

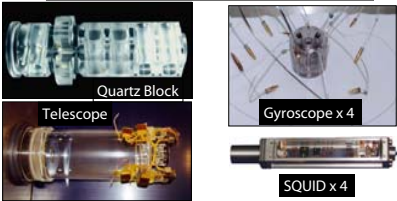
THE GRAVITY PROBE B SCIENCE INSTRUMENT ASSEMBLY



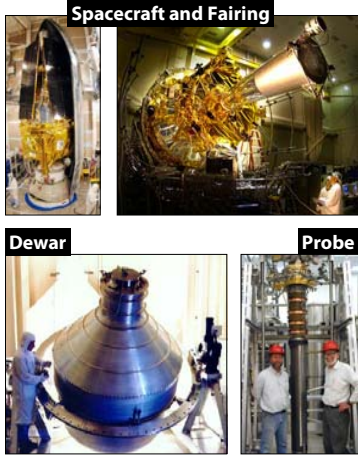
Saps Buchman, Barry Muhlfelder, and John Turneure

The Science Instrument Assembly

Science Instrument Assembly - SIA



SIA in Relativity Probe



The SIA "Near-zeroes"

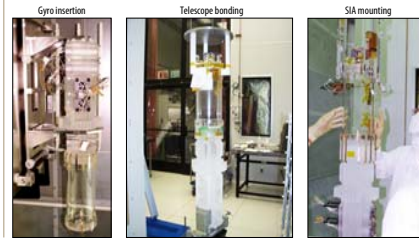
What is Required for GP-B Performance?
Critical "Near-zeroes" and Superlatives

1. "Zero" rotor asphericity → **Best Gyros**
2. "Zero" rotor inhomogeneity → **Best Gyros**
3. "Zero" electric charge
4. "Zero" residual acceleration
5. "Zero" gas pressure
6. "Zero" magnetic field
7. **Lowest noise gyroscope read-out**
8. **Most sensitive star-tracking telescope**
9. Largest flight dewar
10. Best proper motion of star

All Requirements Achieved or Surpassed

The SIA Assembly

1. Bond telescope to Quartz Block
 - > Potassium hydroxide bonding
 - > Matching CLE to 1 ppb/K
2. Mount Gyroscopes
 - > Rigid mounting to 50 μm and 2 arcsec
3. Connect to support structure "bird cage"
4. Mount SQUIDS
5. Complete connections
 - > Gyroscope suspension, thermometers, heaters
 - > SQUID rf thermometers and heaters
 - > Telescope electronics and thermometry



The Gyroscopes

Fused-Quartz Gyroscope



- > Materials:
 - > Fused silica, Nb coating
 - > Diameter: 3.8 cm
 - > Sphericity: < 1 ppm
 - > 1.8×10^{-7} of diameter
 - > Homogeneity: < 2 ppm
 - > Mass unbalance: < 1 ppm

Gyro	Spin Speed (Hz)	df/dt (μHz/Hr)
1	79.4	0.57
2	61.8	0.52
3	82.1	1.30
4	64.8	0.28

Mass Unbalance (nm)

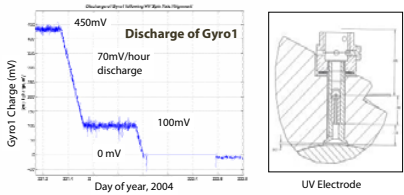
Gyro #	1	2	3	4
Ground Estimate	18.8	14.5	16.8	13.5
On-orbit data	6.9	4.4	3.3	6.0

Space improves gyro accuracy by > 1,000,000!

UV Charge Management

- > Rotor charge controlled via UV excited electrons
- > Charge rates ~ 0.1 mV/day
- > Continuous measurement at the 0.1 mV level
- > Control requirement: 15 mV

1 mV corresponds to 1 pC (gyro capacitance = 1 nF)

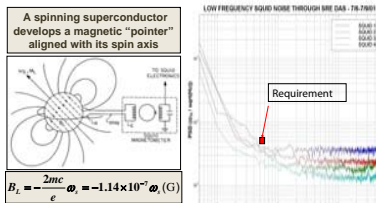


Charging rates to day 390		
Average Charging Rate	Sun Spot 720	
mV/day	mV	
Gyro 1	0.098 +/- 0.003	0.63 +/- 0.05
Gyro 2	0.114 +/- 0.003	0.74 +/- 0.05
Gyro 4	0.152 +/- 0.003	1.15 +/- 0.05

Charge controlled to < 5 mV

The SQUIDS

- > London moment read-out with dc SQUIDS
- > Superconducting pickup on gyroscope housing

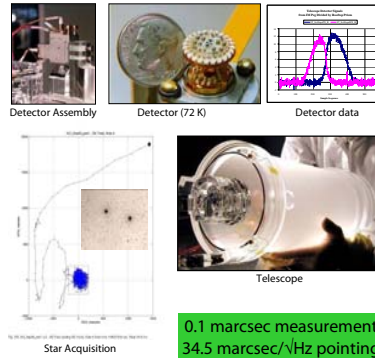


Trapped field:	Gyro 1	Gyro 2	Gyro 3	Gyro 4
	3.0 MicroGauss	1.3 MicroGauss	0.8 MicroGauss	0.2 MicroGauss

< 8×10^{-29} J/Hz (< $50 \mu\phi$ /√Hz) at 5 mHz
190 marcsec/√Hz (5×10^{-11} G/√Hz)
On Orbit Performance Met Requirements

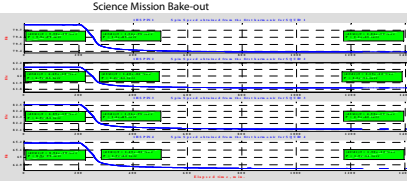
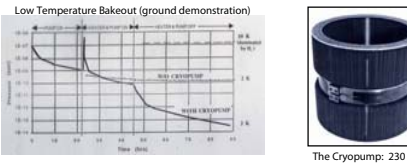
The Telescope

- > 150" focal length, 5.6" aperture
- > All quartz construction
- > Potassium hydroxide bonding
- > Image splitting with roof prisms



0.1 marcsec measurement
34.5 marcsec/√Hz pointing

Low Temperature Bake-out



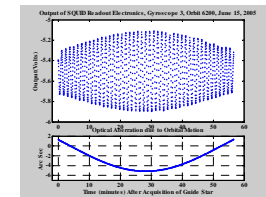
Gyro spin-down periods on-orbit (years)	before	after
Gyro #1	~75	15,900
Gyro #2	~62	13,600
Gyro #3	~60	7,200
Gyro #4	~46	26,400

Spin-down in Science Mission was not limited by gas pressure

Pressure at gyroscopes is about 10^{-14} torr

Operations

- I. GP-B Launch: Apr. 20, 2004
 - Initial orbit checkout - 4 months
 - Plan was 40-60 days
- II. Science Mission Start: Aug. 27, 2004
 - Science Mission - 11.5 months
- III. Science Mission End: Aug. 15, 2005
 - Post Mission Calibrations - 1.5 months
- IV. Helium Depleted: Sep. 29, 2005
- V. First Data Release: April, 2007



ALL MAJOR SYSTEMS WORKED WELL
Discoveries occurred at all stages

