LIGO-II Seismic Isolation Development

By the seismic isolation team members* at

Stanford, MIT, JILA, LLO and LSU.

August 15, 2000

Abstract

This talk is an overview of the last 6 months of development towards a LIGO-II seismic isolation system, as well as an outline of out long-term plans.

*G. Allen, S. Chatterji, S. Cowley, D. DeBra, J. Giaime, G. Hammond, C. Hardham, J. How, W. Hua, W. Johnson, L. Jones, B. Lantz, K. Mason, S. Richman, J. Rollins, G. Stapfer, R. Stebbins. . .

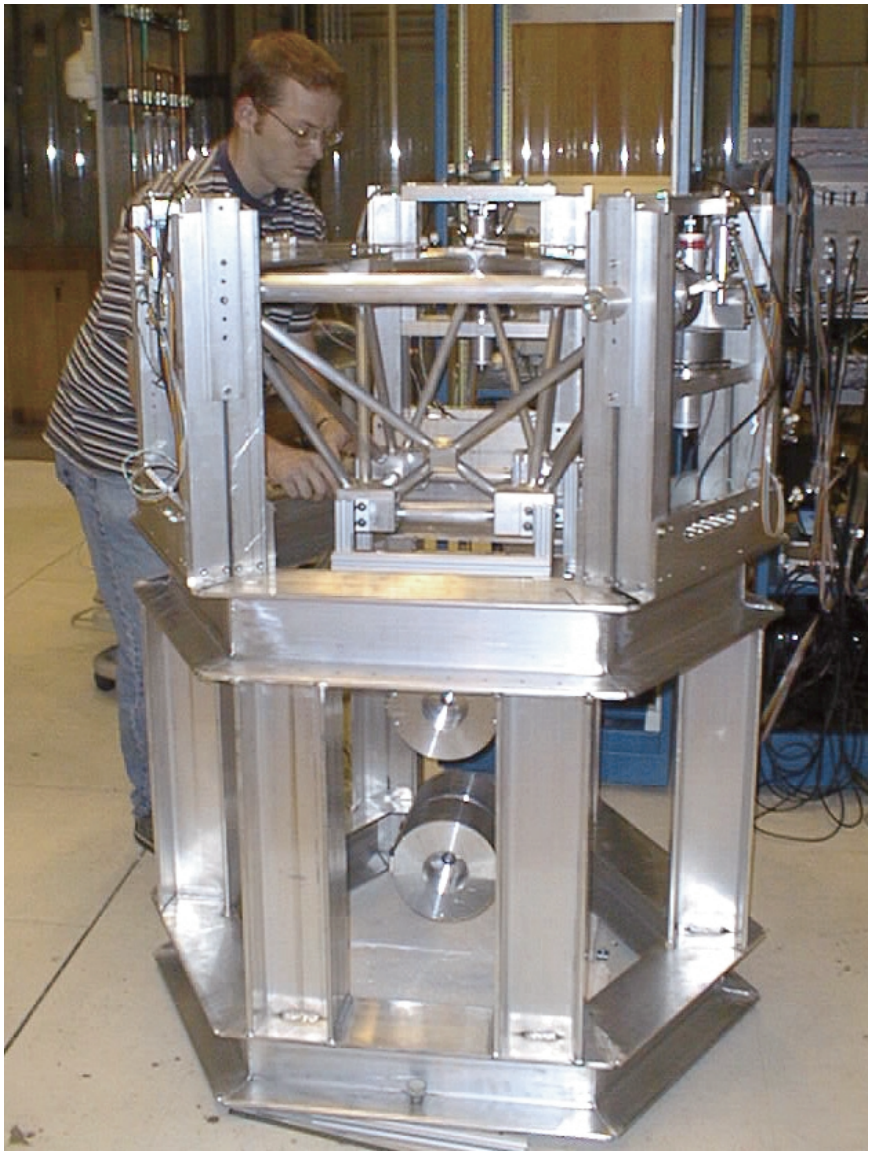
LIGO-G000266-00-D

Talk outline

- Experimental progress
  - Active platform with pendulums
  - Two-stage active platform
  - Hydraulic actuator
  - Voice coil actuator tests
- Modelling progress
  - "Constructor" development
  - Parameter variation analysis
  - System ID n
- Development plan
  - Prototype at ETF
  - Technology development
  - Pathfinder platforms for LASTI
  - Production at LLO

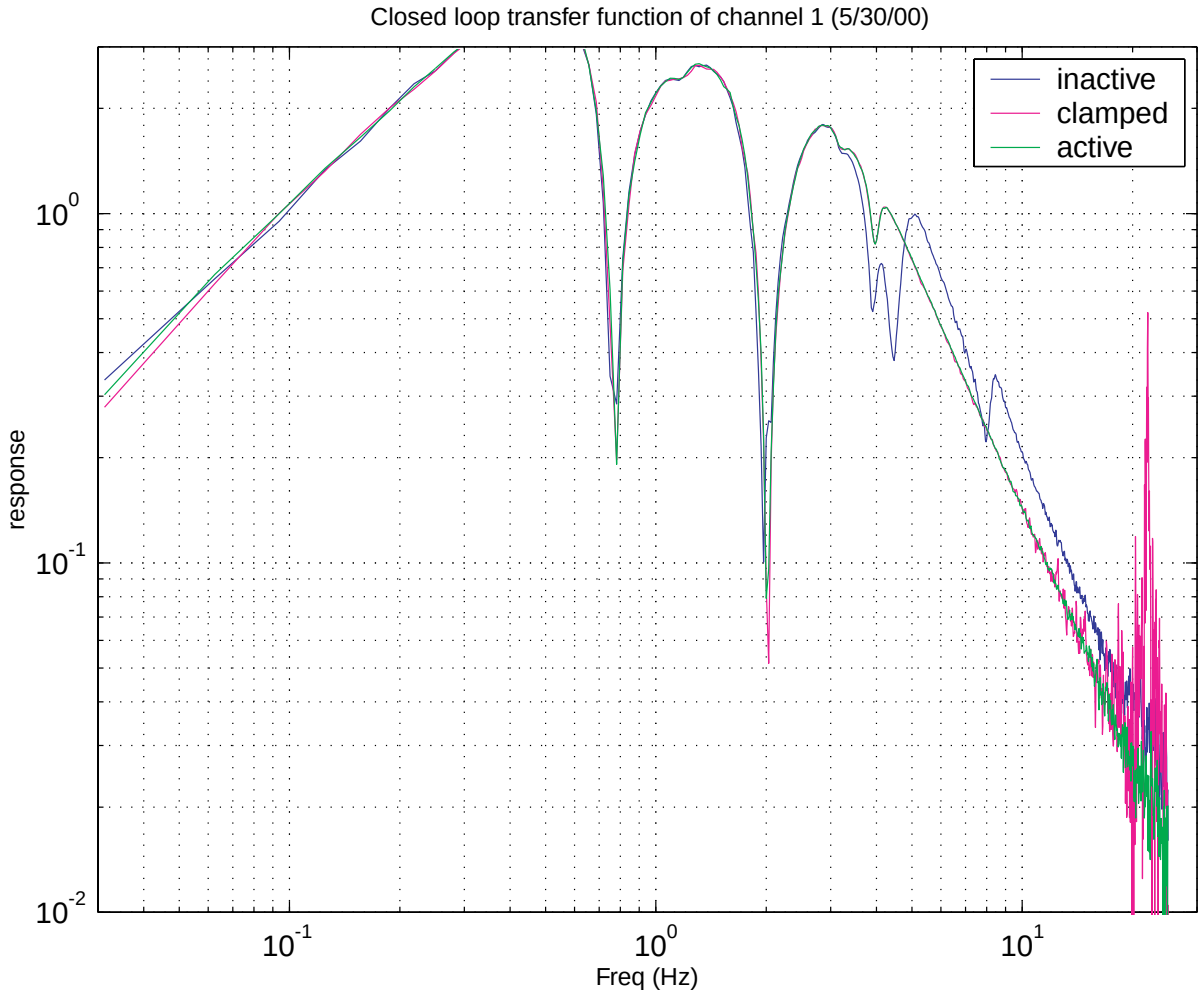
Stanford active platform with pendulums

- Two back-to-back GEO-600-size triple pendulums supported by a single active isolation stage.



Stanford . . .

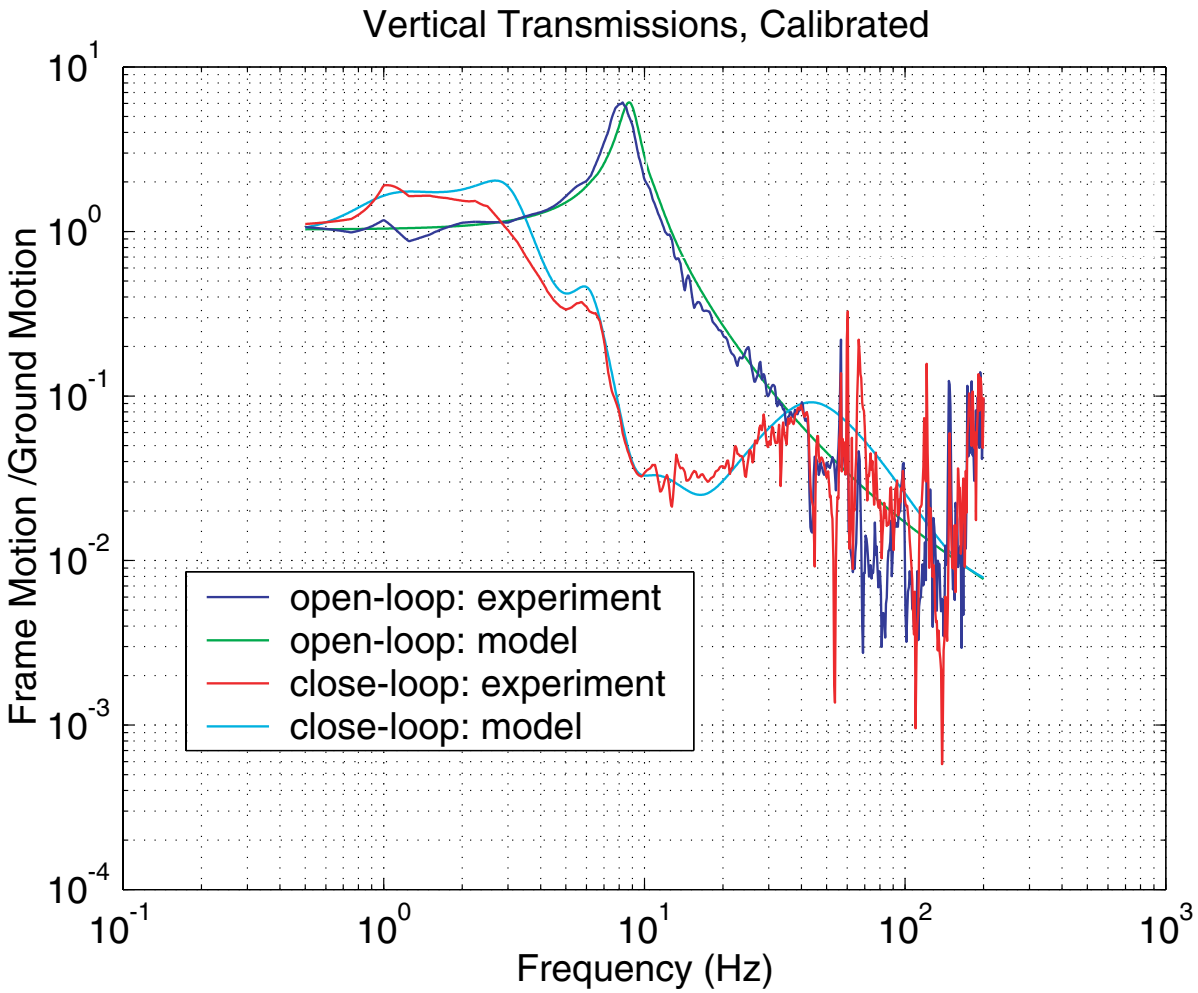
- Interaction between pendulum damping loops and active isolation servos. The pendulum damping loop behavior changes only slightly when the platform "lock state" is changed.



Stanford . . .

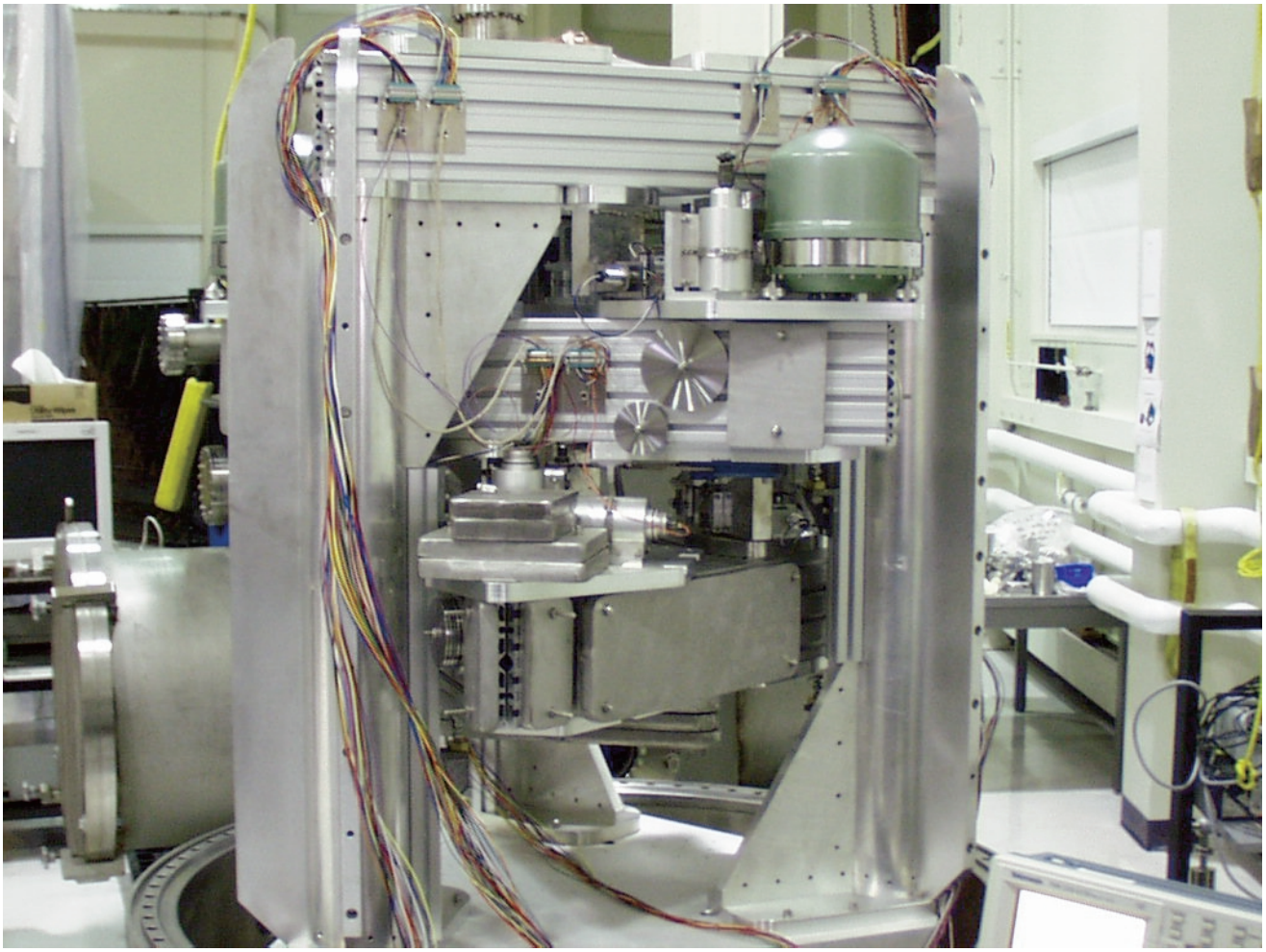
- SEI mock-up and SUS mock-up can function independently of each other

- 3-D dynamic / control model agrees extremely well with the measured plant and closed-loop performance.

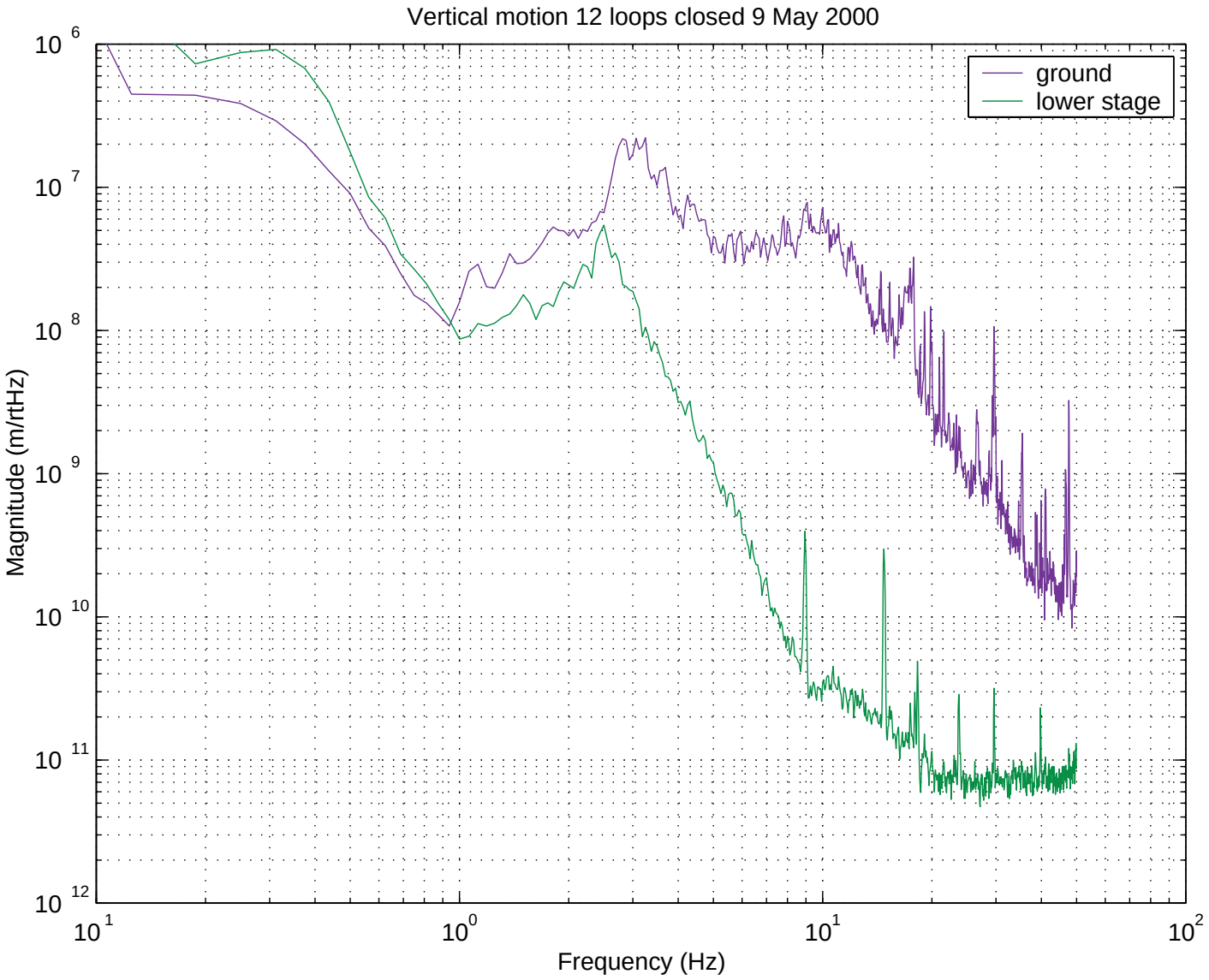


Two-stage active platform

- Two-stage active platform operated robustly closed-loop in 12 DOFs over multi-hour runs, using geophones and position sensors.

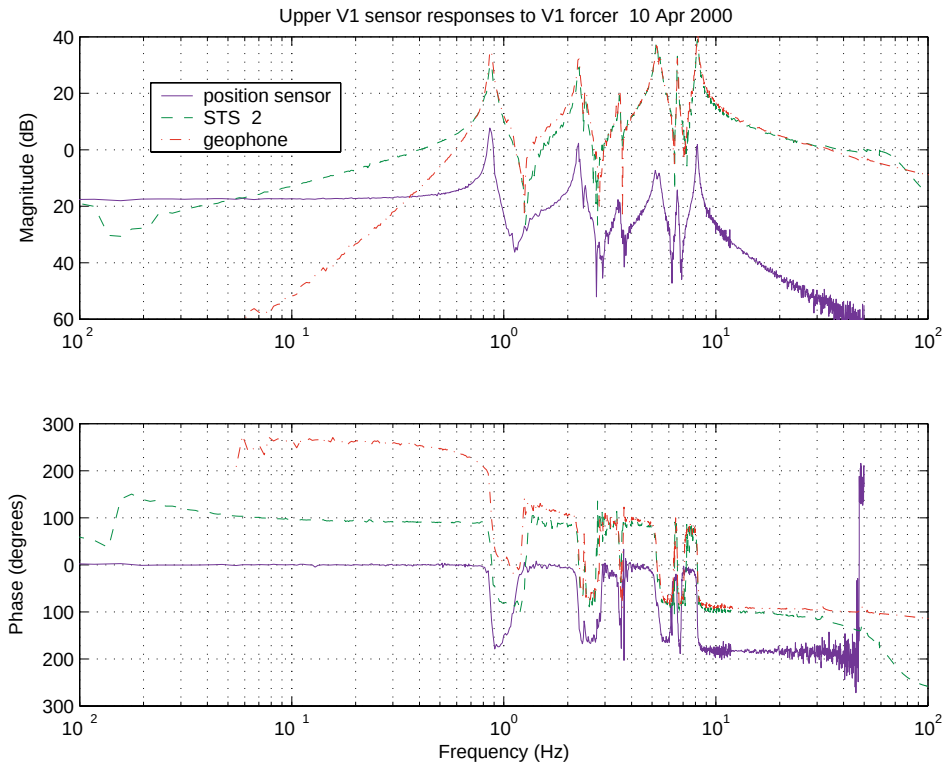


Two-stage. . .


Vertical motion 12 loops closed 9 May 2000
ground
lower stage
Magnitude (m/rtHz)
Frequency (Hz)
10^6
10^7
10^8
10^9
10^10
10^11
10^12
10^1
10^0
10^1
10^2

Two-stage. . .

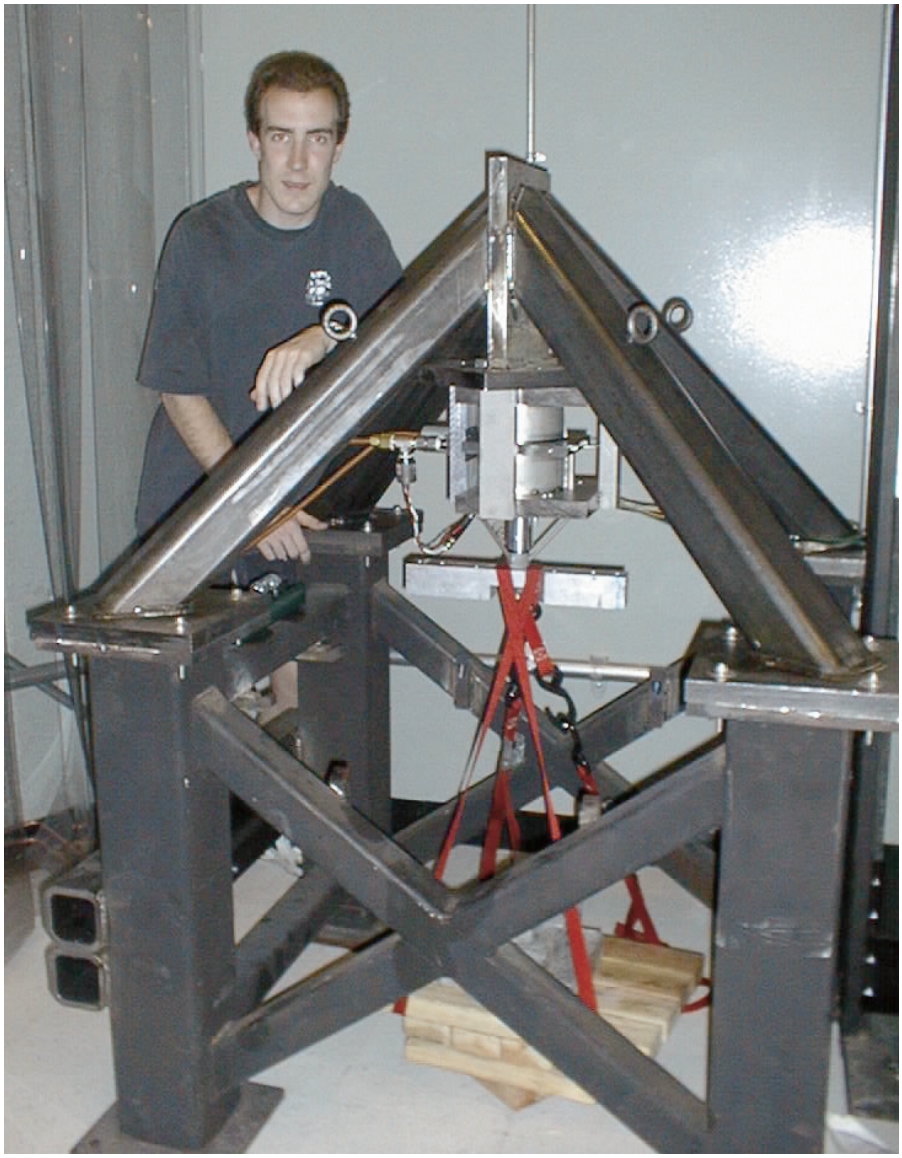
- Stable controller for 4 of 6 low-frequency loops on upper stage tested, but still lack one that is stable for all 6.



- Two approaches underway to design final controller, one using a state space based on system ID, and the other using sensor- and actuator-correction matrices to overcome plant deficiencies.

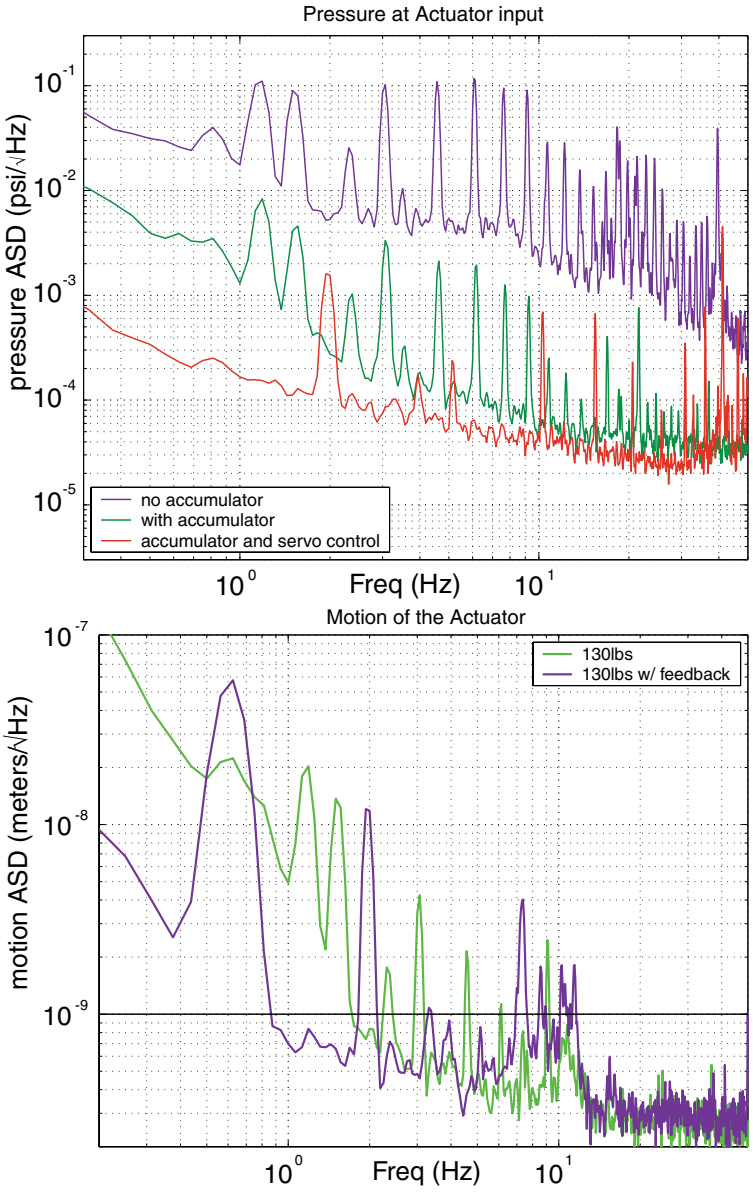
Hydraulic actuator

- Hydraulic external actuator under test using large load mass.



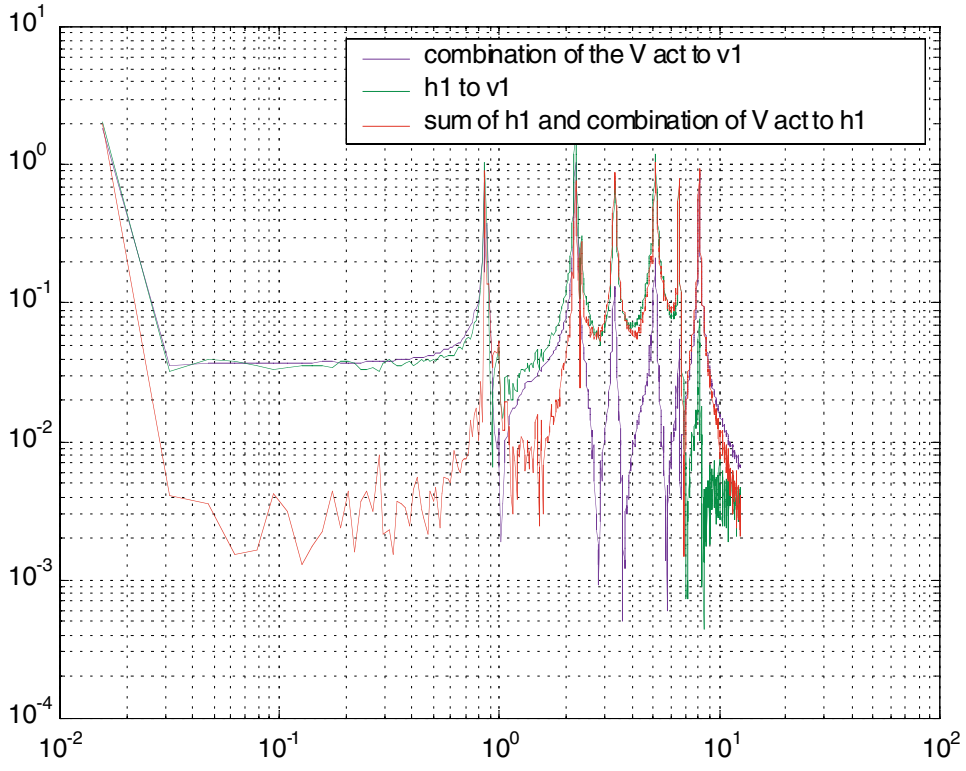
Hydraulic. . .

- Effects of hydraulic accumulator and flapper-valve fluid pressure servo studied.



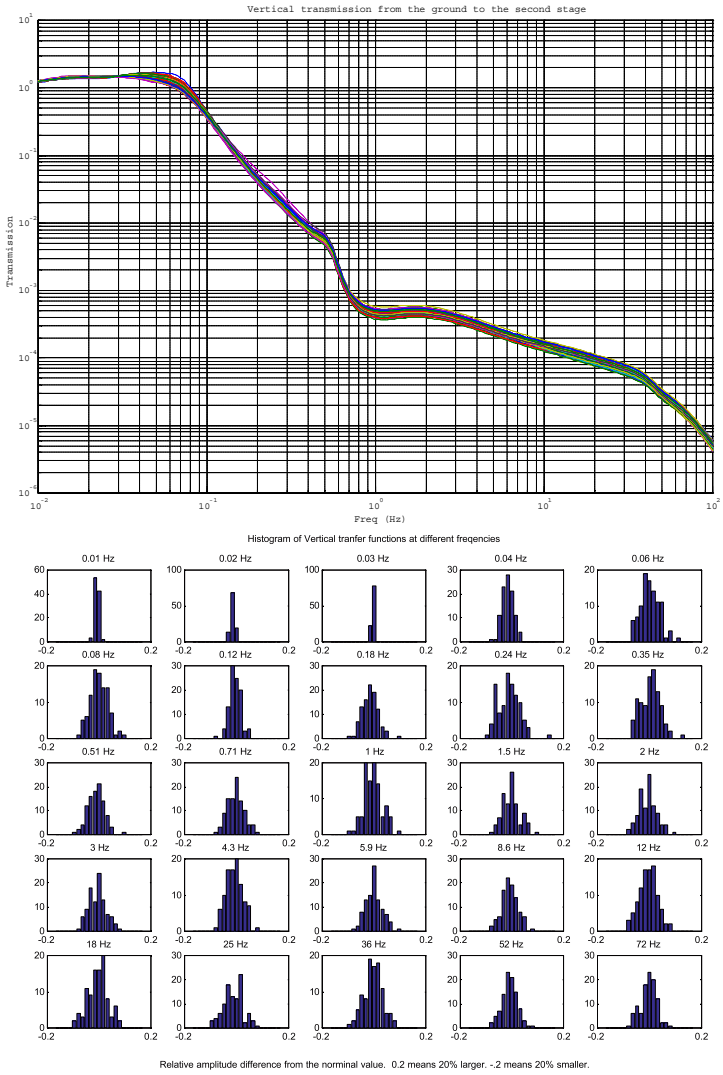
Modelling progress

- Added cross-coupling spring object, used to model the two-stage pre-prototype's blade flexure attachment.
- Added tilt sensitivity of horizontal seismometers
- Application of forcer correction to two-stage pre-prototype:



Modelling. . .

- Techniques developed to test modelled design for sensitivity to physical and control law parameter variation. e.g., Monte Carlo:



Development Plan

Prototype: We will design, build, and test at the Stanford ETF a full-scale prototype LIGO-II HAM SEI, using the same sensors, actuators, and control laws. This will greatly resemble the final LIGO-II design, but will not be UHV compatible, may not be be of the same materials and fab. methods, and will use dSpace control hardware. Its purpose is to develop the near-final versions of the control scheme and sensor/actuator designs. Work will continue at the ETF after the Pathfinder begins, to develop final "supervisory" system.

Engineering and design duties to be shared among the science groups, together with some "borrowed" LIGO engineers.

Pathfinder (A.K.A., Preliminary Design): LASTI experiments will begin early to mid 2002, and will need (tentatively) one HAM and one BSC SEI system installed by then. The systems we will build for this will be a nearly-final UHV-compatible design. We plan to build a HAM design for early '02 followed six months later by a BSC version. The purpose of these is to test the performance of the near-final design, as well as to test the installation and commissioning procedures.

Engineering and design process starts move LLO, pending hiring of engineers.

Final Design, First Article, Production: After the Pathfinders, design ought to be in a state where it can be bid out for component fabrication and procurement. Tentative plan is to carry out the SEI assembly, initial alignment, and component testing at LLO, followed by shipment to LHO or local installation.