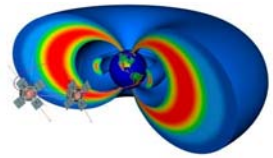

RBSP
Radiation Belt Storm Probes

RBSP Magnetics: Swing Test Analysis

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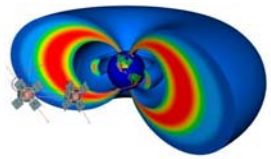
Outline

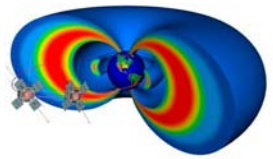
- **Purpose and results**
- **Analysis assumptions and most significant tests**
- **Test setup and execution**
- **Data analysis of swing and spin tests**
- **Spacecraft magnetic moments and conclusions**

Purpose and Results



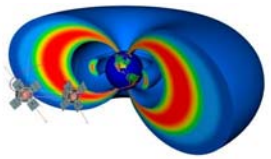
- **Purpose of magnetic swing tests:**
  - To verify that all sources of the spacecraft DC magnetic field are accounted for.
  - To estimate the spacecraft magnetic moment.
  - To verify that the static spacecraft magnetic field at the EMFISIS DC Magnetometer sensors is less than 5 nT in orbit.
  - To verify that no magnetic contamination occurred during shipment of the spacecraft to Astrotech.
- **Results of test data analysis:**
  - The latch valves and compensation magnets are the only significant sources of the spacecraft static magnetic field.
  - The dipole moments in SC coordinates are [-0.82, 0.14, 0.99] and [-0.83, 0.25, 0.93] Am^2 for RBSP A and B, respectively, and have not changed since the spacecraft left APL.
  - The magnetic field magnitudes at the locations of the EMFISIS DC Magnetometer sensors are 2.96 and 2.90 nT for RBSP A and B, respectively, demonstrating that the requirement limit of 5 nT was met for both spacecraft.

Analysis Assumptions

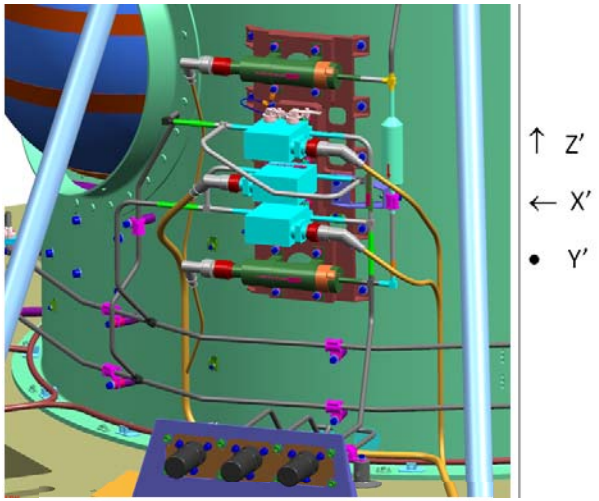


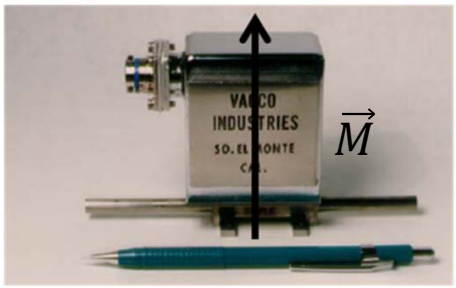
- **Spacecraft magnetic field sources:**
  - All hardware was carefully selected and tested for remanent magnetization. Components without a non-magnetic option were demagnetized prior to installation.
  - PCB layouts were designed to minimize current loops.
  - All instrument and subsystem boxes underwent powered and unpowered magnetics testing to screen for remanent and current-induced magnetic fields.
  - Solar panels were back-wired to create magnetic field compensating current loops and generated magnetic fields were verified by operating the panels in reverse-bias mode.
- **Analysis assumptions:**
  - The latch valves and cancellation magnets are the only significant sources of the spacecraft magnetic field.
  - The superposition of magnetic fields from individual sources can be approximated by a dipole moment.
  - The location of the dipole moment is given by the average location of its sources.

Magnetics Test: Latch Valve Assembly



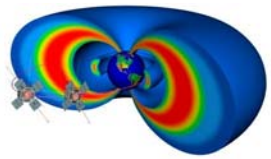
- **Latch valves employ magnets in the design.**
- **Magnetic moments of 3 latch valves mounted side-by-side add constructively.**
- **Net moment points radially outward, to be cancelled by a compensation magnet.**
- **Radial magnetic field at 1 m distance is 440 nT, requiring a cancellation magnet with moment 2.2 Am^2.**
- **Safe-distance requirement for mounting of cancellation magnet compromised the potential for perfect cancellation.**



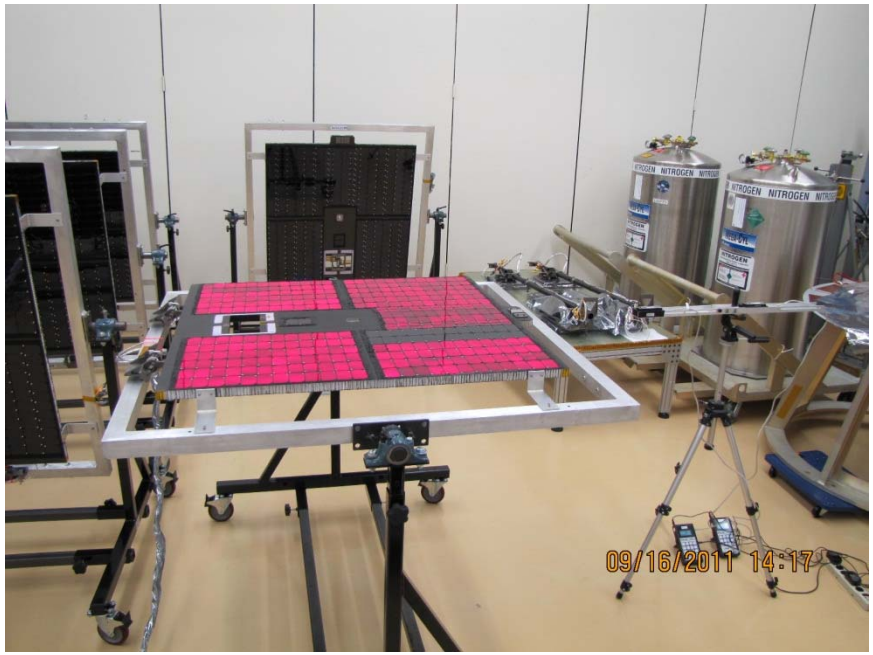


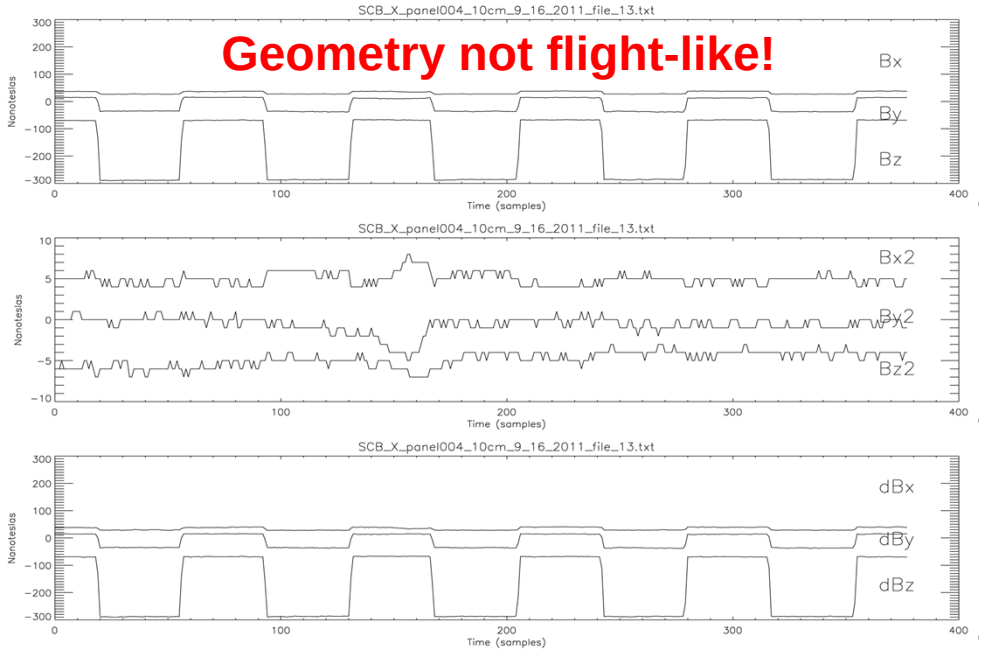
	@ 2 m			@ 3.5 m		
	Bx [nT]	By [nT]	Bz [nT]	Bx [nT]	By [nT]	Bz [nT]
Assembly 1	17.5	53.0	5.5	3.3	10.1	1.0
Assembly 2	10.0	55.0	2.0	3.6	10.5	0.4

Magnetics Test: Solar Panels



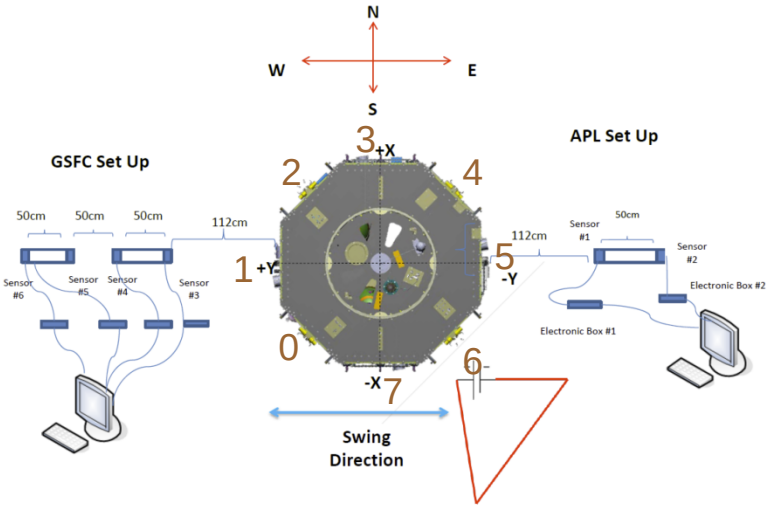
- **Panels powered by a reverse-bias square-wave current with 0.4 A amplitude (flight-like), magnetic field measured in plane of panel at 0.5 and 1 m distance.**
- **All panels measured <1 nT (below noise level) in this configuration.**
- **Cross check: Amplitudes >200 nT were observed 10 cm beneath panel.**





Swing Test Setup

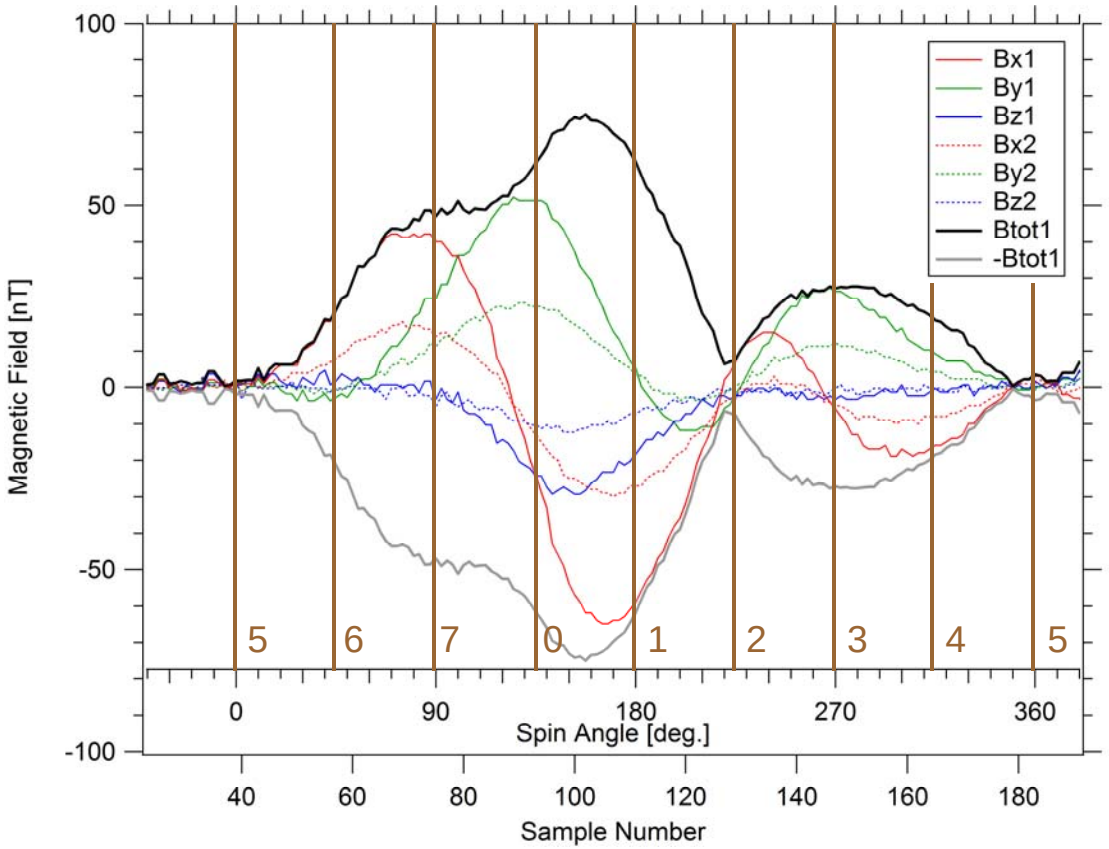
- Spacecraft suspended from crane.
- Two sets of magnetometers placed on opposite sides of spacecraft; closest distance to SC at rest: 1 m.
- Magnetometers were configured in gradiometer mode to separate use signal from background variations.
- SC swung toward magnetometers for 5-10 periods with an initial deflection of 60 cm.
- Signal amplitudes up to 100 nT with <10% contribution from crane.
- Rotation of spacecraft used to verify location of most significant source.



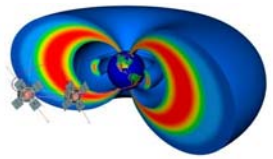
Swing Test in Action

Spin Test

- **To verify at the system level that the latch-valve and compensations magnets present the only significant source of magnetic fields, the magnetic field was mapped for a 360° rotation of the spacecraft.**



Swing Test Analysis



- **Rotation test showed largest magnetic field magnitude near Panel 0, consistent with the location of the latch-valve assembly.**
- **Here: Analysis of SC A with Panel 0 toward APL test magnetometers.**
- **Fit observations with function:**

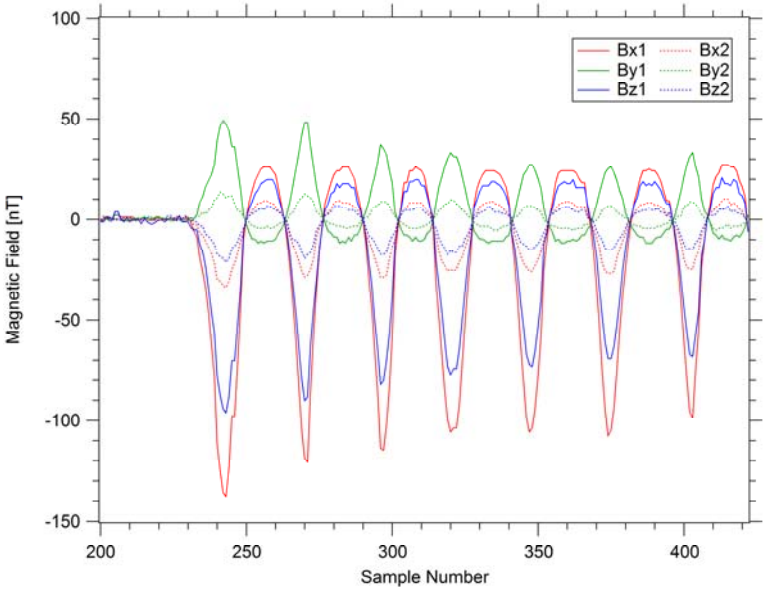
$$B(t) = k/r(t)^3 + c$$

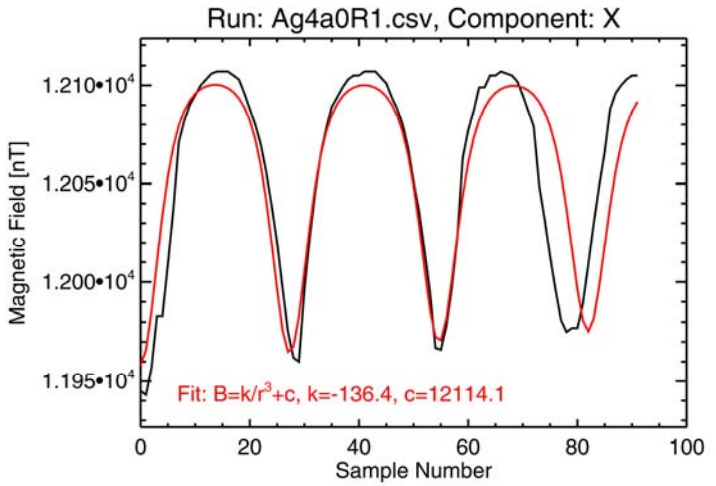
- **Compute magnetic moment:**

$$M_x = k_x/200 = 0.68\ \mathrm{Am}^2$$
$$M_y = k_y/100 = 0.48\ \mathrm{Am}^2$$
$$M_z = k_z/100 = 0.99\ \mathrm{Am}^2$$

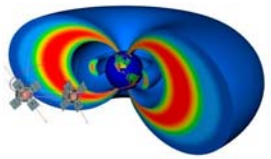
- **Rotate into SC coordinates:**

$$\overrightarrow{M} = [-0.82, 0.14, 0.99]\ \mathrm{Am}^2$$





Spacecraft Magnetic Moments



- **Magnetic moments in spacecraft coordinates from analysis of Panel 0 swings:**

  SC A: $\vec{M} = [-0.82, 0.14, 0.99]\ \mathrm{Am}^2$

  SC B: $\vec{M} = [-0.83, 0.25, 0.93]\ \mathrm{Am}^2$

- **Use dipole equation to compute magnetic field at location of EMFISIS DC Magnetometer:**

$$\vec{B}(\vec{r}) = \frac{\mu_0}{4\pi}\left(\frac{3\,\vec{r}\,(\vec{M}\cdot\vec{r})}{r^5} - \frac{\vec{M}}{r^3}\right)$$

  SC A: $\vec{B} = [1.81, -0.83, -2.19]\ \mathrm{nT}, B = 2.96\ \mathrm{nT}$

  SC B: $\vec{B} = [1.92, -0.31, -2.15]\ \mathrm{nT}, B = 2.90\ \mathrm{nT}$

- **Both spacecraft meet requirement to contribute no more than 5 nT at the location of the EMFISIS DC Magnetometer with a 40% margin.**

- **The estimates for the SC magnetic moments obtained from the tests at APL and Astrotech agree within the measurement uncertainties.**