



LIGO Laboratory / LIGO Scientific Collaboration

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ADVANCED LIGO

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**ETM Upper Structure
Product Design Specification**

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INTRODUCTION

The design of the structure for the ETM controls prototype must meet many requirements. The structure will be constructed from two sections. This document captures the requirements for the top part of the structure. It is assumed that the bottom part of the structure will be made to interface with the top part of the structure. The bottom part of the structure may or may not be the catcher detailed in **Advanced LIGO ETM (Quad) Controls Prototype Catcher Jig Design Specification, LIGO-T040080**. It is assumed that the top part of the structure will house the Top Masses and the Upper Intermediate Masses of the quadruple pendulum suspension. The ETM controls prototype has a full reaction chain, the top of which will be housed by this upper structure. This is a working document and as such, will evolve with the design. It will be updated periodically to capture any requirements/specifications changes.

This document is to be used in conjunction with the following documents: **ETM Controls Prototype: - Mass Estimate of an ETM Suspension Layout, LIGO-T030137**. Details of the naming convention (pg 3) may be found in this document along with the historical details of the mass budgeting for the suspension components, including the structure, currently estimated to total 66kg (pg 9). Also, older versions of T030137 detail the ETM layout of the suspended items and assumptions on the structure footprint and length, but are now in an appendix of this document.

Advanced LIGO Suspension System Conceptual Design, LIGO-T010103. This provides information about the modeling and parameters of the quadruple suspension conceptual design to which the upper part of the structure must meet.

A concept for the top of the quad structure is detailed in:

Frequency Analysis of the Quadruple Pendulum Structure, T030044 and

Coupled Dynamics Analysis of the Seismic Isolation System (SEI) Stage 2 Structure and the Quadruple Suspension (SUS) Structure, T04xxxx. Although these are conceptual designs, the requirements for the structure with respect to its interaction with the structure upon which it is mounted are detailed in these documents. It had been assumed that the entire ETM structure, along with its non-suspended components, have a requirement of a first natural frequency greater than 150 Hz, so that interactions of this structure with the SEI system do not destabilize the SEI controls, however this 150 Hz requirement is still not vetted. The actual requirement is that the suspension, mounted on the SEI platform shall not produce a phase lag of >90 deg between non co-located sensors in the SEI system. The coupled dynamics analysis paper listed above details the work so far on this analysis. This is an important requirement of the entire structure but will not directly be referenced in this document.

Specifications for the design of the upper part of the structure start with our general specifications. From there, the attachment requirements and the accessibility requirements along with the serviceability requirements are derived.

GENERAL SPECIFICATIONS

- It is assumed that the majority of the initial assembly of the Top Masses and Upper Intermediate Masses shall be done on an optical table, outside of the upper structure. Refer to T040071 and T040096 for details on these designs.
- It is assumed that if repairs are required after installation, the Top Masses and/or the Upper Intermediate Masses may remain in place during the procedure.
- The upper structure design shall facilitate the mounting and precise positioning of the upper blades, top masses and upper intermediate masses relative to the structure and relative to each other.
- The upper structure will allow for the catcher to move up into it, to allow for the looped wires that hold the upper intermediate masses to the penultimate masses. The catcher will move up into a stationary upper structure, however, the upper structure shall have allowances for accurately locating the catcher to the upper structure.
- The upper structure shall have allowances for accurately locating the earthquake stop assembly (which may or may not be a stripped down version of the catcher) for the penultimate masses and the test masses.
- The upper structure design shall address the process of assembling and aligning the top parts of the main chain to the top parts of the reaction chain.
- The upper structure design shall facilitate the precise positioning of the upper blades, top masses and upper intermediate masses relative to the structure and relative to each other.
- The upper structure will provide sufficient clearance for the SEI support tubes.
- The overall structure (the upper and lower parts of the structure) must meet the length requirement defined in RODA M040099.
- The design of the upper structure shall be in conformance with the assumptions detailing the suspension component placement and structure footprint and length shown in Appendix 1 of this document.
- Stiffeners for the upper structure, to meet the SEI/SUS dynamic coupling requirements, need not be included during the assembly process nor during the mounting of the SUS to the SEI table. They may be mounted at the last minute, just prior to cartridge installation or in the chamber itself.
- The upper structure shall be capable of being dis-assembled to support repair and replacement work.

- The controls prototypes, in particular, shall be designed to be as modular as possible to determine practical accessibility points. It shall be designed with removable sections that may be welded for the noise prototype, although analysis shall be done to determine if this will impact the stiffness of the overall structure.
- Uniform fasteners shall be used whenever possible. For example, utilization of ¼-20 screws wherever appropriate is recommended.

ATTACHMENTS

- The interface plate will (most likely) mount to the upper structure. The interface plate is the mounting and positioning device for the upper blades. The structure must be stiff and strong at this connection. The interface plate and its suspension components (both chains) will weight about 600 lbs or more. See T030137.
- The upper structure must allow for the attachment of the tablecloth brackets for the top and the upper intermediate (UI) mass tablecloth(s). During assembly into the structure, the tablecloth(s) must be adjustable to provide a uniform gap between the inside of the tablecloth(s) and the outside of the top masses and the UI masses. To do that, the tablecloth brackets will have to have vertical and possibly tilt allowances. The design of the upper structure will allow adequate room to design these brackets with these (possible) features.
- The upper structure must be designed to allow for the mounting and precise positioning of the catcher and the earthquake stop assembly, per the approaches detailed in the general specifications. This design must consider assembly inside or outside of a chamber.
- It is assumed that the upper structure, or possibly the interface plate, will be clamped to the SEI optical table. A suitable interface to allow for a multiple dog-clamp type of attachment to the optical table must be included in the design. However, this approach is not concrete and may change over time. (Reference Larry Jones's document on number of clamps...)

ACCESSIBILITY – before mounting to the SEI gazebo, while assembling the suspension chains

- The upper structure must allow for access to the top blade rotational adjusters, blade stops.
- The upper structure must allow for the top reaction mass and the UI reaction mass to be moved into place next to the main chain, along the beam axis.
- The upper structure must allow for interface (quasi-adjustable) of the brackets that mount the tablecloth to the structure.

The upper structure must allow the upper masses together with their tablecloth(s) to be installed fully assembled. However, consideration should be taken to allow for installation of the upper masses and the tablecloth(s) separately. There are three installation approaches for the masses, listed below:

- along the beam axis.
- along the axis perpendicular to it in the XY plane, assuming the Z axis is vertical.
- by moving up vertically through the bottom of the upper structure.

All of these accessibility requirements, below, may not be needed – especially if meeting them makes the design impossible. If that is the case, an acceptable approach must be agreed upon and the design must proceed with this understanding.

ACCESSIBILITY – after mounting to the SEI gazebo, aligning the chains to each other and to the optical table.

- The upper structure must allow for access to the top blade rotational adjusters, blade stops and blade ECD.
- The upper structure must allow for access to the top masses’ stops, local control osems, blade wire clamps, ECDs, pitch adjustments, +/- masses for vertical adjustments and upper wire blade attachment points.
- The upper structure must allow for access to the upper intermediate masses’ stops, blade wire clamps, blade wire attachments, pitch adjustments, +/- masses for vertical adjustments. It must also allow for positioning of the hybrid osems. The global control hybrid osems are mounted in the reaction mass of the UIM. Visibility of the magnets on the UI is required along with being able to look down the hybrid osems to adjust their placement.

ACCESSIBILITY – serviceability requirements.

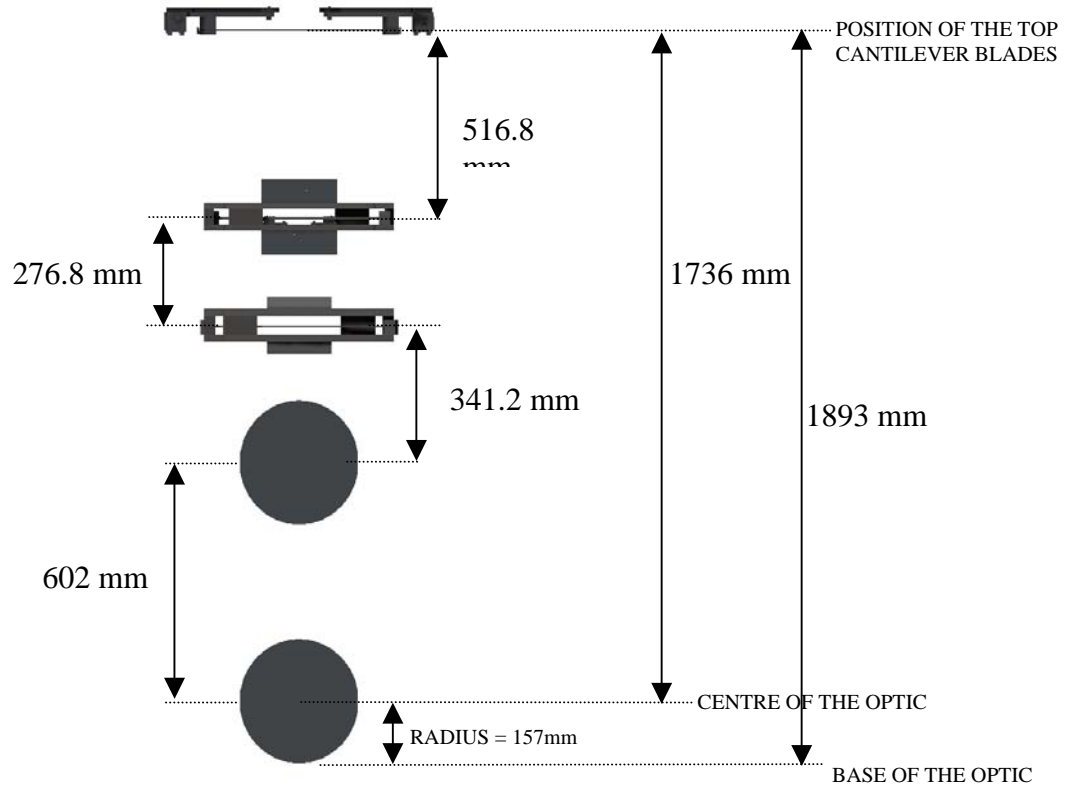
- The upper structure must allow for access to the top blade rotational adjusters, blade stops and blade ECDs. One must be able to see the wires coming off of the blades.
- The upper structure must allow for access to the top masses’ stops, osems, ECDs, pitch adjustments, +/- masses for vertical adjustment and top wire blade adjustment points. One must be able to see the wires.
- The upper structure must allow access to the upper intermediate masses’ stops, blade wire clamps, blade wire attachments, pitch adjustments, +/- masses for vertical adjustments. It must also allow for positioning of the hybrid osems. The hybrid osems are mounted in the reaction mass of the UI. Visibility of the magnets on the UI is required along with being able to look down the hybrid osems to adjust their placement.

- Reference E040329, Advanced LIGO Quadruple Pendulum Suspension Failure Modes and Subsequent Repair approaches, for more accessibility information with respect to repairs.

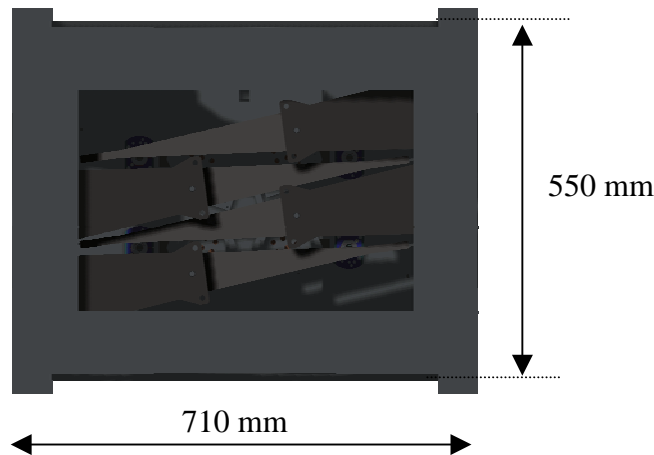
APPENDIX 1 LAYOUT DESIGN, WITH NUMBERS

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1. SUSPENSION (assumes Sapphire masses) Distances shown centre to centre. FACE ON ²

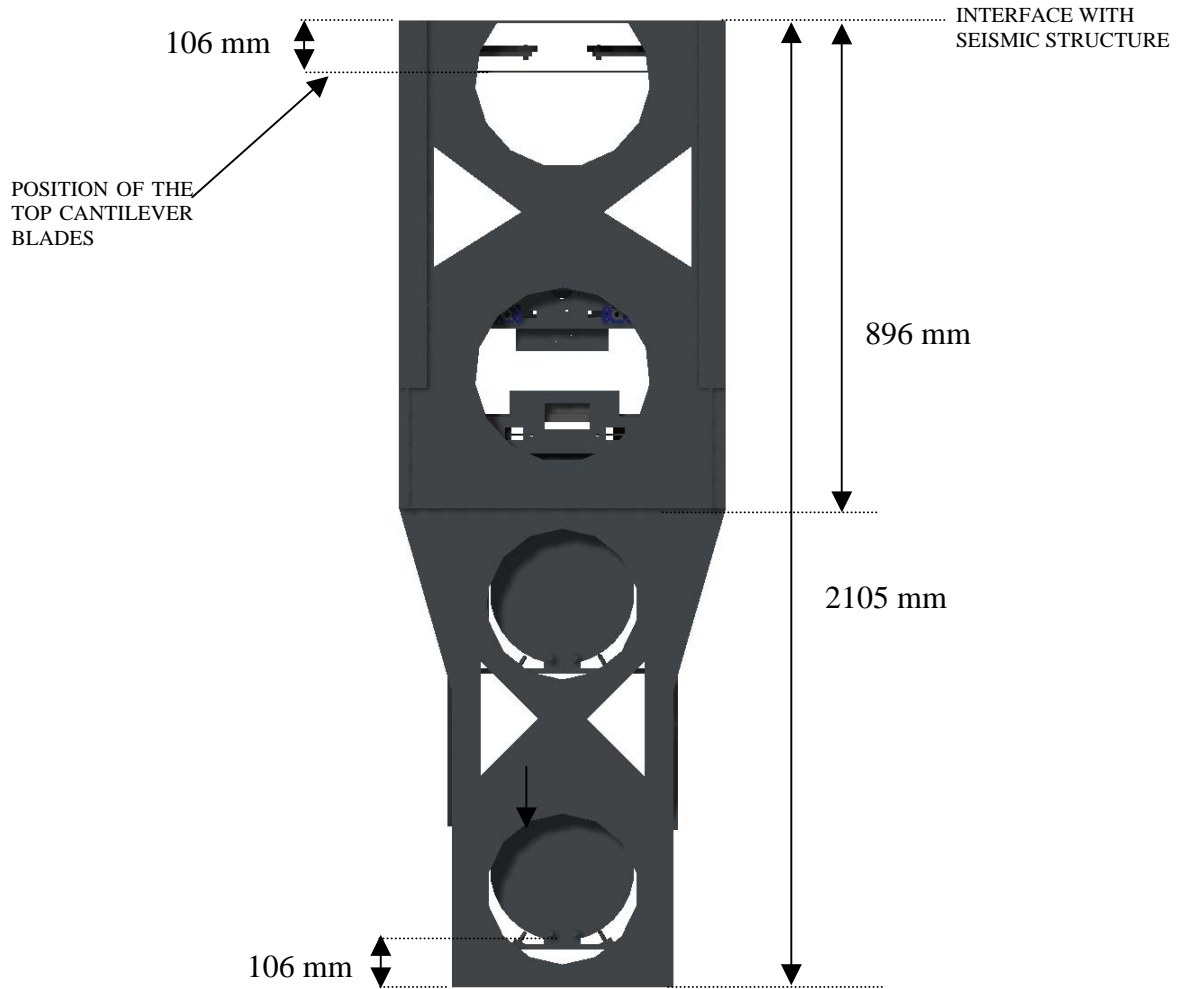


2. STRUCTURE (includes concept layout) & SUSPENSION FROM ABOVE ³



² The individual numbers for the length of the quadruple pendulum suspension are from a as yet unreleased quadopt.m parameter file. They are being left open due to the stage of design. Until release please contact Norna Robertson or Calum Torrie for up to date numbers.

3. STRUCTURE (includes concept layout) & SUSPENSION FACE ON³



³ The overall length of the structure comes from an email from Dennis Coyne on 29th July 2003. The width and breadth in D2 came from the March 2003 Systems Tele-con.