LIGO MIT LABORATORY
MIT NW17-161
175 ALBANY STREET
CAMBRIDGE MA 02139

MEMORANDUM

DATE: September 29, 2006

TO: Phil Willems, Mike Smith, Dennis Coyne, David Shoemaker, Carol Wilkinson

FROM: Advanced LIGO TCS review committee: P Fritschel (chair), Muzammil Arain, Bill Kells, Guido Mueller, Dave Ottaway, Ken Strain, Mike Zucker

SUBJECT: Report on the AdLIGO TCS Design Requirements & Conceptual Design Review

Refer to: LIGO-L060066-00

The committee named above has reviewed the design requirements and conceptual design for the Advanced LIGO Thermal Compensation System (TCS). These are documented in:

- T000092, *Auxiliary Optics Support System Design Requirements Document, Vol. 1 Thermal Compensation System*
- T060083, *Auxiliary Optics Support System Conceptual Design Document, Vol. 1 Thermal Compensation System*

The committee reviewed v02 of T000092 and v00 of T060083, and generated a set of issues and questions for the TCS design team (Phil Willems and Mike Smith) to address. The team responded to these questions and issues in a review presentation, delivered during the August 2006 LSC meeting; the presentation document is G060498-00, *Thermal Compensation System Design Requirement and Conceptual Design Review Presentation*. Additional technical notes were provided in follow-on discussions between the committee and the design team:

- T060214-00, *Test Mass Thermal Compensation Strategies*
- T060224-00, *TCS Actuator Noise Coupling*

The review committee is satisfied that, to the best of our knowledge, the TCS requirements are complete, appropriate and well-motivated, and that the design is ready to enter the preliminary design phase.

Recommendations of the committee:

1. Compensation Plate Ring Heater. The original thermal compensation concept included ring heaters for the four test masses and the two compensation plates (CP). However, there were conceptual problems with simultaneous compensation on the ITM and CP using the ring heaters (with the ITM compensation applied to correct the ITM HR

surface, the resulting bulk distortion in the ITM could not be compensated by the CP ring heater). Furthermore, there were significant design difficulties found in trying to incorporate the CP and ring heater into the suspension system. The TCS design team proposed to eliminate the CP ring heaters, and rely solely on the carbon-dioxide laser projector compensation of the CP. The review committee concurred with this proposal.

2. TCS Sensor Strategy. The conceptual design provides thermal aberration sensors for the two recycling cavity optical paths, and the four test mass HR surfaces. This information could be very useful, however the hardware required to implement the design appears to be fairly complex. For the recycling cavity paths, bringing the sensor probe beams in through the interferometer input and output beam telescopes may be viable and involve less in-vacuum hardware. We encourage the team to look at other possible simplifications to the sensor implementation. The committee recommends that the team continue developing their concepts for providing the proposed sensors, and that the issue of whether the information they would provide is worth the complexity of the system continue to be examined at future TCS reviews.
3. Beamsplitter Sensing and Actuation. Thermal aberrations in the beamsplitter (BS) are smaller than those in the ITMs, but 'not ignorably small'. The design calls for a dedicated sensor for the BS aberrations, though there is no BS actuator (BS aberrations can be compensated for in the CPs). This is a reasonable approach given the assumed conditions, but the committee suggests that if the BS could be made of lower absorption fused-silica (0.5 ppm/cm or so, versus 2-3 ppm/cm), its aberrations would be small enough that they could be ignored, and the BS sensor could be eliminated from the design. This suggestion has been passed on to the COC team to look into.
4. Effectiveness of Arm Cavity Compensation. Phil W presented us with an initial analysis of the effectiveness of the thermal compensation, in an isolated arm cavity, with the expected thermal loading (in an email communication). This analysis said that the diffraction loss of the compensated cavity mode was 22 ppm round-trip. This is much larger than the diffraction loss of a TEM00 gaussian mode in an undistorted cavity (~1 ppm), and a significant fraction of the total arm cavity round-trip loss budget of 75 ppm. This question obviously needs looking into, and should be analyzed with Hiro's FFT simulation.