Output Modecleaner (OMC) Suspension Design

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Caltech and University of Glasgow

For the OMC suspension design team

LSC meeting, Baton Rouge
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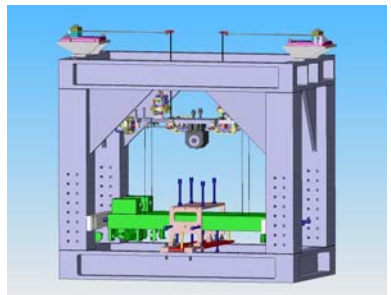
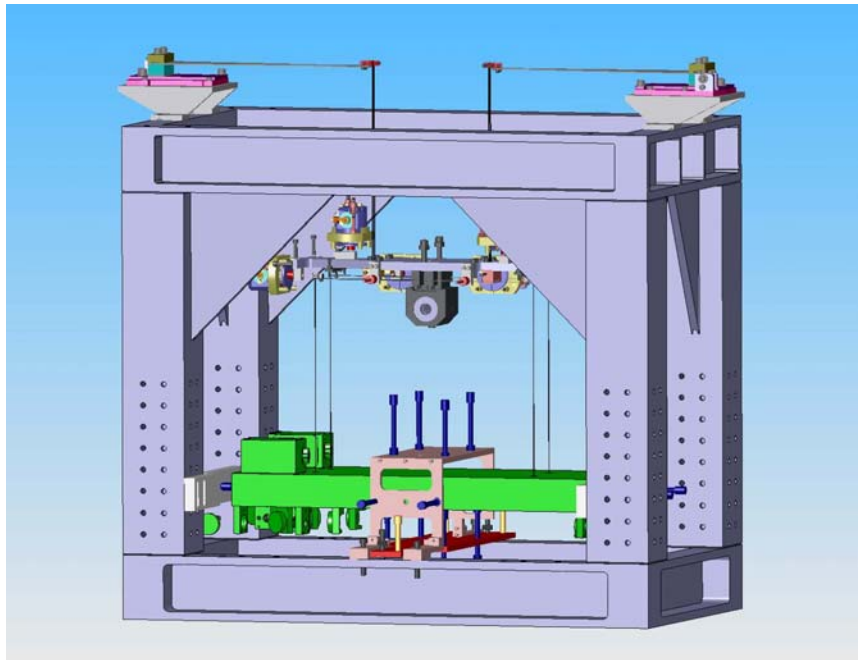


Design Team

- Rich Abbott
- Dennis Coyne
- Chris Echols
- Peter Fritschel
- Jay Heefner
- Vuk Mandic
- Norna Robertson
- Janeen Romie
- Calum Torrie
- Sam Waldman



+ Chris Cueva (Stanford summer student 2006)

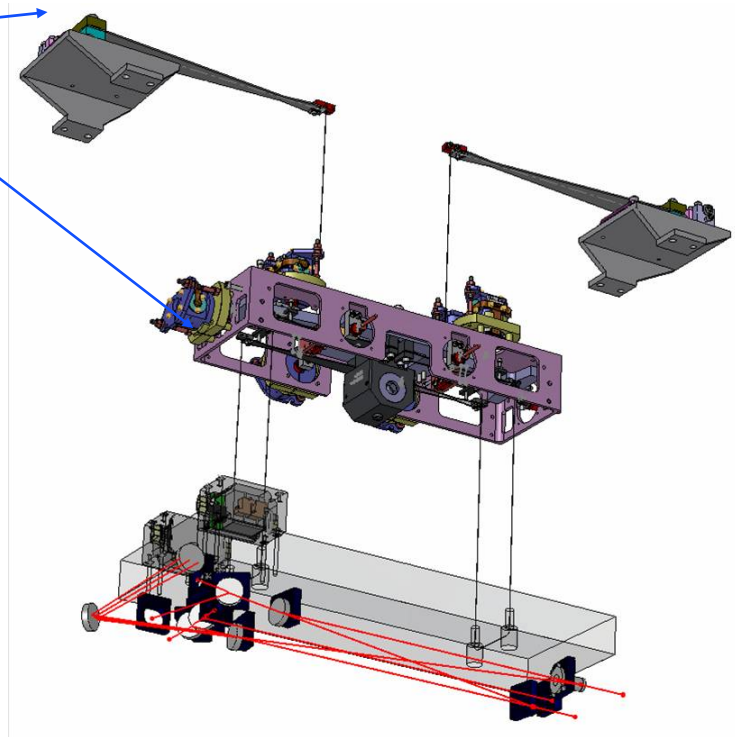
OMC Suspension Design Specifications/Requirements

- **Major features:**

Property	Value/Description
Baseplate (optical bench): mass, size, material, first internal mode	6 kg, 450 x 150 x 38 mm, fused silica or lightweighted aluminium, >1000Hz
Isolation	Double pendulum with blades Steel wire suspension
Pendulum solid-body frequencies	0.8 – 2 Hz (guideline)
Damping	Active, 6 DOF Use OSEMS developed for quad (0.7 mm pk-pk, 2.05 N/A)
Support Structure	First resonance >150 Hz, footprint as small as practical
Wiring from baseplate	Routed via top mass to structure Preamps mounted on baseplate
Range and noise requirements for coil drivers (to give +/- 0.5 mm)	Current range ~ 9 e-2 A Ratio range to noise ~ 8e7 √Hz

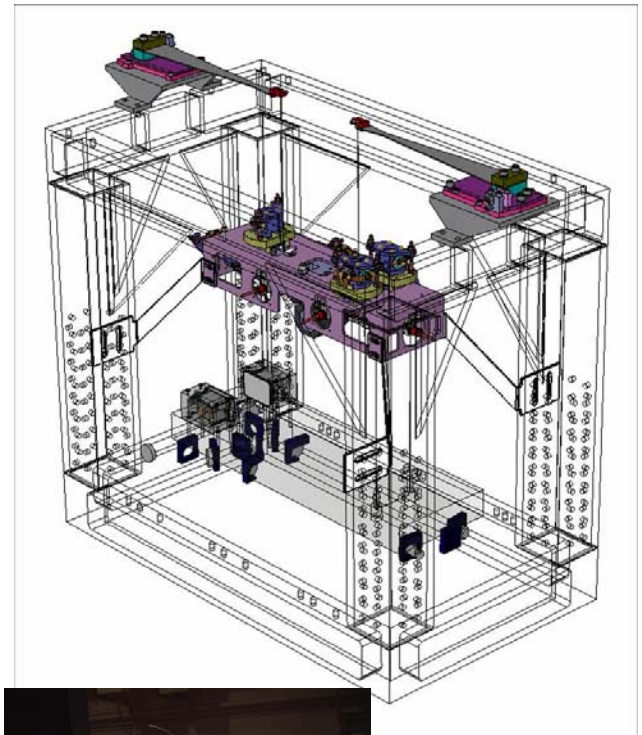
OMC Suspension Conceptual Design

- **Double pendulum suspension with two stages of blade springs**
  - » **Damping can be applied at the upper mass and design can proceed without detailed knowledge of bench layout**
  - » **Static adjustments for pitch, yaw and roll (as needed) can be incorporated at upper mass**
  - » **Uncertainty in the required isolation argues for the additional isolation provided by the double pendulum**
  - » **Builds on GEO experience with multiple pendulums**



OMC Suspension Parameters

- Pendulum lengths : 25 cm at each stage
- Masses: 3 kg, 6 kg (+/- 10%)
- Blades: two supporting upper mass, 4 at upper mass supporting lower mass
  - » Inclusion of second set of blades reduces highest vertical pitch and roll modes to below 10 Hz
- OSEM arrangement: 3 on top for vertical pitch and roll, two on front for longitudinal and yaw, one on side for transverse
- Optical bench: optics and diodes mounted on lower side (upper side known as “dark side”)
  - » This reduces interference between suspension wires and optical beams
- First assembly will use aluminium bench, final assembly - silica bench
- Choice of masses allowed use of aspects of input modecleaner suspension design (a triple with masses 3 + 3 + 3 kg) - blades, wire clamps, and parts of the upper mass.

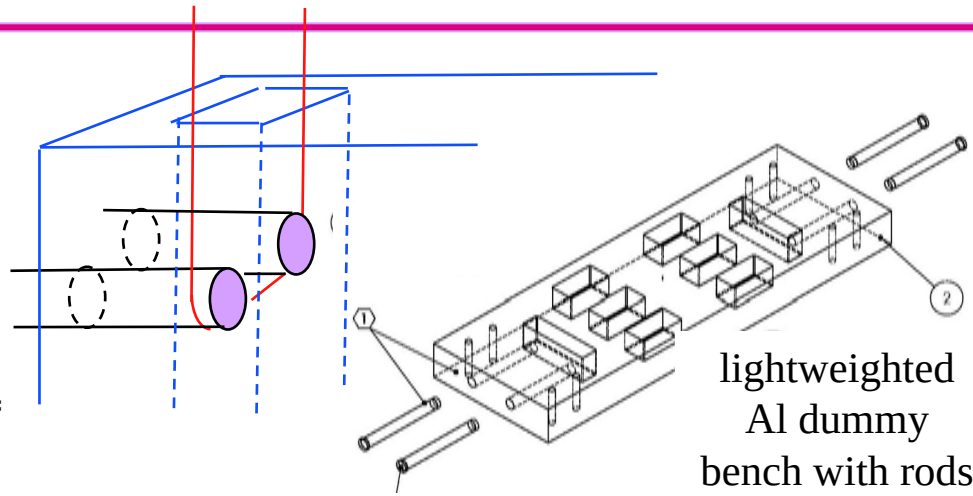


Some Design Choices

- **Mass of optical bench**
  - Original concept: vacuum compatible optical table 0.5 x 0.5mm (approx 40 kg)
  - Changed to silica bench (6 kg) – lighter and easier to handle. However
    - Need to develop method to attach optics: UV epoxy currently baseline, silicate bonding as for LISA optical bench is fallback, discussed with Glasgow group
    - Need to develop method to attach suspension wires (more on this later)
- **Two stages of blades versus one**
  - Takes highest vertical, roll and pitch modes from 30 to 75 Hz range to 4 to 9 Hz range
    - Removes from GW band
    - All modes can be easily damped
- **Positioning of wire attachments**
  - Moved from outer edges of bench to inside bench
  - Takes highest pitch mode from ~9 Hz to ~ 4 Hz
  - Eases design of filtering to cope with sensor noise
  - More challenging for design of wire attachment
- **Use of eddy current damping at upper mass**
  - Considered for damping high frequency modes when only one set of blades
  - Coupling to ambient magnetic fields does not compromise isolation
  - Not currently in baseline – need OSEMS for alignment control anyway

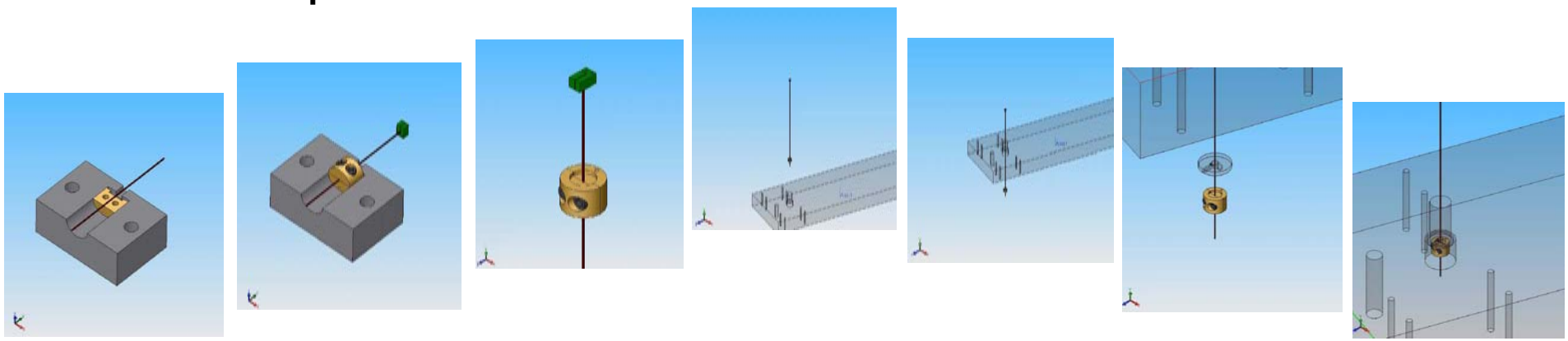
Wire Attachment to Optical Bench

- **Several ideas explored**
  - » **Pocket cut out of glass and rods inserted through holes from side**
    - – **Allows use of two loops rather than four wires, eases installation and removal of bench**
    - – **More challenging for manufacture of glass bench**



lightweighted Al dummy bench with rods

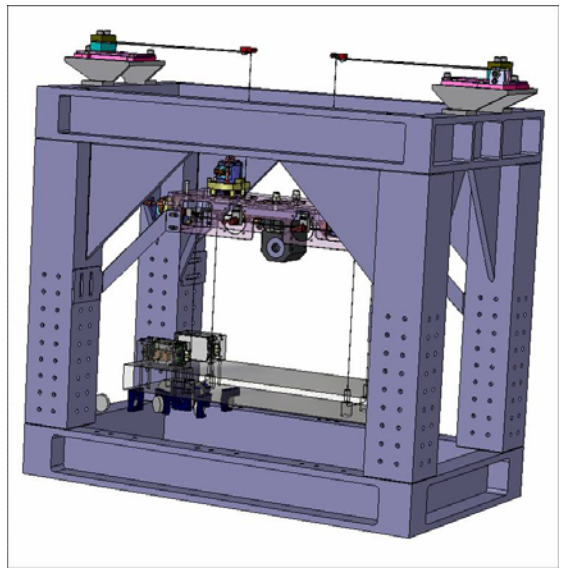
  - » **Through holes in glass with sleeve and clamp**

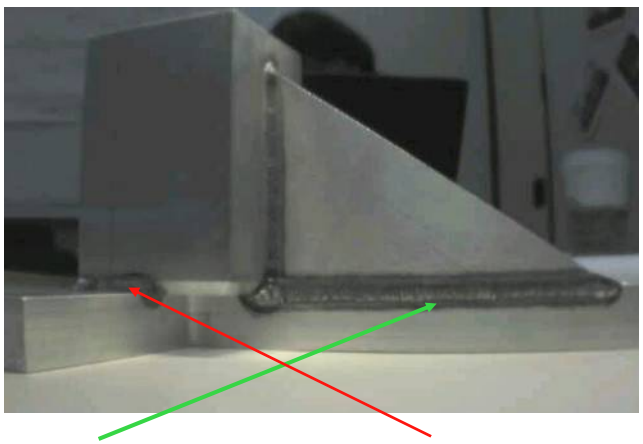


- **This is work in progress**

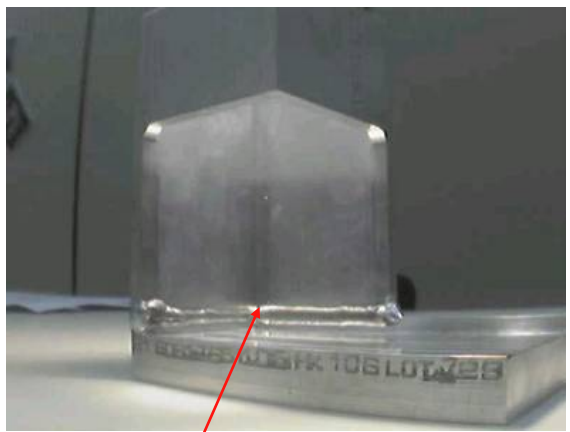
Support Structure

- The support structure is made of welded aluminium
- Design similar to the top section of the quad support structure
  - » known to have high resonant frequencies
  - » reduces design effort
- Problems with achieving full penetration welds: several options investigated
  - » Current option: holes cut in legs where join to base to allow welding from both sides and not at corner – will be strengthened with plates
  - » Possible future option – use stainless steel
  - » Collaborating with team in UK building quad structure

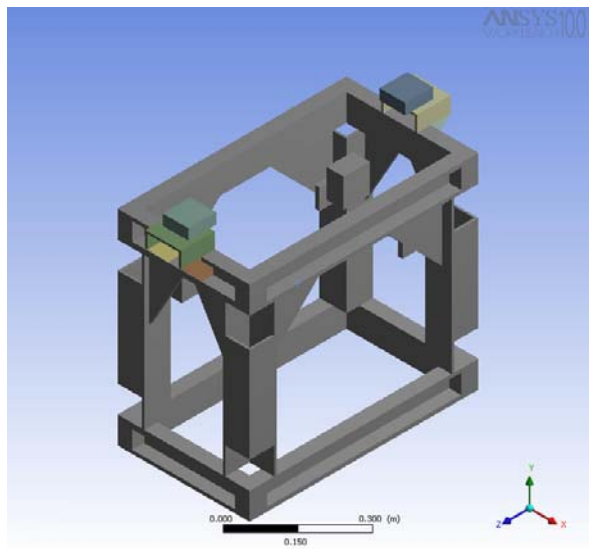




Gusset weld – OK, butt weld not OK

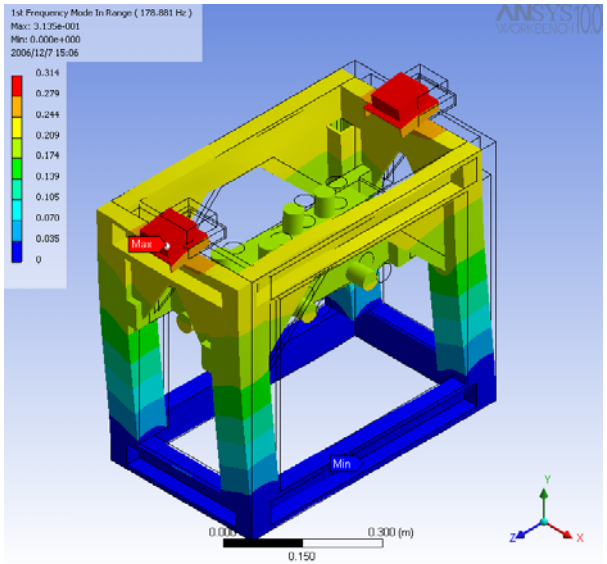


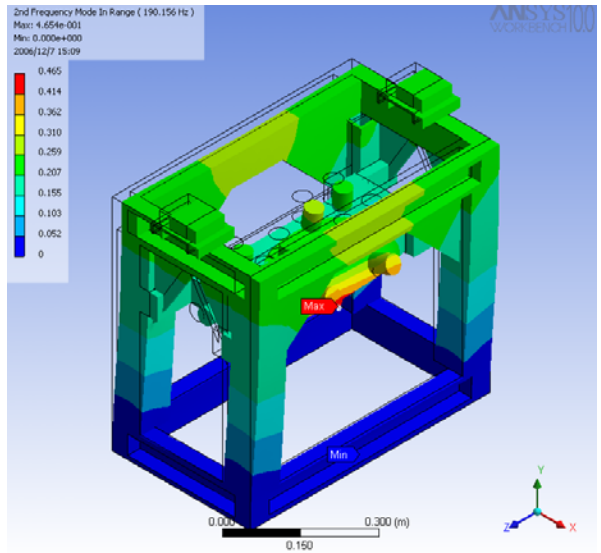
Butt weld – not OK



Finite Element Analysis (ANSYS)

Structure



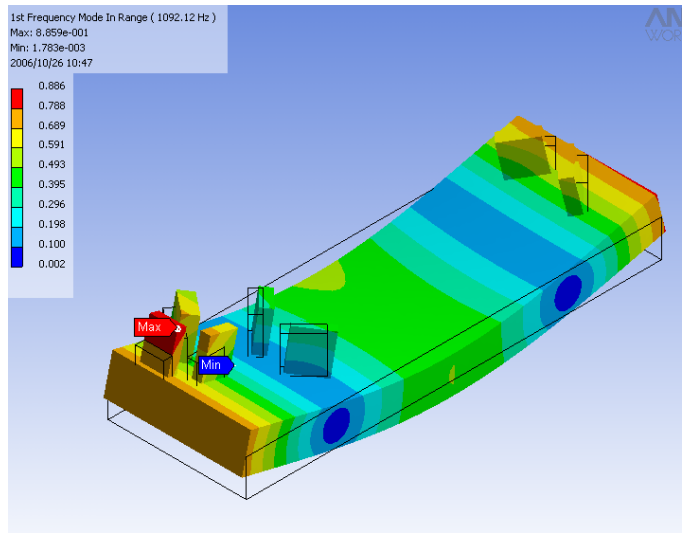


1st mode (transverse)
180 Hz

2nd mode (longitudinal)
190 Hz

c.f. requirement >150 Hz

Optical Bench

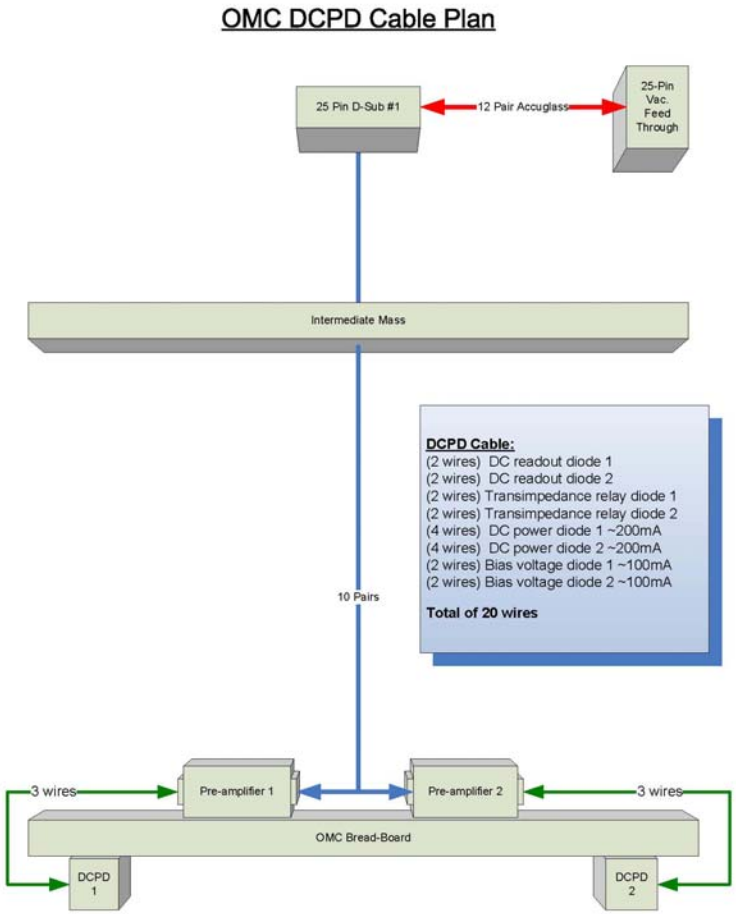


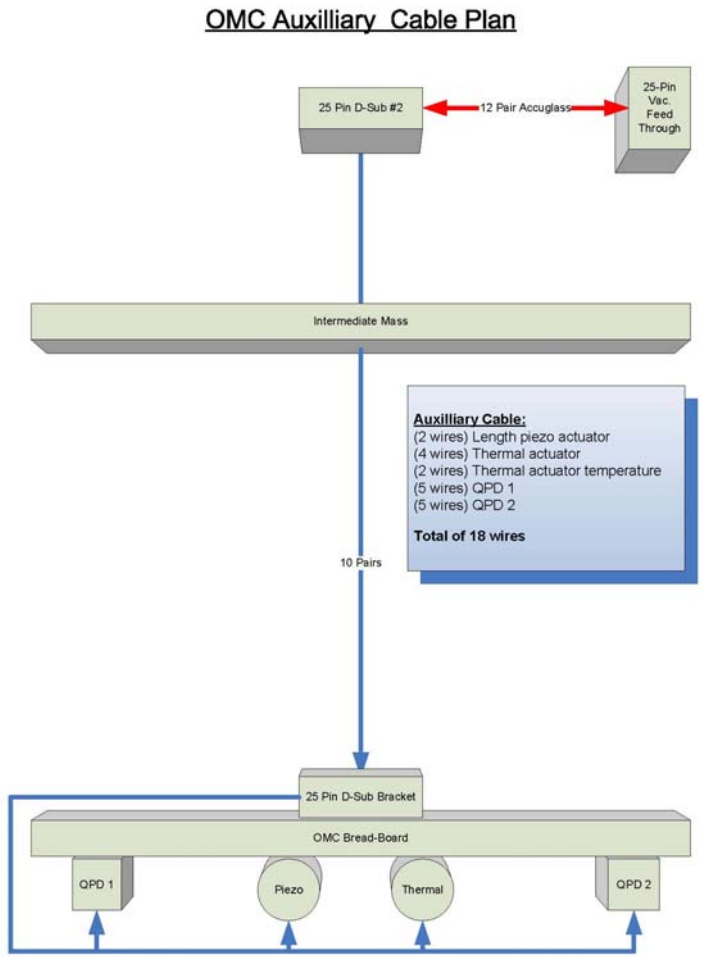
First mode ~ 1100 Hz

c.f. requirement >1000 Hz

Wiring Plans

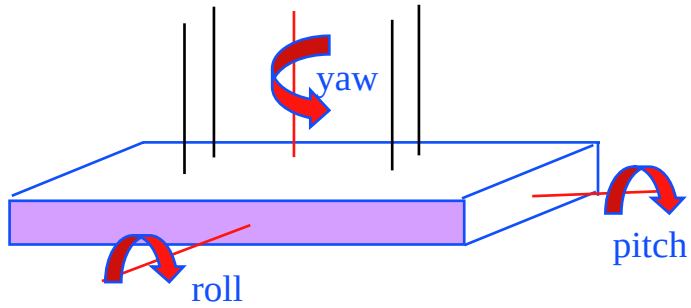
- **Analysis suggests that wires taken directly from optical bench to structure may compromise isolation: route wires via upper mass.**





Expected performance

- **Pendulum resonant frequencies (Hz):**
  - **longitudinal and transverse: 0.74, 2.4**
  - **vertical: 1.2, 4.5**
  - **pitch: 0.59, 3.8**
  - **yaw: 0.52, 3.36**
  - **roll: 0.80, 6.9**

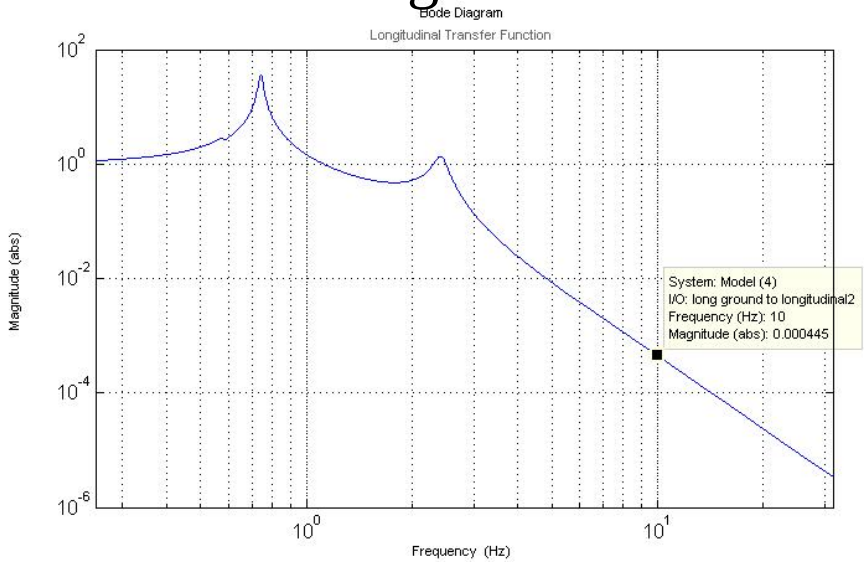


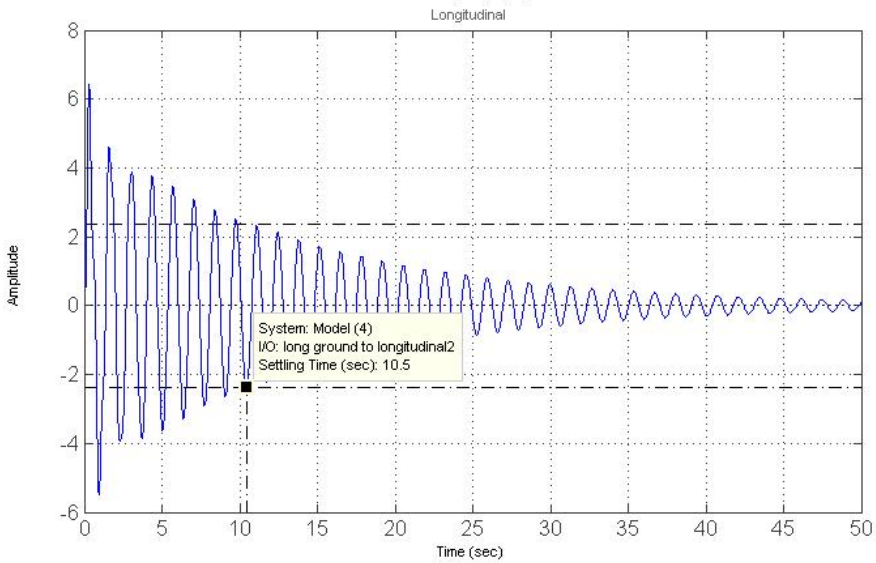
- **Isolation at 10 Hz (with damping time ~10 secs)**
  - **Longitudinal: 4.5 x 10^-4**
  - **Vertical: 3.9 x 10^-3**

(Note – above numbers are approximate, lower mass currently modelled as simple box shape, and some design details are still being finalised)

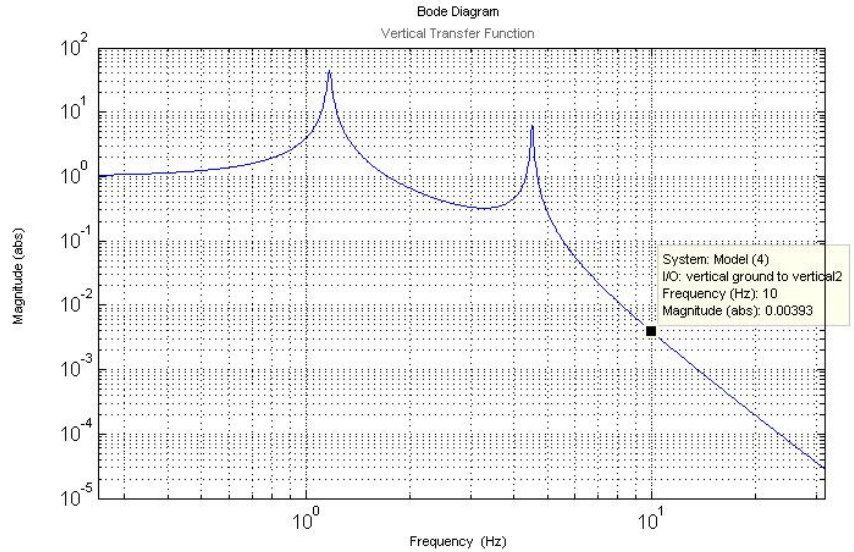
Transfer Functions and Impulse Responses

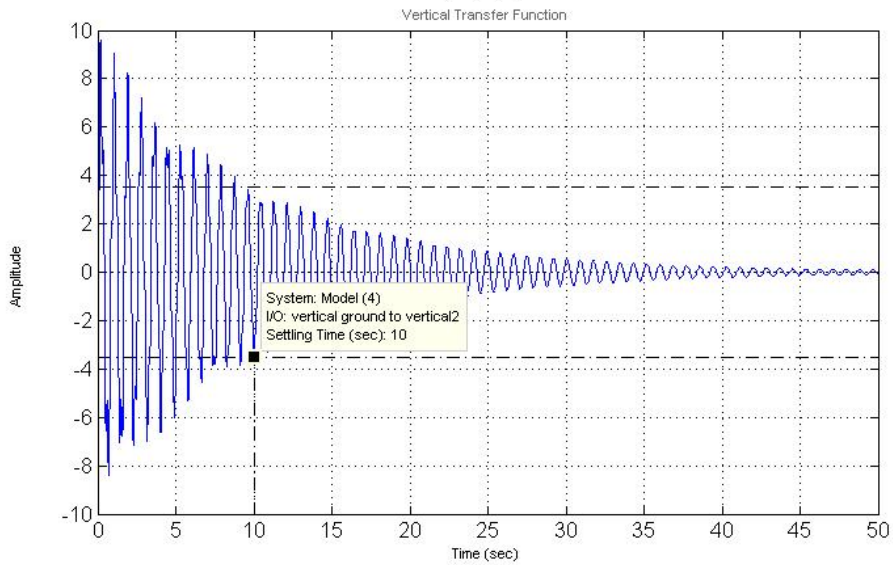
Longitudinal





Vertical





Progress and Schedule

- Design was reviewed in Nov and Dec 2006 (R Adhikari, D Shoemaker, M Zucker).
- Blades (spares from input modecleaner) characterised and chosen and other useful spare parts (clamps etc) identified Jan/Feb 2007
- Production of parts is currently underway, delivery now through early April 2007
- First (dirty) assembly and testing of suspension with an Al dummy bench at Caltech April/May 2007.
- Preliminary Design Review (suspension) June 2007
- Fabrication of 2nd unit – start after PDR
- Glass bench will be added and further tests carried out (led by ISC team). Optics and bench delivery due early July 2007
  - Assembly and test likely to be at Caltech (not LASTI as previously planned).
- Rework of first unit as needed after PDR or further testing
- Delivery of first unit (cleaned and baked) to meet start of OMC commissioning currently scheduled for Nov 2007