Summary Report of Visit to LIGO, Caltech: June 26th – July 24th 2003

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The purpose of my latest visit to LIGO at California Institute of Technology was to continue the previous detailed work on the triple suspension controls prototypes and to finalise the layout design for the quadruple pendulum suspension prototype. This work on the quadruple pendulum was critical in that these design details must be provided to the seismic group by mid-August. Aside from that work, the visit also gave an opportunity to write up and conclude several documents related to the design of triple and quadruple suspensions that had been started by the Caltech and Glasgow suspension teams.

In conjunction with Calum Torrie, the main tasks accomplished on this visit were:

- **End Test Mass (ETM) Quadruple Suspension** – A number of factors were considered to conclude our layout design of the ETM. The primary reason for this exercise was to give credence to the mass budgets previously set for each of the suspension by Dennis Coyne and now required by the Seismic group. The key risk areas covered were:
  a) **A review of the Top Mass Layout Design** (formerly known as the Upper Mass). The top mass has been developed with three different configurations of within the SolidWorks model. There now exists:
     i) A basic configuration with adjustability for PITCH at the upper wire break-offs, Adjustability for PITCH and ROLL by way of offset masses in the T-pieces;
     ii) A configuration further developed from the above that includes rotational adjusters for the blades to add YAW adjustment in the Top Mass; and
     iii) A configuration that incorporates the usage of two eddy-current dampers.
  b) **The Layout Design of Upper Blade Rotational Adjusters**. Having now developed and had manufactured a prototype Rotational adjuster for the Upper blades of a Recycling Mirror Suspension, we were able to evaluate the design and then consider the key design requirements for a similar ETM Upper blade adjuster. The greatest factor in up-scaling the design was always going to be the suspended mass, as a Recycling mirror suspension is 36kg whereas a End Test Mass Quad Suspension would require to support a load of 124kg.
  c) **The Layout Design of the Tablecloths** for both the Top and Upper-Intermediate Masses were drawn up, adding the likely cutouts for attaching eddy-current dampers and OSEMs.
  d) **Fitting the Suspension and Reaction Layouts to the Structure.** After understanding the various aspects of each of the ETM's individual masses it was then possible to model it as a full suspension with it's reaction chain within the Structure – to give us confidence that the structural design by Dennis Coyne would be suitable for the geometry of the suspension that would go inside.

  Following the analysis of these risk items an overall mass could now be more accurately calculated and have since been collated in a document[1] that will be reviewed at the August meetings in Glasgow.

[1] T030137-02 ETM Mass & Layout, http://www.ligo.caltech.edu/docs/T/T030137-02.pdf

- **RM and MC Blade drawings** – The drawings of the RM and MC blades have now been updated to contain all the information used in the design of the blades. This includes notes about how to edit the dimensions so that the SolidWorks drawings exactly match Mike Plissi's blade calculations and various design values used in these calculations.

- **Experiments with Offset Masses** – An experiment was set-up to quantify the effect that the Pitch and roll offset masses in both the Recycling mirror and Mode Cleaner upper mass so that, in future suspensions, we can make a better judgement of what size these should be in comparison to the upper mass. Since a simplified recycling mirror upper mass has now been manufactured, with offset masses in the T-pieces, it was possible to suspend this alongside a mode cleaner upper mass and compare the effect of moving the mass offset in each. With both of the upper masses not being suspended with intermediate and test masses, we could also confirm our suspicion that the test was not entirely accurate, by comparing the mode-cleaner upper mass test with a test on a full MC suspension. A report on these results will be written up in the future when a deeper investigation into the effect of the offset mass has been completed.

- **Development of and Documentation of LIGO Custom Tools for SolidWorks** – A considerable amount of time since my first visit to Caltech in November 2002 has been involved in developing several SolidWorks function so that they are customised for use in suspension design and for the LIGO project. These developments include:
  a) Creation and personalisation of a LIGO Bill of Materials (LIGO BOM) that exploits the SolidWorks Bill of Materials function to create BOMs, Materials Lists and Indented Drawing Trees.
  b) Increasing our understanding of the SolidWorks Custom and Material Properties functions. This function can be used to embed hidden information into parts, assemblies and drawings which in turn can then be linked to other SolidWorks functions such as the BOM and the following custom tools:
     i) Smart CAD Templates – These are Engineering Drawing Borders that are inherently linked to the custom properties such that *all* information for a part, assembly or drawing is now entered in one place.
     ii) Smart Data Templates – These are the blank start-up documents on which the user draws a part, assembly or drawing have been personalised so that the user is prompted for the correct information to link in to the BOM and CAD templates.
  c) A Customised Toolbox of the metric and imperial nuts, bolts, washers and hand tools that are commonly used within LIGO suspension design.

  All of the above developments are now written up in a document[2] which describes the purpose of each of these tools, explains how they are used and gives an idea of these can help improve quality and save time in future LIGO designs.

- Meetings with Caroline Cantley, Dennis Coyne, Justin Greenhaulgh, Janeen Romie and various others – Over two days, Wednesday 2nd and Thursday 3rd July, Caroline Cantley and Justin GreenHaulgh (RAL) visited Caltech to discuss the integration and distribution of work between the US and UK Suspension teams. In summary,

[2] T030134-02 Designing in Solidworks – Customised Tool for Design and Documentation of LIGO Parts, Assemblies and Drawings, http://www.ligo.caltech.edu/docs/T/T030134-02.pdf

during these meetings I gained a better understanding of the future path for the suspensions team and Calum and I both learned that the work already done on the ETM development had gone a long way to satisfying the targets set by the Seismic group.

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