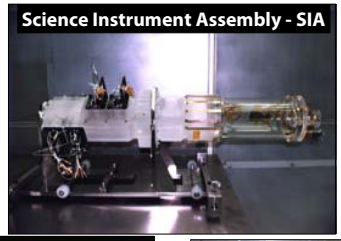
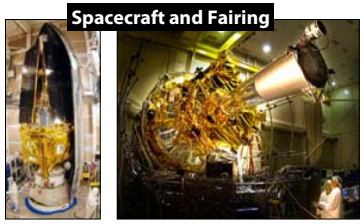
The Gravity Probe B Science Instrument Assembly

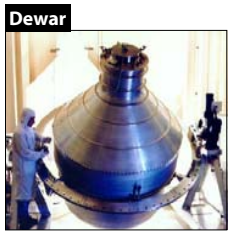
Saps Buchman , Barry Muhlfelder , and John Turneaure

The Science Instrument Assembly



SIA in Relativity Probe





The SIA "Near-zeroes"

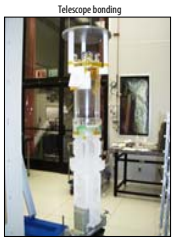
What is Required for GP-B Performance?
Critical "Near-zeros" and Superlatives

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)

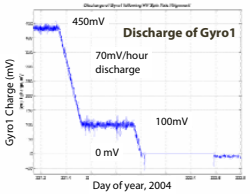
Gyro #	1	2	3	4
Ground Estimate	18.8	14.5	16.8	13.5
On-orbit data	6.9	4.4	3.3	6.0

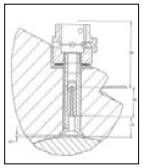
Space improves gyro accuracy by > 1,000,000!

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)





UV Electrode

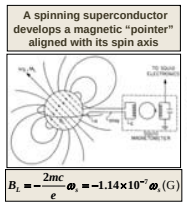
Charging rates to day 390		
	Average Charging Rate	Sun Spot 720
	mV/day	mV
Gyro 1	0.098+/-0.003	0.63+/-0.05
Gyro 2	0.114+/-0.003	0.74+/-0.05
Gyro 4	0.152+/-0.003	1.15+/-0.05

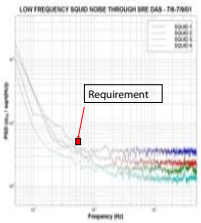
UV Lamp Assembly

Charge controlled to < 5 mV

The SQUIDS

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





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 (<50μϕ_0/√Hz) at 5 mHz
190 marcsec/√Hz (5×10^{-11} G/ √Hz)
On Orbit Performance Met Requirements

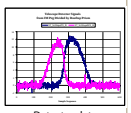
The Telescope

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

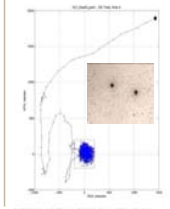
Image divider

Detector Assembly

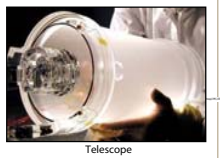
Detector (72 K)



Detector data



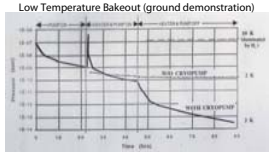
Star Acquisition



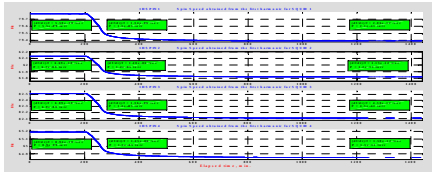
Telescope

0.1 marcsec measurement
34.5 marcsec/√Hz pointing

Low Temperature Bake-out



The Cryopump: 230 m²



Gyro spin-down periods on-orbit (years)	before bake-out	after bake-out
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

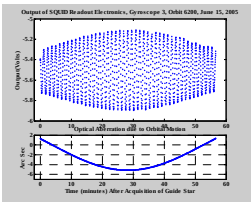
I. GP-B Launch: Apr. 20, 2004
   - Initial orbit checkout - 4 months
   - Plan was 40-60 days

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 SYSTEM WORKED WELL
Discoveries occurred at all stages

W. W. Hansen Experimental Physics Laboratory • Stanford University, Stanford, CA 94305-4085 • http://einstein.stanford.edu

This research supported by NASA on contract NAS8-39225