Attachment Number B to the

Memorandum of Understanding (LIGO-M950060-A-M)

between the

Stanford Advanced Gravitational Wave Interferometry Group

and the

Laser Interferometer Gravitational Wave Observatory (LIGO) Laboratory

February 15, 2000

This Attachment to the Memorandum of Understanding LIGO-M950060-A-M covers the role of the Stanford Advanced Gravitational Wave Interferometry Group (Stanford Group) as a Charter Member of the LIGO Scientific Collaboration (LSC) and a member of the Isolation/Suspension/ Thermal Noise Development Group (ISTNDG). The period of performance for the activities in this Attachment is from February 15, 2000 to August 15, 2000. This period may be modified by agreement to a revision of this Attachment.

1. LIGO Scientific Collaboration - The LIGO Scientific Collaboration is organized as a separate organization from the LIGO Laboratory. It includes scientists from the LIGO Laboratory, and those from collaborating institutions, and has its own leadership and governance. The Collaboration will ensure equal scientific opportunity for individual participants and institutions. It will organize the research, publications, and all other scientific activities. The Collaboration will report to the Laboratory Directorate for final approval of its research program, technical work, observational physics publications, and talks announcing new observations and physics results. This will be done through regular reports to the Directorate and its PAC.

2. Charter Membership - An initial period for formation of the Charter group of institutions in the LIGO Scientific Collaboration commenced on March 1, 1997 and ended following the first full meeting of the Collaboration at which the Collaboration Council assumed its role.

   Following the charter period proposals will be evaluated through the Collaboration Council. With Collaboration approval, an MOU with the LIGO Laboratory, including Attachments defining specific work, will be required for any participating institutions.

3. This document is an agreement between the Stanford Group and the LIGO Laboratory concerning the activities of the Stanford Group as a Collaborating Institution in the LIGO Scientific Collaboration (LSC) and in the Isolation/Suspension/Thermal Noise Development Group (ISTNDG), and as indicated in Item No. 8 below.

4. Isolation/Suspension/Thermal Noise Development Group - The Isolation/Suspension/Thermal Noise Development Group (ISTNDG) is the scientific collaboration for defining and developing future isolation and suspension improvements for use in advanced subsystems for the ini-

tial LIGO interferometers or in entirely new advanced interferometers. A specific Attachment will define the roles and responsibilities of groups in this development group. Members of this group will normally be authors on publications reporting the work of the group and will normally be eligible to participate in data runs and science beyond the LIGO I data run.

5. Report of Progress - The Stanford Group will provide a status report on its activities in support of LIGO every six months. The report will consist of: a) a summary status on research by topic as indicated item No. 8 below including progress against the milestones if any, significant accomplishments such as new insights/discoveries or publications, issues of concern if any, and an indication of invested time, b) updated List of Collaborators, and c) a plan of activities for the succeeding six-monthly period. The report will be due one month before the close of the period of performance under the Attachment in question.

6. Term of Membership - The membership will be renewed every six months upon evidence of satisfactory performance of agreed upon duties.

   The Stanford Group coordinates are included in Attachment Z to the Memorandum of Understanding LIGO-M950060-A-M.

7. Intellectual Property Rights - The rights to intellectual property developed under this Attachment will be subject to the National Science Foundation Grant Policy as indicated in Section 730, Intellectual Property.

8. During the period February 15, 2000 through August 15, 2000 Professors Dan DeBra, Jonathan How, Martin Fejer and James Harris; Senior Research Associates Roger Route and Eric Gustafson; Post Doctoral Research Affiliates Alex Alexandrovsky, Sheila Rowan and Brian Lantz; Graduate Students Sam Cowley, Wensheng Hua, Corwin Hardham and David Jackrel; will continue work on suspensions and test mass materials and their fabrication techniques as well as active alignment, isolation and control systems for LIGO II and high power photodiodes. The Stanford Group will:

   Materials and Fabrication

   a) In collaboration with LIGO and GEO, investigate the properties of sapphire samples including: Q of large samples, Q of samples with optical coatings, Q of silicate bonded samples, transmissive uniformity, surface figure, microroughness, birefringence, optical absorption at 1064 nm, silicate bonding of silica to sapphire, and issues related to the optical coating of sapphire.

   b) Study issues related to the possible increase in test mass acoustic loss when silica attachments are silicate bonded to sapphire acoustic resonators. This will be done using a sapphire acoustic resonator which is a 3 inch long by 1 inch diameter right circular cylinder with a polished flat surface whose surface normal is at a right angle to the long axis of the sample. The mechanical Q of this resonator has already been measured. A silica attachment will be silicate bonded to the flat surface and the Q will be remeasured to investigate the possibility that silicate bonding increases acoustic loss. These measurements will then be confirmed by the GEO collaborators.

c) Two 4 inch high, 4 inch diameter silicon acoustic resonators have been obtained and polished on both the barrel and flat faces. One sample is oriented along the 100 axis and the other along the 111 axis. The mechanical Q's of these samples are being measured.

d) Sheila Rowan will continue the bonding studies at Stanford which will involve optimizing the bonding solution chemistry and measuring the strength of bonds. This will be done, in collaboration with Phil Willems at LIGO/Caltech, in two pilot studies with relatively small sample sizes. Stanford will be responsible for the pilot study bonding of samples of silica to silica and later silica to sapphire and to silicon. The training in the silicate bonding technique on the part of LIGO/Caltech personnel will begin. The pilot study stage of the development program will provide the data necessary to scale up the experiments to larger sample sizes and by this time the bonding technology and art will have been transferred to LIGO/Caltech. P. Willems will be responsible for the systematic destructive testing of the bonds and building an apparatus for these measurements for both the pilot study and the scaled up study. Stanford, in collaboration with GEO, will provide support to LIGO for the investigation of nondestructive diagnostic testing of the silicate bonds.

e) Continue the collaboration with the Syracuse group on the effects of optical coatings on high Q materials. The Syracuse group is leading the effort on making measurements of optical coatings on silica and the Stanford group will lead on the measurements on optical coatings on crystalline materials. The initial measurements have been made on small microscope slide like samples which are melted and pulled into a series of three flat plates connected with two thin silica fibers. The device is suspended from the top plate and the Q of the bottom plate is measured first when uncoated and then coated. This technique is showing great promise but additional development work is required to be able to insure that the measurements are unambiguous in measuring the change in Q due solely to the coating. Also, while the geometry of the samples is attractive for silica, the fabrication technique is not directly applicable to sapphire attachment because it cannot be melted and pulled or easily welded. However, by silicate bonding silica attachments to sapphire plates and then welding silica fibers to those attachments, a similar device can probably be fabricated. Greg Harry of the Syracuse group has visited Stanford and worked with S. Rowan in the silicate bonding of the silica attachments blocks to large (approximately 2 cm thick by 10 cm in diameter) flat silica resonators. If this scheme works on silica it will then be tried on sapphire.

f) Optical absorption measurements at 1064 nm and at 514 nm will be carried out on sapphire samples from Crystal Systems, Inc., as part of the study to reduce residual optical absorption in their material (at 1064 nm) by identifying responsible impurities and/or defects. These measurements will be made by A. Alexandrovsky using the Photothermal Common-Path Interferometry method. The Stanford group will then work with Crystal Systems, Inc., to develop growth strategies to reduce the defect levels.

Active Alignment, Isolation and Control

g) Complete fabrication of a long throw low noise, laminar flow hydraulic actuator. The actuator will be used outside of the vacuum system in a control scheme to reduce the microseismic peak and to provide course alignment actuation. The fabrication of a testing apparatus for the above device will be completed and the noise measurements will begin. The apparatus will make it possible to exercise the actuator through its range of motion while measuring noise. The noise measurements will be initiated.

h) Complete the testing in air of the single layer, 6 degrees-of-freedom (DOF) active isolation platform. This will include the optical displacement sensors, developed in the previous 6 months, to provide length information to be blended with the geophone sensors.

i) Build a copy of a GEO triple suspension as part of an experiment to develop control algorithms for single stage (feedback) and multistage (feed-forward and feedback) active platforms.

j) Begin the integration of the GEO triple pendulum and the single layer 6 DOF isolation and control platform.

k) Continue the development of 6 DOF dynamic models of the single stage active isolator and GEO triple and quadruple suspension and use this code in the development of control algorithms to be implemented in the real time control computer. Compare this code with the GEO suspension model for the GEO triple pendulum.

l) Provide design and modeling support for JILA, LSU and LIGO/MIT in the development of a stiff rapid prototype isolation system. This system, consisting of a two stage, 6 DOF active isolation, alignment and control platform, will be used ultimately to demonstrate robust operation of a two layer, active, stiff seismic isolation system.

m) Collaborate with LIGO/MIT, JILA and LSU in the development of a reference design for a stiff isolation and control system which will support the GEO quadruple pendulum under development for LIGO II.

High Power Photodiode Development

n) The main task for the development of the photodiode during this time period is the fabrication of several low power, unpackaged, rear-illuminated InGaAs p-i-n photodiodes. The device structures will be grown using MBE graded growth techniques previously developed and then fabricated with particular attention to the contacts and resistive layers to improve power handling and linearity. These devices will then be tested at MIT.

9. As part of the research collaboration under this agreement the LIGO Laboratory will share, as requested and appropriate, LIGO data of relevance to the research topics in Item No. 8 above.

10. The research effort pursuant to this Attachment B will be coordinated by Eric Gustafson and Syd Meshkov on behalf of Stanford Group and the LIGO Laboratory, respectively.

11. Resource Sharing:

LIGO Laboratory will:

Contribute resources including allocation of appropriate scientific and engineering personnel, research facilities and funding in support of the effort in Item No. 8 as indicated below. These resources will be in addition to the coordination effort and data to be made available per Item No. 9 above.

a) Provide accommodations for Stanford Group investigators while on LIGO research assignment at Caltech, and/or LIGO sites.

b) Exchange its sapphire samples with the Stanford Group.

Stanford Group will:

a) Exchange its sapphire samples with the LIGO Laboratory.

b) Provide facilities for the LIGO/Caltech personnel while on training in the silicate bonding technique.

Approved:

Barry Barish
LIGO Laboratory Director

6-12-00
Date

Robert L. Byer
Principal Investigator

June 26, 2000
Date