LASER INTERFEROMETER GRAVITATIONAL WAVE OBSERVATORY

LIGO Laboratory / LIGO Scientific Collaboration

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Suspensions Acceptance Documentation: Output Modecleaner Suspension (OMCS)

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Introduction

The DCC tree for suspensions (SUS) documentation starts at E1200482: aLIGO, SUS. From that top-level DCC page the related documents appropriate to this type of suspension are

- E1200933: aLIGO SUS General Documentation
- E1300429: aLIGO SUS OMCS Assembly and Installation Documentation
- E1000434: aLIGO SUS OMCS Testing and Commissioning Documentation
- E1201043: aLIGO SUS OMCS Acceptance Documentation

The SUS electronics documentation tree is found by following the path

E1200482: aLIGO, SUS

> E1200933: aLIGO SUS General Documentation

> E1100337: Suspension Electronics Drawing Tree

In sections 1 to 10 below we address the 10 items as cited in the Acceptance Review template E1300457-v3 with information appropriate to all OMCS suspensions. Individual suspensions will have their own acceptance documentation, to be found from the filecard for this document (i.e. from E1201043) going to related documents, and then following the link to E1201048 aLIGO SUS OMCS Individual Acceptance Reports.

It should be noted that this document refers only to the OMC *suspension.* It does not cover the OMC itself, which comes under the Interferometer Sensing and Control (ISC) subsystem. Also it should be noted that in older documentation the acronym used for the OMC suspension was OMC-SUS, now shortened to OMCS.

1 Requirements documentation

The design requirements document must be brought up to date, and pointers to background material, analyses, etc. added to the Requirements document. Pointers to prototyping endeavors including testing results if they are not superseded by subsequent testing should be included here.

a. Design Requirements Document (DRD):

T070189 Design Specifications for the OMC Suspension

T0900079 AdL OMC Suspension Electronics Requirements

b. Supporting documents (models, analyses, …)

Further info on modeling is found on the SVN, see section 8.

Prototype tests are superseded by tests on production items.

2 Design overview and detailed design documentation

a) Final Design Document (FDD): must bring the FDD up to date.

T0900060 OMC Suspension Final Design Document

b) Review reports:

- *cite the final design review committee's report*

- *cite the design team's response to the final design review (note that any resulting changes to the design should have been incorporated into the FDD).*

T1200463: Summary of Suspension Final Design Reviews, of which items 13 and 15 are of relevance to the OMCS. References to the reports for each of these reviews are given in this summary document.

c) Supporting design documents: models, analyses, specifications, etc. If not applicable, then state so.

E1200933: aLIGO SUS General Documentation: this DCC filecard lists references to aLIGO SUS documentation that this generic to many or all suspensions.

E1100337: Suspension Electronics Drawing Tree: this leads to all the electronics documentation.

T1300535: aLIGO OMCS Controls Design Description

E1200254: Tolerances for Height Measurements of the HAM Suspensions During Assembly

T1300081: OMC Lower Wire Clamp Development, Crimp and Testing Procedures

G1300086: HAM6 Coordinate System Definitions

Also for electronics, the following link is to a wiki in which information on requirements, sensor and actuator electronics chains and wiring diagrams for all suspensions are linked:

https://awiki.ligo-wa.caltech.edu/aLIGO/SuspensionElectronics

Control range document and Noise Model document – these are on Jeff K's to-do list.

Further info on modeling is found on the SVN, see section 8.

d) Drawings: cite the top level assembly drawing for each major assembly or subsystem. In the DCC, all subsidiary drawings (sub-assemblies and part drawings) must be linked in a drawing tree manner.

D0900293: OMCS Overall Assembly with Fixtures: see related documents on this filecard for all assemblies.

e) Bill(s) of Materials (BOM): cite any collected BOMs. If the BOMs are only to be found on the Assembly and Sub-Assembly drawing sheets, then state so.

BOMs are found on the assembly and sub-assembly drawing sheets. There is also a separate document E0900061 OMCS Bill of Materials.

f) Interface control: cite any documents (such as RODAs) with interface definition/control and/or cite the relevant sections of the DRD and FDD.

Relevant RODAs:

M040189 Record of Decision/Agreement (RODA) - Output Mode Cleaner to be a monolithic cavity

M0900034 Use of SmCo and NdFeB Magnets in Advanced LIGO Suspensions

M0900087 All in vacuum cabling will be shielded

M0900234 SUS (US) blades will use maraging steel 250

M0900271 Division of Responsibilities for Harnesses for Adv. LIGO Suspensions

M1000047 RODA - Decision to modify HAM structures (HLTS, HSTS, OMC)

All of these have been acted on.

g) Software: cite any software design description documentation. If not applicable, or not available, then state so.

Software is documented on the SVN, see section 8.

h) Design source data:

- Confirm that all mechanical design CAD models are in the SolidWorks/PDMWorks vault, or explain what is not and why.

Mechanical CAD models are in PDM works.

- Confirm that all electronics design CAD models (schematics and PWB layouts) are backed up and available on LIGO Lab archives, or explain what is not and why.

Electronics CAD models are available on the DCC.

3 Materials and fabrication specification

Any special materials, or treatment of materials including preparation for in-vacuum use; this may be integrated into the Design documentation.

The process used for manufacturing maraging steel blades, given in E0900023, is referenced on all drawings for the blades. Producing acceptable blades is a complex multi-step process which has been developed from external input and internal experience with prototypes over several years.

The process used for producing weldments for in-vacuum use for Advanced LIGO is given in the welding specification document E0900048. This document details the materials to be used and procedures to be followed, and as with the maraging steel blades, the production of acceptable weldments is a complex multi-step process which has been developed over several years.

4 Parts and in-process spares inventoried

All elements of aLIGO must be recorded in the ICS, or in the DCC using the S-number scheme. As-built modifications for parts or assemblies should be found here.

Assemblies are recorded in ICS. Individual spare mechanical parts which have gone through clean and bake are in general recorded in ICS. In some cases spare sub-assemblies have been put together but not yet recorded as such. Electronics are recorded using the S-number scheme. A separate document has been prepared which summarises storing of spare parts, see T1300908.

5 Assembly procedures

All assembly procedures must be in the DCC and annotated or updated for lessons learned. Storage, if used, should be described here along with procedures to maintain the equipment in good condition (e.g., purge frequency). Transportation procedures and cautions must be noted.

T080117: Output Mode Cleaner Suspension (OMCS) Assembly Procedure

T1200527: Long Term Storage of Suspension (SUS) Parts for the 3rd aLIGO Interferometer

6 Installation procedures

All installation procedures must be in the DCC and annotated or updated for lessons learned.

E070271: OMCS Installation Procedure.

This document has been updated to capture what was done in aLIGO.

7 Test documents

Test rationale, plans, and data for each unit must be documented as described in M1000211. That tree structure should be pointed to by the overall tree structure laid out in this Acceptance prescription. The top-level objective is to make clear how the measurements performed, which often will not directly measure a required performance parameter, give confidence that the subsystem will fulfill the requirements.

7.1 Suspension testing

G1200070: Ideal Order/Contents of aLIGO Triple SUS Testing / Commissioning.

This is the top level description of testing which covers the OMCS (despite its name).

A useful link for key testing procedures is the Checkout/Testing page in the Operation Manual at

https://awiki.ligo-wa.caltech.edu/aLIGO/Suspensions/OpsManual/Testing

Testing related documentation is kept on the SVN repository at

https://redoubt.ligo-wa.caltech.edu/websvn/

The "SUS" svn, linked from the above site contains:-

(a) Suspensions models (Mathematica & Matlab, Damping Filter Design)

(b) Testing tools (DTT templates & Matlab Testing Scripts)

(c) Results from all testing Phases 1-3 (i.e. TFs, Power Spectra & B&K)

For example the transfer functions for all OMCS are found by following the route

"sus" -> "trunk" -> "OMCS" -> "Common" -> "MatlabTools" -> "plotallomcs_tfs.m"

Key test results for each individual suspension are linked from the DCC filecard for the acceptance documentation for that suspension.

In addition to TFs, power spectra and B&K results which are on the SVN, the following results which are called out under phase 1 testing in G1200070 can be found on the DCC.

a) HAM Blade Characterization Data E1000169 and HLTS/HSTS/OMCS Blade Pairings, T0900559

b) Vibration Absorber Test Reports E1101122, and the testing procedure, described in E1200009.

c) OSEM inventory with open light current data, E1200343 (continually being updated as builds proceed)

d) BOSEM test data, T0900496

BOSEM and AOSEM test data are also archived on the SVN at

WebSVN link:-

https://redoubt.ligo-wa.caltech.edu/websvn/listing.php?repname=sus&path=%2Ftrunk%2Felectronicstesting%2FAOSEM%2F&#a44646e7e36d81f2cf1e45386c48e2dda

and

https://redoubt.ligo-wa.caltech.edu/websvn/listing.php?repname=sus&path=%2Ftrunk%2Felectronicstesting%2FBOSEM%2F&#aac680895873bf8fd434d4adf1cffdf72

e) Confirmation of magnet strengths within +/-5%. This formed part of the procurement requirements (C1103521) for the magnet order for HAM suspensions magnets, with inspection reports being required from the manufacturer. The certifications which were received can be found at C1105361 and C1102164 for magnets delivered to LLO, and are linked to C1303339 for magnets delivered to LHO (note that these documents cover more than just the OMCS magnets). In many cases the vendor states the requirements were met but notes that the magnetic test data were "on file and available for inspection" rather than supplying it.

f) Information on alignment/positioning of suspensions (so called "shootings" which include heights etc): this is attached to the relevant ICS entry for a particular suspension for LHO suspensions, and the same will be done for LLO suspensions in due course.

7.2 Electronics testing

The results of the reports are posted in the DCC, under the serial number of the chassis, e.g.

<https://dcc.ligo.org/LIGO-S1000254-v6>

These can be found for LLO by following through the electronics tree, an example of which is given here:

E1100337 - Suspension Electronics Drawing Tree

> S1200522 - LLO Suspension Electronics Racks

> S1105377 - L1-SUS-C7 HAM5-6

> S1101565 - OMC Coil Driver Chassis

A similar structure for LHO is TBC at time of writing.

See also

https://awiki.ligo-wa.caltech.edu/aLIGO/SuspensionElectronics

Testing data can be found linked there.

8 User interface software

User interface software, and the test routines indicating proper functioning of the software, must be described in words and have code under configuration control (SVN). Watchdog and Guardian routines must also be treated in this way.

Each suspension has a user model that is constructed referencing wiring diagrams, built and installed, which runs on a front-end computer. MEDM screens are created to present an operator with model information and enable interaction with a running model. Filter coefficients, gains and other settings can be captured using BURT snapshots, which also provide a safe state to revert to following model restarts e.g. due to power loss etc, as well as retaining alignment offsets for the suspension. All of the aforementioned items; Simulink models, MEDM screens, BURT snapshots, and filter coefficients are maintained under svn revision control. For example, the "cds_user_apps" contains:-

(a) SUS Simulink front-end models, located at

- LHO *${userapps}/sus/h1/models/*
- LLO *${userapps}/sus/l1/models/*

Guide:- https://awiki.ligo-wa.caltech.edu/aLIGO/Suspensions/OpsManual/Simulink

(b) BURT snapshots of model configurations (SAFE, ALIGNED, MISALIGNED etc), located at

- LHO *${userapps}/sus/h1/burtfiles/*
- LLO *${userapps}/sus/l1/burtfiles/*

Guide:- https://awiki.ligo-wa.caltech.edu/aLIGO/Suspensions/OpsManual/BURT

(c) FOTON filter blocks deployed in front-end models, located at

- LHO *${userapps}/sus/h1/filterfiles/*
- LLO *${userapps}/sus/l1/filterfiles /*

Guide:- https://awiki.ligo-wa.caltech.edu/aLIGO/Suspensions/OpsManual/FOTON

(d) MEDM screens for interacting visually with front-end models, located at

- LHO *${userapps}/sus/h1/medm/*
- LLO *${userapps}/sus/l1/medm /*

Guide:- https://awiki.ligo-wa.caltech.edu/aLIGO/Suspensions/OpsManual/MEDM

(e) Scripts to automating processes, interact with suspensions and saving alignments etc, located at

- *${userapps}/sus/common/scripts/*

Guide:- https://awiki.ligo-wa.caltech.edu/aLIGO/Suspensions/OpsManual/PythonTools

Other useful links,

https://awiki.ligo-wa.caltech.edu/aLIGO/Suspensions/OpsManual/Computing (overall cds guide)

https://awiki.ligo-wa.caltech.edu/aLIGO/Suspensions/OpsManual/SVN (svn guide)

https://redoubt.ligo-wa.caltech.edu/websvn/listing.php?repname=cds_user_apps (websvn GUI)

https://redoubt.ligo-wa.caltech.edu/svn/cds_user_apps/ (websvn html interface)

Links to html interfaces for snapshots of currently running Simulink models at each site,

LHO https://lhocds.ligo-wa.caltech.edu/simlink/

LLO https://llocds.ligo-la.caltech.edu/daq/simlink/

9 Operation Manual

A manual appropriate for operators, written in accordance with M1200366, covering setup/initialization, check-out, operating instructions, calibration, maintenance, operations spares plan, storage/transport and troubleshooting. It must be accessible from standard user screens.

E1200633: aLIGO SUS Operation Manual.

Note that this covers quads and triple suspensions due to the large element of commonality between suspensions.

There is also a "rogues gallery" to aid in troubleshooting transfer functions, called "TransferFunctionColoringBook". It is located on the aLIGO wiki at

<https://awiki.ligo-wa.caltech.edu/aLIGO/TransferFunctionColoringBook>

10 Safety

Safety documentation must be in the DCC for all phases of the subsystem development, including any needed for normal use or foreseen maintenance/repair scenarios.

E0900042: AdvLIGO Output Mode Cleaner Hazard Analysis

E1300537: Addendum to E0900042 aLIGO OMC Hazard Analysis