LASER INTERFEROMETER GRAVITATIONAL WAVE OBSERVATORY
- LIGO -
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Technical Note **LIGO-T0900156-v3-I** 2009/04/21

Reply to "OMC Suspension FDR comments from reviewers"

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1 Introduction

The reviewees' replies to the reviewers comments are included below, italicised and highlighted beneath the corresponding comment.

The Output Mode Cleaner (OMC) Suspension (SUS) Final Design Review (FDR) committee met March 13, 2009 to prepare preliminary questions for the OMC-SUS design team. The committee reviewed documents on the Final Design Review page at `http://ilog.ligo-wa.caltech.edu:7285/advligo/OMC_Suspension/Final_Design_Review`, specifically T0900060-v1.pdf and T0900049-v1.pdf. We were very impressed with the quality of the documentation and the performance of the OMC-SUS. We believe some additional measurements will complete the FDR package and allow us to quickly approve the OMC SUS for advLIGO.

Since the OMC-SUS was designed and installed for Enhanced LIGO, there was no formal Preliminary Design Review. Consequently, this FDR may exceed the bounds of a traditional FDR as laid out in M050220-09. The installed OMC suspensions provide an excellent opportunity to test against actual interferometer performance and mitigate risks to advLIGO. Before the review committee approves the OMC-SUS design for advLIGO, we'd like to see the test suite expanded and the noise contributions from OMC motion shown to be negligible as calculated.

The advLIGO Output Mode Cleaner will differ from the Enhanced LIGO OMC, perhaps significantly. The new OMC may not be the same mass, nor have the same electronics and cabling requirements. While the major structural components will remain unchanged, a new payload mass would require new blade springs. Consequently, development of an improved blade spring procurement process (per E0900023?) is required for the OMC-SUS.

The remainder of this note presents the review committee's detailed requests for the Final Design Review.

2 Relevant documents

M050220-09 "Guidelines for Advanced LIGO Detector Construction Activities"

T0900060-v1 "OMC Suspension Final Design Document"

T0900049-v1 "Output Mode Cleaner Suspension Lessons Learned, Changes Needed & Problems & Concerns"

T0900080-v1 "OMC Suspension Advanced LIGO Test Plan"

T0900071-v1 "Results of Damping Tests for the LLO OMC"

T0900114-v2 "OMC Suspension FDR comments from reviewers"

3 Detailed comments

3.1 OMC Interface Cables

The OMC electrical cables are the least understood aspect of the OMC-SUS and therefore present the highest possible remaining risk. The Final Design Document offers two somewhat exclusive views: on the one hand modeling predicts a minimal impact from the cabling, on the other hand a 30-fold increase in mode coupling and significant damping is attributed to the cabling. The committee would like to see this issue resolved before advLIGO. Specifically, the committee has the following questions and suggestions:

1. In the worst case model, do the electronics cables compromise the suspension performance to the point of violating the noise requirements?

   We have been doing further modeling which suggests that the natural damping seen is close to the level we might expect from the effect of the cabling. We will be able to comment further on whether the performance obtained violates the noise requirements when such requirements have been supplied to us.

2. The original OMC-SUS designed called for cable routing tied to the intermediate mass before connecting to the structure. Could this feature be re-incorporated into the intermediate mass? If so, how would we prevent the problems we had the first time around? Assuming similar cable stiffness, what does modeling tell us about the impact of such a change?

   We strongly advise against returning to routing the cable via the intermediate mass. When this was done before we found that not only was there coupling of modes, but also the cable significantly affected the DC alignment of the intermediate mass and hence also the OMC bench. Such misalignments were approximately as large as the maximum range of the OSEMs. The cables thus have a significant influence. This is not surprising given that they are relatively bulky and the intermediate mass is only 3 kg. We note that this experiment was done when there was a peek covering on the cabling. However even without this covering we would expect to see an effect. One way to mitigate this might be to increase the mass of the intermediate mass, but that would be a very significant design change.

3. The electronics cables are shielded bundles of wire with non-zero twist that may relax with time. Is this an issue? If so, perhaps an "egg dipper" similar to that found on the quad suspension could be incorporated to explicitly guide the cable routing and ensure excess rubbing doesn't appear after installation.

   We have no evidence for or against relaxation with time being an issue. We are unclear which particular area of rubbing the committee is referring to. We could incorporate an "egg dipper" arrangement if this helps to reduce such rubbing.

4. For eLIGO, the OMC design made "reasonable" design choices to minimize stiffness but did not aim to surpass a specific performance - perhaps there is room for improvement if SUS/ISC can get together.

5. Cable/no-cable tests with the installed hardware can be done in vacuum after Enhanced LIGO. Such a test (or similar) should be used to quantify the impact of the electronics cables before advLIGO. We should all get together on this.

We are happy to help with this.

3.2 Modes and transfer functions

The qualitative agreement between the simulation and measurement as shown in Figure 6 is very impressive. There is less detailed quantitative comparison in T0900060 making it difficult to evaluate whether the suspension meets the requirements. The committee has the following questions and suggestions:

1. Explicitly measure the transfer functions from the ISI to the OMC in units of meter / meter and radians / radian so that seismic noise estimates can be made directly from measured data instead of relying on the models shown in Figures 4 and 5. The upcoming downtime at LLO would be an appropriate time there and SJW will look at this March 22-26 at LHO.

2. The original ISC requirements may not include all the relevant physics. An explicit measurement of the coupling of OMC motion to DARM, followed by an extrapolation to advLIGO will eliminate the risk associated with the OMC suspension. SJW will look at this March 22-26 at LHO.

3. The OMC-SUS to ISI clamping should be improved during the next HAM6 vent and the predicted 140 Hz lowest mode observed. This is already planned by the commissioning teams for the next LLO and LHO vents. Does the 103 Hz modes observed currently impact ISI servo design?

   This is a question for our SEI colleagues. I have asked Brian L.

4. Extend the transfer function measurements to high frequencies. This has at least two advantages: possibly revealing the excess damping in from the electronics cables which are invisible in the 20 Hz transfer functions shown, and checking for electronics cross coupling and failures at higher frequencies. SJW will look at this March 22-26 at LHO.

5. The mode frequency degeneracy makes a complete modal basis control of the OMC difficult and unintuitive. Can anything be done in the advLIGO OMC-SUS to break these degeneracies?

   We assume the degeneracies referred to are in the two horizontal directions (longitudinal and transverse). These are very similar since the wires are vertical. Angling the wires at either or both stages would change the frequencies slightly. However to do this would require significant design changes to clamps, wire jigs and attachment points and (for the lower stage) method of attachment to the bench. It is not clear that a modal basis control is needed.

3.3 Electronics

The OMC-SUS electronics package is in very good shape. The committee has the following questions and suggestions:

1. The current OMC-SUS relies on the CDS borkspace watchdog model. This is inadequate: only 5 DOFs are monitored, the code is un-reviewed, and the watchdog does not conform to T080127 as implied. The ISI watchdog has recently been reviewed and should be modified for use in the OMC-SUS as a part of this FDR.

   Watchdog– The ISI watchdog can be modified and used in the design as the reviewers suggest.

2. Recent ISC work has re-discovered many issues in dealing with ADC and DAC systems. The committee would like to see the in situ spectra for the ADC and DAC along with the advLIGO whitening and de-whitening filter designs to ensure that an appropriate digital dynamic range is used and digitization errors are minimized. These spectra may be taken at the filter module input immediately after the ADC and at the filter module outputs preceding the DACs, eg. L1:SUS-OMC_TOP1_IN1 and L1:SUS-OMC_T1_ACT_LIMIT.

   Agreed. This measurement can and should be made.

3. The BUF634 op amp in the coil driver output will be discontinued in the future. Look for changes to the coil drivers in the future.

   This is a known problem. The coil driver board will need to be redesigned to use a different buffer. We are presently using the OPA544 on the triple coil drivers. Once we verify the performance of this part we can change the coil driver design accordingly.

3.4 Re-use of existing suspension parts

The design team has carefully identified potential issues with the re-use of existing parts. The committee has the following questions and suggestions.

1. SJW has conferred with the VRB representative Mike Zucker regarding the existing 303 stainless parts. Future parts for the H2 suspension and potential redesigns should be made from vacuum approved materials. The existing parts may be grandfathered into advLIGO.

2. Unless the design team demonstrates that the non-linear couplings induced by bent springs compromises the performance, the review committee is satisfied with the current blades. However, the procurement difficulties experienced by eLIGO seemed to limit the installation options at that time. In keeping with the new blade spring development, replacement blades should be fabricated for both OMC suspensions assuming the current mass (or slightly higher). The decision to replace the blades may be deferred.

3. Nickel plating and corrosion resistance may be a significant problem. As mentioned above, replacement blades should be fabricated, including nickel plating so the blades may be replaced if corrosion is observed or if the OMC suspension is left outside of vacuum for extended periods.

4. The SUS transfer functions should be repeated at intervals to evaluate long term consequences of shot-peening. No further action is required at this time.

5. Please detail the changes between LLO and LHO. Unless the changes provide significant operational enhancement, the committee does not *a priori* see any requirement to rework the LLO suspension.

6. Please detail the IO chassis and cabling changes envisioned.

   The new IO chassis is in the prototype stage of design. Once the design has be completed and tested the details can be made available. The design should be more mature by late summer 2009.

In addition to the issues raised by the design team, the committee strongly recommends that the OSEM shadow sensor electronics be modified to conform to the initial LIGO usage. Specifically, the shadow sensor signals should have a gain and offset such that the digitized signal extends from -10 to 10 volts (or similar) and the nominal, centered OSEM position returns 0 volts.

3.5 Documentation

A few pieces of documentation weren't linked to the FDR WIKI page. The review committee would like to see a subsystem functional block diagram, links to software design, and final specifications. The production plans are unclear or inaccessible by the review team: how many suspensions are required? Similarly, we have found no cost estimates. Once production has started, what is the marginal cost for additional spring sets? For replacement intermediate masses?

Software design: This can be obtained from LLO. (TBD) Block diagram: i) a signal flow diagram for the electronics is on the wiki, see `https://dcc.ligo.org/DocDB/0000/D0900339/001/D0900339-v1.pdf` There is also a block diagram on the wiki that shows the ISI and SUS controls for the OMC, see `https://dcc.ligo.org/DocDB/0000/D0900316/001/D0900316-v1.pdf` Cost information and procurement plan have been provided separately

4 Conclusions

The OMC Suspension design team has put together an excellent design and extensive documentation. The majority of comments above should be considered non-critical suggestions. The few issues that are critical: test the cable damping or calculate that it does not compromise the noise performance, measure the ISI to OMC-SUS transfer function in meter per meter, excite the OMC motion and observe DARM response, and demonstrate a cantilever spring fabrication technique. The upcoming shutdown at LLO provides a great opportunity to monopolize ISI and HAM6, completing the testing.