LASER INTERFEROMETER GRAVITATIONAL WAVE OBSERVATORY
- LIGO -

CALIFORNIA INSTITUTE OF TECHNOLOGY
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	LIGO-E950087-A	-D	9/28/95
Document Type	*Doc Number*	*Group-Id*	*Date*

__LIGO Detector Subsystem Review Report__

DESIGN REQUIREMENTS REVIEW
Alignment Sensing and Control (ASC)

Title

Review Board: W. Althouse (Chairman), J. Camp, P. Fritschel, S. Kawamura, R. Savage, V. Schmidt, R. Spero, R. Weiss, S. Whitcomb

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This is an internal working note
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REPORT ON THE DESIGN REQUIREMENTS REVIEW OF THE ALIMENT SENSING AND CONTROL (ASC)

Signature Page

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PARTICIPANTS

Presenter

D. Shoemaker.

Review Board

W. Althouse (Chairman), J. Camp, P. Fritschel (via telephone), S. Kawamura, R. Savage, V. Schmidt, R. Spero, R. Weiss (via telephone), S. Whitcomb.

Other attendees

G. Billingsley, K. Blackburn, D. Jungwirth, A. Lazzarini, N. Mavalvala, G. Sanders, L. Sievers, N. Solomonson, R. Vogt, M. Zucker (via telephone).

DOCUMENTS PRESENTED AND DISCUSSED

Reviewed Design Requirements Documents (DRD)

DRAFT Detector Alignment Sensing/Control Design Requirements Document, David Shoemaker, LIGO-T952007-00-I, April 30, 1995

Viewgraph Handouts

ASC Design Requirements Review

REVIEW BOARD REPORT

The review was conducted on May 11, 1995, in the LIGO Engineering Conference Room. The presenter summarized the design requirements, illustrated by the viewgraph handouts, and the Board reviewed the Design Requirements Document, page-by-page. The Review Board charge (as specified in document LIGO-L950413) and its response:

1. **Charge:** Determine whether the requirements identified in the Design Requirements Documents are complete; advise whether proposed requirement values are appropriate; if needed, recommend additional requirements to be specified; and recommend other appropriate actions.

   Response: The ASC subsystem requirements are subdivided into System Level Requirements, Initial Alignment, Wavefront Sensing, Optical Levers, and Centering, each with connection to the Control and Data System (CDS). The DRD review covered primarily the System Level Requirements; the other parts of the ASC Subsystem, and their interaction with the CDS, will be included in the DRD as the document evolves. Except as specified in the list of Action Items below, the requirement values in the current DRD draft (LIGO-T952007-00-

I), are appropriate to the task of designing the LIGO Alignment System.

2. **Charge:** Evaluate the conceptual design of the ASC system.

   Response: The conceptual design is appropriate and complete at the current stage of design, except as noted in the action items below. The review board supports the adoption of "local" (lever arms of approximately 5 to 50 m) optical levers for orientation sensing of critical components, and the exclusion of full-length (2 km and 4 km) optical levers.

RECOMMENDED ACTION ITEMS

ASC Design Requirements and Flowdown:

1. Derive required centering accuracy and allowed angular motion of suspended components, based on following considerations:
   - 1.1 Interaction between beam miscentering and noise in test mass orientation (including effect of noise in optical lever or wavefront sensing).
   - 1.2 Vertical seismic noise coupling to tilt forces on test masses.
   - 1.3 Effect of angular noise in input beam coming from mode cleaner, including effect of recycling cavity on carrier and sidebands, and accounting for the motion of multiple mirrors.
   - 1.4 Static and fluctuating diffraction loss.
   - 1.5 Surface figure imperfections coupled to lateral motion of test masses.
2. Calculate (using the "FFT Program", modal model, or other modeling effort now under development) the interaction between length sensing and alignment wavefront sensing. Estimate the range of the wavefront sensing, and the allowed misalignment range before loss of length sensing signal.
3. Consider the use of wavefront sensing on the mode cleaner mirrors.
4. Calculate alignment sensitivity of recycling cavity, including a comparison of the nearly degenerate case (as may be achieved with very large radius of curvature of recycling mirror) and the degenerate case (recycling and input cavity mirrors perfectly flat).
5. Evaluate whether the centering accuracy requirement necessitates transverse (sideways or vertical) actuators for the seismic isolation stacks.
6. Reconsider specification of 0.9/1.0 allowed signal-to-noise degradation due to imperfect alignment; a value closer to 1.0/1.0 may be feasible.
7. Consider whether a modification to the interferometer configuration, such as a Mach Zender readout, would significantly relax the alignment requirements.
8. Estimate the effect of simultaneous misalignments in several mirrors, as driven by seismic noise, perhaps by Monte Carlo calculation.
9. Document the assumed insensitivity of wavefront sensing to decentering and photodiode non-uniformity.

10. Specify the angular dynamic range required of SUS actuators, in the 0.1 to 10 Hz band.
11. Clarify the distinction between requirements on seismic noise level and noise in suspension actuators.
12. Decide on partition of "dog leg" pick-off beam for initial pointing monitor between IOO and Initial Alignment.
13. Include requirements for CDS Remote Diagnostics.
14. Eliminate the "Alignment requirement for stability of LSC" entry in Table 2; it is redundant with the acquisition requirement.

Design Requirements Document

15. Define the scope of the ASC in terms of functionality, software, and hardware.
16. Define ASC interfaces to other subsystems, including "signal" interfaces (the latter may be included by reference to a controlled version of an Interface Control Document).
17. Define a standard format for state transition diagrams, and implement in Figure 2. Include explanatory text for Figure 2.
18. Standardize and unify naming conventions for mirrors and similar components, and for states of the interferometer.
19. Clarify the numerical value of the centering requirement (numbers between 3.5 mm and 3.8 cm are stated).

Conceptual Design, Implementation, and Testing

20. Consider effect of stray light baffling on available field of view for initial alignment system.
21. Consider interaction between ASC states and transitions with states and transitions of other subsystems; design to minimize these interactions.
22. Include control of pointing of beam incident on interferometer.
23. Explicitly include television cameras in the design where needed.
24. Provide a signal that indicates if alignment is in "acquisition range."
25. Estimate magnitude of microseismic peak at Livingston site; if considerably larger than the Hanford estimate used in DRD, consider implications for conceptual design.
26. Break down the Test Plan by conceptual design tests, tests of subcomponents, and system tests.
27. Expand the Test Plan to include real-time testing of the software.
28. To the maximum extent practicable, select computer hardware for the test plan that is compatible with the hardware to be installed in LIGO.
29. Move the fabrication and implementation of the optical levers, currently carried in COS and IOO subsystems, to the ASC subsystem.
30. Include CDS design in the ASC System Level design.

Other Recommendations

31. Consider a measurement of long-term angular drift of the stacks in the 40 m interferometer.
32. Establish and maintain a Detector dictionary of terms and names.
33. The interfaces to Vacuum Equipment should be frozen at the Initial Alignment DRR.