Report of LASTI Technical Advisory Committee,
based on its first meeting, 17 March 2000 (at the LSC meeting, LLO.)

Summary:
The LASTI team presented a very clear and well thought out plan to the Technical Advisory Committee. One outstanding issue requires further analysis and then a decision by LIGO as a whole: What should be the sensitivity goal of displacement noise tests at LASTI? The answer should come in the context of a general policy decision, relevant to all LIGO test facilities, on the question, "How close to the LIGO II sensitivity level do tests need to come?"
The TAC agrees with the LASTI team that the White Paper schedule is very aggressive. We endorse the plan to recruit LSC members to help with the tests in LASTI, and recommend that commitments be sought through the regular process of MOU attachment revision.

Members in attendance: Rolf Bork, Dennis Coyne, Riccardo DeSalvo, Brian Lantz, Fred Raab, Peter Saulson (chair), and Alan Weinstein.

Before the meeting, the TAC received a written description of the LIGO Advanced System Test Interferometer, *LASTI LIGO II Mechanical Subsystem Tests: Objectives and Approach* by David Shoemaker and Mike Zucker (LIGO T000025-00-R). The meeting began with a presentation by Shoemaker and Zucker that summarized and discussed the plans for LASTI. This presentation was the occasion for questions from the TAC and from other LSC members in attendance.

Additional discussion was focused on the following questions:
1) Are the goals worthwhile, and do they fit well with LIGO's needs?
2) Is the plan a sensible way to reach the goals?
3) Are the facilities well suited to the plan?
4) Is the schedule sensible?
5) Is the labor adequate to meet the schedule?

Goals:

At the highest level of abstraction, the goal of LASTI work for LIGO II is to test at full scale the seismic isolation (SEI) and suspension (SUS) subsystems of LIGO II. Those tests can be logically divided into tests of
a) installation and fit,
b) seismic isolation,
c) control function, and
d) noise level.
(Of course, a particular test may not necessarily fit into just one of these four categories.)

There is no doubt that this set of tests will make a crucial contribution to LIGO II. The tests at LASTI will play a key role in ensuring that the tested subsystems are ready for

installation. These kinds of tests can be performed nowhere else, short of the LIGO observatories themselves. The observatories will be occupied by the operating LIGO I interferometers, so LASTI will provide a large part of the data that can show that LIGO II hardware is mature enough to justify the replacement of LIGO I.

If the world were simpler, then it would make sense to insist that all LIGO II requirements on the SEI and SUS subsystems were met in LASTI tests. Unfortunately, the smaller scale of LASTI (maximum arm length of 16 meters) means that a realistic displacement noise test may be difficult, if not impossible. Thus, it is important to sort the goals by the degree of realism that LASTI tests can achieve, so that realistic performance targets can be set. The challenge for LIGO will then be to examine alternative ways of learning what cannot be learned with LASTI, or to decide to accept the risk of learning some things only after installation of a full-scale interferometer.

LASTI was designed so that the installation and fit tests could be performed, with an excellent match to the vacuum chambers at the observatories. The lower crane hook height may make a slight difference in how a tall isolation system was installed, but this does not sound important, as long as the SEI design does not call for any extension in the height of the BSC chambers.

Seismic isolation measurements can also be performed with few impediments, using conventional seismometers first, and then interferometric measurements for differential motion between systems in separate tanks. Although sensing noise in these measurements will limit the frequency range over which they can be extended, they will nevertheless cover a large interesting range, and will enable crucial tests of performance to be made.

Control tests cannot be a perfect match to LIGO, since the optical plant of the interferometer will necessarily have crucial differences in LASTI. For this reason, modularization of the control scheme into “generic” and “LASTI-specific” subsystems is planned. This will enable much of the set of control functions to be exercised in a realistic way, and would be sufficient to catch problems like the ones that were only diagnosed in LIGO I after installation at the observatories.

It is principally in the displacement noise tests that it may be difficult to reach performance comparable to the LIGO II requirements. The major reason for this is the beam diameter dependence of test mass internal thermal noise, and especially of its thermoelastic component. The short length of the LASTI arm cavities would most naturally support narrow optical beams, and thus over-emphasize (by about a factor of 1000) the thermoelastic thermal noise. It was emphasized that aggressive use of wider beams could bring the gap down to a factor of 30 before reduced cavity stability caused overwhelming problems.

This raises the question of how valuable would be the proposed displacement noise tests. One overly harsh judgment might be that the tests as proposed would not be even as good as what has already been learned in LIGO I. Of course, it would be new designs that

were being tested in LASTI, so even tests at poorer-than-LIGO I levels would rule out certain kinds of problems.

Clearly, some additional examination of the displacement noise tests is required. Several technological options were discussed at the meeting, including replacing the proposed 20-cm cavity with a full Michelson configuration using all of the available 16 meters of arm length. Another alternative would be to perform many of the displacement noise tests with fused silica test masses in place of the proposed sapphire ones, to take advantage of the fact that thermoelastic thermal noise is small in fused silica. (Perhaps tests of sapphire are best done at the Thermal Noise Interferometer, although that facility faces exactly the same beam size issue.) But if fused silica masses were used for some of the noise tests, how big is the risk that sapphire-specific problems would be thereby overlooked? Both of these alternatives (16 meter arms and fused silica test masses for noise tests) deserve further technical consideration, with support from the Suspension Working Group as required.

(There is, in principle, a third testing option: finding a way to decommission only a single long LIGO interferometer, and use it for tests that cannot be performed on smaller scale facilities. But it is not obvious that this can be done without intolerable interference with observations being made by LIGO I.)

Once the technological options are laid out, then the strategic question can be asked: *to what noise level must LIGO II suspensions and isolation systems be tested before they can be declared ready to install?* This question is clearly an important one, requiring detailed consideration by LIGO as a whole, and in the context about overall judgment about similar questions for other LIGO II tests.

Nevertheless, the TAC wishes to emphasize its judgment that the other goals of LASTI are both very important and quite achievable. It is merely the last stage of the goals that requires clarification.

Plan:

The plan for achieving the LASTI goals appears to be very well thought out. One attractive feature is that the set of tests is modular, allowing separation of tests that don't depend crucially on displacement noise levels from those that do. Thus, to a large extent the plan can be carried out regardless of the judgment on the displacement noise question.

Facility:

The LASTI facility at MIT appears eminently suitable for performing its function. The TAC was happy to hear the news of successful commissioning of the LASTI vacuum envelope.

Schedule:

The first milestone on the White Paper schedule, “LASTI envelope commissioned”, was passed, albeit a bit later than the planned 4Q99 date. The milestone for 1Q00, “LASTI external structures installed” has not been passed, but the TAC agreed it is not necessary yet and can be quickly performed when it is needed.

We recommend that the LASTI infrastructure review be held on schedule by the end of 2Q00. At this review the LASTI team should present a straw-man optical design, specifying beam sizes, radii of curvature, g-factors, etc, and resulting thermal noise limits for the small-beam case and for the expanded beam size. The LASTI TAC will then hold a brief meeting during the next (Aug ‘00) LSC meeting, for follow-up of any outstanding issues. The TAC will make a recommendation to the LSC by the end of the Aug ‘00 meeting.

All agreed that the schedule is aggressive. The compressed nature of the schedule is expressed in several features. The 1Q02 milestone for installation of high-quality isolation system prototypes and controls prototypes for the suspension system will stress the LSC groups charged with supplying them. The preceding milestone at 3Q01, completion of LASTI infrastructure, will perhaps stress the PSL and CDS groups just as much. (Here is another place where an overall LIGO II test plan may be needed, since the stress on deliveries will come in part from competition between LASTI’s needs and those of other testing programs.) Finally, the schedule allots only 6 months to performing displacement noise tests, which many in attendance agreed was unrealistically brief if the displacement noise tests are to be performed at a challenging level.

To a large degree, the compressed nature of the LASTI schedule reflects that of the whole LIGO II schedule. Indeed, LASTI’s schedule was primarily determined in a top-down way to dovetail with the overall needs of LIGO II.

Labor:

While the present LASTI workforce is quite small, the proposed workforce appears to be adequate. Growth will be partly achieved by new hires at MIT and by reassignment of present staff as they complete LIGO I tasks. But it is also clear that the required work can not be achieved without the willingness of LSC members to come to MIT for visits of substantial duration. This will be a new mode of work for the LSC. Over the next six months to one year, such work will have to start being included in the MOU attachments of Suspension Working Group members.

ACTIONS:

1. LIGO needs to develop an overall LIGO II test plan, so that the roles of individual facilities like LASTI can be developed in the proper context.
2. Within the context of this plan, determine the appropriate sensitivity target for LASTI displacement noise tests, and adapt the LASTI plan as necessary.
3. Recruit LSC members for participation in LASTI tests, through the standard MOU attachment update process.
4. LASTI should hold its Infrastructure Design Review on schedule (by the end of 2Q00.)
5. The TAC will report to the LSC at the next meeting (Aug ’00.)