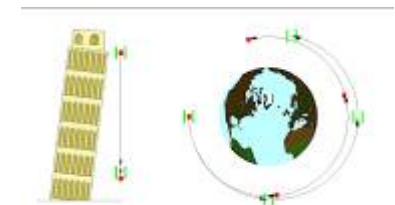
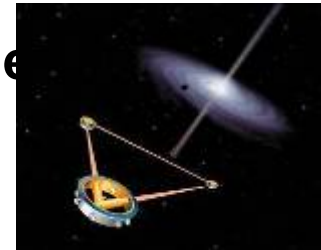
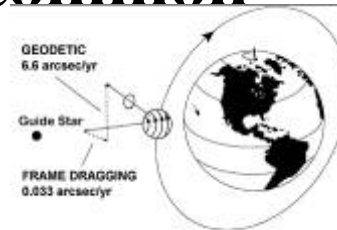


Three unique experiments with common interests

- Gravitational Experiments
- Satellite Technology
- Low disturbance environment
- Precision control
- Highly demanding



**GP-B Experience is invaluable to STEP, LISA
and physics in space generally**

GP-B shows feasibility of complex experiments in space



GP-B Lessons for Lisa and STEP

Particularly valuable GPB Experience

–Demonstration of Technologies

- Cryogenic
- Drag-free

–Operations with spacecraft

- Day-to-day
- Anomaly recovery

–Data Analysis Techniques

–The data itself



GP-B Lessons for LISA and STEP

Generic lessons for space missions

Only one chance

- Test it like you fly it
- Test and inspect at all levels
- Have the right people and experience
- Maintain program continuity (keep a core team)
- Need independent assessment
- Adequate funding profile is critical
- Satellite must be designed as a single integrated system

These are Exemplified in GP-B's Lessons



GP-B Lessons for LISA and STEP

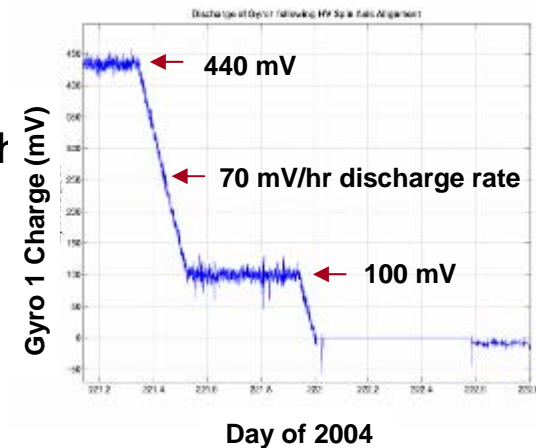
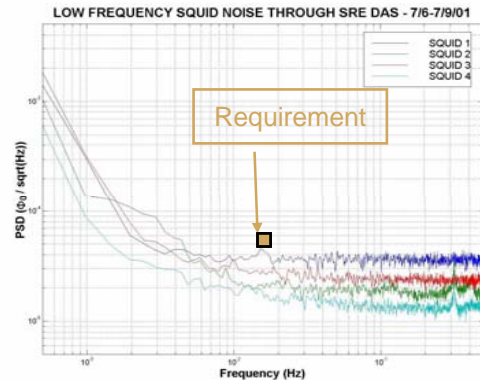
Specific Lessons From GP-B

- **Verify drag-free and attitude control systems prior to launch with a high fidelity fixed-base payload/spacecraft simulator. Include flight hardware as much as possible.**
- **Experimentally verify assumptions about the instrument to the extent possible on the ground. Test as much like the flight instrument as possible.**
- **Perform end-to-end and environmental testing on the integrated payload/spacecraft as early as possible and *fully* analyze the data. *Pay attention to detail.***
- **Allow sufficient time for spacecraft initialization, experiment setup, and unanticipated problems.**
- **Have the ability to measure everything on the spacecraft, including power supply voltages, to high precision. This requires a very flexible telemetry system.**

GP-B Lessons for LISA and STEP

More Specific Lessons

- The SQUIDs met requirements with margin during ground testing and perform even better in space.
- Test mass charging is less important than expected before launch
- Surface-related and patch effect forces are more important than expected before launch



GP-B Lessons for LISA and STEP

GP-B Attitude and Control

–Unexpected thruster failures

- Longer than expected recovery
- Extra 20 days



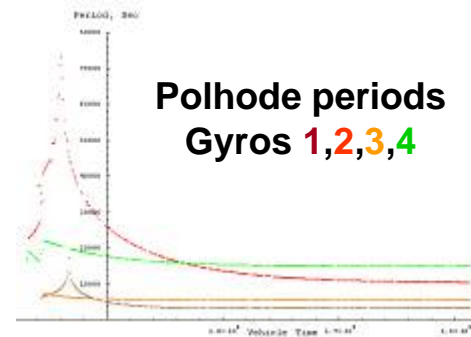
–Much longer than expected initialization period

- 120 rather than 60 days
- Risk to mission, science

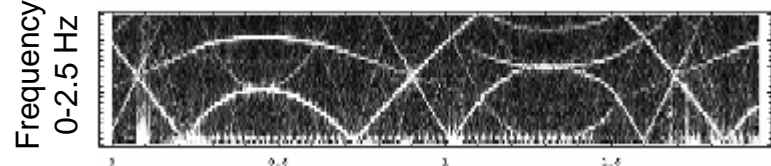
Allow extra schedule

GP-B Instrument

- Changing polhode period
 - Complex data analysis
 - Varying scale factors
- Classical torques present
 - Disturbance from patch effects
- Electronic noise
 - ECU noise
 - Conversion errors



Spectrum of ECU Noise, Detail



Verify assumptions
Early end-to-end Test
Pay attention to detail
Expect the Unexpected

GP-B Lessons for LISA and STEP

Conclusions

- GP-B experience is invaluable to LISA and STEP
- Experience gained = Lessons learned
- Verification of technologies



It is possible to take advantage of the unique space environment to do physics experiments