ETM/ITM Quad Suspension Noise Prototype Test Plan

May 10th 2007, Norna A Robertson for the SUS team

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Note: This document lists the tests we plan to carry out but not necessarily in the order given below. For detailed information on the schedule and timescale, the following documents should be referred to. The revision at time of writing is given here.

a) **M070046-04-K-LASTI** Noise prototype LASTI schedule- UK perspective. Note that the references in this schedule "TEST1, TEST2" etc refer to the items listed below.
b) **T070096-00-R** Quad Noise Prototype Outline Test Plan, OJEU Timing and Associated Risk. The tests listed in this document correspond to the items listed below.
c) **M060304-10-K** UK/US Quad suspension Milestones: Planned and Needed Dates
d) http://ligo.phys.lsu.edu:8080/SEI/070406_091356/BSC+proto+schedule+3-15-2007.pdf
This is a link to the current schedule for the work on the BSC ISI over the next few months, which schedule is necessarily linked to the quad noise test schedule due to the joint tests.

List of tests.

1) Mechanical fit and alignment test

The mechanical fit test is meant to make sure that all mechanisms work, all parts fit together and no fabrication errors or drawing errors exist. It will be confirmed that the dummy optic can be positioned and oriented according to the requirements. Requirements detailed in the Design Requirements Documents, LIGO-T000053 and LIGO-T010007.

2) Structure freq measurements (to be carried out in UK)

A piezo, impact hammer or another mechanical means will be used to induce vibration in the clamped-down structure. The mass to which the structure is clamped shall be much more massive than the suspension assembly and mechanically as stiff and non-lossy as possible. A large milling machine bed is ideal – an optical table is not suitable. All non-suspended parts shall be assembled onto the structure. About as many clamps should be used as will be used in production. Low mass accelerometers with strain relieved cables will be used to identify at least the lowest-order longitudinal and transverse leaning modes. Comparisons will be made with the finite-element model of the structure produced by the CAD software.

3) Functional electronics tests part 1

This is a stand-alone test of analog parts in UK prior to installation.

4) Pendulum frequency and transfer function measurements

These may be done stand-alone (limited by gazebo stiffness) and/or after attachment to SEI, 6) below. These tests and 5) below may initially use control prototype electronics or some combination of those electronics and the electronics from UK.

The OSEMs will be used to measure the pendulum frequencies of the suspension. A step input of order 10 mN in x, y, z and 0.5 mN·m in yaw, 0.1 mN·m in pitch and 1 mN·m in roll will be applied via the OSEMs at the top mass with the local servo <u>off</u>, to excite as many low frequency modes as possible. All of these numerical values are rough recommendations based on what was found was good for a triple pendulum suspension. They excite the pendulum to give displacements at the OSEMs that are a significant fraction of the linear range of the shadow sensors. The values are as suggested for the triple and TBD for the quad. The output of the top mass OSEMs, and, if available, any OSEMs on lower masses, will be logged for approximately 5 minutes and FFTed to produce frequency spectra. Swept sine excitation of suitable combination of OSEMs for each degree of freedom will be used to generate transfer functions in 6 degrees of freedom at the top mass (from coil drive to OSEM sensor output), both with and without damping. Comparison will be made with transfer functions and frequencies predicted using the Matlab/Simulink design model of the suspension. The frequency range will be as large as practicable within the limitations of sensor noise and acoustic noise in the lab and stiffness of gazebo. Comparison will be made with the Matlab/Simulink design model of the pendulum as well as the Mathematica model.

5) Damping tests/electronic plus ECD

These may be done stand-alone (limited by gazebo stiffness) and/or after attachment to SEI 6) below. The OSEMs will be used to measure the damping response of the pendulum under local control. A step input of order 10 mN in x, y, z, 0.5 mN.m in yaw, 0.1 mN.m in pitch and 1 mN.m in roll will be applied via the OSEMs at the top mass with the local servo <u>on</u>, to excite as many low frequency modes as possible. The output of the top mass OSEMs, and, if available, any OSEMs on lower masses, will be logged for approximately 1 minute and plotted to check that all modes are dying away as expected according to the Matlab/Simulink model of the pendulum and local control system, and in compliance with the 10 s (or TBD) or less requirement.

As before, these step inputs are rough recommendations for a triple pendulum suspension, although they will probably be about right for the quad as well. For the test with damping off, we're trying to get good resolution of the mode frequencies, so we want to sample for many periods. 300 s should give roughly 1% accuracy for modes around 0.3 Hz. For the test with damping on, if there are any modes still ringing significantly after 1 minute there is something wrong in the design of the controller or dampers and debugging needs to commence.

Install eddy current damping (ECD) units and investigate ease of alignment. Measure level of damping in all degrees of freedom and compare to expected damping from MATLAB model. (Note: direct ECD damping is applied in all degrees of freedom except transverse. Some transverse damping will come from coupling of modes).

6) SEI +SUS tests part 1

These are tests outside tank. Assemble SUS on ISI optical table. Look at interaction of SUS structure strut resonances on control of ISI. Characterise dynamic coupling.

7) Initial Installation Test

An installation test will be performed in two stages (as required at LASTI) due to limited head height). The upper section of the noise prototype attached to the ISI will be lifted into the vacuum chamber. The lower section of the noise prototype will be maneuvered through the side and joined to the upper section. Assembly and positioning of ISI+SUS along with final alignment techniques will be practiced.

8) Functional electronics part 2

This includes all electronics inside, through and outside tank. In addition to checking connectivity etc, investigation of pick-up of ESD drive signals on OSEM coils at penultimate and upper intermediate masses will be carried out to ascertain whether pigtails need braiding.

9) Assembly with glass, reinstallation and further SEI+SUS tests

Remove lower structure from tank. Replace appropriate metal parts with silica suspension (ETM version). Test releasing and locking down. Reinstall in tank. Release suspension. Evacuate tank. Perform dynamics testing for seismic isolation and transfer functions for 6 degrees of freedom. Characterise dynamic coupling.

10) Thermal behaviour w/ ring heater

Investigate expansion of structure and any consequences thereof when ring heater in use.
Note that there will also be further extensive testing of the TCS (thermal compensation system) by the AOS group when the ITM/CP suspension is installed- see 12) below.

11) Cavity tests

Test locking of a cavity between noise prototype and available triple prototype (IMC or RM). Tests to include use of modal damping, hierarchical control, investigation of any low frequency control interactions between SUS and ISI, offloading of global control from SUS to ISI. See also 13) below.

12) Assembly of alternative suspension – ITM with CP

Testing will proceed similar to 9) above. After this assembly TCS testing will take place (AOS group).

13) Violin mode damping tests

Remove lower structure. Add sensors. Reinstall. Incorporate electronics as required. Test damping.
This may be done in conjunction with cavity tests.