

Seismic Isolation

Requirements and Design Breakout Presentation
NSF Review of Advanced LIGO Project

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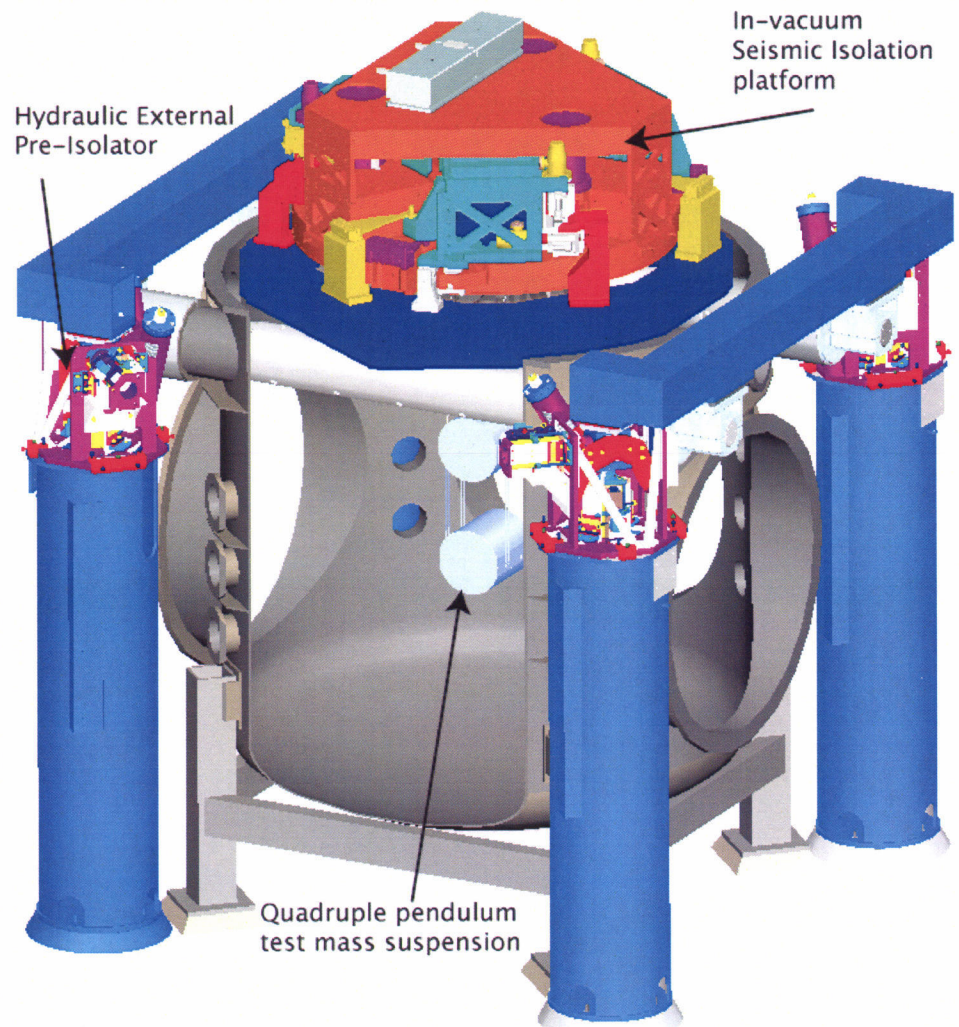
May 31–June 2, 2006

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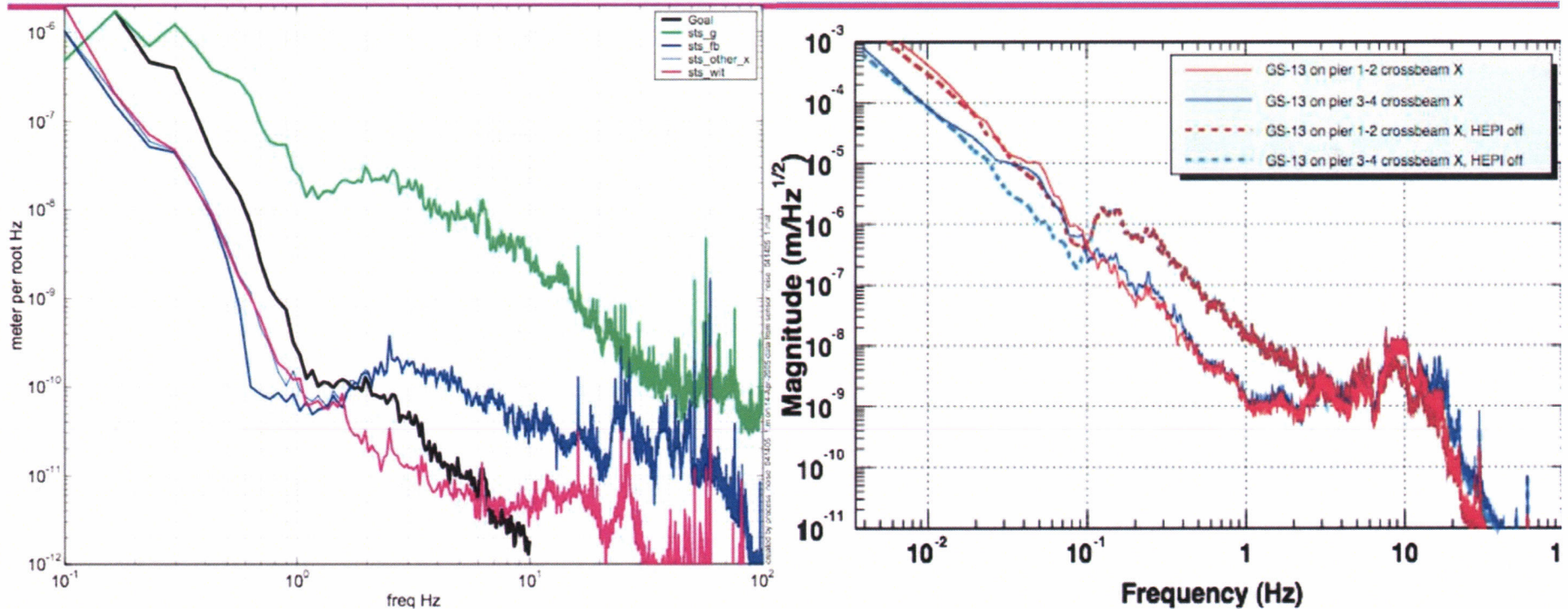
- The test mass is isolated from mechanical vibration in three cascaded stages:
 - » Hydraulic External Pre-Isolator (HEPI), which tracks Earth tides and reduces vibration in the 0.15–2 Hz band. The technique is mostly **feedforward**, based on signals from a floor-mounted seismometer.
 - » A two-stage Internal Seismic Isolation (ISI) platform, which is responsible for isolation in the 1–10 Hz band, to greatly reduce RMS motion. The technique is **active seismic isolation**, which employs force **feedback** based on signals from inertial sensors on the payload.
 - » A quadruple pendulum suspension; transmitted vibration falls with 8 powers of f above several hertz. Isolation is **passive**.
- The seismic isolation system provides physical support of a matrix-drilled optics table for suspension and other components, allows global alignment and positioning, and carries electrical signals.

\$8.6 M

\$13.5 M +
\$21.4 M



Horizontal FIR blending performance X



- 2-stage in-vacuum “Technology Demonstrator” platform in Stanford’s Engineering Test Facility (ETF) validated critical sensor noise floor, design robustness to reactive load, and allowed refinement of design parameters.
- HEPI already deployed in LIGO Livingston detector (before S4 run), and has met isolation performance expectations and increased Livingston duty cycle.

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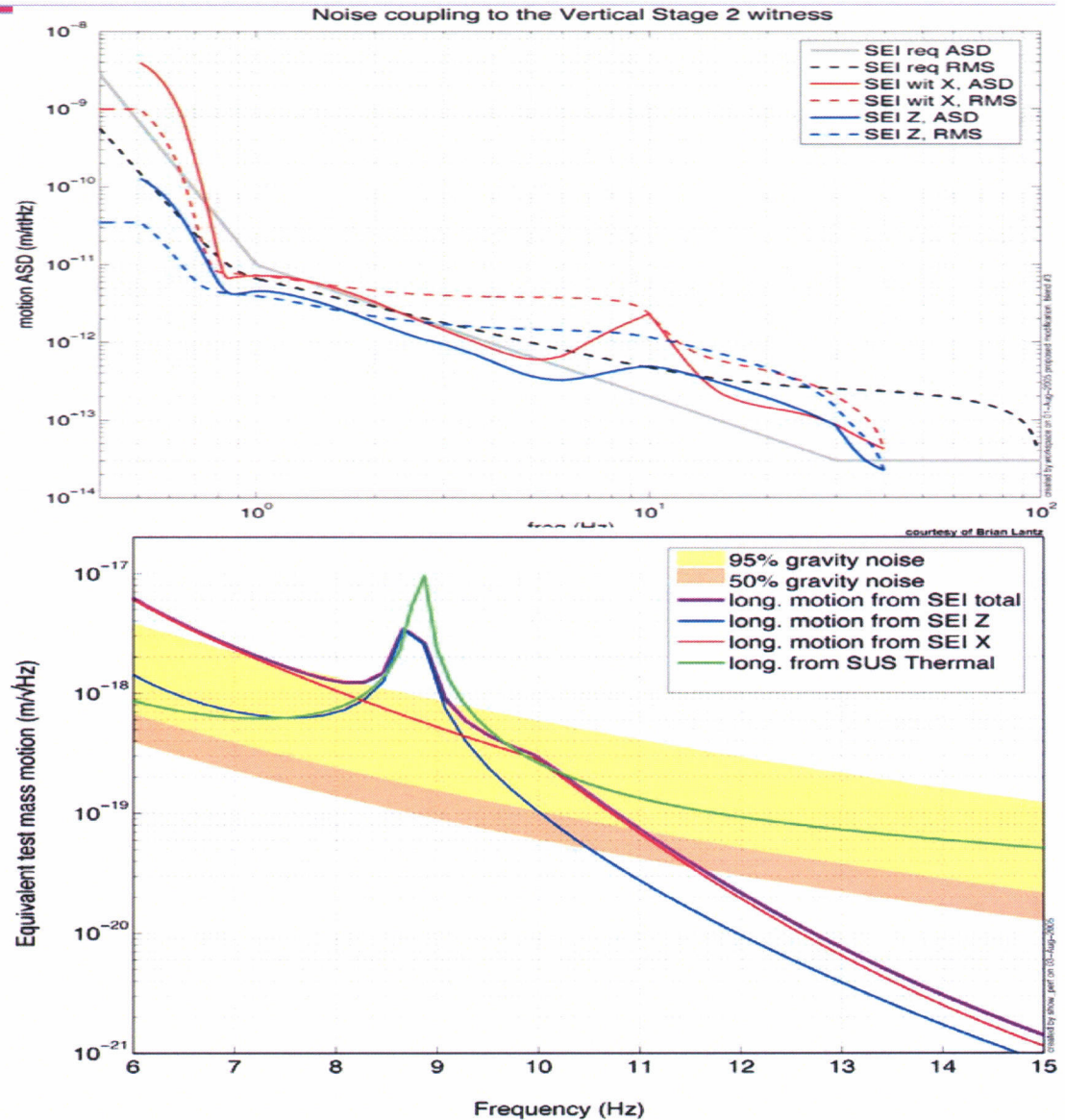
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Requirement	Value
Payload mass	800 kg
Range	± 1 mm, ± 0.5 mrad
Optics table noise	few $\times 10^{-13}$ m/ $\sqrt{\text{Hz}}$ (at 10 Hz)
Angular noise	1×10^{-8} rad RMS

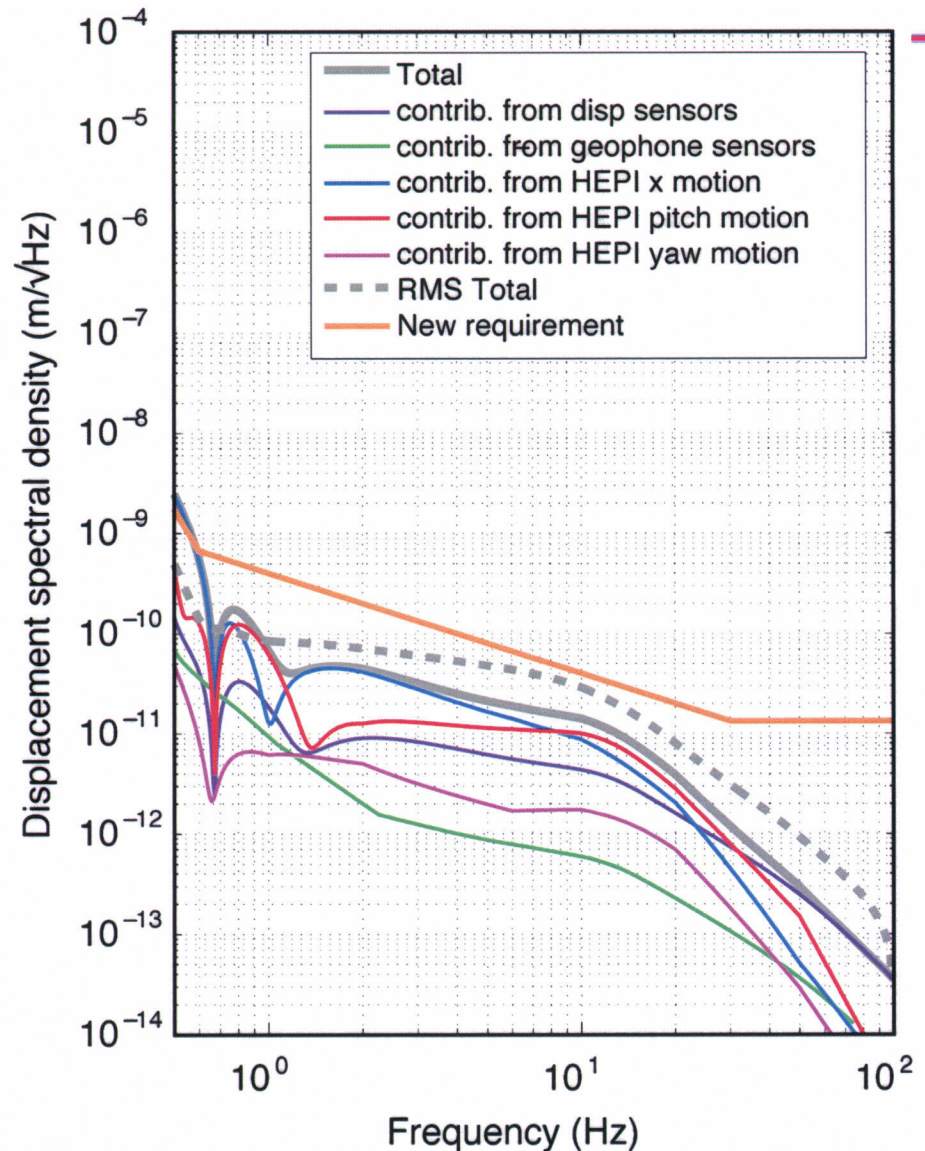
- HEPI isolates by factor of 10 over “double-frequency microseism” band up to about 2 Hz.
- ISI Isolation requirement is approximately a factor of 100 at 1 Hz and 1000 at 10 Hz
- Passive isolation in Quad pendulum provides bulk of isolation in GW band.
- Noise due to transmitted vibration below gravity gradient and/or suspension thermal noise over most frequencies.
- ISI presently not meeting strict requirement at 10 Hz due to vacuum tank resonance; Critical review held last year approved variance, though MIT experiments suggest new technique to recover difference.
- Payload: 800 kg
- Range: $\pm 1\text{mm}$, $\pm 0.5\text{ mrad}$
- Angular: $< 10^{-8}\text{ rad}$, 1–30 Hz.

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- Recently revised in light of better understanding of interferometer design.
- Single stage design chosen as baseline.
 - » Omitted second stage served to reduce 1–10 Hz noise; not needed for HAM payloads
- Payload 510 kg.
- Optics table motion: $< 4 \times 10^{-11}$ m/ $\sqrt{\text{Hz}}$ at 10 Hz.
- Yaw $< 10^{-8}$ above approx 0.5 Hz, factor of 10 higher when lower f 's included.
Pitch $< 10^{-8}$ rad



- **HEPI deployed successfully at Livingston, costs & performance understood.**
 - » Study underway to determine ideal configuration for LHO.
- **Results from Tech. Demo. at Stanford:**
 - » 12-DOF controllers.
 - » Measured instrument noise floors at required level.
 - » Active isolation factor at required level.
 - » Accommodation of reactive load (prototype SUS cage).
- **Prototype of BSC (tall tank, for test masses) for MIT Lab:**
 - » Mechanical procurement complete, assembly underway.
 - » New design of motion-limiting stops ensures safety of humans and sensors during assembly and operation.
 - » Electronics and data systems designed, fabrication underway.
- **Prototype of HAM (short tank, for aux. optics) for MIT Lab:**
 - » Fabrication to begin in one year.
- **Dynamic modeling carried out in 6 DOFs for HEPI and for ISI, tested against prototypes.**
 - » Joined ISI-Suspension model with full back-reaction is next step.

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