Summary Report on Visit to LIGO, Caltech **January 30th-February 22nd 2005**

Michael Perreur-Lloyd

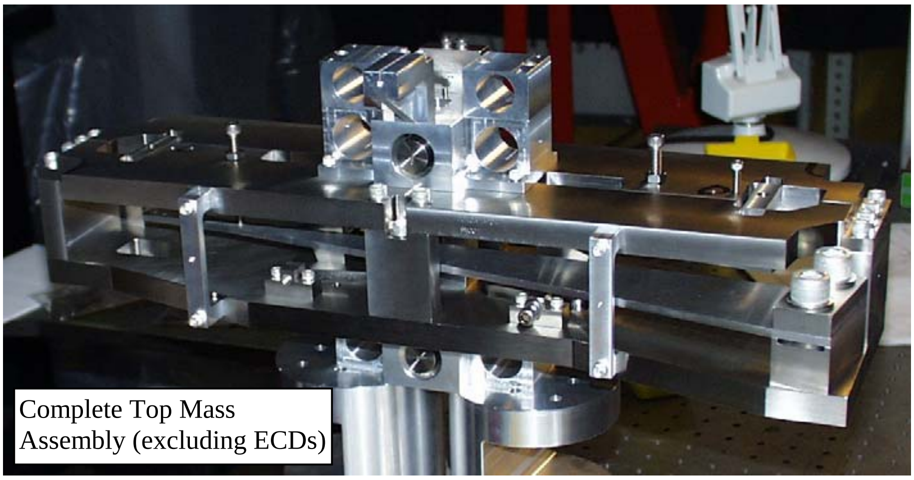
This document summarises the work completed during a recent visit to Caltech. The purpose of this visit was to assist with the continued collaborative design work being undertaken by the Advanced LIGO Suspension Team. The work displayed in this document is both work that I did on my own with some interaction from others, and work done by my LIGO Colleagues in which I was involved.

The primary aim of this visit was to receive the parts for the C-Ptype ETM U-I Mass assembly and to perform the first build of all the components, solving any interference issues along the way. Similarly it was useful to rebuild the Top Mass with the now available cantilever blades. Finally I could work closely with Calum Torrie to develop and run analyses of the ETM overall structure to bring it closer to manufacture.

Thanks again must go to Calum Torrie, Janeen Romie, Dennis Coyne and Cindy Akutagawa for inviting me over and helping set-up this visit. Thanks also to Mike Gerfen and Ricardo Paniagua in the Engineering workshops whom I worked closely to solve any outstanding problems with the Mass assemblies. And finally, thanks to Jim Hough and Caroline Cantley for approving my visit and to Anne McGinn who helped in organising the PPARC funded visit from the Glasgow end.

Build of Top Mass with Cantilever Blade Springs

The Top Mass was first built in November 2004 on my previous visit, however this was without the cantilever blade springs and a few minor parts. To check that all parts and bolts were now accounted for and as a final 'static' check for interface problems, the mass was rebuilt with dummy blades on the bench top.

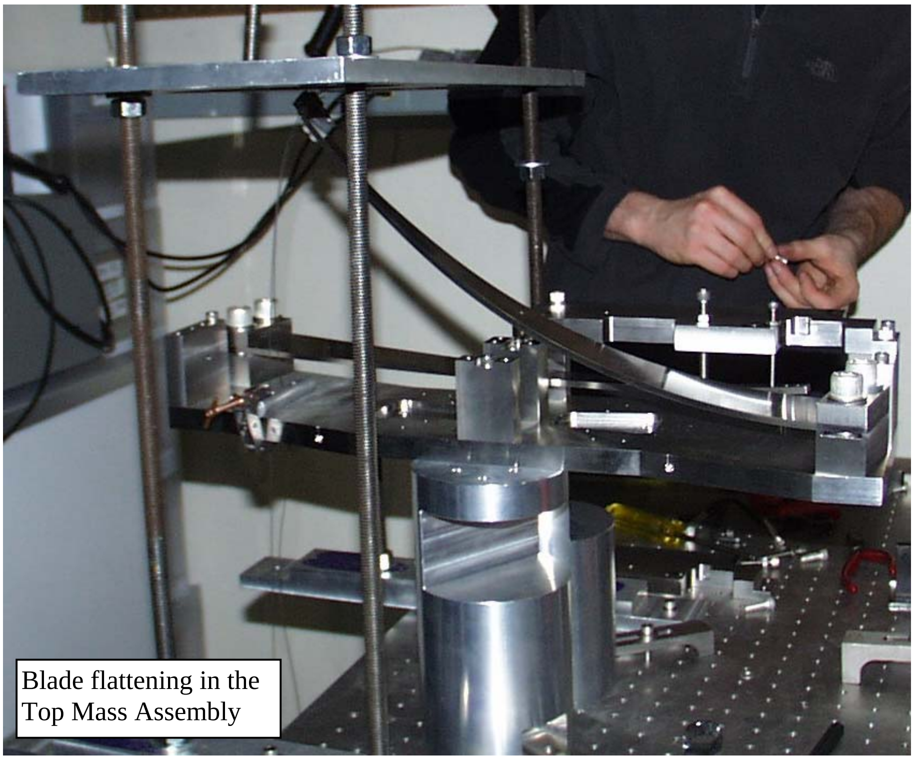


Complete Top Mass Assembly (excluding ECDs)

Following the successful 'static' build with dummy blades, we then tried to and assemble the mass with cantilever blades, flattened using Ian Wilmut's (RAL) blade flattener. Following his instructions provided via email and telephone we were unable to successfully use the flattener to remove the top blade from the blade test facility. The problem being that, as the load was released from the blade, the blade was able to bend upwards and thus caused the flattener carriage device to interfere with the safety straps on the Blade Test Facility. We tried the flattener both in the furthest forward and furthest back position. However we still encountered the same interference problems. Suggestions for possible redesign were forwarded to Ian; he will also be able to test the fixture on his upcoming visit.

To counter the problems of the blade flattener, a simple safety cage was manufactured so that we could bend the blade in a more traditional method of applying a downward force from a dummy blade wire clamp on the end of the blade. Using this method, we were able to complete the full assembly of the Top Mass with Cantilever blades. Two positive outcomes from this test were:

1) The mass bending was, as predicted by FEA and calculations, in the region of 0.5mm.
2) We could identify a couple of minor re-machines that were needed to allow smoother assembly and disassembly of the mass. Both of which were incorporated and tested during my visit.



Blade flattening in the Top Mass Assembly

With the assembly now complete including all re-machining and bolts for assembling the mass accounted for, the SolidWorks assembly of the mass was brought up to date and readied for the DCN (Document Change Notice) Process. The release of the DCN and updated PDS (Product Design Specification) for the C-Ptype ETM Top Mass design was not quite finished during my visit but is nearing completion. This will be finalised on my return to Glasgow.

Build of U-I Mass with Cantilever Blade Springs

Having set-up a safety rig for flattening cantilever blades on the top mass, we could then easily test the Upper-Intermediate Mass assembly with cantilever blades. On my arrival at Caltech around 90% of parts were available for the Upper-Intermediate Mass, and most importantly all of the parts required to build the mass up with cantilever blades. In the first week of my visit the U-I mass was built as a static model to check that all parts fitted together as expected and again that the appropriate bolts were available to complete the assembly.

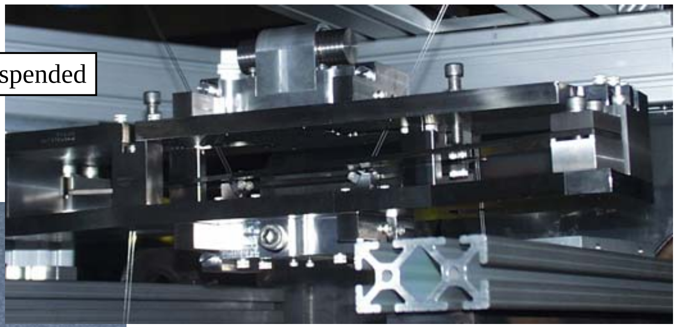
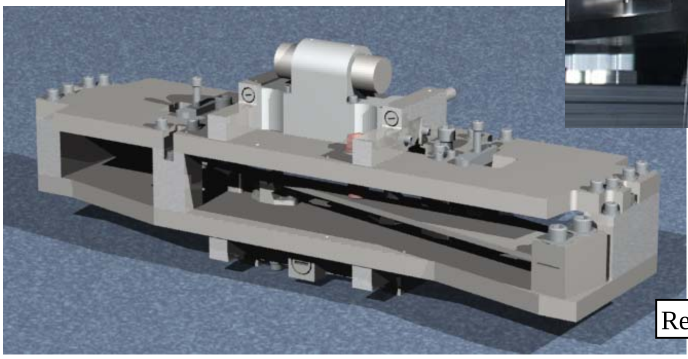


Photo of U-I Mass Suspended

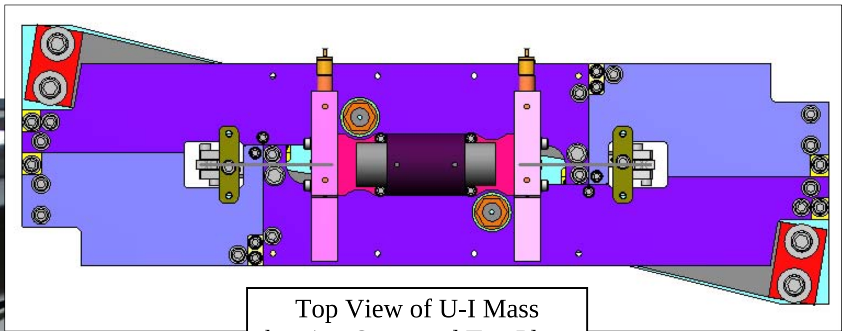


Rendering of Fully Assembled U-I Mass

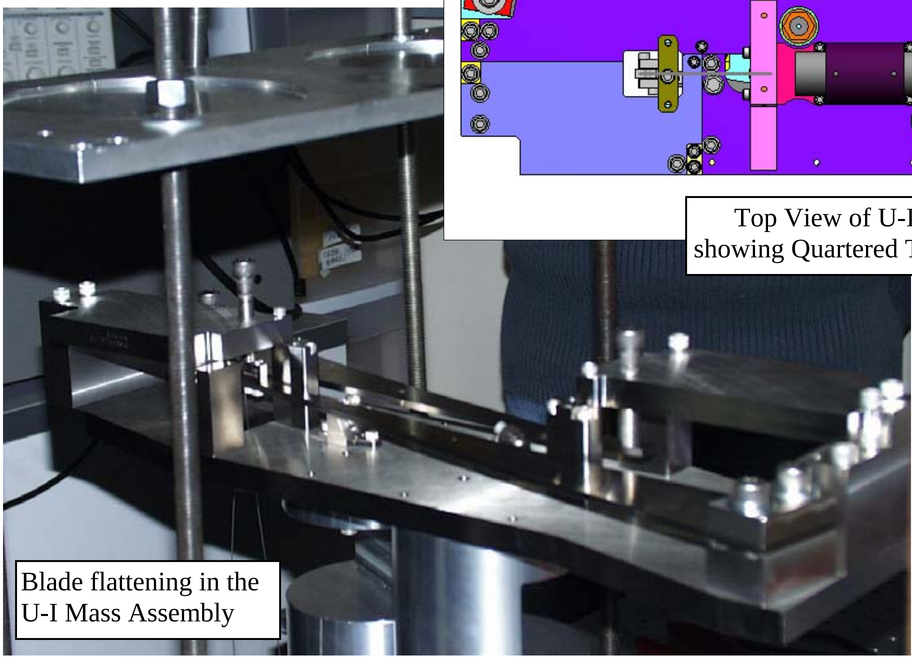
Some minor re-machining to the U-I mass was required and was dealt with this promptly by Mike Gerfen of CES (Central Engineering Services), allowing me to continue the validation of my design.

The test assembly of the U-I mass was completed successfully with the cantilever blades revealing the following:

1) The deflection at the ends of the mass was measured to be 0.5mm, again, as predicted.
2) Adaptations should be made to allow more visibility to the blade tips and wire clamps
3) Consequently (from point 2.) a bridging piece would be required to host the blade stop at the blade tip (similar to that on the Top Mass).
4) The design of the quartered top plates in a staggered long-short configuration works quite well as the blade can be contained in the mass with either plate removed.



Top View of U-I Mass showing Quartered Top Plates



Blade flattening in the U-I Mass Assembly

Development of Overall Structure Design

During the visit a considerable effort was made in pushing the overall structure design to a conclusion. My effort was in supporting this with respect to the area around the upper-intermediate mass and in helping edit models following suggestion from Russell Jones and the rest of the design team.

Lower Structure / Assembly Rig & Box Ring

Prior to visiting, Russell Jones and I had amalgamated our designs (for Lower Structure and U-I Enclosure) and posted these on the Caltech PDMWorks vault to allow us to work in parallel. Our model of the overall structure, recently modified following the action to widen the lower structure[1], had a 1st resonant mode of around 85Hz (cantilever mode in the longitudinal direction). Thus, changes were required to bring the structure back up around the 100hz first mode mark (the earlier target set by Dennis Coyne).

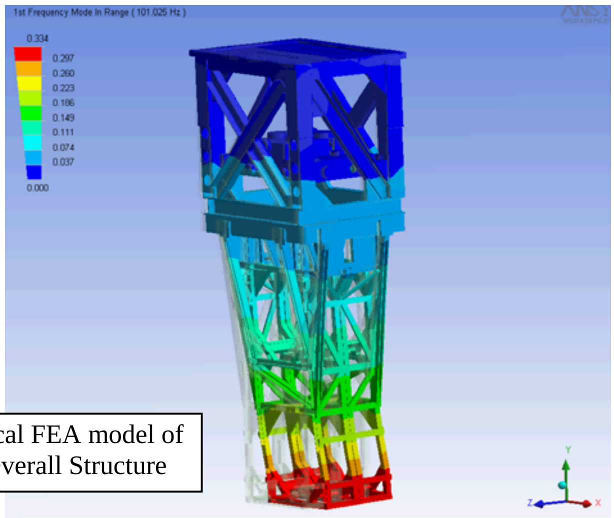
Initially, iterations of the lower structure to add stiffness to outriggers and the lightweight box ring were made with no great success. At the same time, however we were able to add more realism to these parts making the design of these as bolt on parts rather than integral parts of the structure. Laterally, on suggestions from the design team, angled strapping was added successfully to the lower structure to raise the first mode (of the overall structure) to around 100Hz (this figure includes the X-strap & plates mentioned below).

Upper Structure

With Tim Hayler (RAL) busy working on the detail of the drawings of the main welded components of the Upper Structure, Calum & I helped support the Upper structure design with adaptations, primarily to the bolt on parts, which it was hoped could help raise the 1st mode of the overall structure.

Two successful adaptations were 'scabbing-on' plates to the vertical legs of the structure and changing the angled cross-strap on the front and back faces of the upper structure to an X-strap. These changes raised the first mode to 91Hz and 94 Hz (from 85 Hz) respectively. The changes have however brought the mass of the overall structure up to around 138kg, therefore we now need to remove mass in areas not providing structural stiffness.

A report detailing all of the modifications and analyses on the structure will be written up in the near future.



Typical FEA model of the Overall Structure

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[1] Action was set during the Glasgow Monolithic Suspension workshop that directly preceded my visit. Ref: T050010 - Monolithic suspension workshop (Glasgow January 2005): Minutes & Actions

Other Work

On the final day of my visit, Calum, Russell Jones (who had just arrived from Glasgow) and I spent some time in the lab firstly considering how to arrange the gazebo, height adjustable trolleys and the Glasgow Quad frame such that in the following two weeks, Russell and Calum could perform the first quad build with all suspended stages and including cantilever blades.

Having concluded that the appropriate facilities were available to do this, we then went on to look at the Upper-Intermediate mass with respect to its integration into the 3 + 1 structure assembly. As it turned out, attaching the blade wire clamps to the U-I mass was hindered more by the bolts having to come up through the blade, than any interference by parts of the mass. Subsequently we looked at possible designs for an adapted blade wire clamp, which would allow us to bolt downwards through the blade, removing the problem for later prototypes.

Revision Notes:
Rev-01: Includes comments from Caroline Cantley and Calum Torrie