A study of transient noise sources in LIGO

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- Summary of recent results and proposed work.
- ". . . the relationship of the proposed work to other ongoing and proposed work in the context of most effectively improving the performance of LIGO."

Objectives of proposed work

Detector Diagnostics: Development of DMT monitoring software, use of DMT to understand and improve LLO detector. (with LIGO DMT developers, DetChar group)

Seismic Isolation: Development of Advanced LIGO seismic isolation, seismic isolation retrofit at LLO. (with Stanford, LIGO Lab (all), JILA)

Data Analysis: Participation in analysis with unmodelled burst and stochastic search groups.

Transient Noise Study: Construction and use of facility to measure transient noise in stressed mechanical assemblies. (at LLO)

Detector Diagnostics, current work

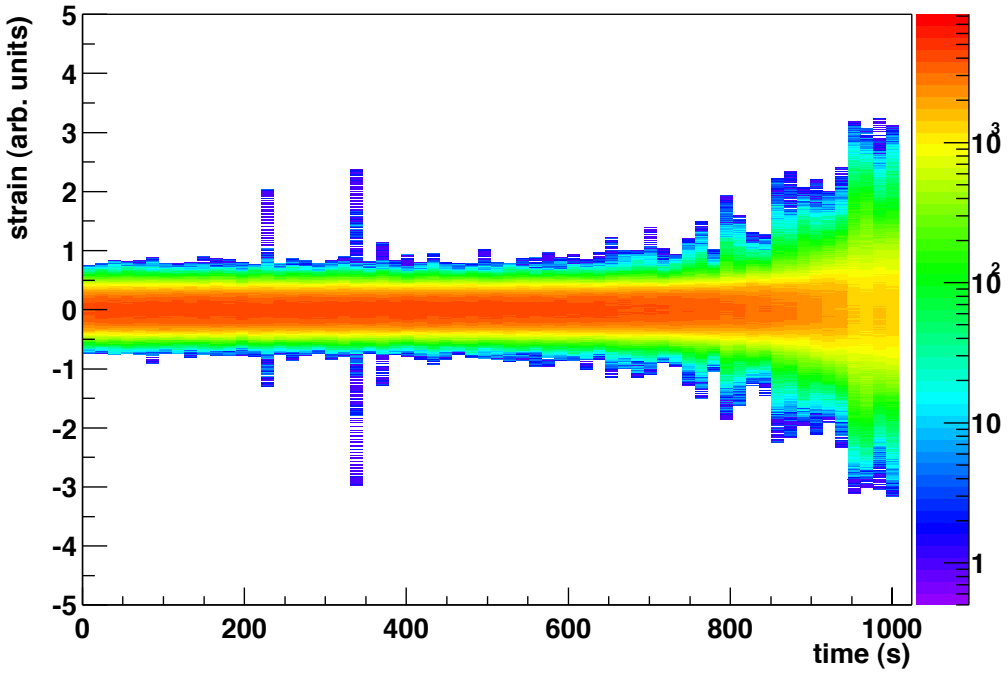
Human scientific monitoring: Giaime, Johnson, and Daw have continued to spend significant time at LLO working to commission the detector and during engineering runs.

- "unscientific" measure: over 500 LLO electronic detector log entries in support of commissioning and data monitoring.
- During E4–E7 & S1 runs, 28% of expert scientific monitor shifts at LLO supported by this grant.

Diagnostic monitor programing: Daw has been spending approx. half time on monitor software.

- First monitor used regularly by Ops at LLO: Band-limited RMS (BLRMS). Used to see minute-by-minute RMS trends in PEM and interferometer channels. (example later.)
- PeakMon: Provides sequential histograms of filtered data, and makes time series of peak event available on DMT viewer.

Detector Diagnostics, current work 2



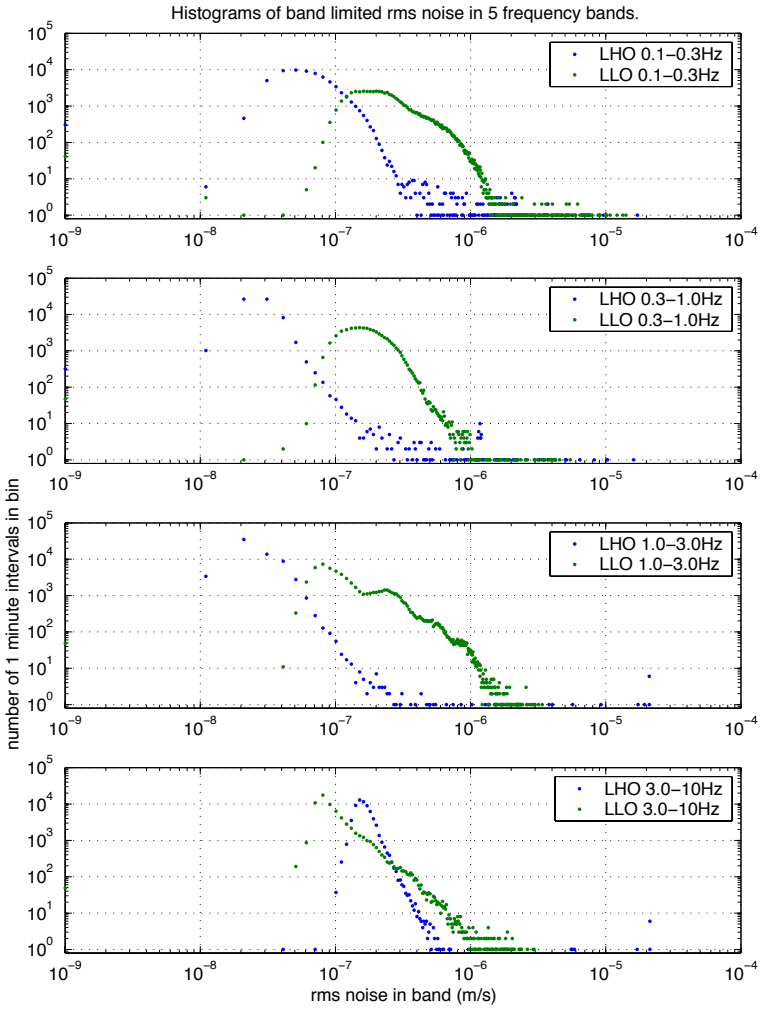
Example of PeakMon output. Each vertical stripe is a histogram of a 16-second frame of AS_Q data. Three things can be seen: an occasional non-gaussian bursty segment, a gradual increase in noise due to misalignment, and (for the sharp-eyed) an overly-broad center possibly indicating a significant line feature in the data.

Detector Diagnostics, proposed work

1. Update the BLRMS and PeakMon monitors to generate trend data and database entries in order to allow wider use of the monitor output. (already begun. . .)
2. Develop a transient signal monitor that produces output representing the magnitude ratio and time delay among various LIGO channels. As of our 1999 proposal, we planned to study the propagation of transients using modelling, but we now feel that using the DMT and the working instrument will provide better and more timely information. We would like to expend considerable effort on the graphical and statistical output formats that are most useful to commissioning and "transient noise hunt" activities.
3. Train young graduate students and new postdoc to feel at home with detector. They will become frustrated with the software, and improve it.
4. Johnson intends to continue the work began in Summer 2002 to define a procedure to find this thermal noise sweet spot.

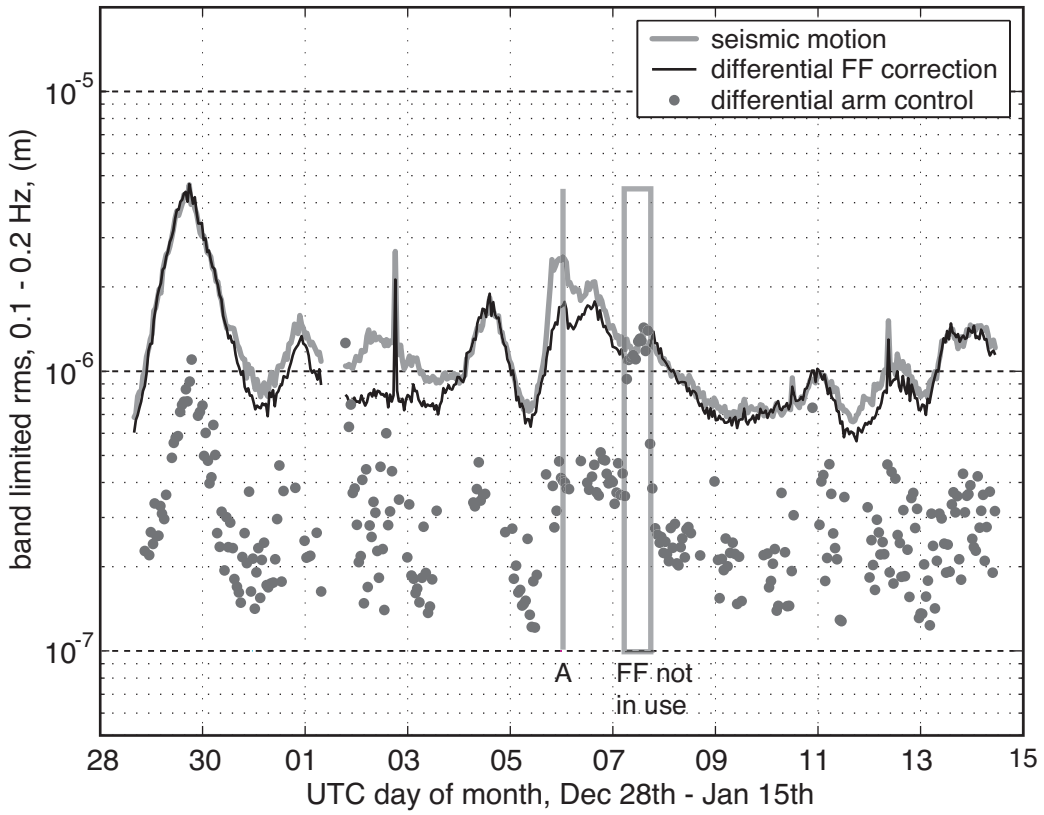
LIGO Livingston noise enemies

LIGO seismic noise, Summer '02. LHO LLO



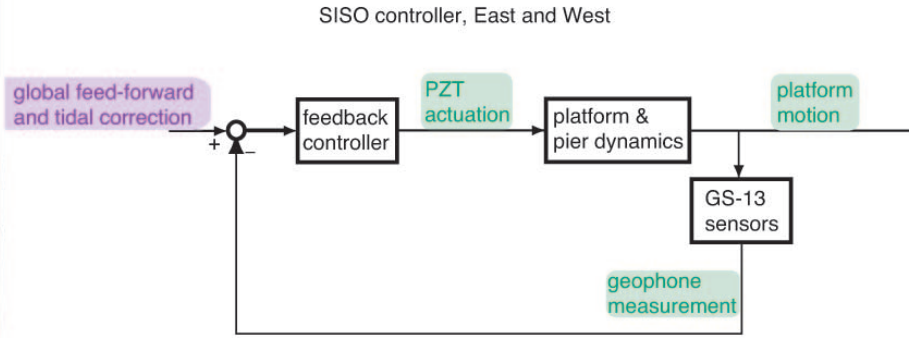
- Noise in the 1–3 Hz band, often from timber harvesting, is enhanced by the stack resonances, making daytime operation difficult.
- Noisy season velocities shown, which included S1; during 90% of this 7 week period, the 1–3 Hz rms displacement was less than $3 \times 10^{-7}\mathrm{m}/\sqrt{\mathrm{Hz}}$, so factor of 30 improvement is needed to reach goal.
- Noise in the 0.3–1 Hz band sometimes adds excessive noise to 0.75 Hz suspension resonance; retrofit design should attempt to reduce this by factor of a few.
- Noise in 0.1–0.3 Hz band now reduced by 10 dB with microseism feedforward system.

Microseismic feedforward correction



Seismometer signals from each building used to correct arm lengths for ocean-wave-produced, ≈ 7 s period, surface waves. *Rev. Sci. Instrum.* paper in press.

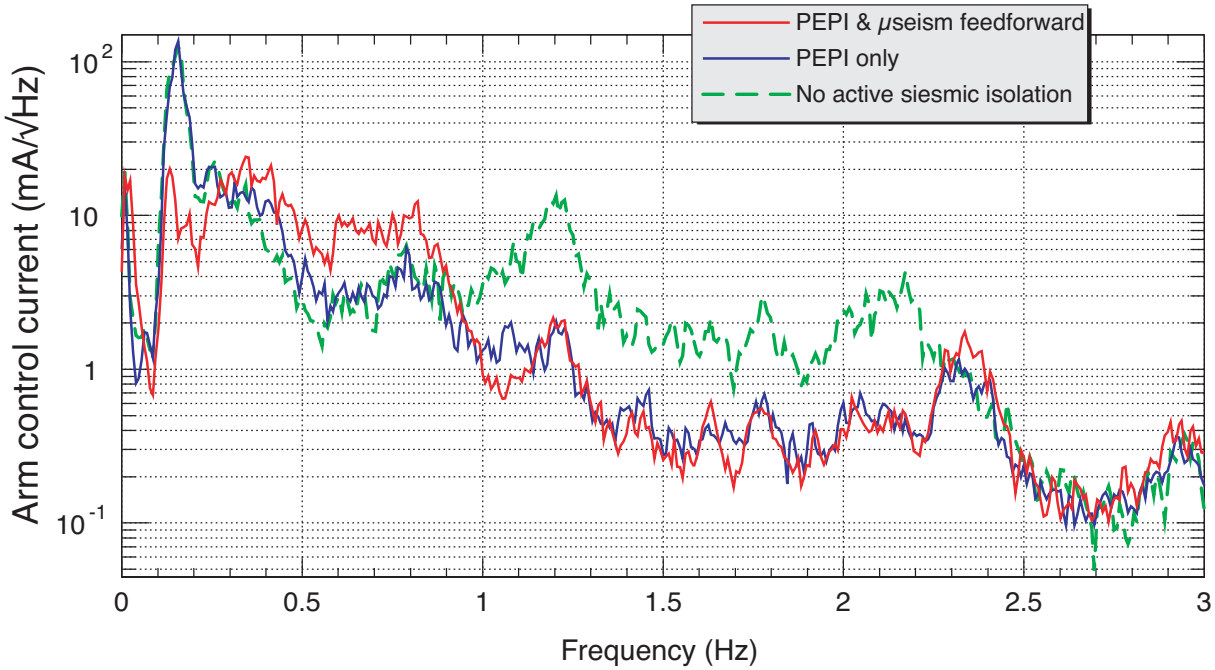
PEPI at LLO.



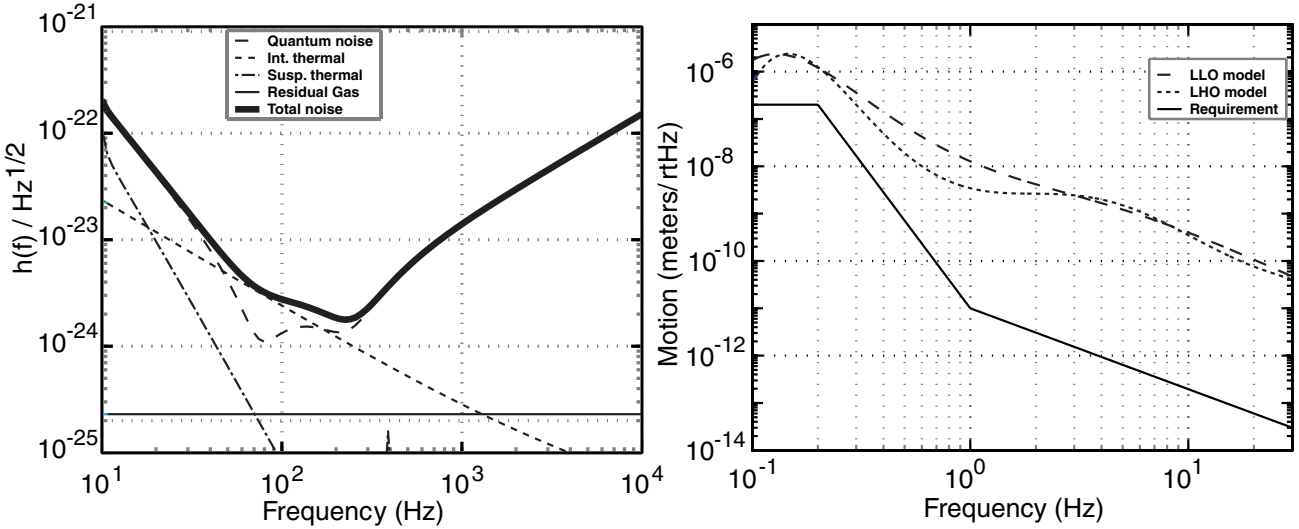
- Geophone is mounted on each crossbeam filtered to make error signal for local active isolation loop.
- Loop gain shape set to enhance reduction at stack modes at 1.2 and 2.1 Hz.

PEPI at LLO, 2

- Factor of 5 reduction in arm length control signals seen in active band, 1–3 Hz.
- Similar reduction of pitch excitation seen at test masses; yaw not affected much.
- Nice test on feasability of physical retrofit and pier-top active control.

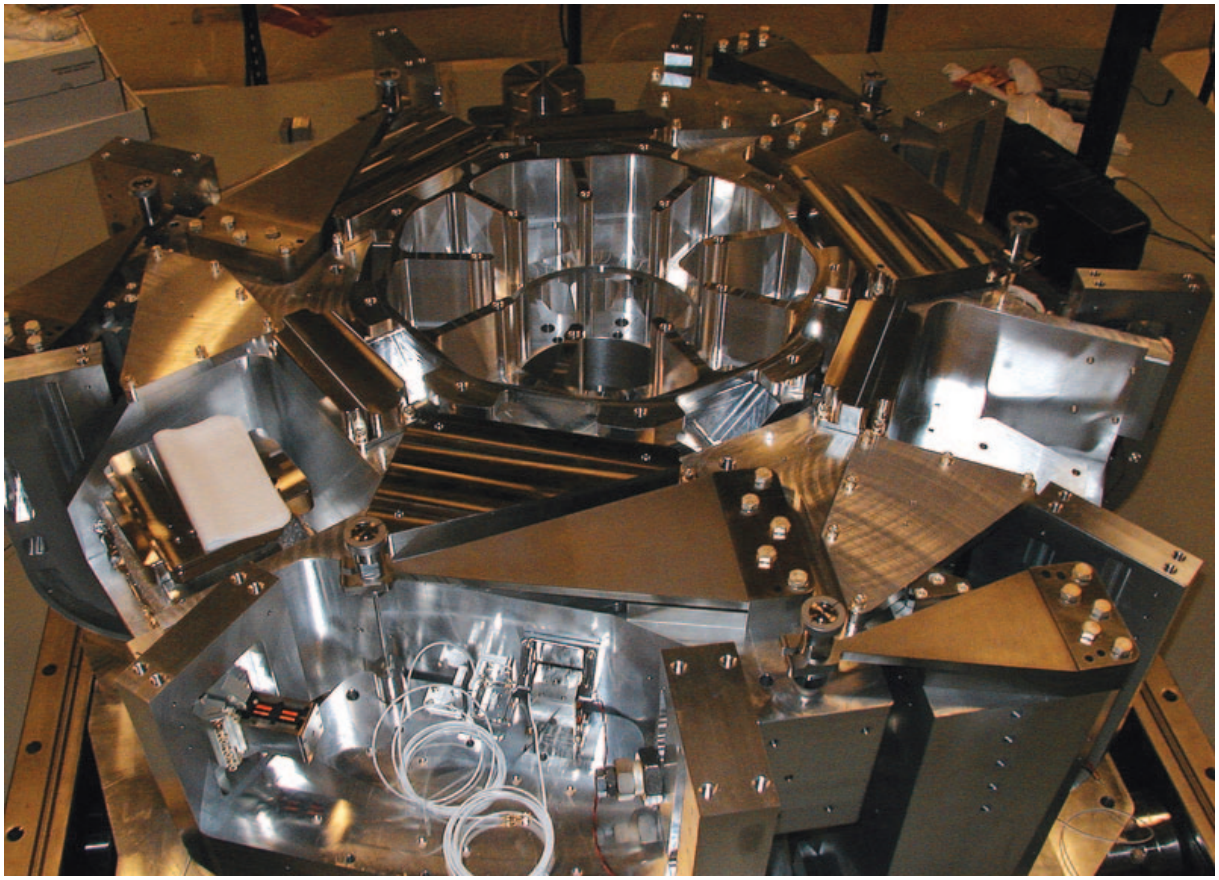


Advanced LIGO Seismic isolation, proposed work



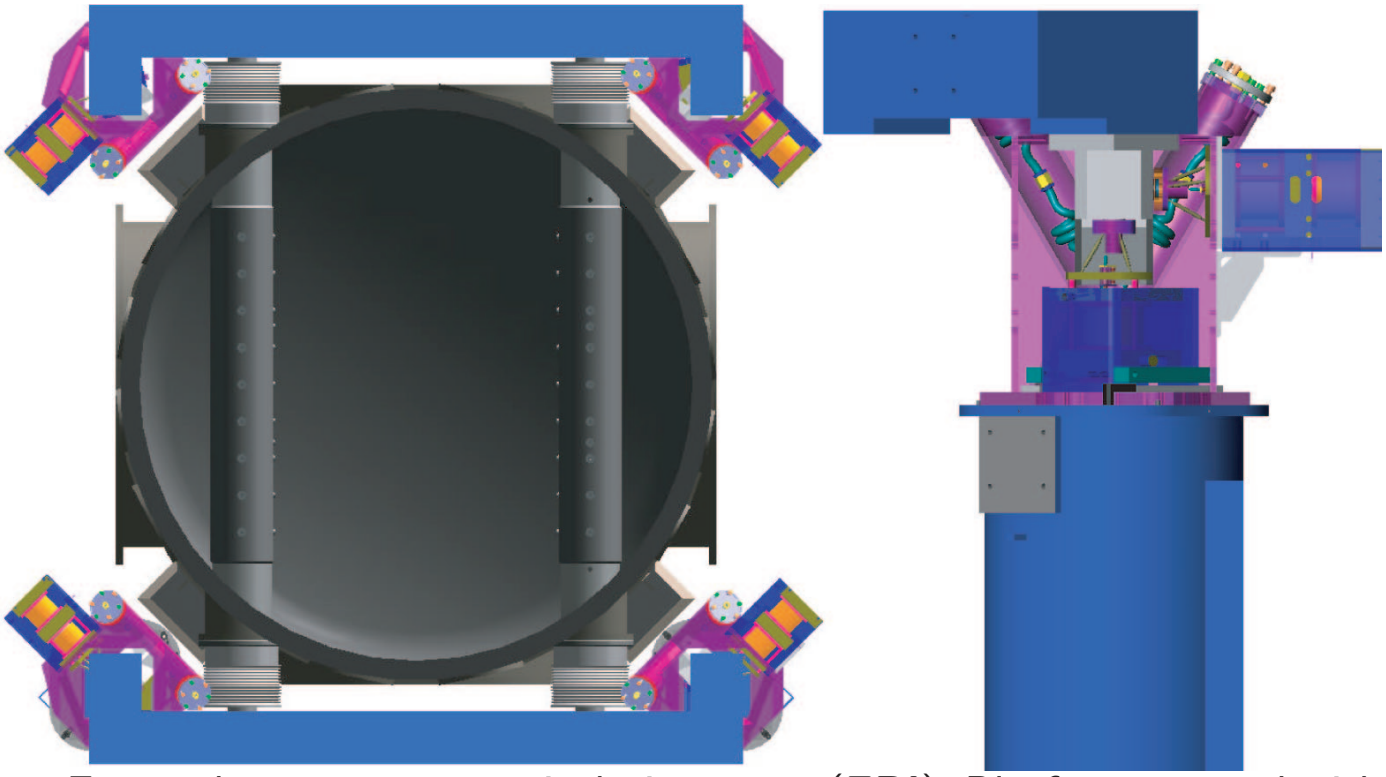
- Giaime, as LSC/LIGO Adv. SEI system lead scientist, together future shared postdoc, to contribute to design and testing of prototypes and (we hope) AdLIGO units. System consists of an in-vacuum, two-stage active platform supported by an external pre-isolation stage.
- Seismic isolation global control optimization in LIGO-1 after retrofit.

Advanced LIGO System Development: In-vacuum



- 2-stage in-vacuum platform uses feedback from inertial sensors to reduce noise in $\approx$ 1–30 Hz band.
- Work currently focused on ETF prototype under assembly in Stanford ETF vacuum system. Loops should be closed within months.
- Pre-prototype being used to test low-noise capacitive sensors and control techniques.

Adv. LIGO System Development: External Pre-isolation



- External, mm-range, pre-isolation stage (**EPI**). Platform servoed with large gain to local sensors, corrected for coupled ground noise and global signals. Effective in 0.1–10 Hz band.

Data analysis, current and proposed work

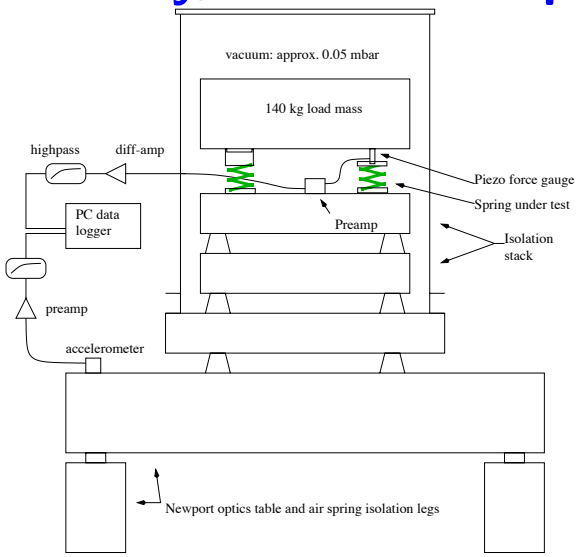
Burst group: Build upon Ed Daw's development of slope event trigger package:

- Develop a quantitative understanding of the efficiency of the slope trigger generation using Monte Carlo techniques and by injection of test signals into the interferometers.
- Try to use optimal filtering techniques with this search (Johnson).
- Understand the physical origin of anomalous events in the LIGO detectors seen through the slope algorithm set, eliminating their sources or developing efficient vetoes for them.
- Develop the slope algorithm set to correlate the outputs of multiple interferometers and generate a single overall event list.

Stochastic group: Together with Allegro,

- Contribute to the joint analysis of LIGO and ALLEGRO data for a stochastic background using the upcoming S2 and S3 LIGO science run data.
- Continue the collaboration with the stochastic group, particularly the Loyola New Orleans group, to analyze these data for astrophysical upper limits.

Transient noise study, current and proposed work



- Experiment to carefully measure energy release in stressed LIGO mechanical components.
- High-reliability DAQ system assembled and working.
- Vacuum system assembled on seismically-isolated granite table
- Currently in LLO Y-end; to be moved to LSU before S3.
- New postdoc and post-exam grad student now working on this.