AdvLIGO Modecleaner Design and Testing Status

Mark Barton

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LSC Meeting, LHO, 8/19/04

G040402-00-D

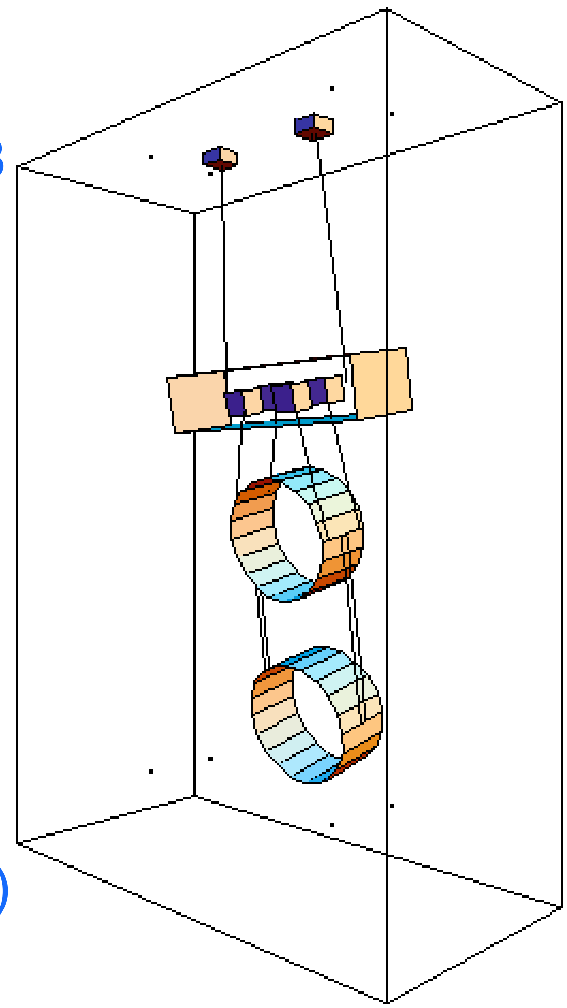
Requirements

- Design requirements for seismic platform + suspension (from T010007-01):
  - Longitudinal noise (all sources): 3×10^{-17} m/√Hz at 10 Hz, falling to 3×10^{-19} m/√Hz at 100 Hz (based on coupling to frequency noise)
  - Pitch noise: 3×10^{-14} rad/√Hz at 10 Hz, falling to 3×10^{-16} rad/√Hz at 100 Hz (assumes ±1 mm beam centering)
  - Yaw noise: 3×10^{-14} rad/√Hz at 10 Hz, falling to 3×10^{-16} rad/√Hz at 100 Hz (assumes ±1 mm beam centering)
  - Vertical noise: 3×10^{-14} m/Hz at 10 Hz, falling to 3×10^{-15} m/Hz at 100 Hz (assumes 0.001 coupling to longitudinal)
  - Transverse noise: 3×10^{-14} m/Hz at 10 Hz, falling to 3×10^{-15} m/Hz at 100 Hz (assumes 0.001 coupling to longitudinal)

LIGO

Conceptual Design

- Conceptual design given in T010103-03
- Based on GEO triple design
  - 2 maraging steel blade springs (on structure)
  - 2 wires
  - T-shaped upper mass (3 kg)
  - four maraging steel blade springs
  - four wires
  - fused silica intermediate mass
  - four fused silica fibres
  - fused silica optic (15 cm x 7.5 cm, 3 kg)



Analysis

- Matlab model by (Torrie et al.)
  - » Quick to run
  - » Models springs indirectly by adding their compliance to that of the wires
  - » Does not allow for asymmetries
- Mathematica model (Barton)
  - » More general but slower
  - » Useful as a double-check and to investigate effects of asymmetries

Normal Modes

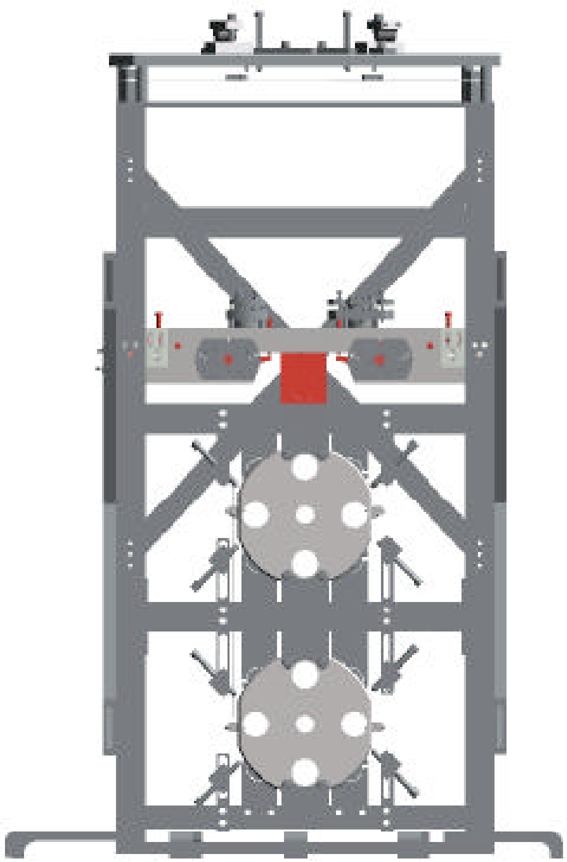
- 18 normal modes:
  - » all with anti-node at top mass for controllability
  - » all well below measurement band except for vertical and roll modes at 19.8 and 28.5 Hz

N	f_ref (Hz)	type
1	0.670382	x
2	0.677404	y
3	0.849997	pitch
4	1.08049	yaw
5	1.11008	z
6	1.5153	y
7	1.51551	x
8	2.03232	yaw
9	2.09333	roll
10	2.27611	roll
11	2.64008	x
12	2.7755	yaw
13	3.55017	pitch
14	3.57592	roll
15	3.91252	z
16	4.0387	pitch
17	19.8397	z
18	28.5362	roll

Controls Prototype Purpose/Limitations

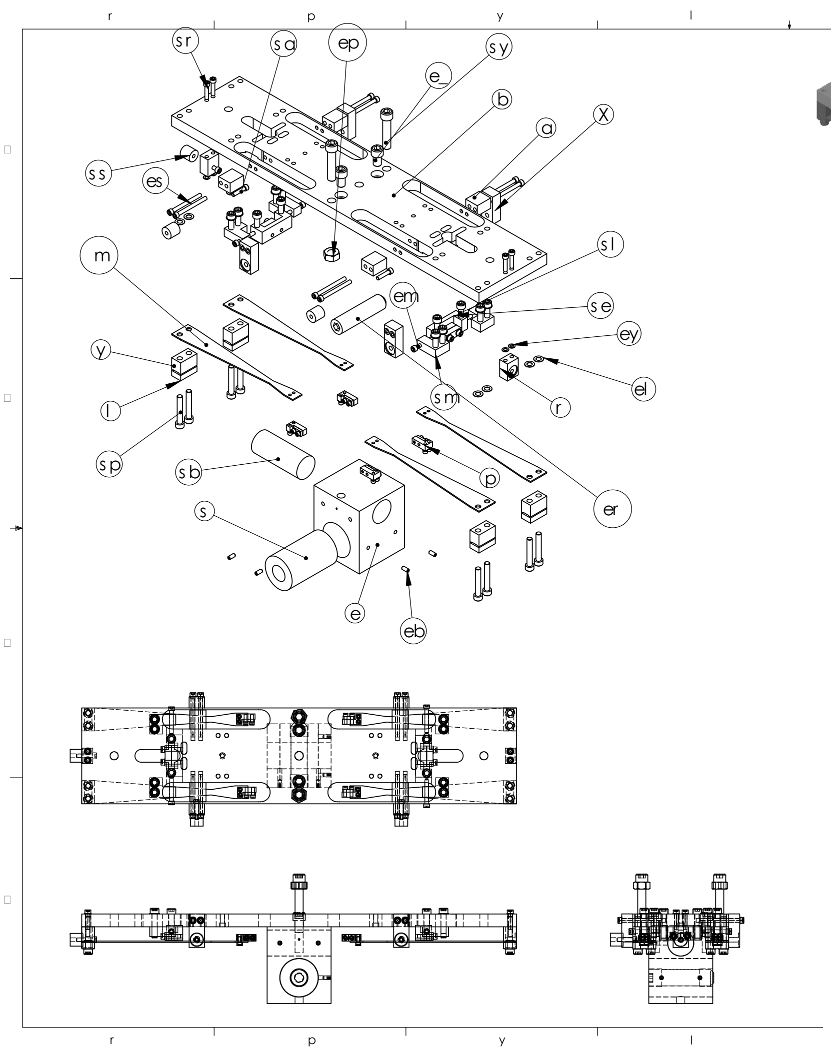
- For test of mechanical behaviour, assembly techniques, local control
  - » 6 “hybrid” OSEMs (LIGO-I sensor, larger magnet/coil) on upper mass for local control (analog electronics by GEO)
- Limitations
  - » Preliminary structure design (does not yet meet 150 Hz internal mode requirement)
  - » Dummy masses for I.M. and optic (same mass, MOI)
  - » Wires instead of fibres between I.M. and optic (no attempt to match elasticities -> frequencies of highest frequency vertical and roll modes are unrepresentative)
  - » 4 LIGO-I OSEMs on each of I.M. and optic for monitoring position/pitch/yaw, and as a stand-in for future low-noise actuators for global control

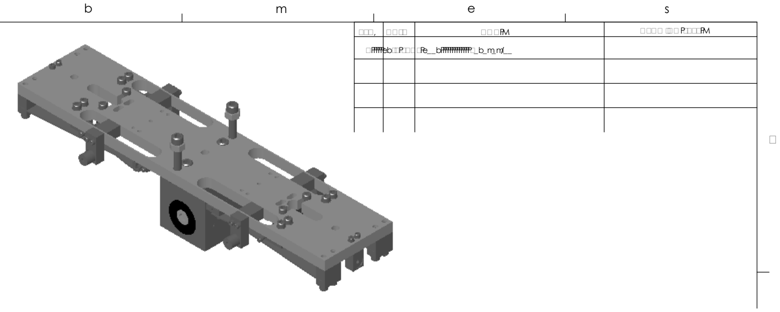
Controls Prototype Structure



- Footprint:
  - » 220 mm x 400 mm x 890 mm
- Mass
  - » Suspended - 9 kg
  - » Non-suspended - 18 kg
  - » Bare structure - 11 kg
- Centre of gravity
  - » 365 mm from bottom

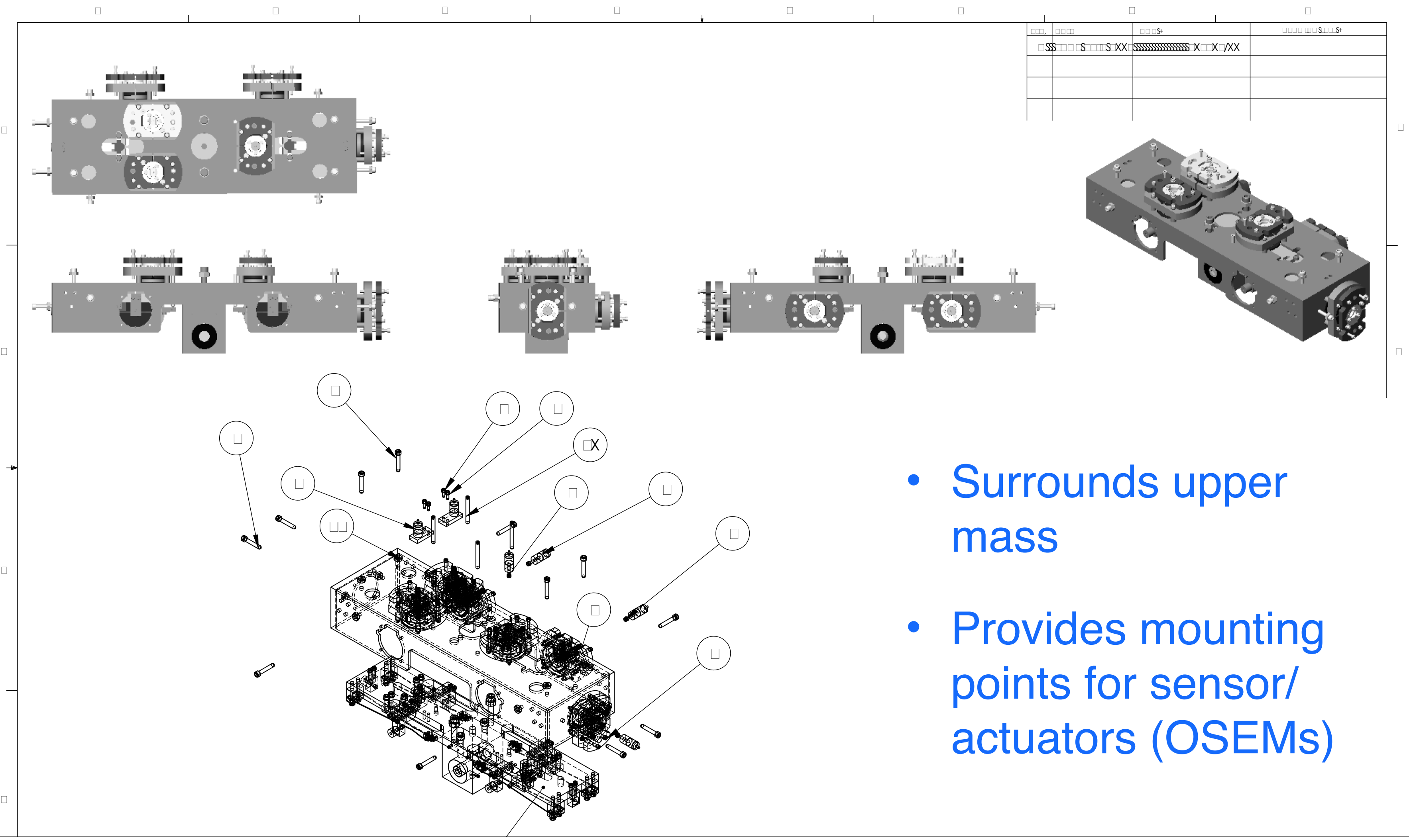
Upper Mass





- 4 blade springs for vertical isolation
- T-shape for COM positioning
- Trim weights for pitch/roll adjustment

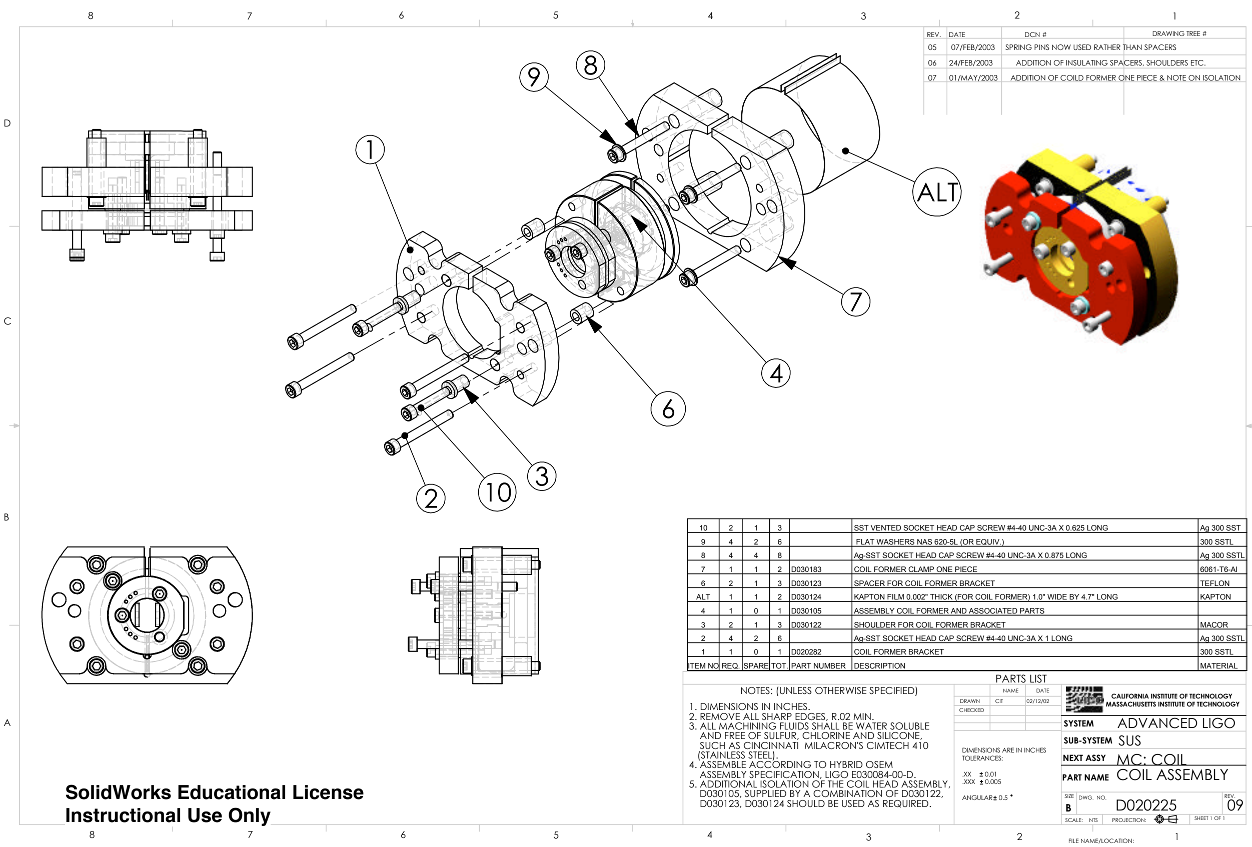
“Tablecloth”



- Surrounds upper mass
- Provides mounting points for sensor/ actuators (OSEMs)

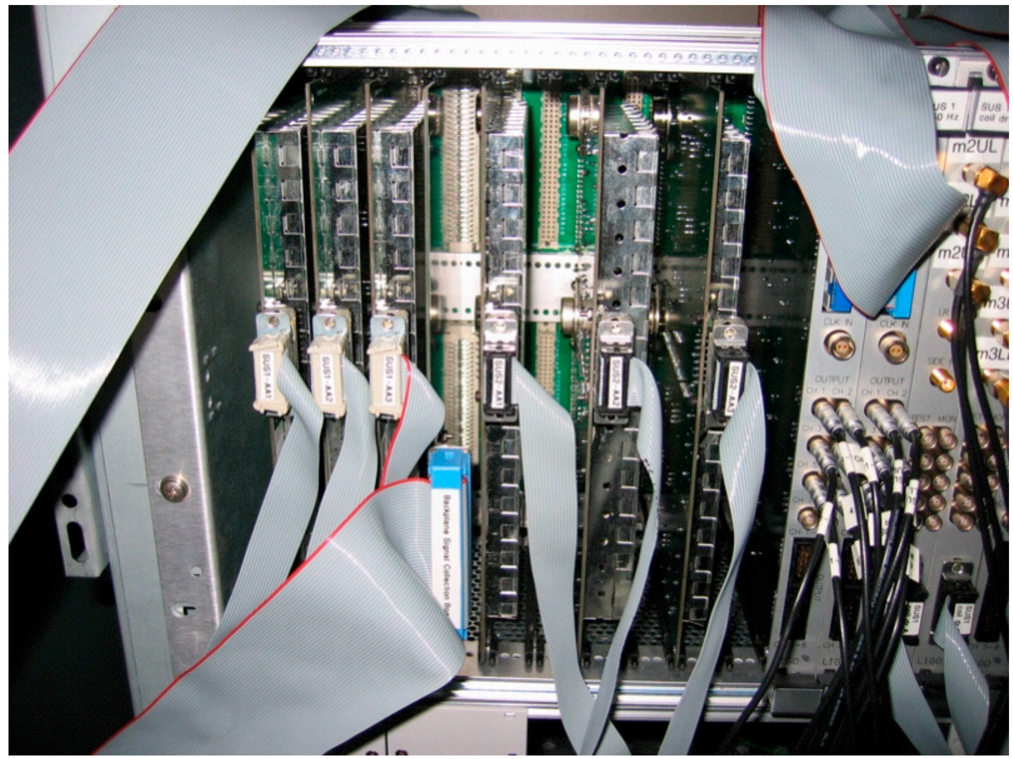
Hybrid OSEM

- Shadow sensor identical to that in LIGO-I OSEM
- Larger coil to accommodate larger magnet for greater force



Electronics

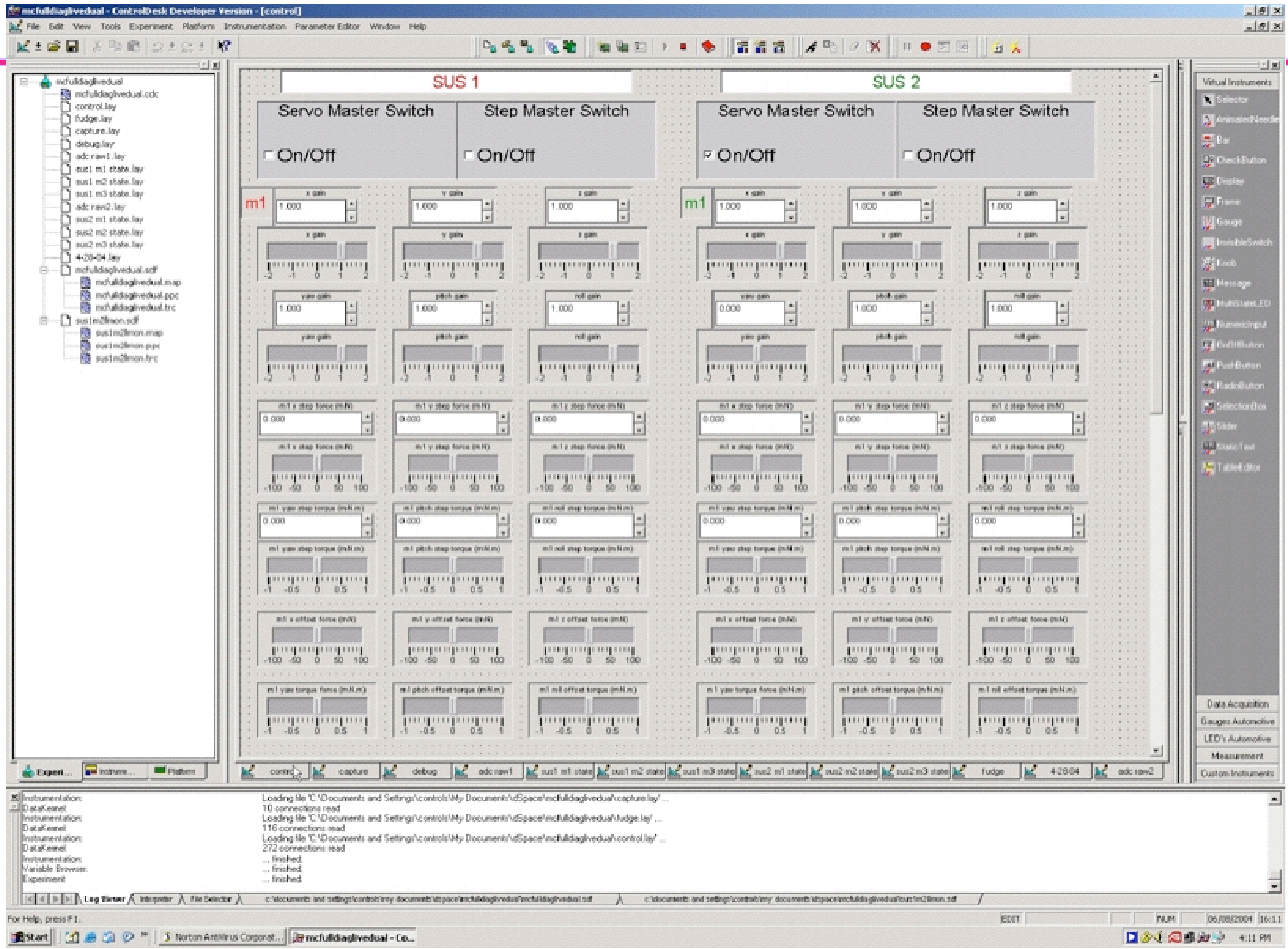
- dSpace digital controller (http://www.dspaceinc.com/)
  - » PPC processor in expansion box, linked to Wintel PC by optical fibre
  - » control algorithm programmed in Simulink on PC
  - » user-interface programmed in dSpace ControlDesk on PC
- Drivers for 6 hybrid OSEMs on upper mass by GEO
- Drivers for 8 LIGO-I OSEMs on lower masses and other analog electronics by CDS



Control Algorithm

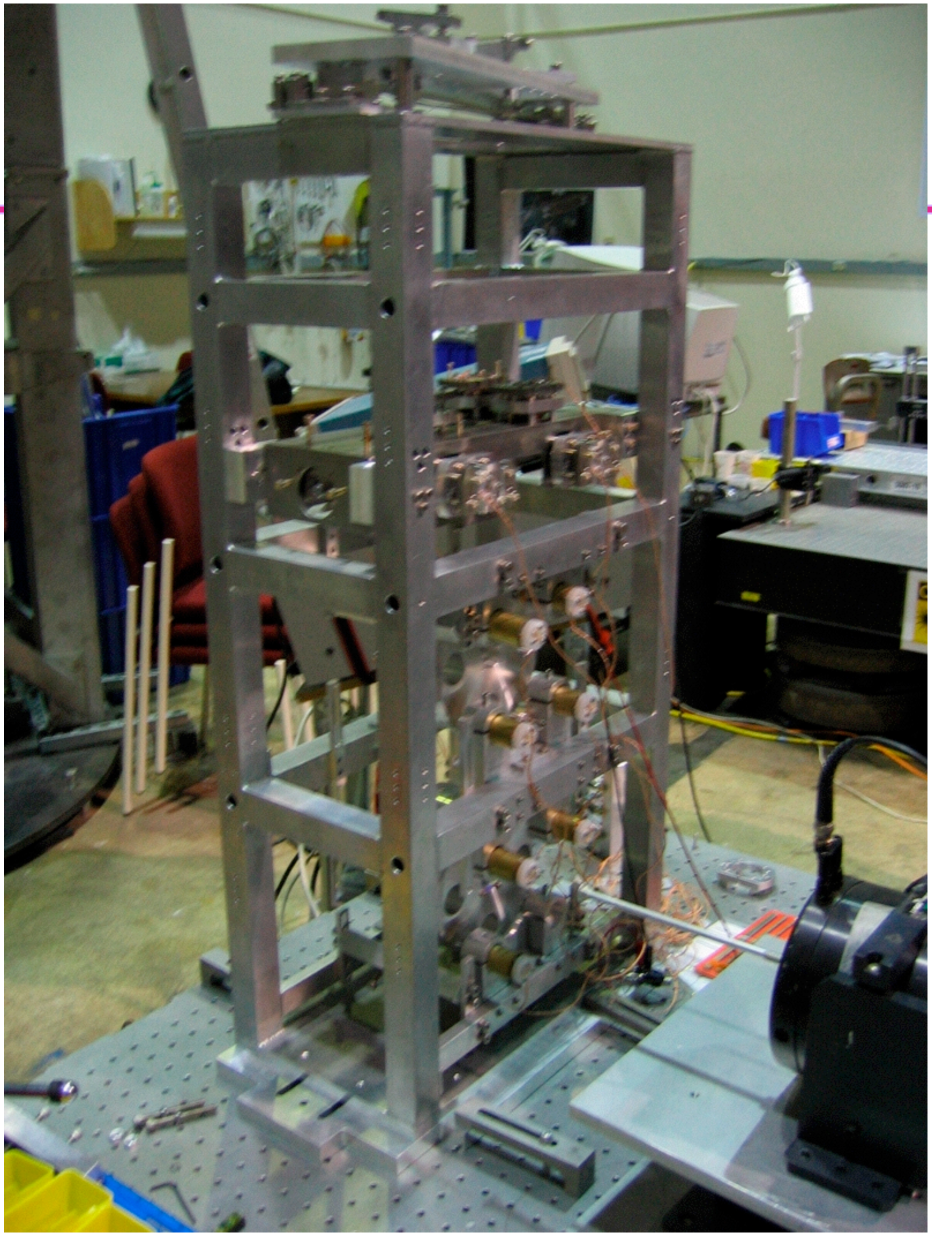
- Simple diagonalizing controller
  - » output from 6 hybrid OSEMs converted to x, y, z, yaw, pitch, roll
  - » standard GEO control law (velocity damping with rolloff above ≈10 Hz) in all DOFs
  - » de-diagonalization to individual OSEM drive signals

Controller UI (ControlDesk)



Mode Identification

- Mode identification measurements done in air at Caltech
- Shaker in swept-sine mode was applied to strategic points on structure to excite preferentially in x, y, yaw etc



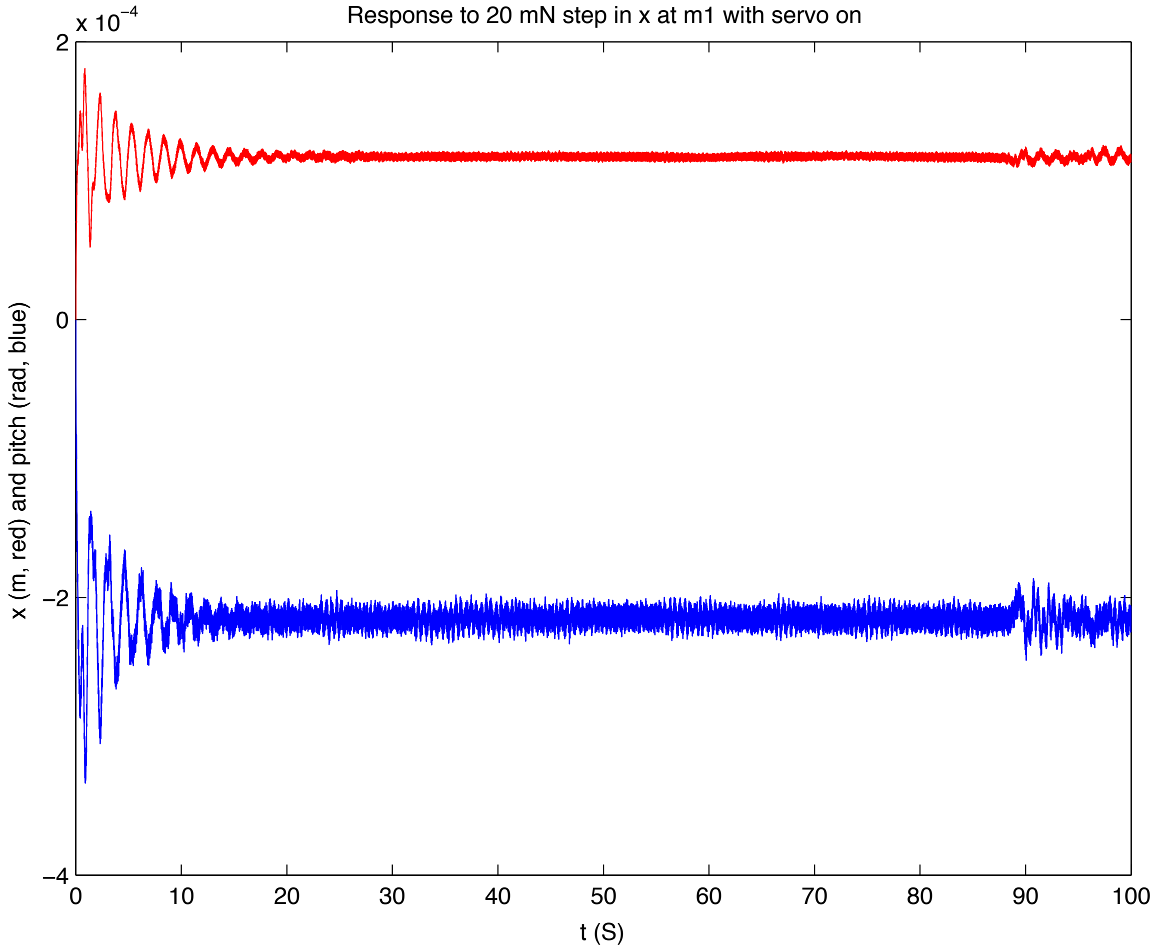
Mode Identification Results

- Theory:
  - » Mathematica model
  - » As-built parameters
  - » One fudge: set elasticity of “fibres” to reproduce highest vertical frequency
- Very good agreement (<10%) in other 17 frequencies

N	f (as-built)	f (meas)	type
1	0.667414	0.66	x
2	0.673777	0.671	y
3	1.05552	1.172	pitch
4	1.08668	1.094	yaw
5	1.1875	1.125	z
6	1.53096	1.516	y
7	1.53112	1.518	x
8	1.95707	1.742	yaw
9	2.22731	2.141	roll
10	2.74927	2.672	roll
11	2.82618	2.813	x
12	3.53868	3.563	yaw
13	3.61966	3.75	pitch
14	3.76754	3.578	roll
15	4.33279	4.047	z
16	4.84859	4.813	pitch
17	34.5714	34.875	z
18	49.1598	49.875	roll

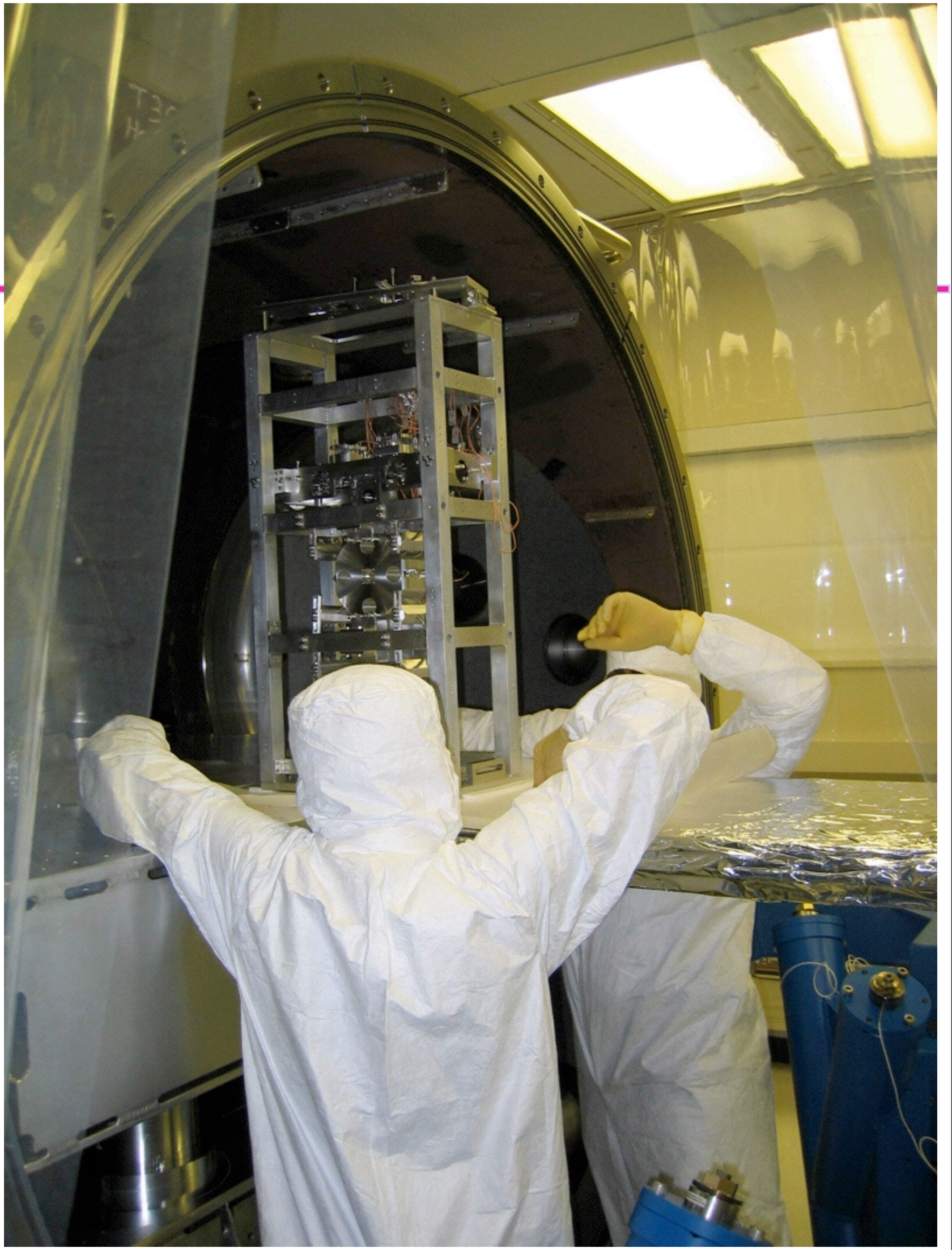
Damping Response

- Preliminary damping results in air at Caltech
- Good damping in all modes



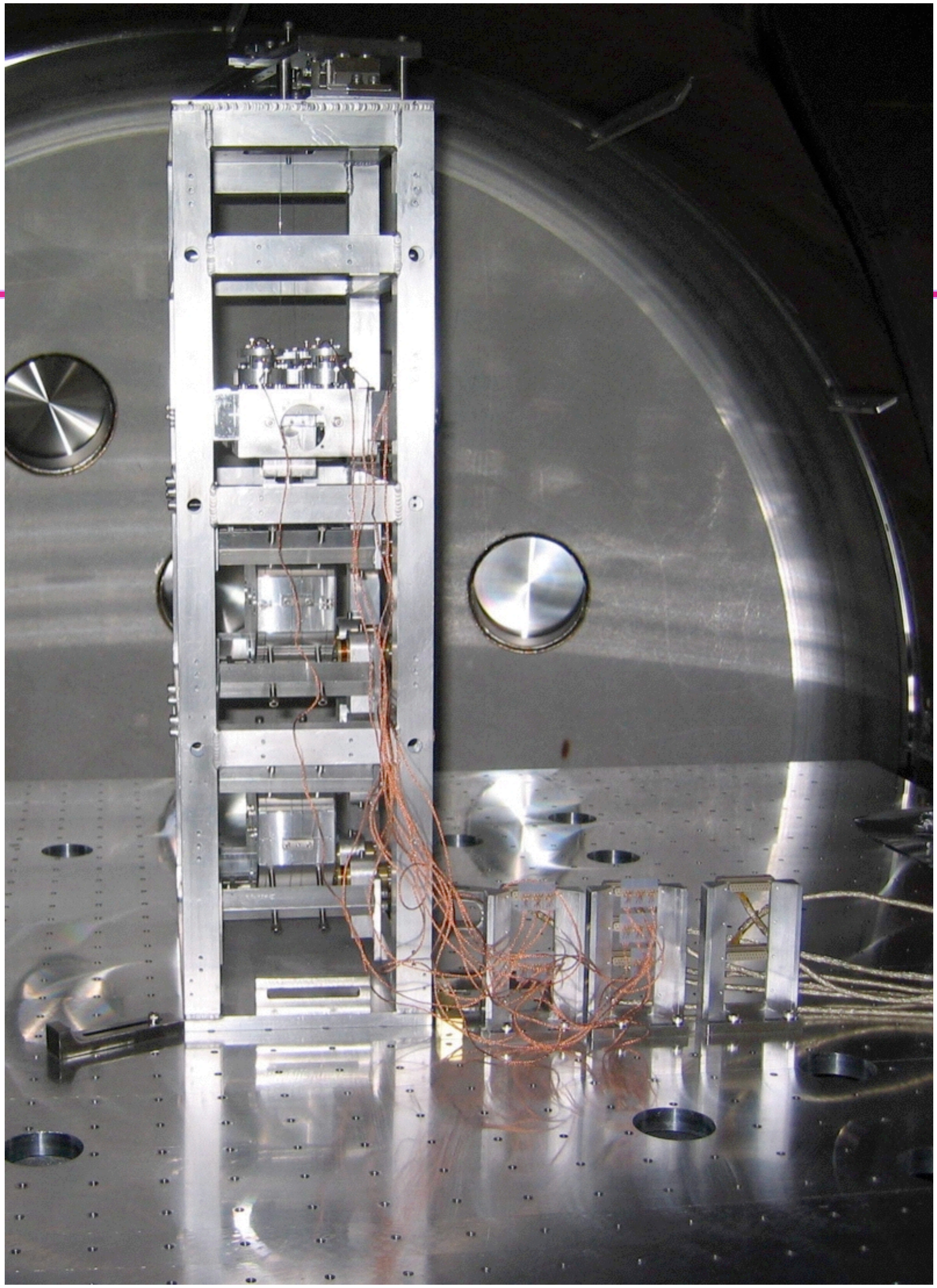
Installation

- Structure is manhandled onto bed of forklift and raised to level of HAM optical table
- “Teflon highway” is used to slide structure into position
- Structure was tipped onto one edge to allow removal of highway - need a safer procedure



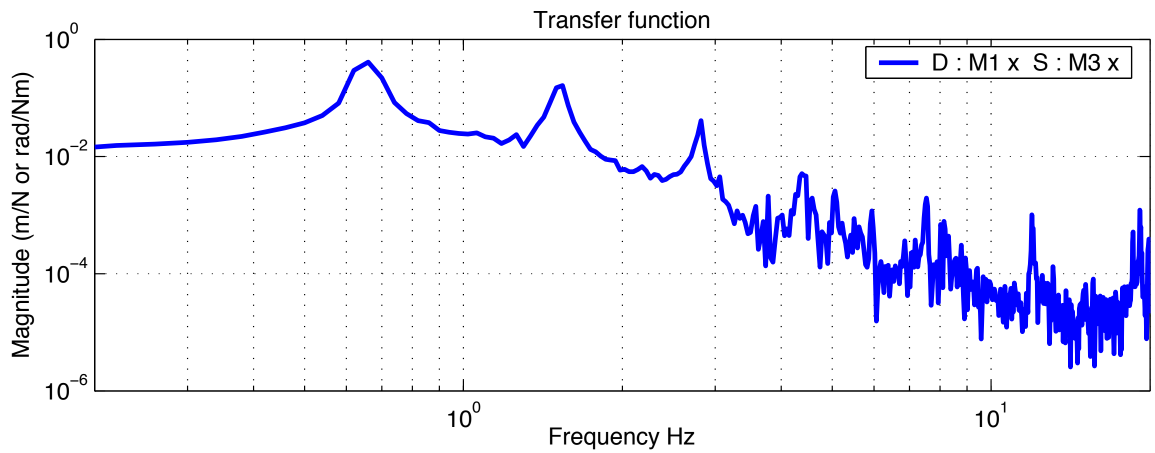
In Position

- After installation and alignment in LASTI

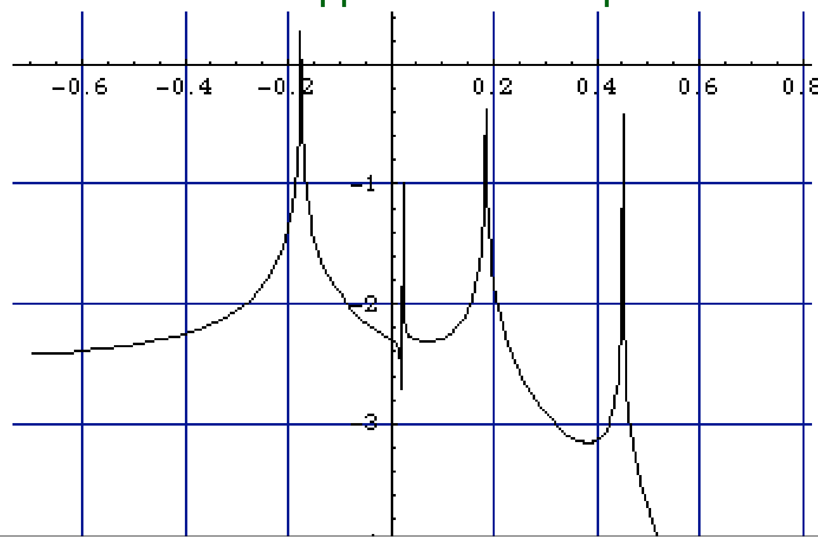


Transfer Function Results

- First transfer function results by Laurent Ruet at LASTI
- All combinations of OSEM actuator input to OSEM sensor output



Force in x at upper mass to displacement in x at optic



Future

- Continued testing at LASTI
  - » Use HEPI as shake table to do true displacement transfer functions
- Design team focussed on quad
- Structure needs beefing up to meet (or more closely approach) 150 Hz structure resonance goal
- Noise prototype with fused silica masses, fibres