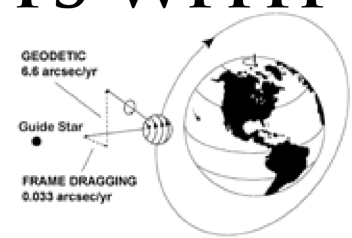
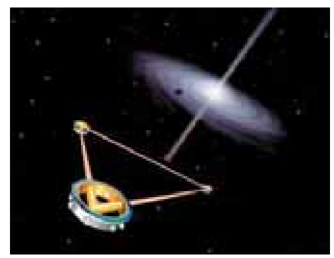
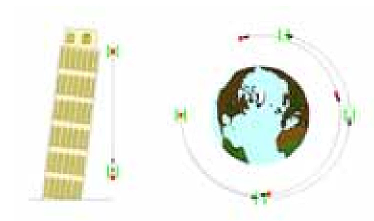
P. Worden and S. Buchman

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

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

SPECIFIC LESSONS FROM GP-B

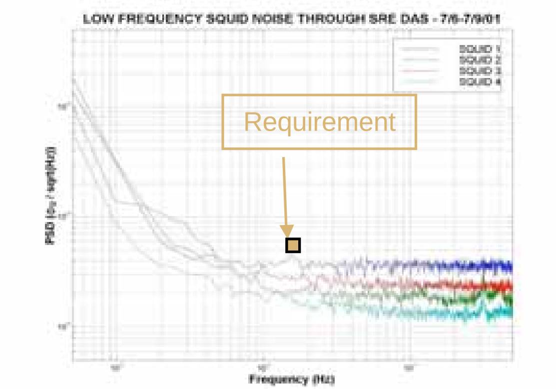
- **Verify drag-free and attitude control systems prior to launch with a <u>high fidelity</u> fixed-base payload/spacecraft simulator. Include flight hardware as much as possible.**
- **Experimentally verify assumptions about the instrument to the extent possible on the ground. Test as much like the 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.**

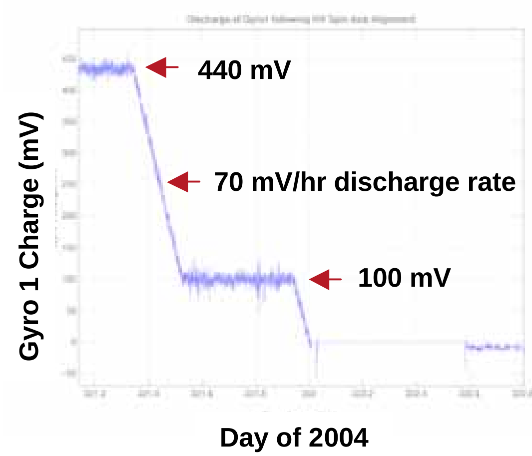
MORE SPECIFIC LESSONS

- 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

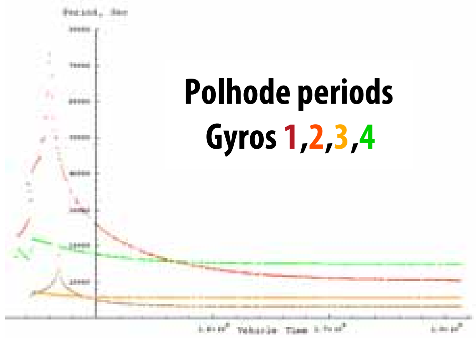
–Much longer than expected initialization period

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

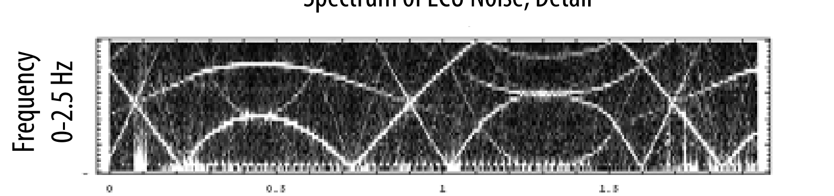
Allow extra schedule

GP-B Instrument

- Changing polhode period
  - Complex data analysis
  - Varying scale factors
- Classical torques present
  - Disturbance from patch effect?
- 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

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