LASER INTERFEROMETER GRAVITATIONAL WAVE OBSERVATORY
- LIGO -

CALIFORNIA INSTITUTE OF TECHNOLOGY
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LIGO Detector Subsystem Review Report

DESIGN REQUIREMENTS REVIEW
Suspension (SUS)

Title

Review Board: W. Althouse (Chairman), J. Camp, P. Fritschel, A. Lazzarini, R. Savage, V. Schmidt, D. Shoemaker, R. Spero, S. Whitcomb, M. Zucker

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This is an internal working note
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REPORT ON THE DESIGN REQUIREMENTS REVIEW OF THE SUSPENSIONS (SUS)

Signature page

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PARTICIPANTS:

Presenters

S. Kawamura, F. Raab.

Review Board

W. Althouse (Chairman), J. Camp, P. Fritschel*, A. Lazzarini, R. Savage, V. Schmidt, D. Shoemaker*, R. Spero, S. Whitcomb, M. Zucker* (*via telephone).

Other attendees

J. Heefner, N. Solomonson, R. Vogt.

DOCUMENTS PRESENTED AND DISCUSSED:

Reviewed Design Requirements Documents

Suspension Design Requirements, S. Kawamura and F. Raab, LIGO-T950011-06-D, May 26, 1995

Viewgraph Handouts

Suspension Design Requirements Review

REVIEW BOARD REPORT:

The review was conducted on June 8, 1995, in the LIGO Engineering Conference Room. The Review Board charge is included in this report (LIGO-L950370, Attachment I). Summary presentations of the Design Requirements document were given (see Agenda, LIGO-L950467, Attachment II), followed by page-by-page review of the document (submitted to the review board in advance). V. Schmidt and D. Shoemaker were unable to attend the review meeting, and were represented by J. Heefner and P. Fritschel, respectively.

Responses to the Board charge and recommended action items arising during the presentations and document reviews are listed below.

- **Is the list of identified requirements complete? Are the values appropriate?**

The SUS design team made great progress in sorting out the myriad requirements and specifications affecting the LIGO suspensions. Action items 1 through 8 are recommendations to carry these steps further, primarily by creating a Requirements Flowdown structure for the interferometer (SYS). The SUS Design Requirements may be considered complete once this structure exists and the recommended clarifications and additions listed in Action Items 9 through 22 are accomplished. Some of these recommendations will affect the values listed in the SUS Design Requirements Document. These Action Items should be completed and the results incorporated into the

document before re-submitting it for review at the PDR.

- **Evaluate the conceptual design of the SUS system.**

The conceptual design for suspensions appears complete and satisfactory. Recommendations for additional supporting analysis and suggestions are provided in Action Items 23 through 29. These actions should be completed before the SUS PDR.

- **Recommend other appropriate actions.**

Other recommendations, all affecting the Detector Systems Design/Analysis, are provided in Action Items 30 through 34. Action Items 30, 31, and 32 are considered particularly urgent and need to be completed before the SUS PDR.

RECOMMENDED ACTION ITEMS:

Requirements flowdown:

1. Adopt a reference spectrum for Total Detector Noise as a LIGO System Requirement.
2. Generate a requirements flowdown representation which allocates the System Requirement noise to each subsystem. The flowdown should trace the allocation to individual interferometer components.
3. Adopt a policy that allocates the System Requirement noise to primary contributors; secondary contributions to the noise should be limited to a value to be determined by Detector System Engineering (approximately ~10%).
4. Clarify the allocation of thermal noise between internal loss and pendulum loss; clarify the allocation of internal mode loss between COC (intrinsic) and SUS attachments.
5. Clarify the allocation of thermal noise between each test mass, beam splitter, recycling mirror, folding mirror (Hanford 2 km IFO), pick-offs, mode cleaner mirror, and other individual components.
6. Clarify the allocation of seismic noise attenuation between stack and SUS transfer functions. Incorporate frequency dependence into the vertical-to-horizontal SUS transfer function and adjust coefficients to reflect actual gravity directions at the LIGO stations.
7. Clarify the allocation of SUS displacement dynamic range between installation (static) misalignment, ASC static and dynamic needs, LSC static and dynamic needs in operation, LSC static and dynamic needs during acquisition, stack resonances, and any other needs. Incorporate an actuator bandwidth requirement, including effects of resonances of magnet/standoff assemblies.
8. Recent measurements of ground noise at Hanford exceed the LIGO Standard Ground Noise Spectrum below 1 Hz. Use the measured numbers to determine dynamic range requirement at 0.15 Hz.

SUS Design Requirements:

9. Provide a description/analysis of the parameters leading to choice of pendulum length and pitch and yaw frequencies.

10. Consider whether Pockels cell and Faraday isolator should be categorized as Small Optics (see also Action Item 30 under Systems Design/Analysis, below).
11. Explicitly identify how structural resonances are accounted for in analyzing seismic noise transfer functions. Specify structural properties needed for engineering the suspension supports.
12. Add subsections under Section 4 for vacuum compatibility, particulate shedding, compatibility with cleaning methods and procedures, stray light requirements, environmental constraints (such as Earth's magnetic field fluctuations and electromagnetic interference).
13. The optic installation scenario seems to affect SUS design, but is not described. Develop, adopt (together with COC/COS and IOO), and describe in an Appendix those aspects of the installation scenario needed to completely specify the SUS design.

SUS Design Requirements Document:

14. Add a Safety section to DRD.
15. There are too many details in the conceptual design description. DRD will either become quickly outdated or undergo many revisions. Simplify and condense the conceptual design description to include only the essential elements (those unlikely to change); move the details to preliminary design.
16. Move Large Folding Mirrors and Large Pick-offs from LOS 2 to LOS 1 category.
17. Add Wedge angle and orientation to Table 3.
18. Replace "Stay Clear" with "Optical Clear Aperture" in Table 3.
19. Replace "Interferometer Signal" with "Length Signal" in Table 9.
20. Add IOO to Table 9.
21. Replace "is" with "is required to be less than" in the statements in Sec. 6.6 (e.g., "The equivalent displacement noise of the sensor *is required to be less than* 1×10^{-10} ...").
22. In Sec. 6.8, the clearance distance of the safety cage elements should be specified.

Conceptual Design:

23. There is concern that the simple edge sensor is very sensitive to stray light. Analyze the signal-to-noise degradation, consider using SNR improvement techniques such as wavelength-selective filtering and/or simple modulation.
24. Elimination of the sensor preamp from the sensor head appears risky. Analyze the potential for interference due to RFI, magnetic pickup and crosstalk, taking into account realistic lead lengths and shielding factors. Identify constraints imposed on location of CDS racks within LVEA.
25. Consider using Sm:Co magnets in place of the Nd:Fe:B magnets.
26. Consider alternative methods to adjust static orientation in order to relax the dynamic range requirement for the coil drive system.

27. Clarify the strategy for locating the suspension wire as it wraps around the optical component between wire attachment points. It is unclear whether the design provides adequate control.
28. Describe the method for cabling suspended Pockels cells without degrading the suspension noise (see also Action Item 30 under Systems Design/Analysis, below).
29. Do the specified LED and photodiode meet vacuum compatibility requirements?

System Design/Analysis:

30. Determine whether Pockels cells and/or Faraday isolators need suspending.
31. Determine beam splitter size.
32. Generate specifications for beam center lines relative to SEI/SUS mechanical interface.
33. Determine if mode cleaner mirrors can be adequately damped by SUS orientation control during operation; if SUS control is adequate, then SUS DRD Table 2 must be revised to reflect this method of damping.
34. Ensure that mode cleaner mirror thermal noise is included in system noise model and requirements flowdown (carry out measurements on PNI or 40 m suspended mode cleaner if needed).
35. Evaluate the effect of unintended electrostatic interactions with the suspended mass, and modify the suspension design if necessary to reduce this effect.

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Sorry if I'm holding this up, just thought I should read the final version first...

Ciao,
Mike

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