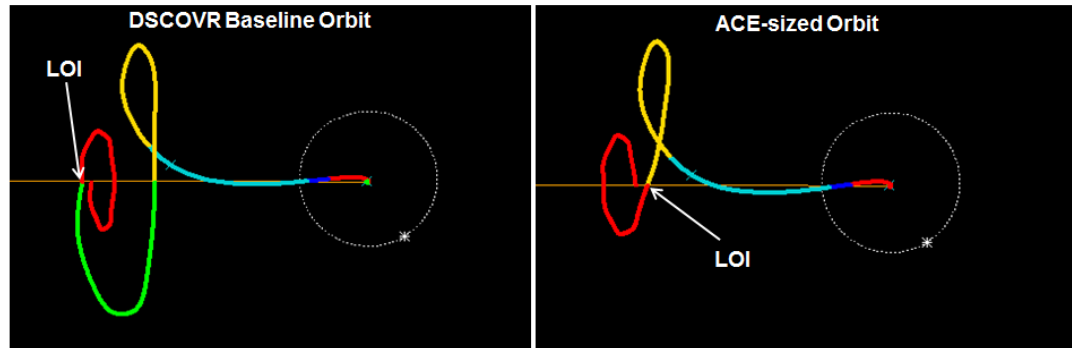




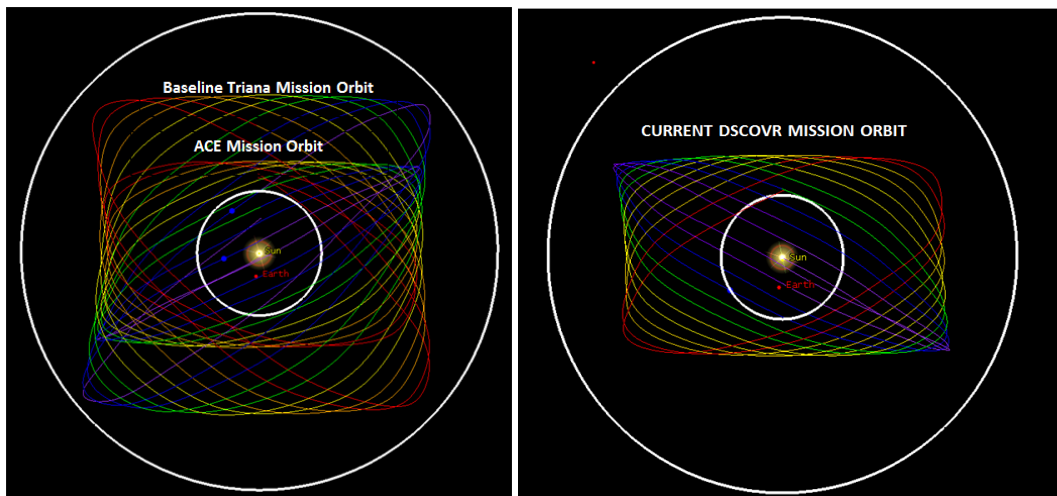
# DSCOVR Orbit



- Transfer Orbit
  - Transfer changed to a more ACE-like transfer to help with Real Time Solar Wind (RTSW) Network gaps (transfer to LOI went from 200 days to about 110 days)



- Mission Orbit



Mission Orbit	Y Amplitude (km)	Z Amplitude (km)
Triana Baseline	292,000	277,000
ACE	269,000	162,000
Current DSCOVR	281,476	160,538



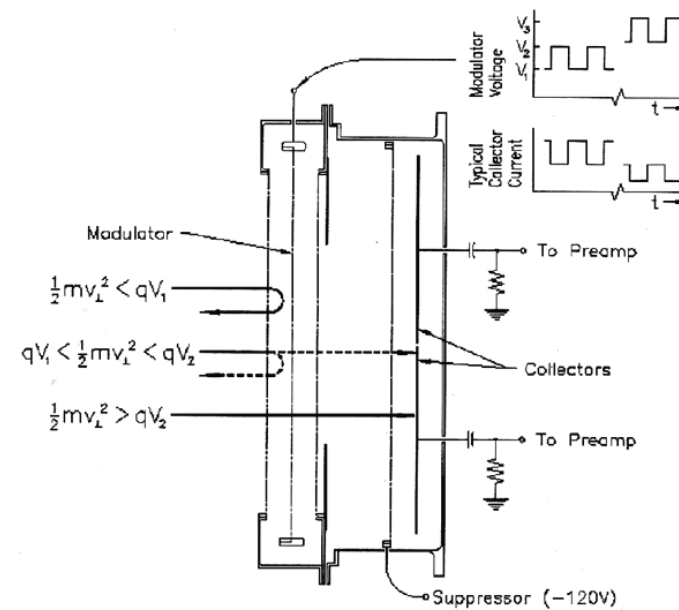
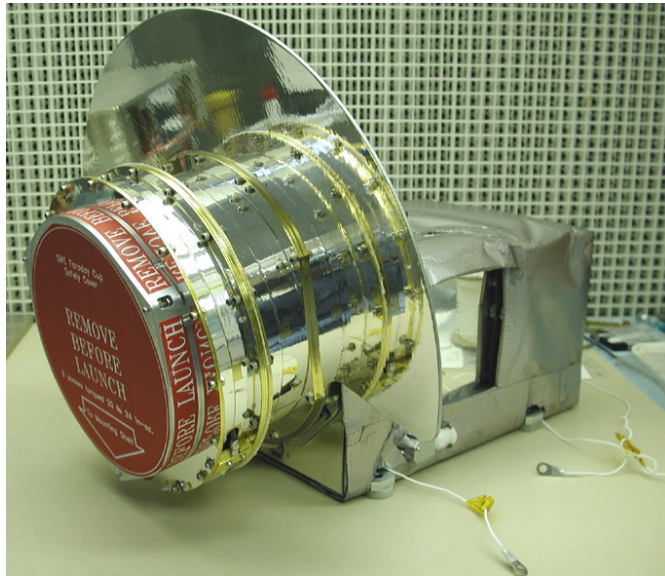
# DSCOVR Faraday Cup - SAO/MIT/GSFC



The Faraday Cup is a retarding potential particle detector that provides high time resolution solar wind proton bulk properties (wind speed, density and temperature)

Robust instrument – Can operate through high energy particle storms that commonly accompany critical space weather events

Located on the spacecraft upper deck facing towards the Sun.





# FC Level 1 Requirement Verification



Requirement	Required Value	Method	Performance
Velocity Range	200-1250 km/s	Test	168-1340 km/s
Velocity Accuracy	20%	Test	2%
Density Range	1-100 cm <sup>-3</sup>	Test	0.22-219 cm <sup>-3</sup>
Density Accuracy	20%	On Orbit/Test	~1% (20% ground)
Temperature Range	4x10 <sup>4</sup> -2x10 <sup>6</sup> K	Test	3.9x10 <sup>4</sup> -7.3x10 <sup>7</sup> K
Temp. Accuracy	20%	Test	<8.9%
Cadence	0.0167 Hz	Test	2 Hz

The FC measurements will meet or exceed all Level 1 requirements.

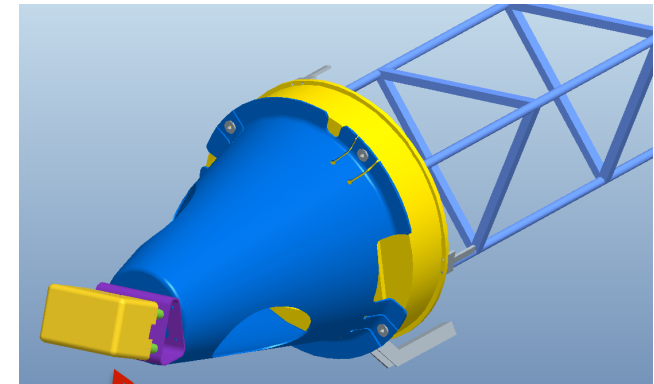


# Goddard Fluxgate Magnetometer

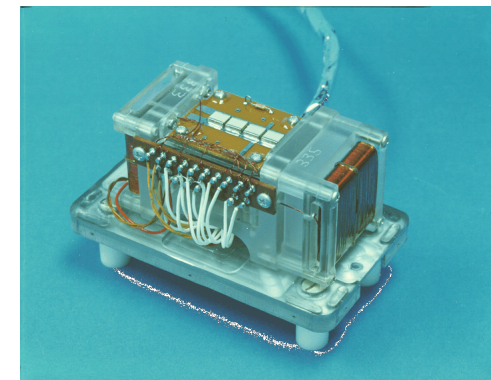


The Fluxgate Magnetometer measures the interplanetary vector magnetic field

It is located at the tip of a 4.0 m boom to minimize the effect of spacecraft fields



Magnetometer



Requirement	Value	Method	Performance
Range	0.1-100 nT	Test	0.004-65,500 nT
Accuracy	+/- 1 nT	Test	+/- (0.5-0.9) nT
Cadence	0.0167 Hz	Test	50 Hz



# Magnetic Test Results/Budget



The magnetic field signatures of the s/c subsystems were measured at several distances from the sources to determine the source dipole strength and the rate of drop-off with distance.

The presence of Invar in the EPIC camera amplifies the magnetic signatures.

Component	Previous location	Tip of the Boom	Boom Extension RW Shielding
Reaction Wheels (Invar effect included)	± 1.33 nT	± 0.46 nT	± 0.15 nT
EPIC	± 0.15 nT	± 0.06 nT	± 0.05 nT
NISTAR	± 0.13 nT	± 0.05 nT	± 0.04 nT
Power System	± 0.27 nT	± 0.09 nT	± 0.08 nT
Solar Arrays	± 0.08 nT	± 0.03 nT	± 0.03 nT
Transponder	± 0.04 nT	± 0.02 nT	± 0.02 nT
Battery	± 0.05 nT	± 0.02 nT	± 0.02 nT
Invar 36 amplification of IMF	± 0.11 nT	± 0.04 nT	± 0.03 nT
Invar 36 amplification of battery	± 0.03 nT	± 0.01 nT	± 0.01 nT
Calibration uncertainties	± 0.20 nT	± 0.20 nT	± 0.20 nT
<b>TOTAL</b>	<b>± 2.22 nT</b>	<b>± 0.96 nT</b>	<b>± 0.62 nT</b>

**Magnetic cleanliness meets the +/- 1 nT requirement**

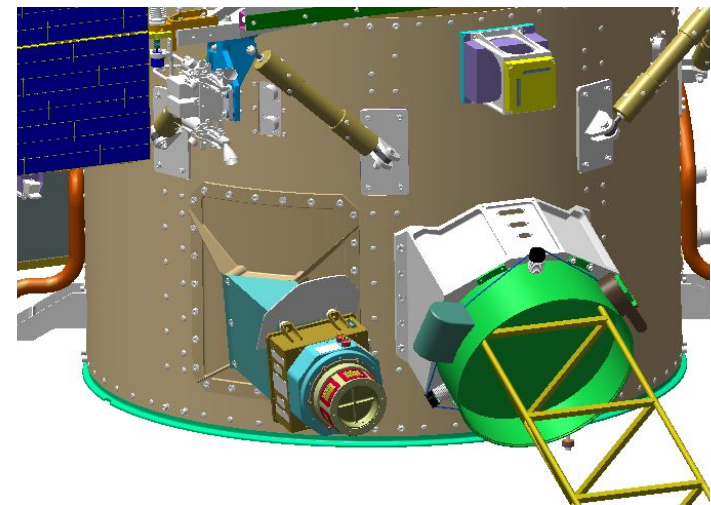


# Electron Electrostatic Analyzer (ESA)



The ESA had to be relocated from the tip of the science boom to the body of the spacecraft to allow the magnetometer to make cleaner measurements.

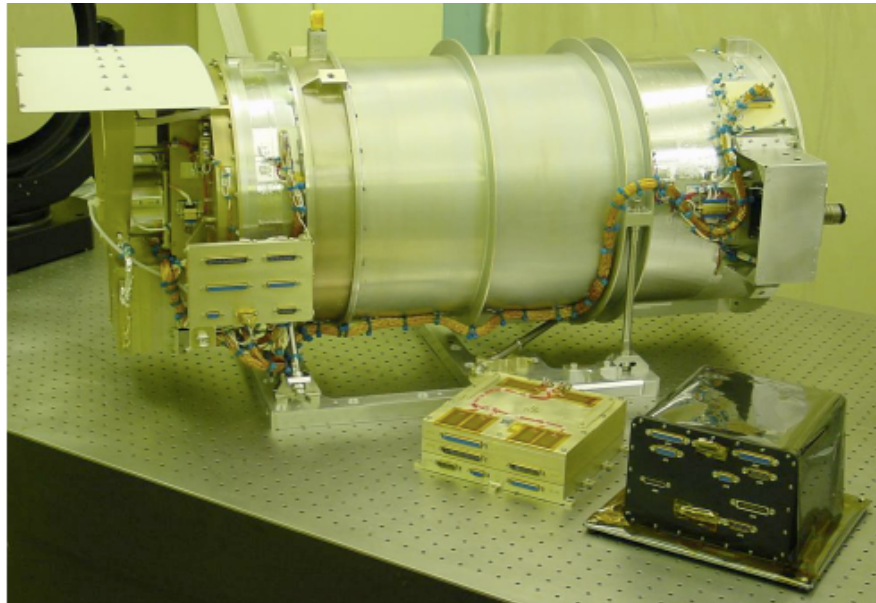
- ESA placed on bracket and will use FC measurements along with solar wind charge neutrality to recover lost information.
- Retains ~75% of FOV
- Selected location to maximize FOV in critical directions for most of the orbit.



Requirement	Value	Method	Performance
Energy Range	5 eV – 1 keV	Test	5 eV – 1 keV
FOV	2 ster rad	Test/Analysis	$2.5\pi$ ster rad
Cadence	0.0167 Hz	Test	1 Hz

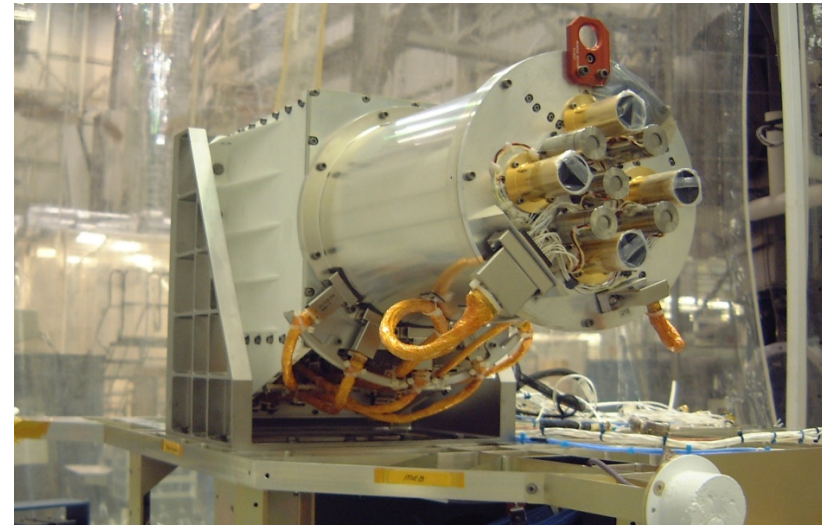


# DSCOVR Earth Science Instruments



## Earth Polychromatic Imaging Camera – EPIC

EPIC images the radiance from the sunlit face of the Earth on a 2048 x 2048 pixel CCD in 10 narrowband channels (UV and visible).  
Resolvable size: ~25 km



## NIST Advanced Radiometer – NISTAR

NISTAR measures the absolute “irradiance” integrated over the entire sunlit face of the Earth in 4 broadband channels.

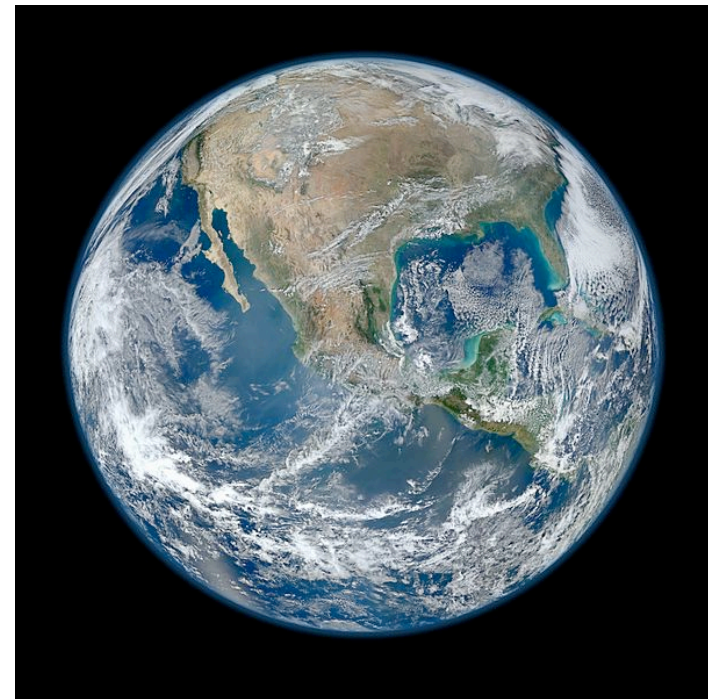
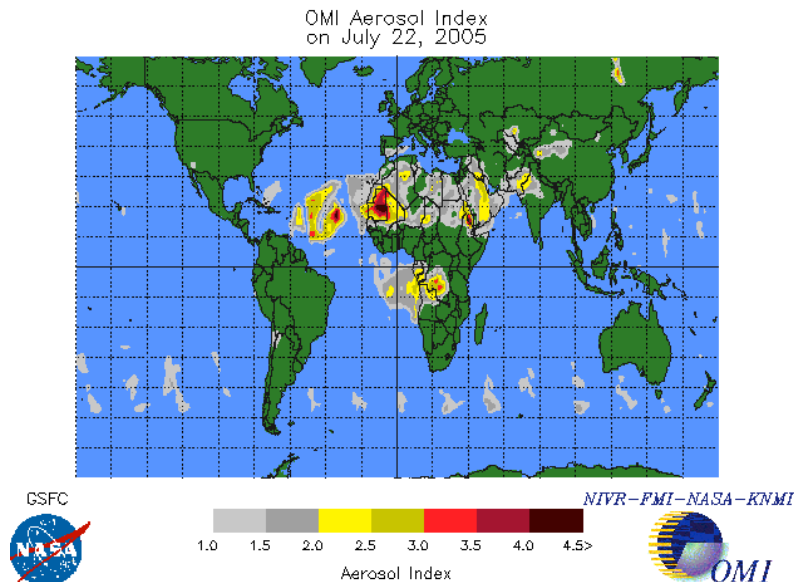




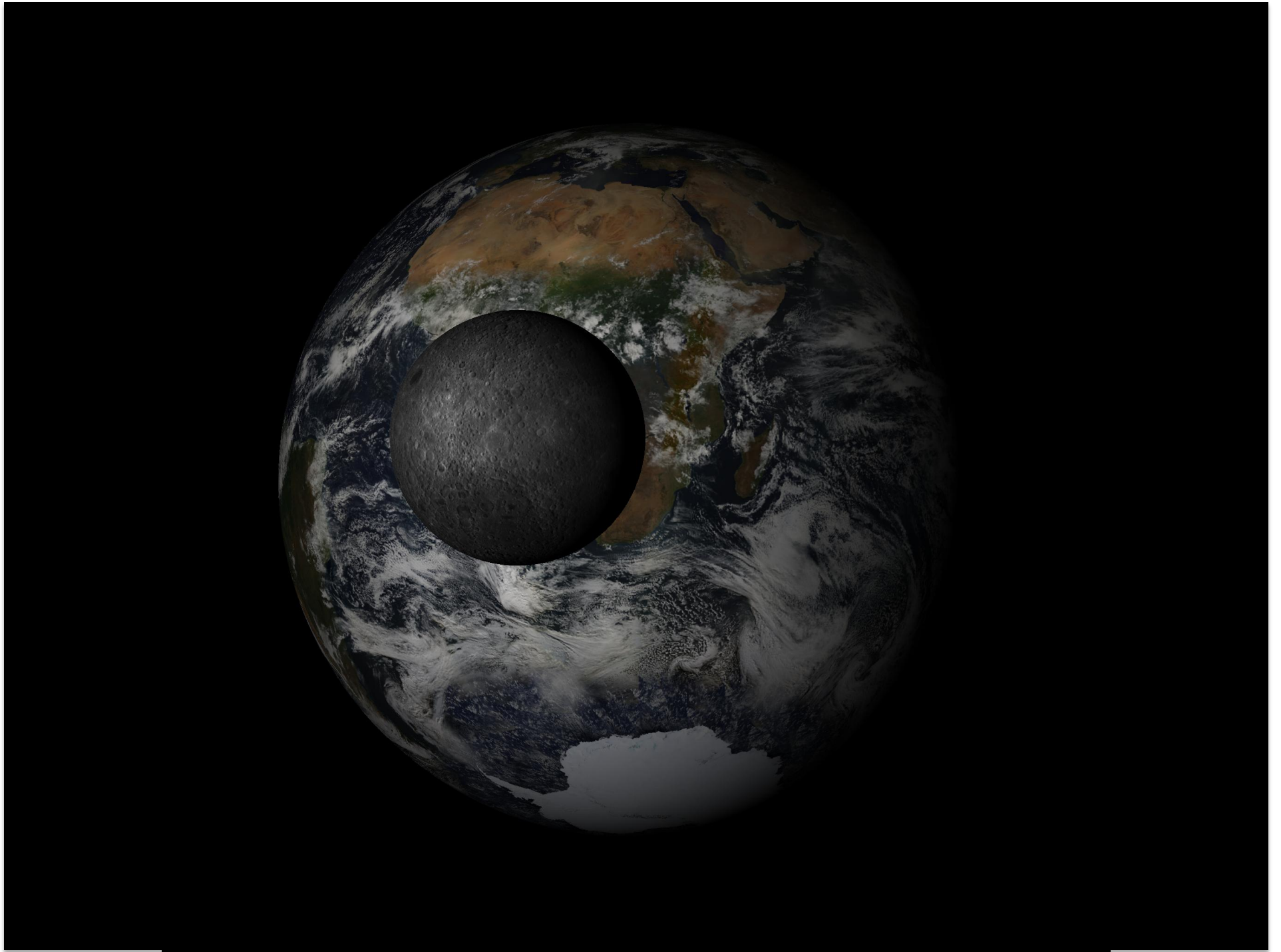
# EPIC Science Requirements



- Image the sunlit disk of Earth to form true RGB pictures of the planet with a spatial resolution of 25 km or better at the meridian with 4 hour cadence
- Image Earth in ten spectral bands that are sufficient to determine ozone, aerosol, cloud cover and vegetation indices at three angles for each Earth rotation (4 hour cadence)



Data from the VIIRS instrument on board the Suomi NPP satellite.

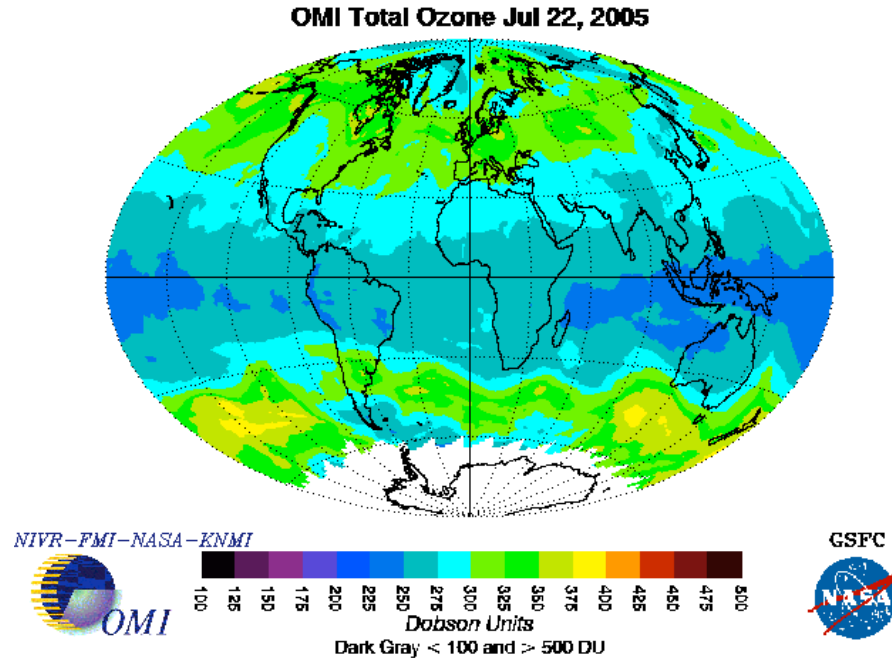




# Ozone



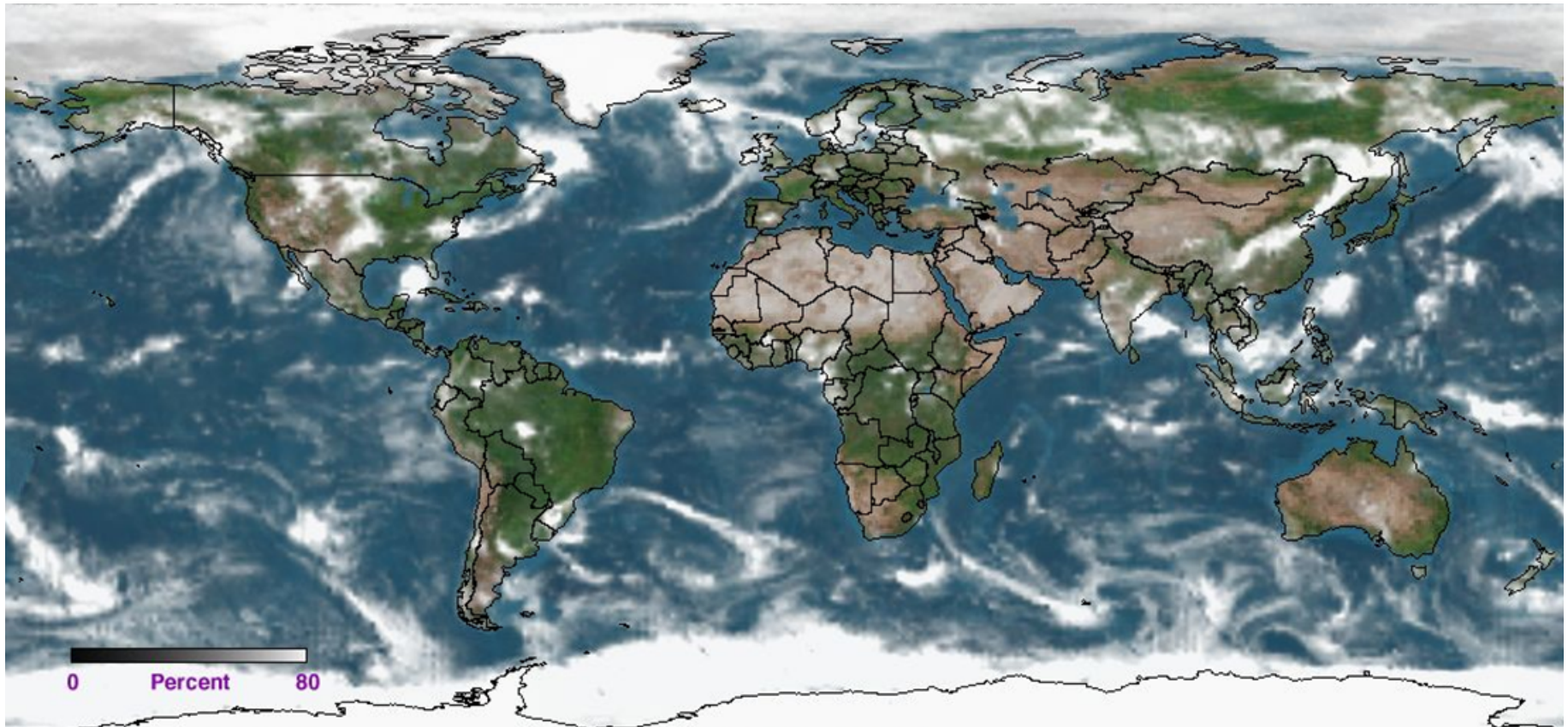
The ozone algorithm uses 3 wavelengths 317.5, 325, and 340 nm and is based on the TOMS/OMI ozone algorithm.



**EPIC will provide Global Sunrise to Sunset Coverage**



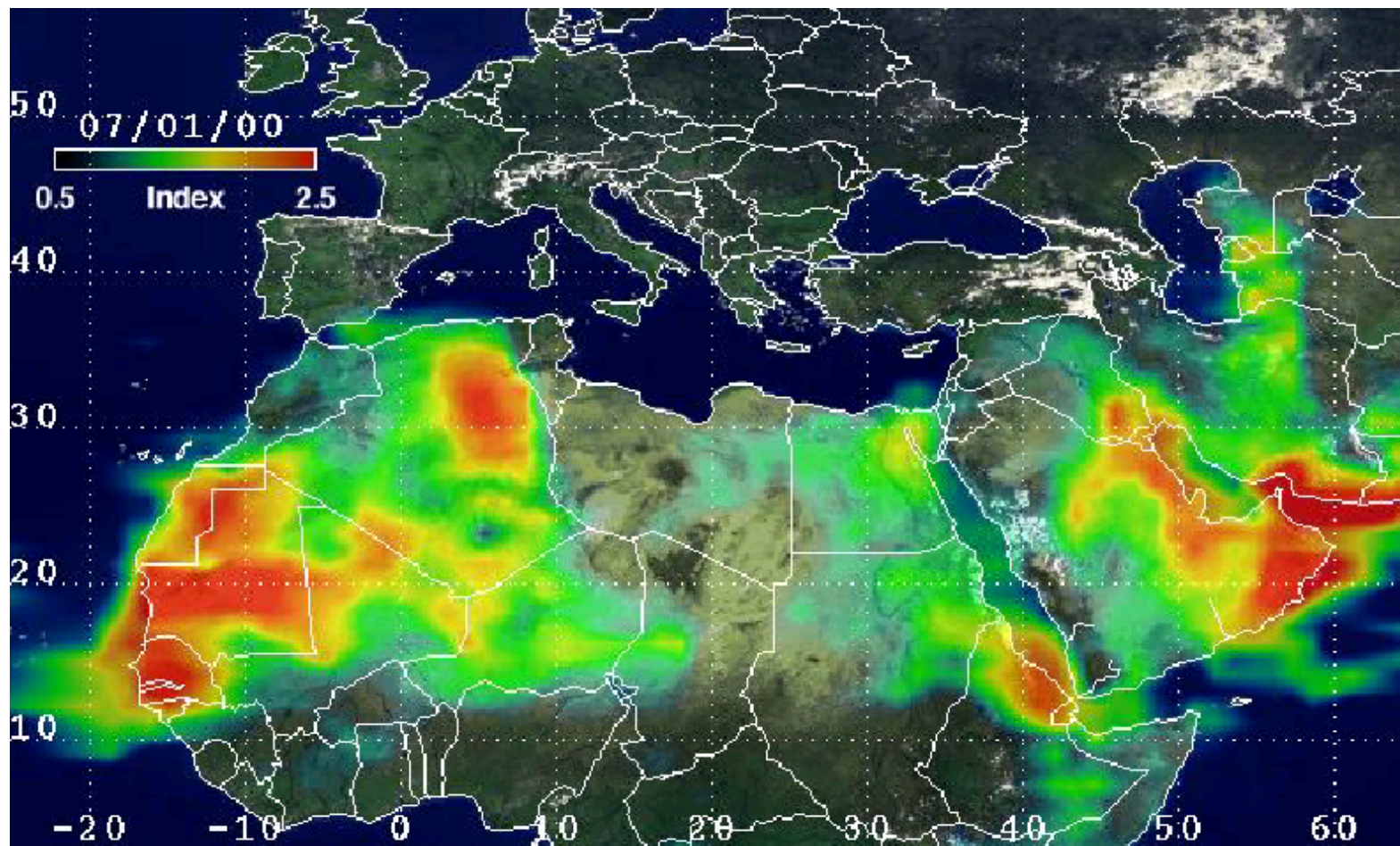
# UV Cloud Reflectivity



EPIC UV Cloud reflectivity will determine cloud amounts and changes between mid-day and sunrise-sunset conditions



# Dust Aerosols Over Africa

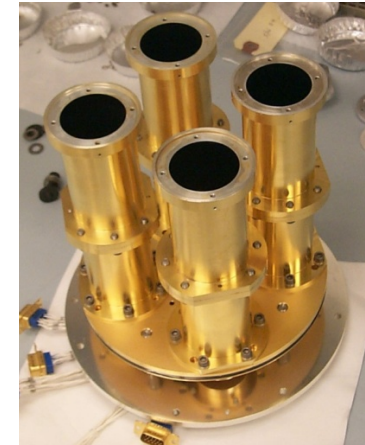




# NIST Advanced Radiometer - NISTAR



NISTAR is a cavity radiometer designed to measure the absolute “irradiance” from the entire sunlit face of the Earth. The measurements performed by NISTAR will be of high accuracy, on the order of 0.1%.



3 broadband channels:

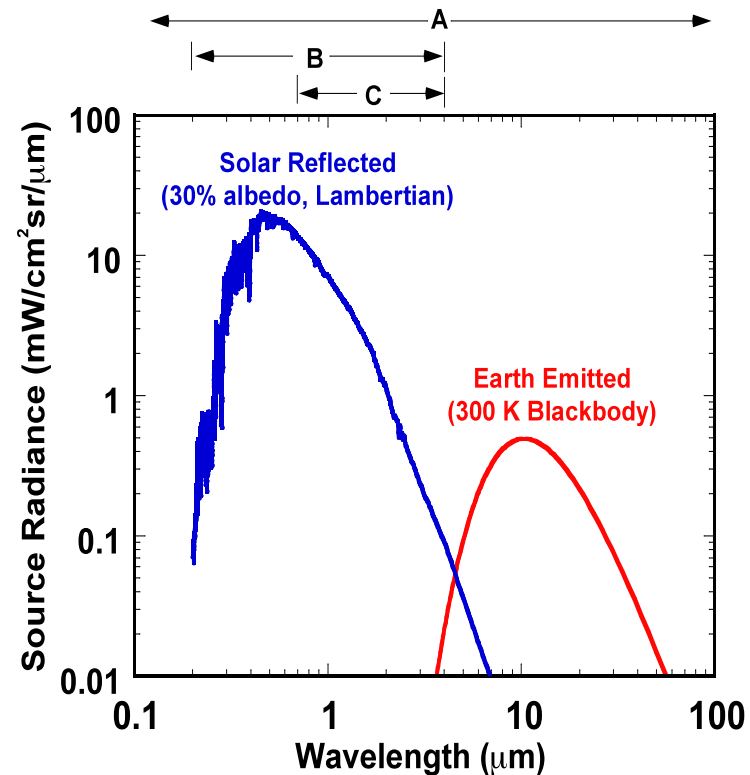
A) 0.2  $\mu\text{m}$  to 100  $\mu\text{m}$

B) 0.2  $\mu\text{m}$  to 4  $\mu\text{m}$

C) 0.7  $\mu\text{m}$  to 1.1  $\mu\text{m}$

+ Photodiode (0.2  $\mu\text{m}$  to 1.1  $\mu\text{m}$ )

Field of view  $1^\circ$ , parallel to EPIC.





# DSCOVR Ready to Launch

