National Aeronautics and Space Administration

DSCOVR Instrumentation Capabilities and Calibration Test Plan

Dr. Adam Szabo

NASA DSCOVR Project Scientist

DSCOVR

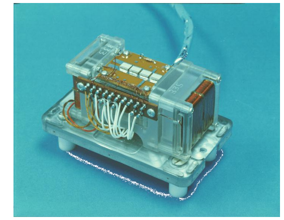
DEEP SPACE CLIMATE OBSERVATORY

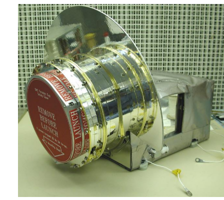
advanced warning of approaching solar storms

Launch Feb 11, 2015

Instrumentation

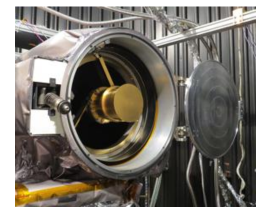
Primary Instrumentation:





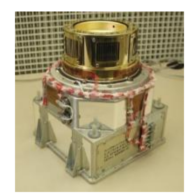
- **Fluxgate Magnetometer**
  - to measure solar wind magnetic field vector
- **Faraday Cup**
  - to measure solar wind thermal plasma velocity, density and temperature

Secondary Instrumentation:



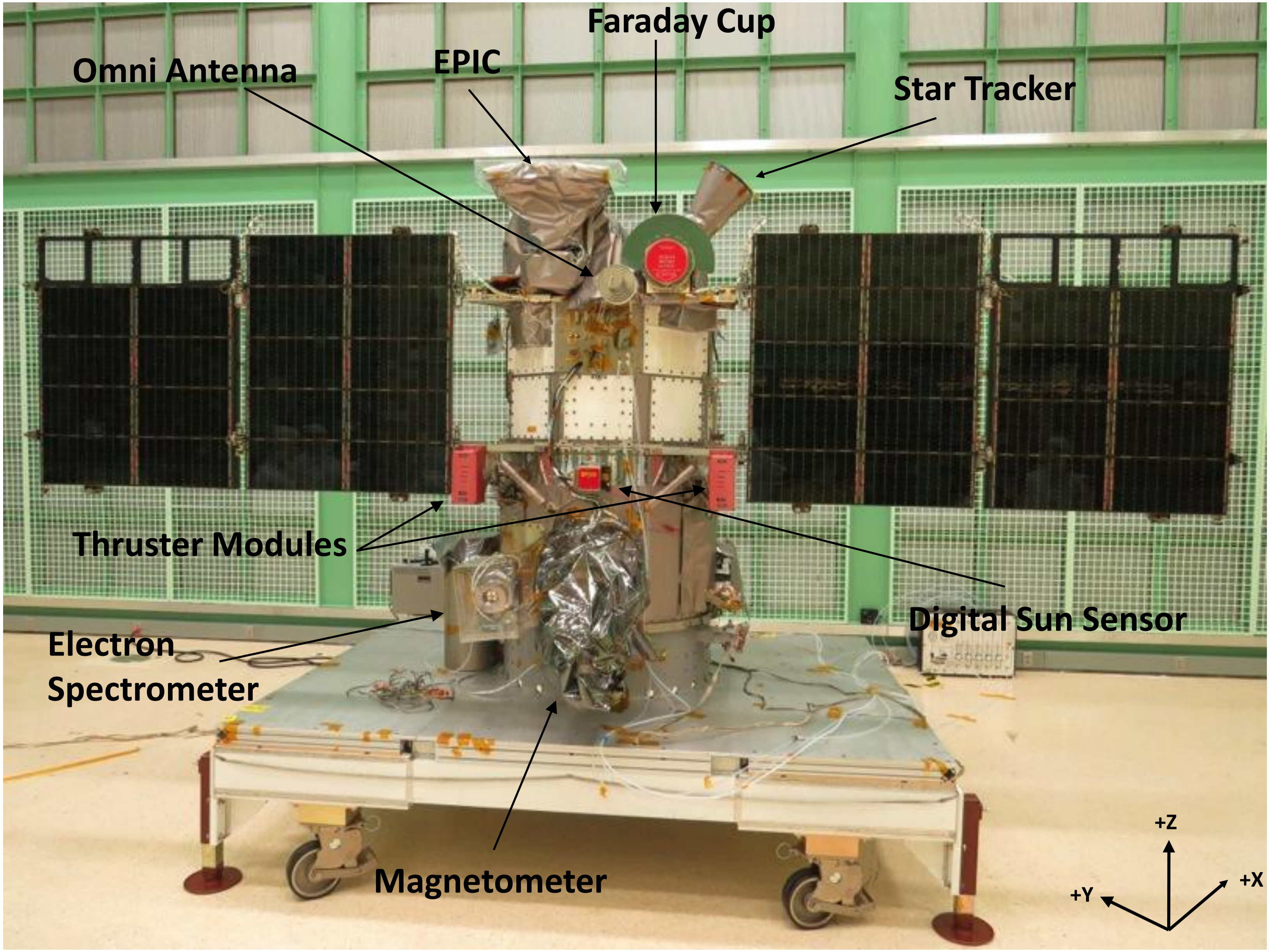
- **Earth Poly-chromatic Imaging camera (EPIC)**
  - to image the sunlit face of Earth in 10 wavelengths

- **NIST Active Radiometer (NISTAR)**
  - to measure the reflected and radiated energy by Earth



- **Electron Spectrometer (ESA)**
  - to measure the solar wind thermal electron population
- **Pulse Height Analyzer (PHA)**
  - to measure energy deposited by energetic particles in electronics

Locations of the Instruments

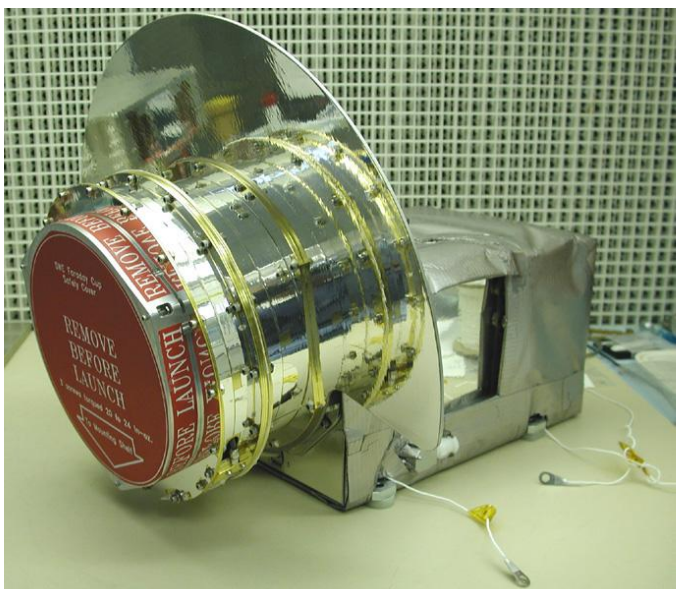


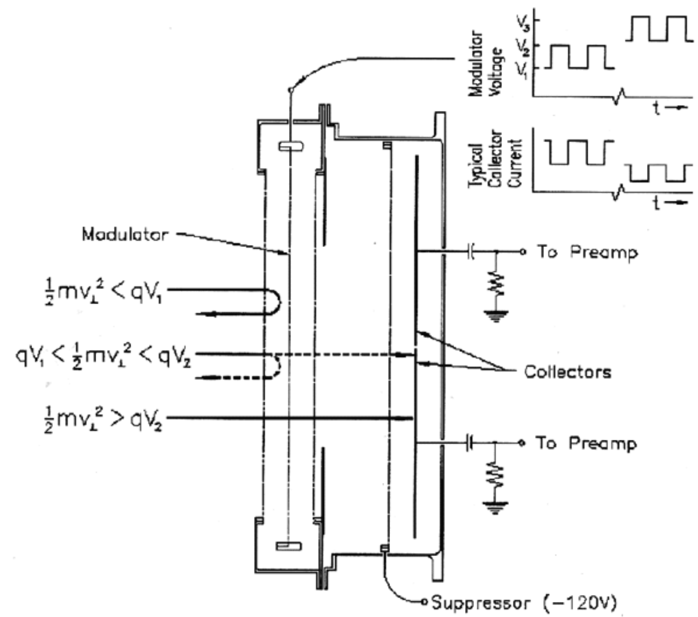
DSCOVR Faraday Cup - SAO/MIT/GSFC

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

The instrument was fully recalibrated on the ground in 2013.
Found no appreciable drifts.



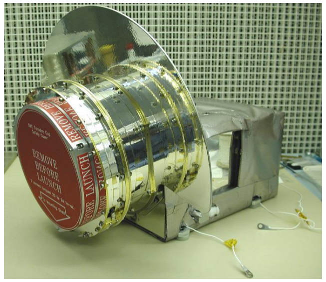


FC Measurement Requirements

Requirement	Required Value	Method	Ground Performance
Velocity Range	200-1250 km/s	Test	168-1340 km/s
Velocity Accuracy	20%	Test	2%
Density Range	1-100 cm^{-3}	Test	0.22-219 cm^{-3}
Density Accuracy	20%	Test	20%
Temperature Range	4×10^4-2×10^6 K	Test	3.9×10^4-7.3×10^7 K
Temp. Accuracy	20%	Test	<8.9%
Cadence	0.0167 Hz	Test	2 Hz

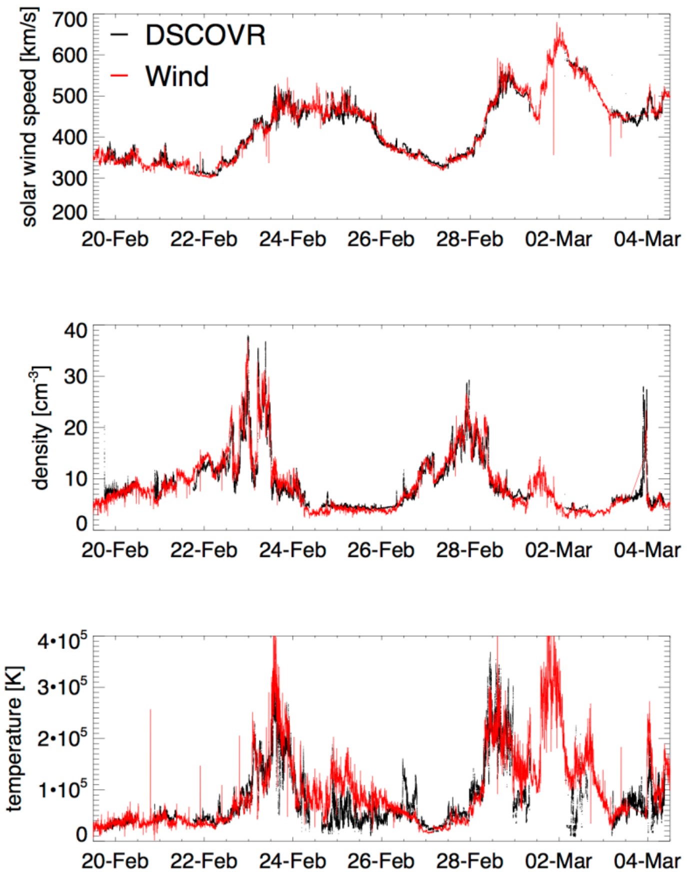
The FC measurements will meet or exceed all Level 1 requirements.

Faraday Cup – In-Flight Calibrations



Faraday Cup is currently undergoing instrument activation and early in-flight calibrations. Instrument required a time period for out gassing and its high voltage is slowly incremented. Currently it is at 4 kV out of the final 8 kV setting.

At the current setting, we started to observe the solar wind flow. Intercomparison with Wind indicate good agreement. DSCOVR data is plotted in black and time shifted Wind data in red.



Anomalously low currents were observed during the first couple of days on one of three collector plates that since corrected itself. It is attributed to contamination that out gassing and UV radiation have resolved.

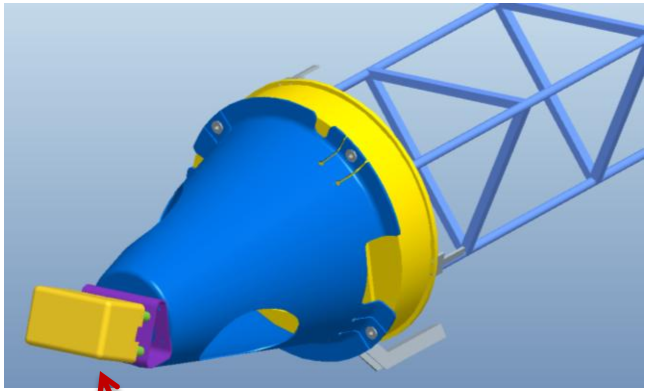
A systematic offsets to smaller signals have been observed. It is highly likely that proper in-flight calibration of the electronics will resolve this issue.

Will meet all NOAA level 1 requirements

Goddard Fluxgate Magnetometer

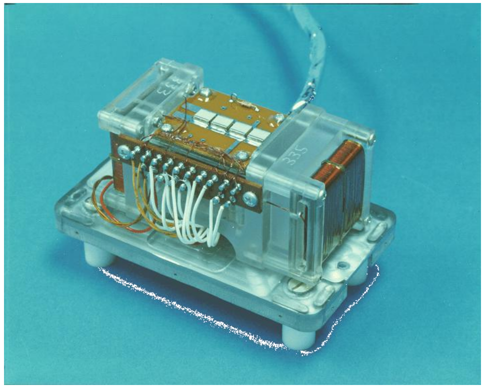
The Fluxgate Magnetometer measures the interplanetary vector magnetic field

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



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

Magnetometer



Magnetometer Ground Calibrations

Static Offsets (vector), nT	
EPIC	(0.68, -0.01, -0.20)
SIU	(-0.59, 0.14, -0.88)
Solar Arrays	(0.03, 0.00, 0.05)–(0.10, 0.00, 0.14)
Propulsion Module Latch Valve	(0.16,-0.20,-0.04)–(0.20,-0.25,-0.05)
Subtotal: vector	(0.28,-0.07,-1.07)–(0.39,-0.12,-0.99)
magnitude	1.07–1.11
Static Offsets (magnitude), nT	
S/C bus	0.76
Battery	0.11
Invar amplification of IMF	0–0.07
Invar amplification of Battery field	0–0.05
Invar amplification of S/C bus field	0–0.24
Subtotal	0.87–1.23
Total static offset (magnitude)	**1.94–2.34**
Dynamic uncertainties (components), ± nT	
Reaction Wheels (**shielded**)	(0.092, 0.049, 0.062)
EPIC	(0.03–0.05, 0.02–0.03, 0.02–0.03)
NISTAR	(0.01, 0.04, 0.03)
Power Subsystem	(0.03–0.08, 0.03–0.05, 0.03–0.03)
Solar Arrays	(0.01–0.02, 0.00–0.00, 0.01–0.03)
Transponder	(0.00–0.02, 0.01–0.01, 0.00–0.01)
Calibration technique uncertainty	**(0.10–0.20, 0.10–0.20, 0.10–0.20)**
Subtotal	(0.27–0.47, 0.25–0.38, 0.25–0.39)
Dynamic uncertainties (magnitude), ± nT	
Battery	0.01
Invar amplification of IMF	0–0.03
Invar amplification of Battery field	0–0.01
Subtotal	0.01–0.05
Total dynamic uncertainty (components)	**(0.28–0.52, 0.26–0.43, 0.26–0.44)**

After in-flight calibration

Meets ± 1 nT requirement

Magnetometer – In-Flight Calibrations

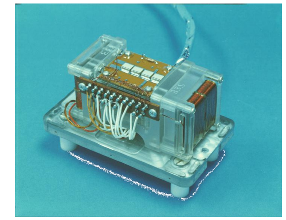
The magnetometer was successfully activated and started to collect data.

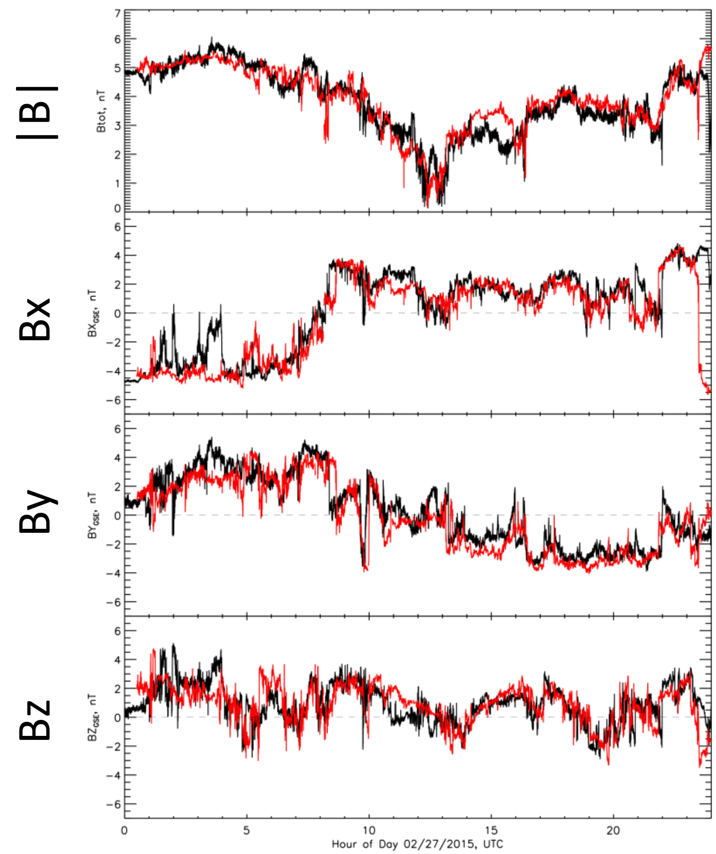
Comparison with Wind spacecraft measurements show good agreement. DSCOVR data is in black. The time shifted Wind data (to allow for solar wind propagation) is plotted in red. Small deviations are consistent with large spacecraft separation.

Early statistical analysis indicate a small, 1-2 nT DC offset due to spacecraft fields, consistent with ground calibration measurements. This offset will be removed during ground processing.

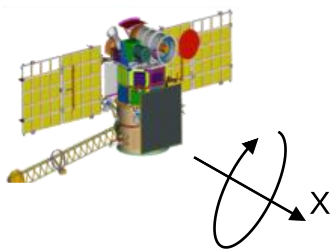
Spacecraft rolls and yaw maneuvers are used this week for more detailed in-flight calibrations along with long-term intercalibrations with Wind and Ace once at L1.

Will meet NOAA level 1 requirements.





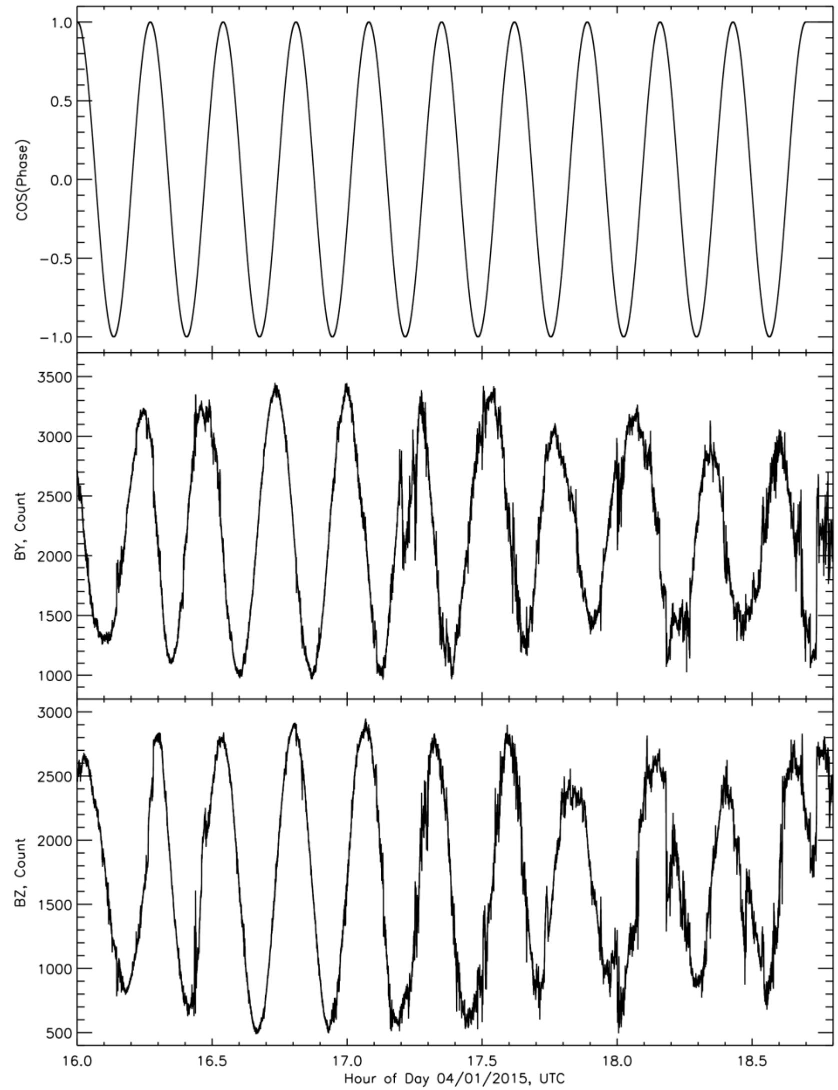
Mag Rolls of the Spacecraft



10 complete rolls around the Earth-s/c X axis is performed monthly

These rolls help calibrating the Y and Z axis magnetic field offsets.

These rolls do not interfere with real-time space weather operations.

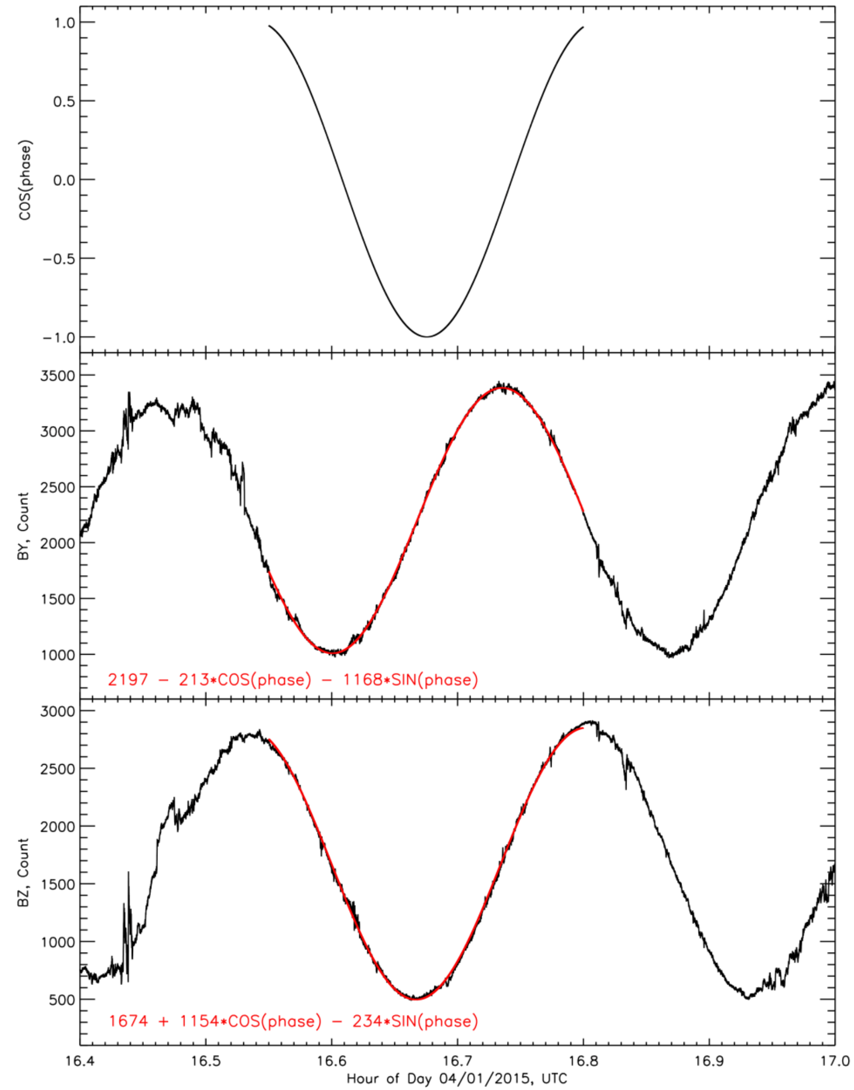


Mag Rolls of the Spacecraft

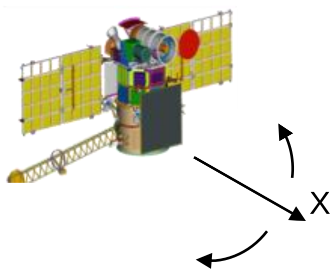
Of the April 1 rolls, the solar wind was steady for only one.

Good offset values were obtained.

To trend the offsets, the maneuver has to be repeated monthly.



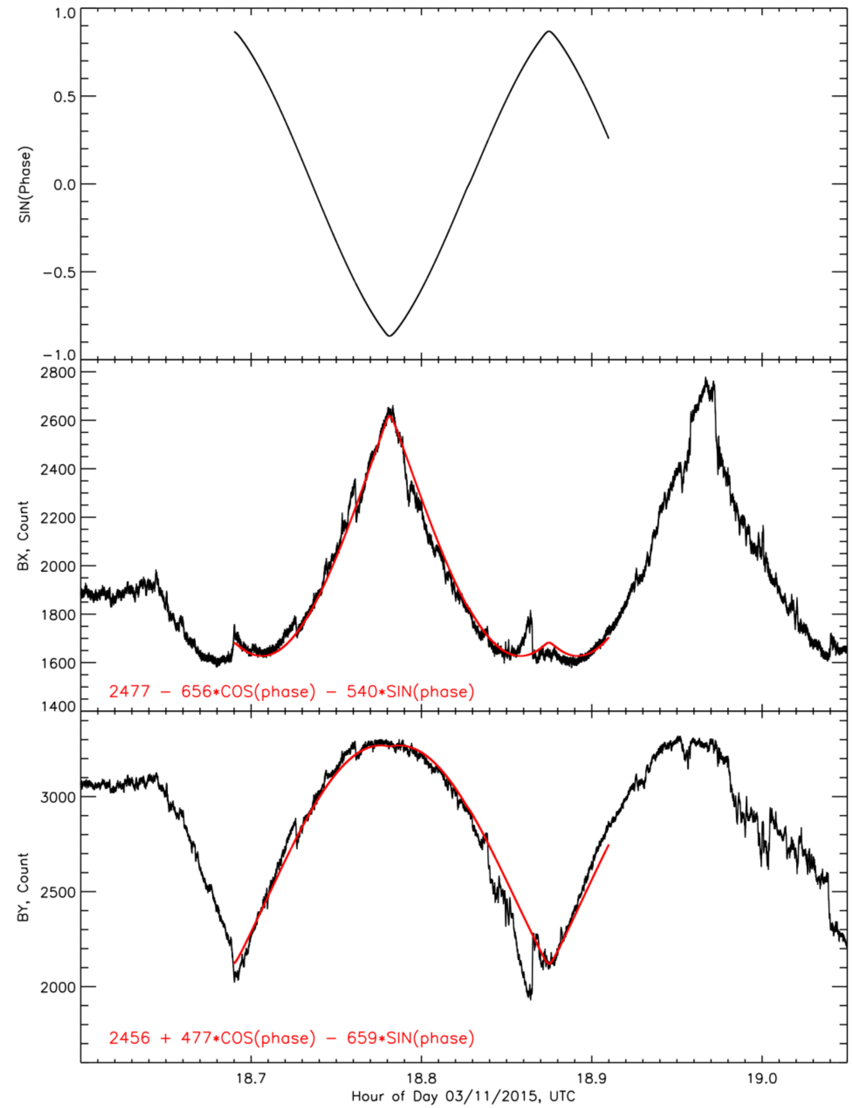
Mag Spacecraft Slews



10 sixty degree slews around the s/c Z axis is performed during the commissioning phase

These slews help calibrating the X and Y axis magnetic field offsets.

During this maneuver, the s/c points away from Earth. Real-time operations are interrupted. During the operational phase of the mission, not performed.



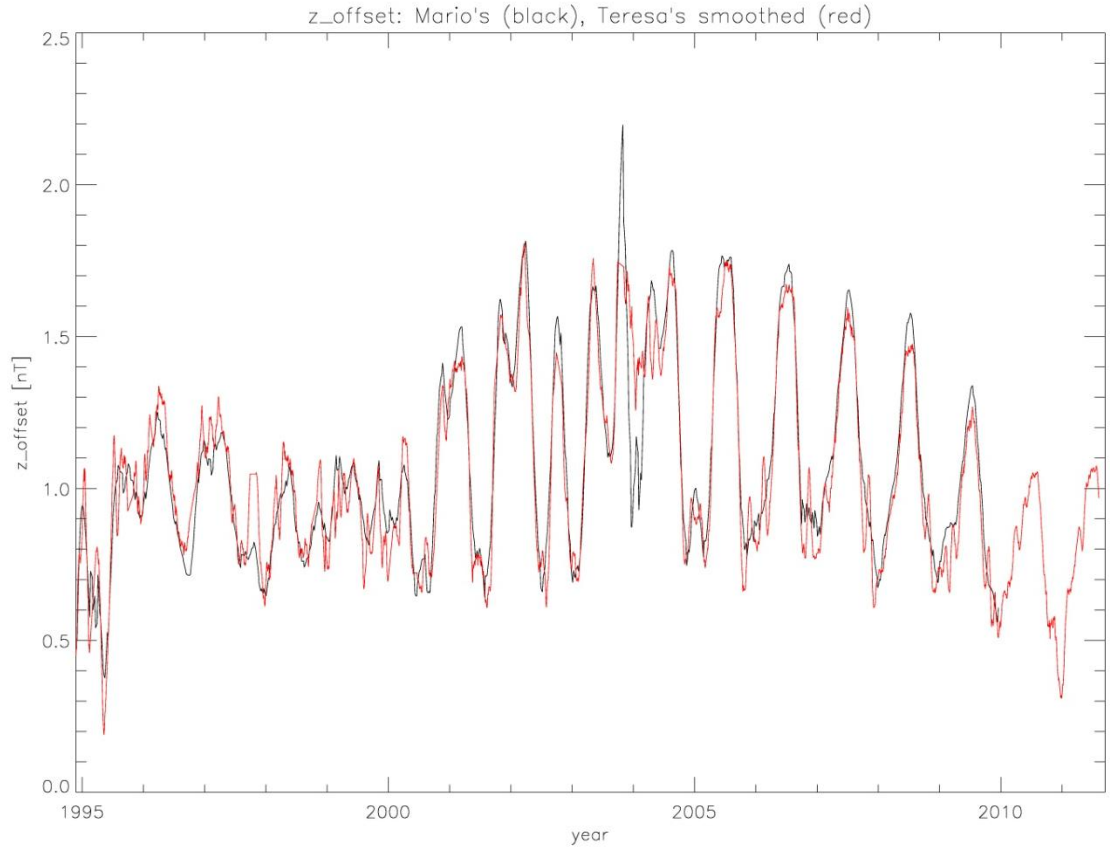
Alfvenicity Calibrations

The 1 AU solar wind is very Alfvenic, many of the field rotations preserve the field magnitude. Using this solar wind property, the three instrument components can be calibrated against each other.

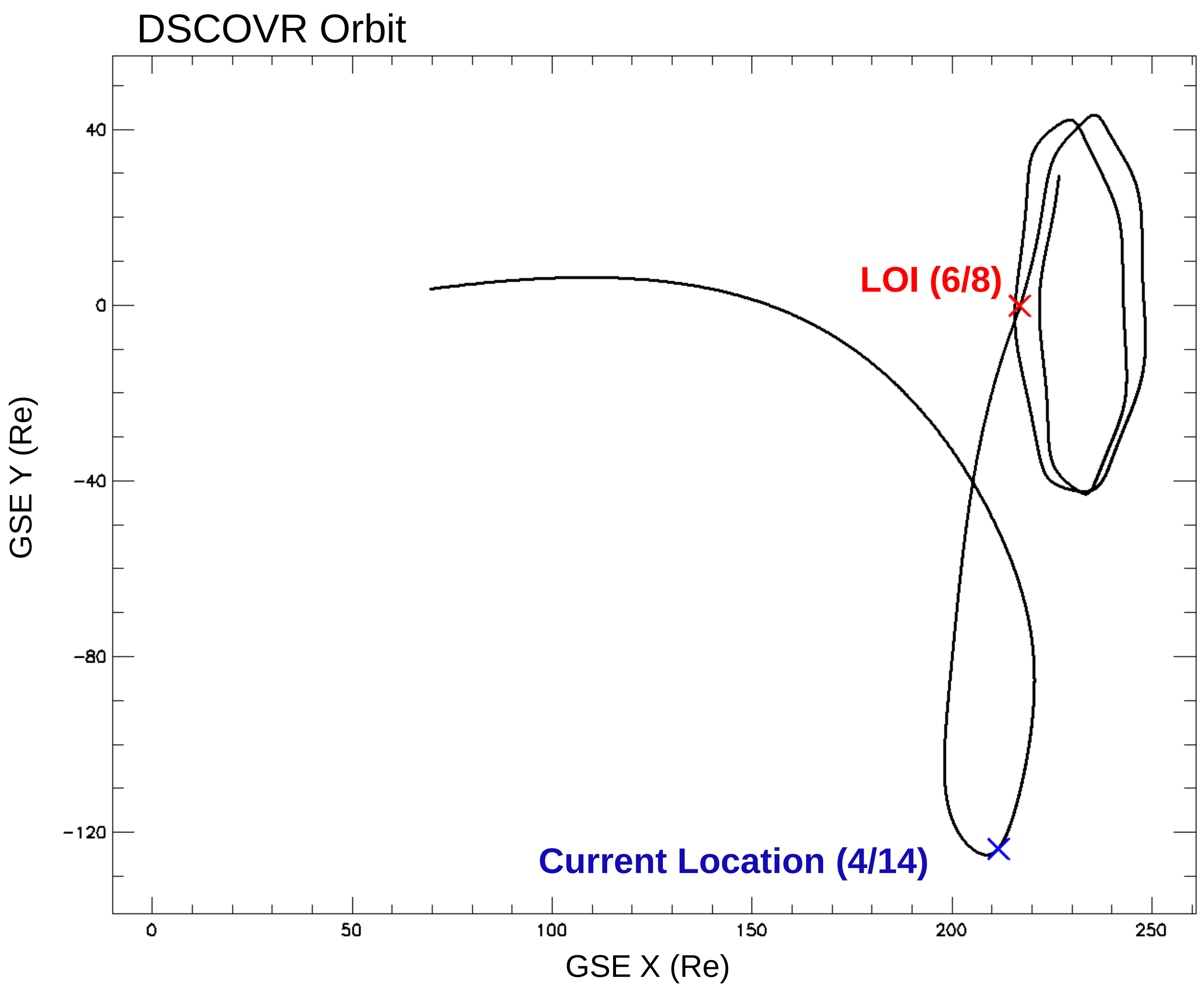
It has been successfully used by IMP 8, Wind and ACE to calibrate the spin axis components.

Yearly variations for Wind are shown on the right using two computational methods.

The same method will be used to obtain continuous X axis offsets and to fill in calibrations between s/c rolls.

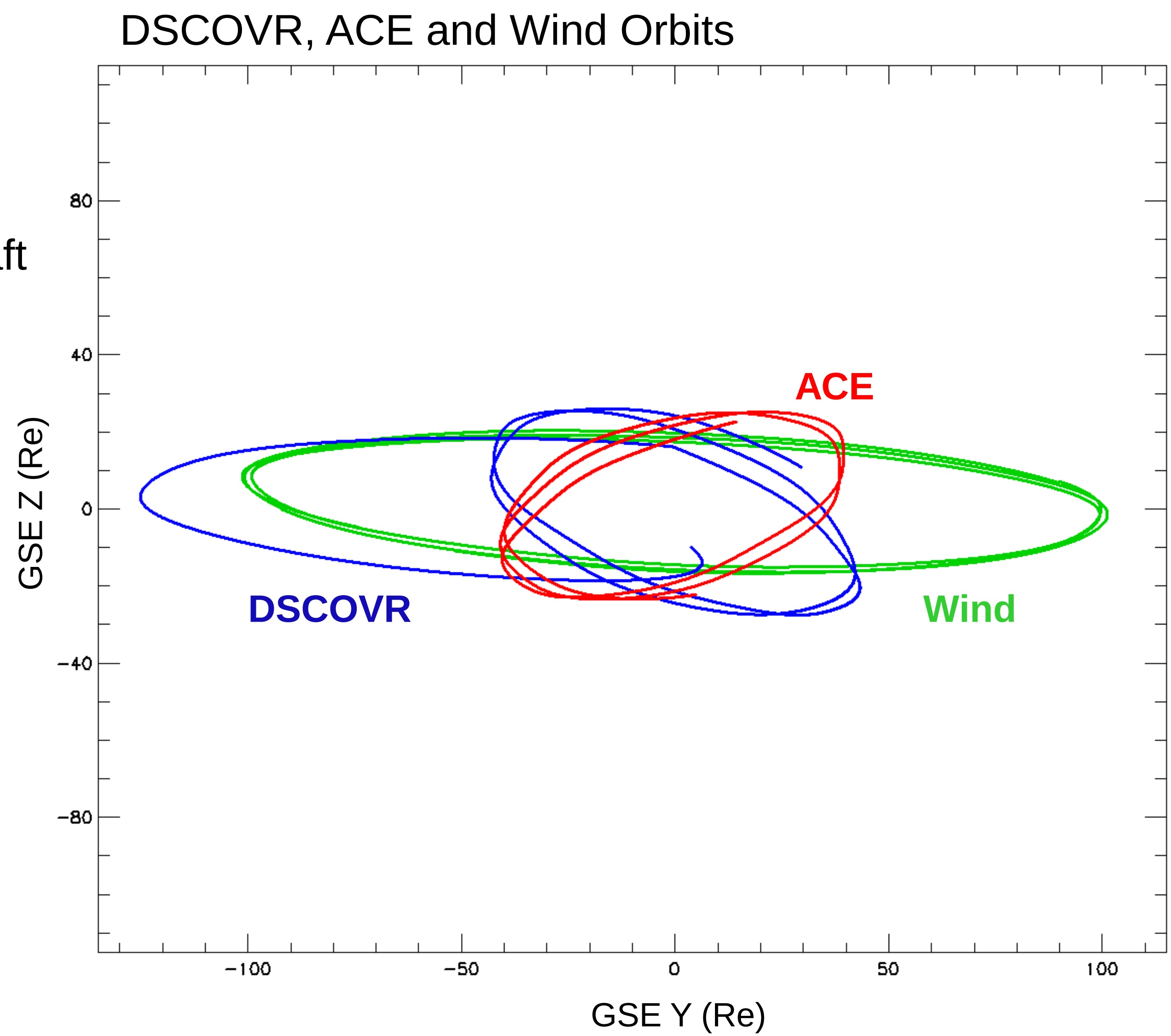


Intercalibrations with ACE and Wind



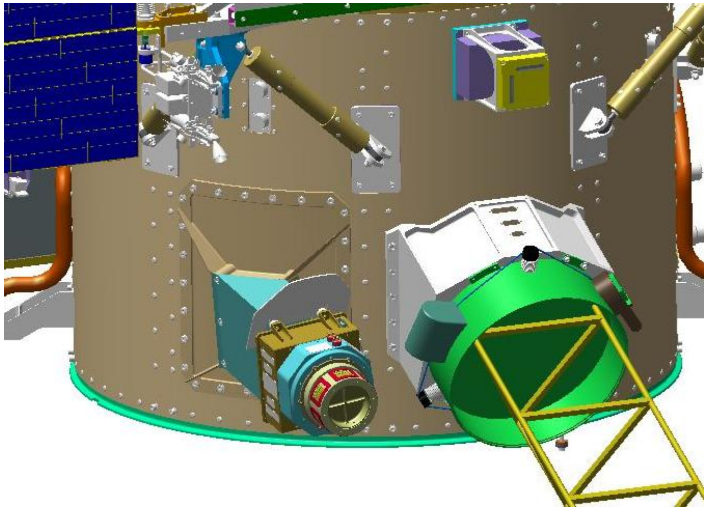
Intercalibrations with ACE and Wind

There will be a number of time intervals when the interspacecraft separation perpendicular to the Sun-Earth line will be small allowing quantitative intercalibrations.



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	2.5π ster rad
Cadence	0.0167 Hz	Test	1 Hz

Recurring In-Flight Calibrations

Magnetometer:

- Rotations around the Sun-S/C line and slew maneuvers
- Alfvenicity calibrations
- Intercalibrations with ACE and Wind

Faraday Cup:

- Intercalibrations with ACE and Wind

Electron Spectrometer:

- Density calibrations with Faraday Cup
- Intercalibrations with ACE and Wind

Instrument Status – EPIC, NISTAR, ESA

The EPIC electronics has been activated. But the camera door will remain closed till after L1 insertion burns to prevent contamination of the mirror. Closed door, dark images have been taken that indicate no hot or damaged CCD pixels. After L1 insertion, about one month of calibration will be required. Earliest first light picture in July, 2015.

The NISTAR radiometer electronics has been activated and mechanical parts fully tested. Instrument is slowly approaching final thermal equilibrium. Dark space calibrations will not start till May when DSCOVR will be further from Earth. Regular data taking will not start till after L1 insertion on June 8, 2015.

The ESA electron spectrometer has been activated. Early calibration results indicate that only one of the six view angles are impacted by relocating the instrument close to the spacecraft body. This was expected based on ground simulation results. Calibrated data is not expected till after L1 insertion.