



G060058-02

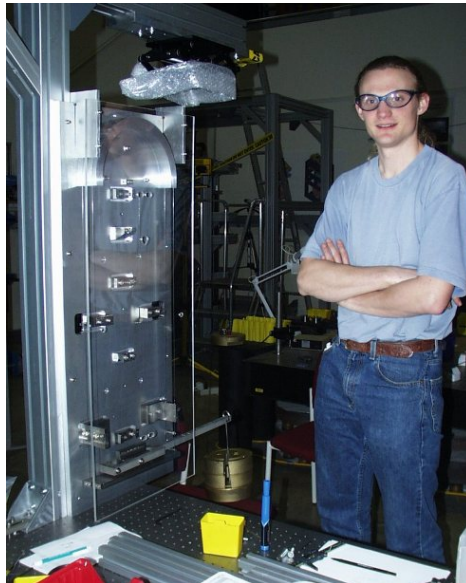
ALL-METAL CONTROLS PROTOTYPE QUADRUPLE PENDULUM SUSPENSION (ETM)

Calum I. Torrie

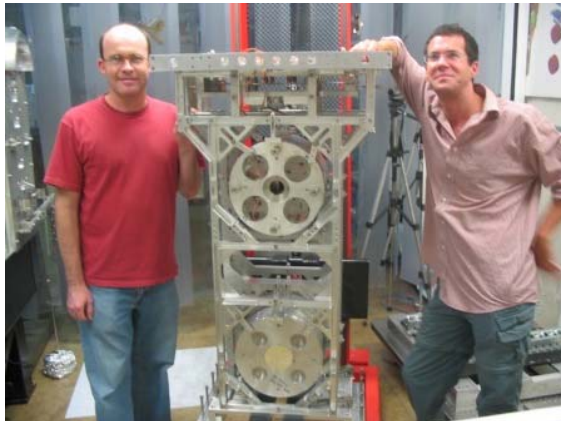
on behalf of the entire team involved in the work associated with the
controls prototype suspensions for Advanced LIGO

LSC MEETING SWG BREAKOUT SESSION
HANFORD MARCH 2006

- Quad controls prototype
 - Pre-assembly (June 2005)
- Quad noise prototype
 - Parallel development in UK
 - Experience from controls



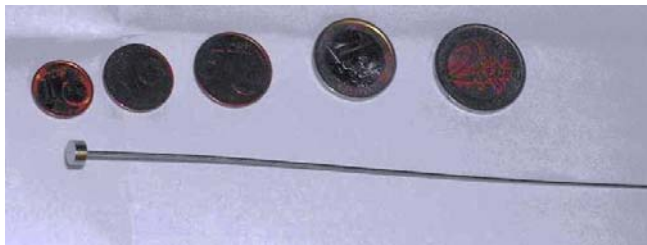
- Quad controls prototype
 - 1st build (August 2005)
 - Included drum ended wires
 - No slip, low creep material
 - No reaction chain or OSEMS
 - Working with UK (noise prototype)



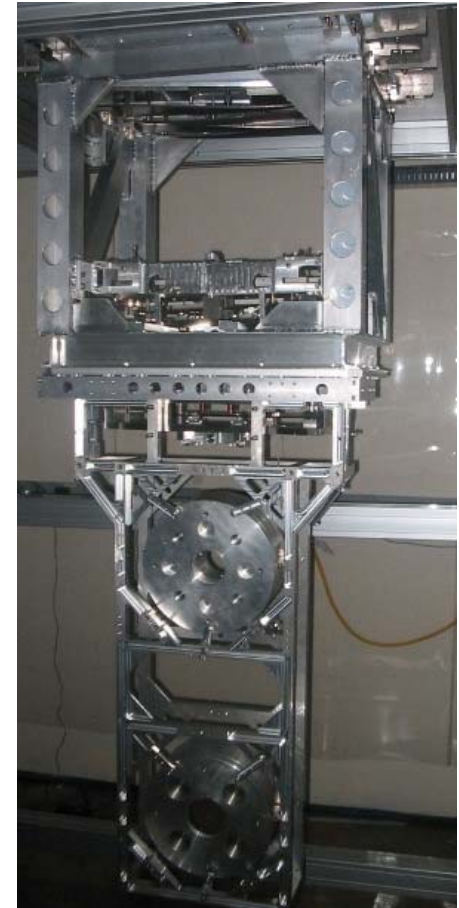
- In suspension, tested wires, broke

Drum Ended Wires

- Removed from base-line controls design
- Replaced by “capstan” device & regular wire
- Drum Wire (double nail) wires back into research mode
 - Found problem with post processing baking
 - New batch made and Rockwell hardness measured
 - 44 C (cf. VIRGO wire 45 C & wire from problem batch 30 C)
 - Currently with RAL for Young's Modulus & hysteresis testing
- Drum and capstan both being considered for noise prototype

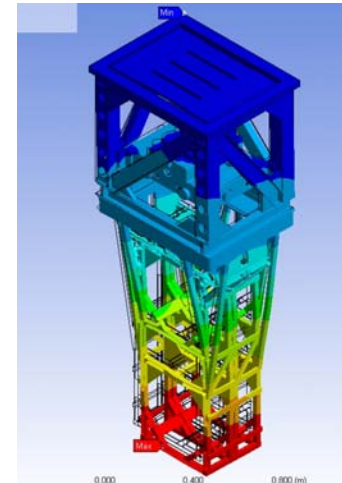
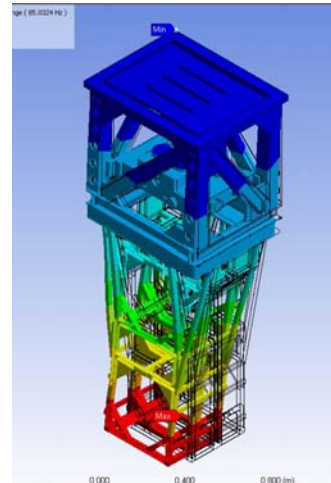


- Quad controls prototype
 - 2nd build (October 2005)
 - Capstan assemblies
 - Working with UK (noise prototype)



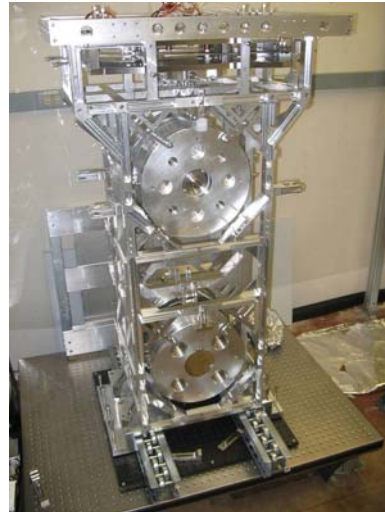
Suspension Structure

- FEA
 - Caltech, RAL Glasgow
 - 84 Hz and 93 Hz
(Long) (Trans)
- Experiment
 - Caltech, RAL Glasgow
 - 54 Hz and 63 Hz
(Long) (Trans)
- Reasons
 - Bolted connections
- 2nd structure going to UK in April for further testing



Caltech – Clean Assembly

- Quad controls prototype
 - 3rd build (December 2005)
 - Parts fully dis-assembled
 - Cleaned and baked on campus
 - Large oven
 - RGA Scans
 - Sync. High Bay clean room
 - Pre-assembled
 - Masses, wires
 - Re-assembled
 - 2 sections
 - Suspended



Caltech Clean room

- Repair – using single chain removal (January 2006)
 - global control coil at upper intermediate mass
 - Wire on electrostatic drive



17 March 2006

Advanced LIGO

G060058-02

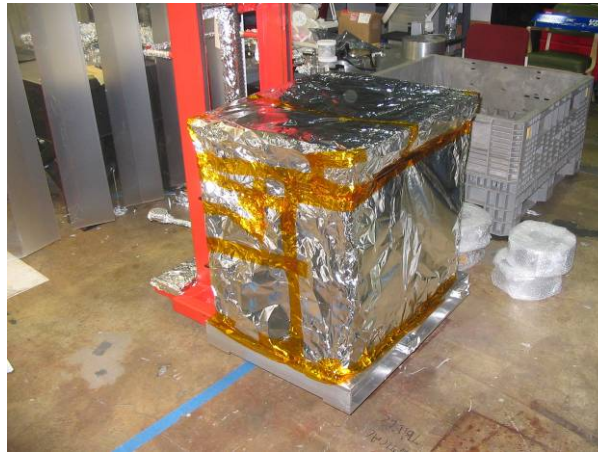
Packing for the road



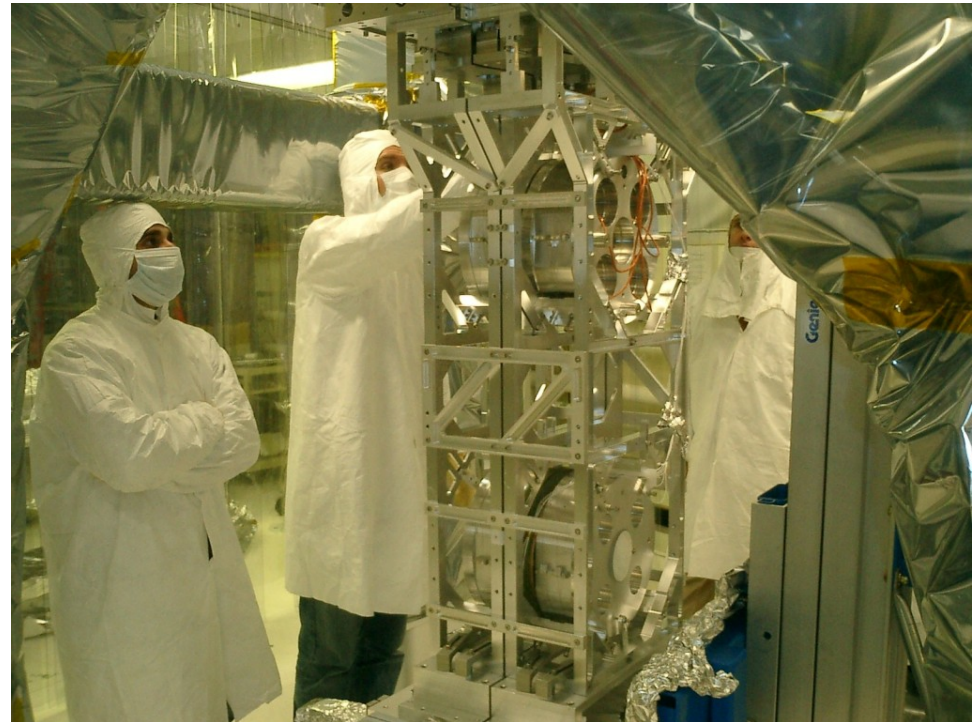
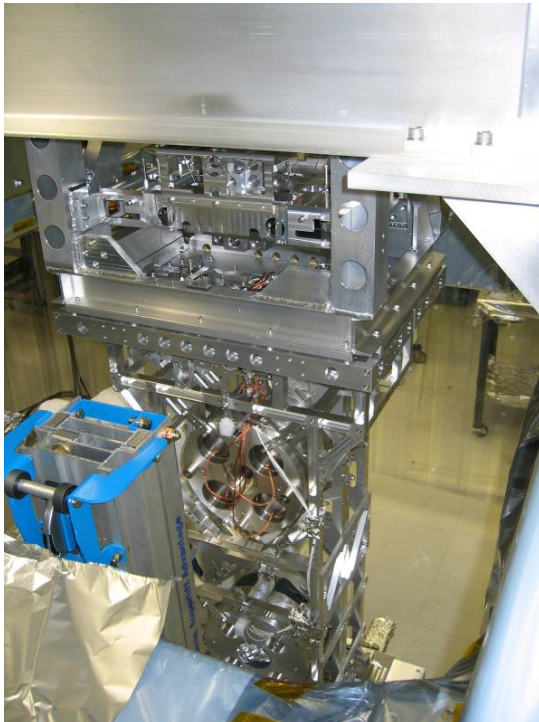
- Late January 2006

Caltech to MIT

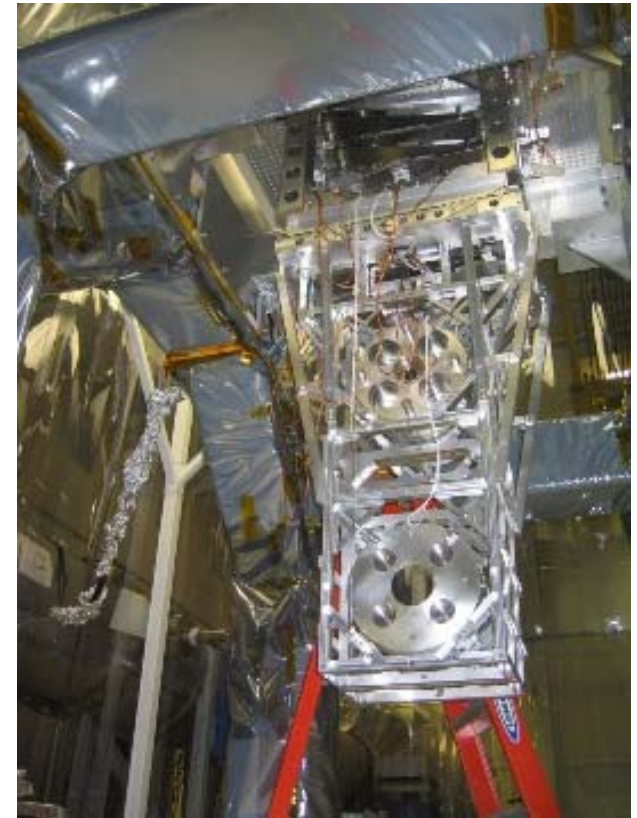
- Quad controls prototype (February 2006)
 - Shipped assembled
 - Stages locked down
 - Air ride truck with motion detectors
 - 2 sections
 - LIGO D040524
 - LIGO D040516



- Quad controls prototype (February 2006)
 - Assemble
 - From crates to mounting on the solid stack on the test stand

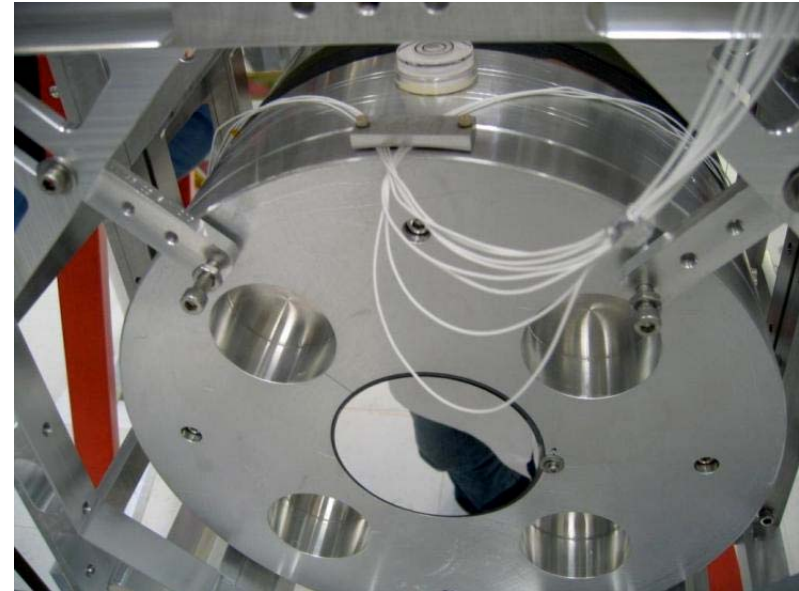
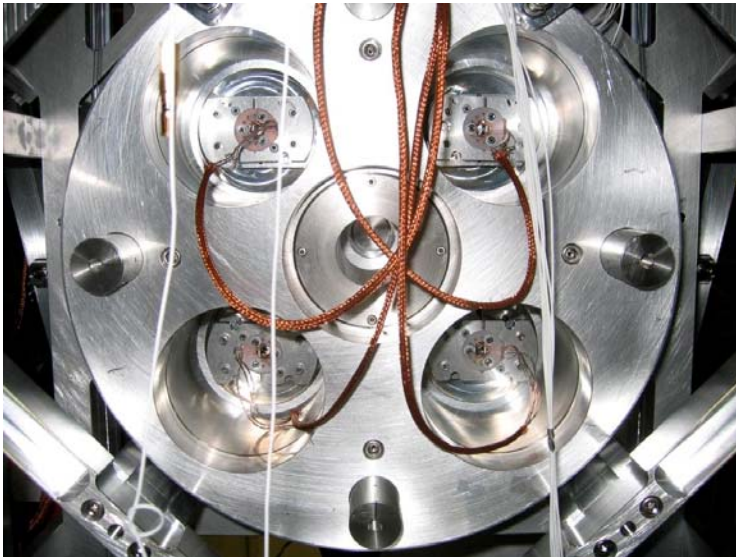


- Quad controls prototype (February 2006)
 - Suspend



- <http://www.ligo.caltech.edu/~ctorrie/quadatmit/quadatmit.html>

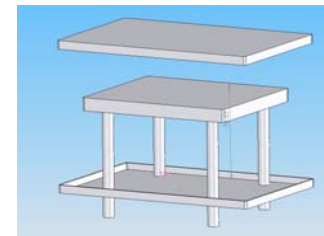
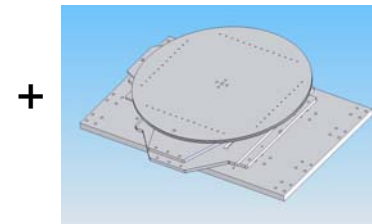
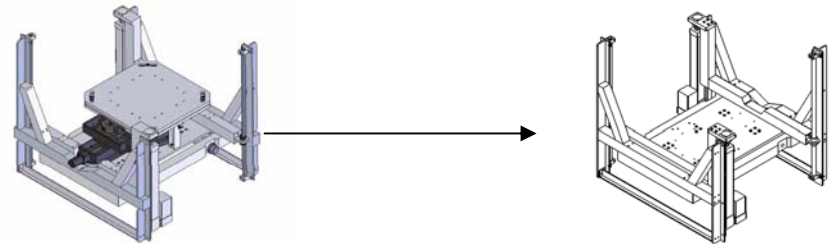
- Quad controls p-type (February 2006)
 - & align
 - Relative alignment of both chains $3/10^{\text{th}}$ milliradian in pitch & yaw



- OSEMS added after alignment completed

Install fixtures

- For Quad controls prototype
 - Mechanised Lift table
 - 300 lbs
 - Tested under 2000lb load
 - X, Y, Pitch, Rotation table
 - 300 lbs
 - Tested under 2000lb load
 - Vertical table (Alternative)
 - 300 lbs
 - Tested under 2000lb load

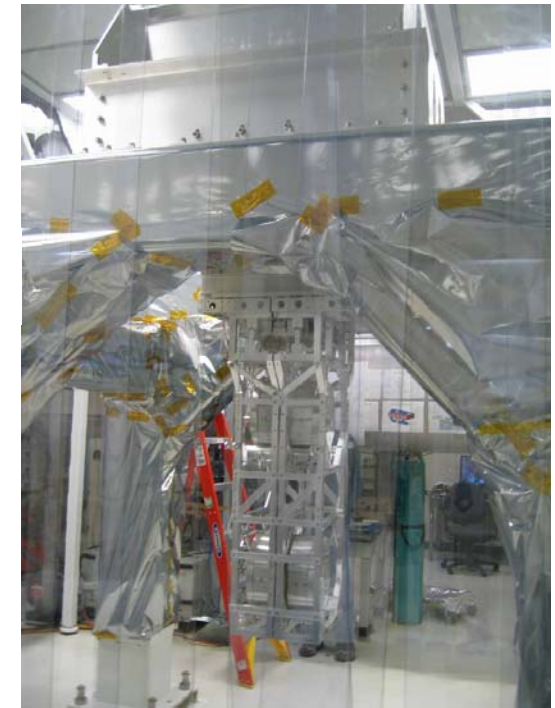


- Future





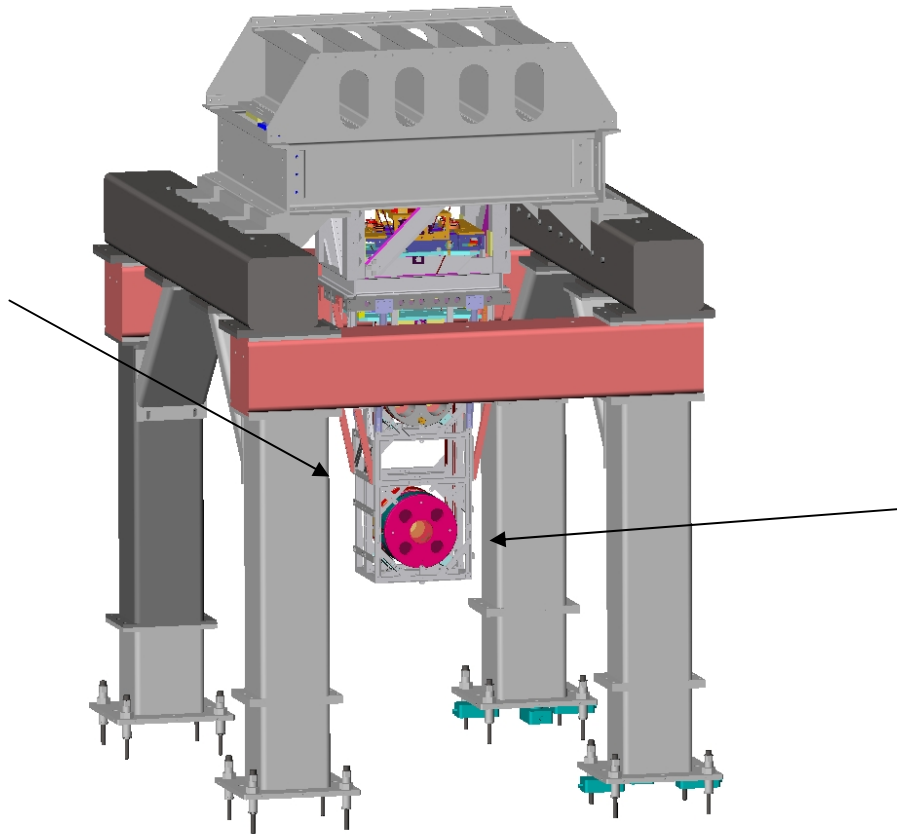
Now @ MIT



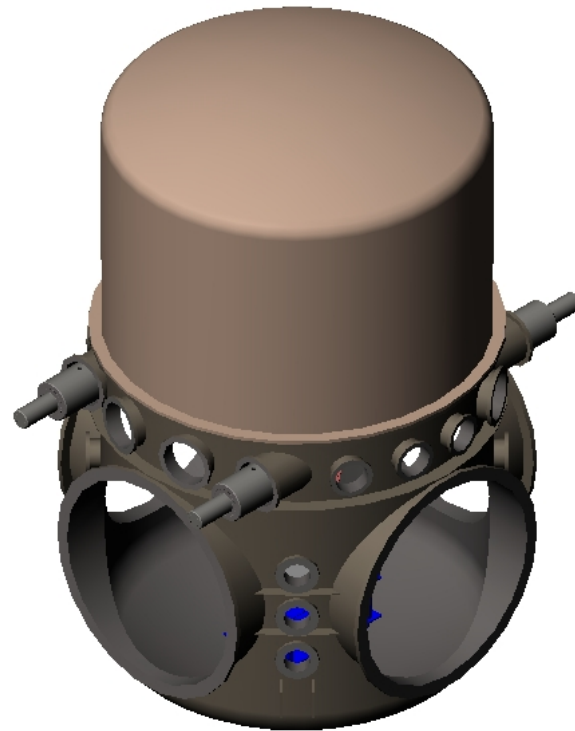
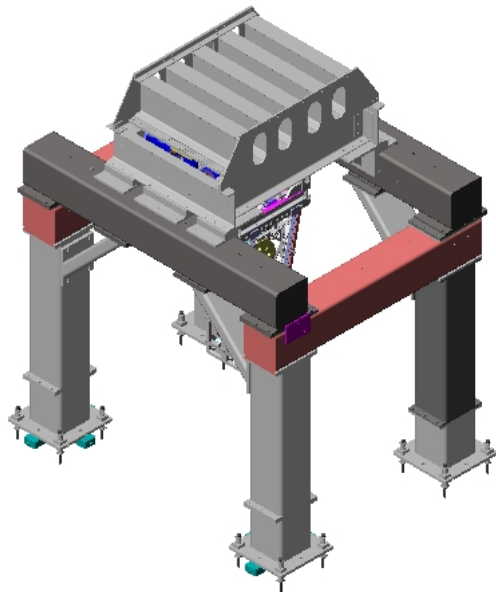
- method for suspending masses in the controls prototype suspension, by M. Barton, C. Torrie et al [LIGO-T060039-00](#)

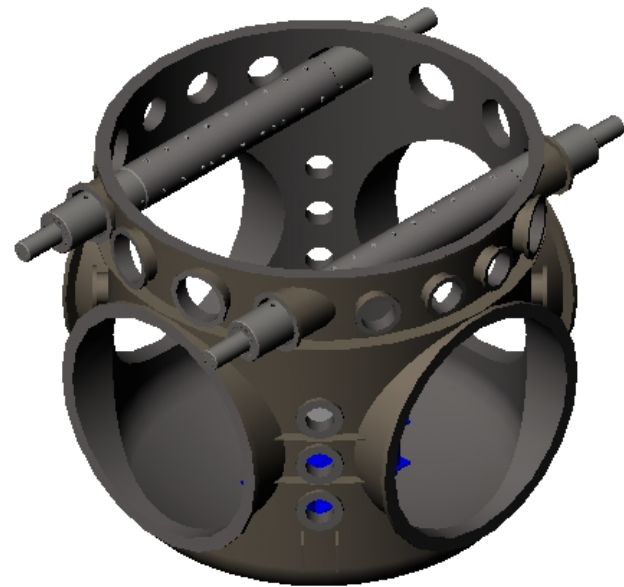
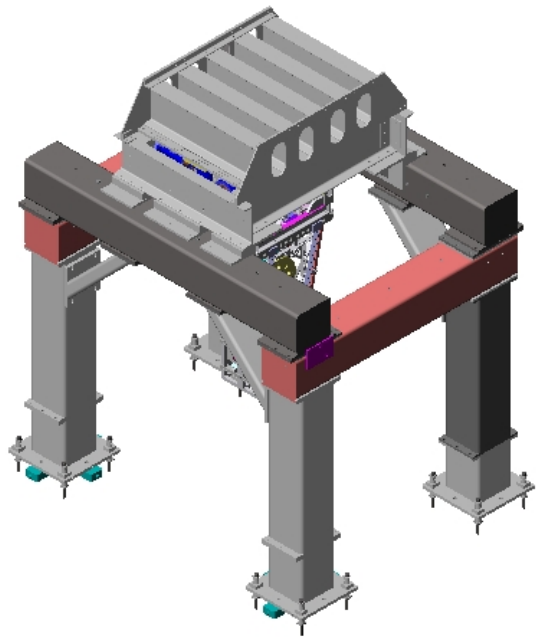
April @ MIT

Structure and both suspension chains already aligned

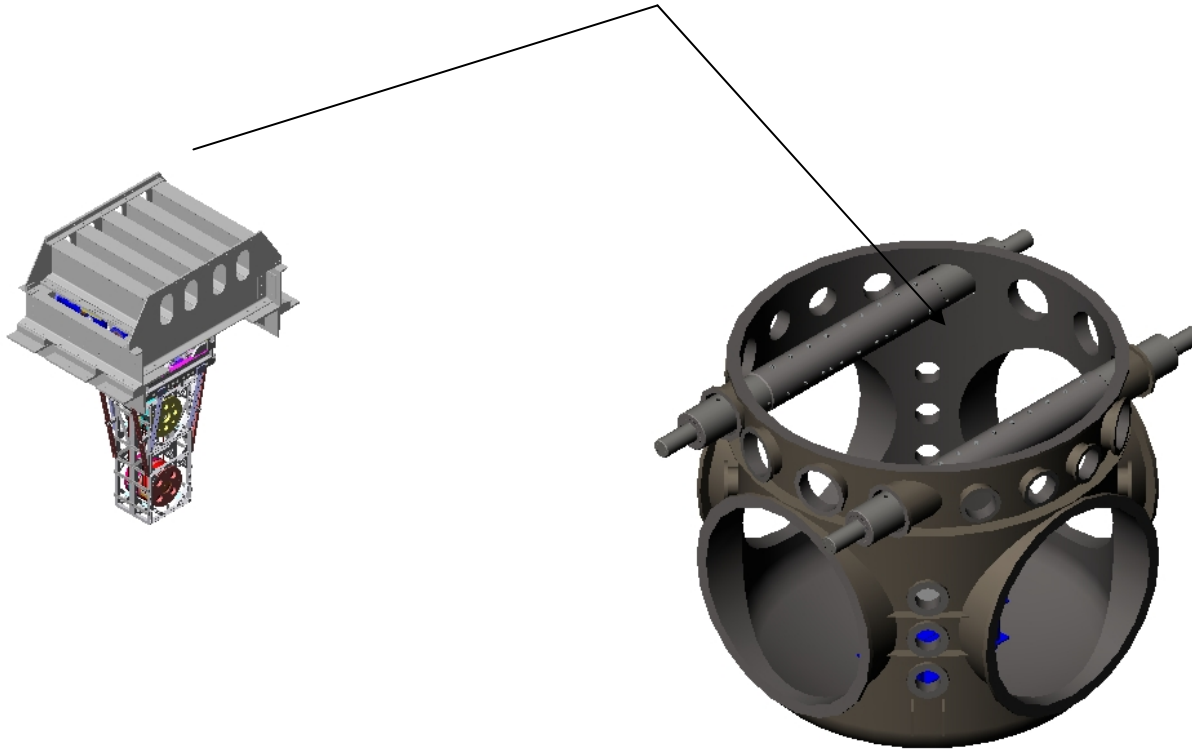


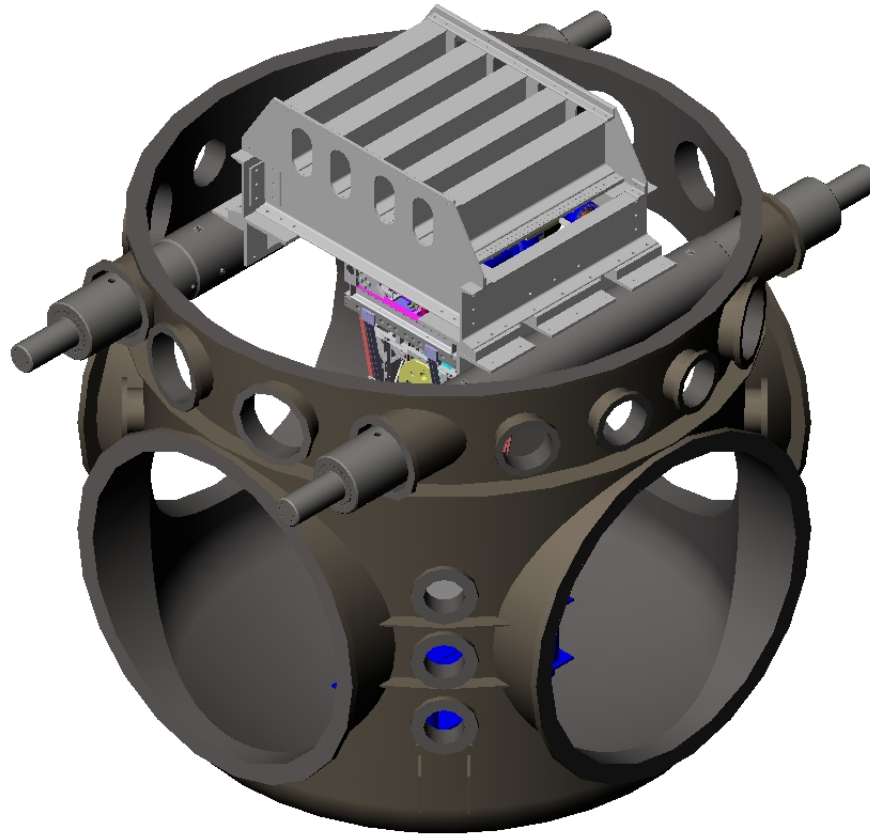
Align structure wrt auto collimator using installation tooling





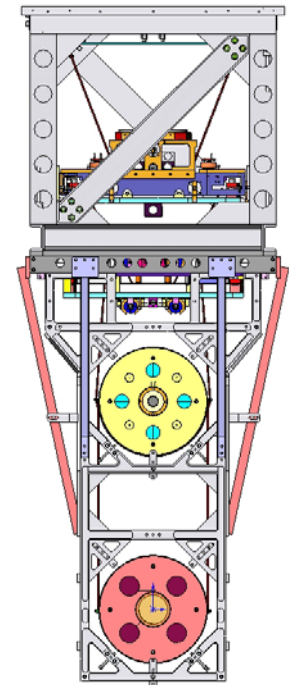
April @ MIT



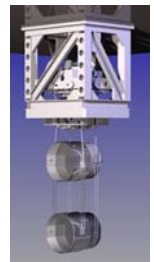


- Storing the Engineering Drawings

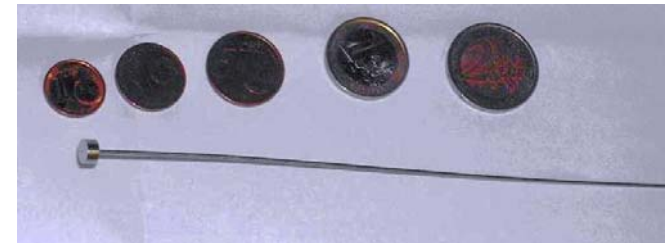
- Controls Prototype Quad files
 - D060100 [revision 00]
 - .sldasm
 - D040400 [revision 06]
 - .sldasm & a .sldprt
 - D040401 [revision 15]
 - .sldasm
 - D040524 [revision 18] , D040516 [revision 17] & D040407 [revision 08]
 - D050266 [revision 00] and D030100 [revision A] exists as drawings!
 - http://www.ligo.caltech.edu/~coyne/AL/SYS/AL_layouts/optomech_key_dwgs.htm
- Recycling Mirror files
 - D030164 [revision 00]
 - .sldasm & a .sldprt
- Controls prototype mode-cleaner files
 - D020700 [revision A2]
 - .sldasm & a.sldprt



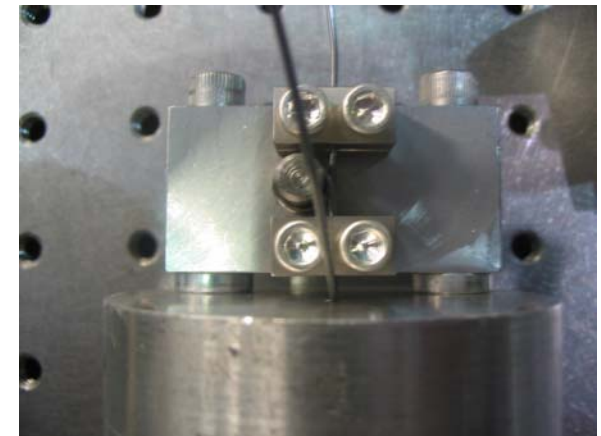
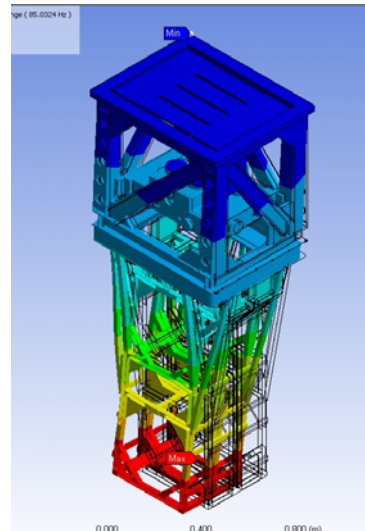
Expts. with RAL for Noise



- Quad controls prototype
 - Wires
 - Capstan clamps with spring steel wire
 - Drum ended wires (Maraging steel)



- Structure
- Blade adjustment
 - Z
 - pitch



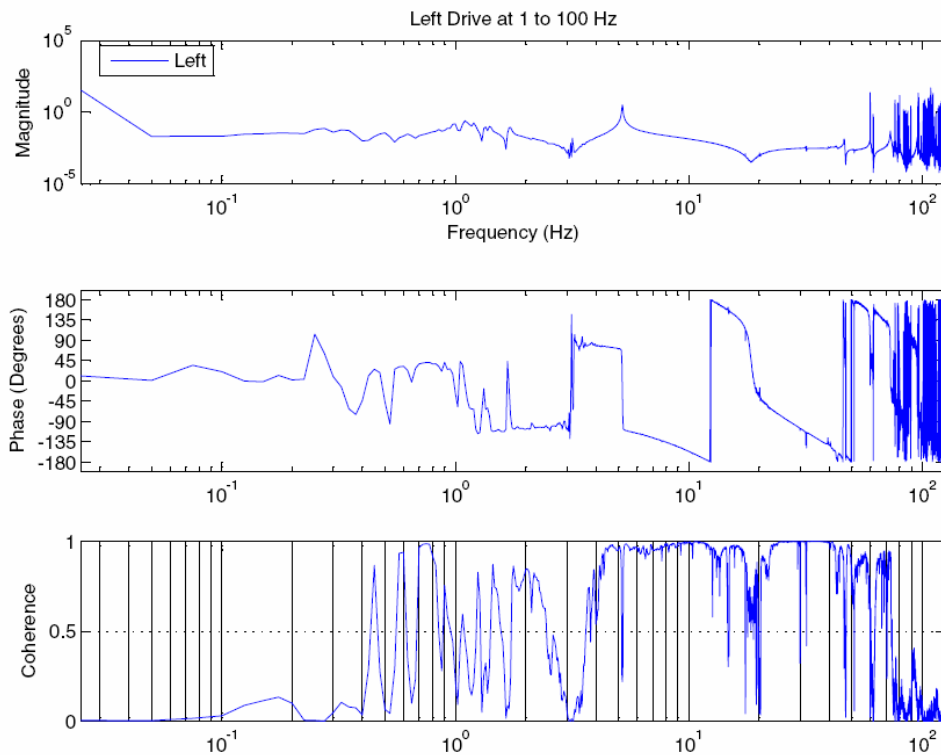


Suspensions (US) Plans for the future

- Quad tests at LASTI to continue
 - Transfer functions, damping of modes, mode frequencies, global control, electrostatic drive
- Design and testing of installation tooling
- Conceptual design of double pendulum pick off mirror suspension
 - Modeling & SolidWorks layout
- Output mode cleaner triple pendulum suspension design
 - double pendulum suspension equiv. to modulators in GEO 600
- Input mode cleaner suspension for noise prototype production
 - stiffen up controls prototype structure
 - incorporate lessons learned from LASTI testing



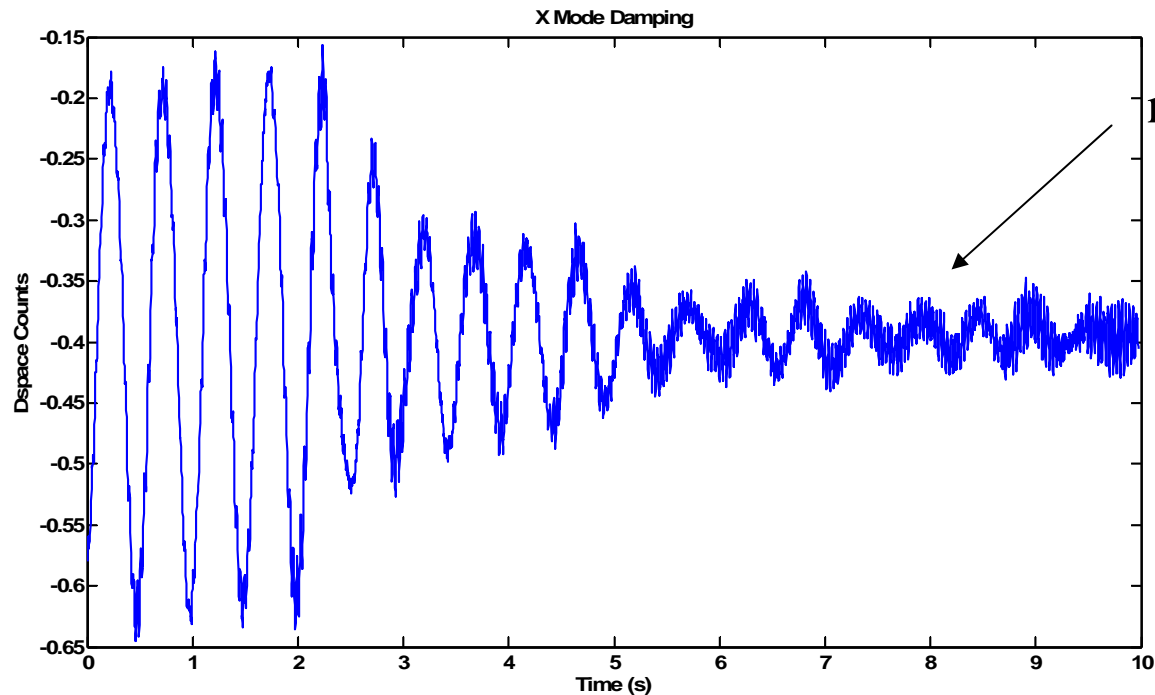
Preliminary Transfer Function



This transfer function shows the response of the top left OSEM of the local control on the main chain. The drive is at the same location.



Local Damping (Preliminary)



This is the response of the local control on the X Mode. The controller has a zero at DC and 2 poles at about 8 Hz. This motion was damped in about 5 seconds.