

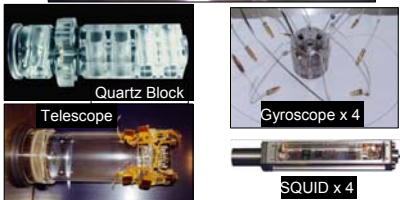
The Gravity Probe B Science Instrument Assembly



Saps Buchman, Barry Muhlfelder, and John Turneure

The Science Instrument Assembly

Science Instrument Assembly - SIA

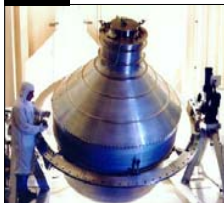


SIA in Relativity Probe

Spacecraft and Fairing



Dewar



Probe



The SIA "Near-zeroes"

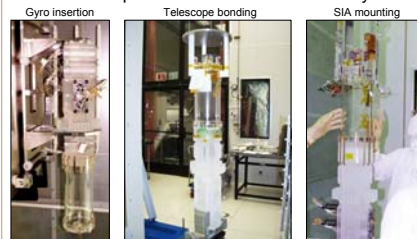
What is Required for GP-B Performance?
Critical "Near-zeroes" and Superlatives

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 Gyroscopes



- > Materials:
 - > Fused silica, Nb coating
 - > Diameter: 3.8 cm
 - > Sphericity: < 1 ppm
 - > 1.8 × 10⁻⁷ of diameter
 - > Homogeneity: < 2 ppm
 - > Mass imbalance: < 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 Imbalance (nm)

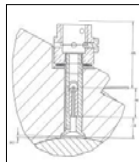
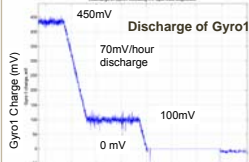
Estimate	16	24	16	13
On-orbit data	8	5	8	5
	6.9	4.4	3.3	6.0

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

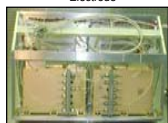
UV Charge Management

- > 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



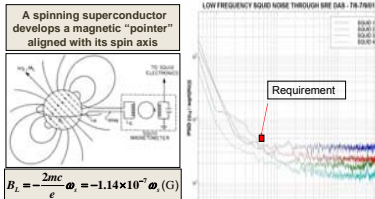
	Average Charging Rate mV/day	Sun Spot 720 mV
Gyro 1	0.098 ± 0.003	0.63 ± 0.05
Gyro 2	0.114 ± 0.003	0.74 ± 0.05
Gyro 4	0.152 ± 0.003	1.15 ± 0.05



Charge controlled to < 5 mV

The SQUIDS

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

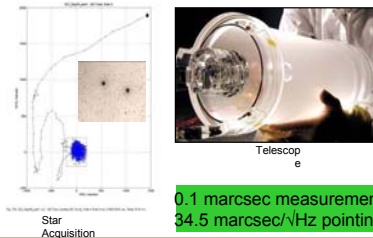
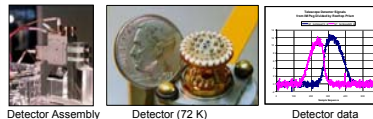


Gyro	Trapped field:
Gyro 1	3.0 MicroGauss
Gyro 2	1.3 MicroGauss
Gyro 3	0.8 MicroGauss
Gyro 4	0.2 MicroGauss

< 8 × 10⁻²⁹ J/Hz (< 50 μφ²/√Hz) at 5 mHz
190 marcsec/√Hz (5 × 10⁻¹¹ G/√Hz)
On Orbit Performance Met Requirements

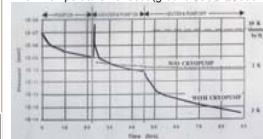
The Telescope

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

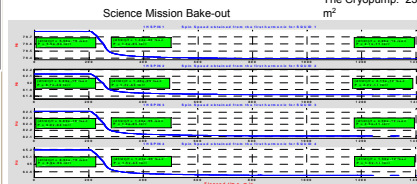


Low Temperature Bake-

Low Temperature Bakeout (ground demonstration)



The Cryopump: 230 m²



Gyro #	before bake-out (years)	after bake-out (years)
Gyro #1	~ 75	15,900
Gyro #2	~ 62	13,600
Gyro #3	~ 60	7,200
Gyro #4	~ 46	26,400

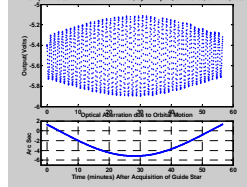
Spin-down in Science Mission was not limited by gas pressure

Pressure at gyroscopes is about 10⁻¹⁴ torr

Operations

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

Output of SQUID Readout Electronics, Gyroscopes 3, Orbit 0200, June 15, 2005



ALL MAJOR SYSTEMS WORKED WELL

Discoveries occurred at all stages

