Memorandum of Understanding (LIGO-M050297-00-M)

between the

Stanford Advanced Gravitational Wave Interferometry (SAGWI) Group

and the

Laser Interferometer Gravitational Wave Observatory (LIGO) Laboratory

August 15, 2005

The purpose of this Memorandum of Understanding (MOU) is to establish and define a collaborative relationship between the Stanford Advanced Gravitational Wave Interferometry (SAGWI) Group and the Laser Interferometer Gravitational-Wave Observatory (LIGO). Both parties to this agreement share the broad goals of developing the instruments and techniques for detecting and studying gravitational waves, and subsequently using them as an astrophysical probe. Under this MOU, the SAGWI Group will be a member group of the LIGO Scientific Collaboration.

1. The Stanford Advanced Gravitational Wave Interferometry (SAGWI) Group consists of Professor Robert L. Byer, who will serve as Principal Investigator for research in LIGO, plus four additional faculty, four staff, engineers, postdoctoral affiliates and students, giving a group typically numbering 20. The focus of the work done by the SAGWI Group under this agreement will be research on high power lasers for future LIGO detectors, research on related aspects of optical interferometry (thermal noise, optical coating designs, bulk and coating optical losses, mechanical Q, etc.), development of suspensions and isolation platforms, research on advanced interferometer concepts for gravitational wave detection, and participation in gravitational source modeling and data analysis.

2. LIGO comprises two parts: the LIGO Laboratory and the LIGO Scientific Collaboration. These two entities report to the LIGO Directorate, consisting of the LIGO Director, the LIGO Scientific Collaboration Spokesperson, and the LIGO Laboratory Deputy Director. The design and construction of the LIGO Observatories was carried out by California Institute of Technology (Caltech) and the Massachusetts Institute of Technology (MIT) under a Cooperative Agreement between the National Science Foundation (NSF) and Caltech. The LIGO Oversight Committee supervises the realization of LIGO.

    A. The LIGO Laboratory is responsible for the operation of the LIGO Observatories, the development and implementation of future detector systems, and participates in all aspects of the research with the LIGO detectors. LIGO is a system of three interferometric Fabry-Perot antennas,

two of them 4 kilometers long and the third one 2 kilometers long, aimed at the simultaneous detection of gravitational waves in the frequency range 40-6000 Hz. LIGO Observatories are located in Hanford, Washington and in Livingston Parish, Louisiana (USA) and began observations in the year 2002. The LIGO Laboratory is funded through a Cooperative Agreement between the National Science Foundation and Caltech, with the portion of the LIGO Laboratory at MIT funded through a subcontract from Caltech.

B. The LIGO Scientific Collaboration (LSC) is organized as a separate entity from the LIGO Laboratory. It includes scientists from the LIGO Laboratory, and those from collaborating institutions, and has its own governance and leadership (which includes the LSC Spokesperson as a member of the LIGO Directorate). The Collaboration ensures equal scientific opportunity for individual participants and institutions. It organizes the research, publications, and all other scientific activities. The Collaboration reports to the LIGO 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 Program Advisory Committee. The organization of the LSC and its governance are defined in its Charter.

3. As a member group of the LSC, the SAGWI Group will participate in the governance of the LSC and in setting its policies and procedures, as defined in the LSC charter. Similarly, it agrees to abide by the policies and procedures adopted by the LSC and posted on its website (http://www.ligo.org/policies.html), concerning publication, data access, software standards, and so on.

4. Membership in more than one collaboration active in the same area of research may present complications. Members of the LSC contemplating joining other gravitational wave collaborations or participating in data analysis efforts with collaborations outside a framework established by the LSC should inform and consult with LSC and the LIGO Laboratory to ensure that no conflicts of interest exist.

5. The LSC is the primary advocate of interferometric gravitational wave research in the U.S. To function effectively in this role, it needs to be informed in advance about major new initiatives. The SAGWI Group agrees to inform the LSC of any major new proposals related to LIGO to be submitted to the NSF, and to consult with the LSC concerning the best approach to support the overall LIGO program. The final decision about the scope of any such proposal shall remain the prerogative of the SAGWI Group.

6. LSC Service Functions - Participation in the LSC brings with it responsibility for service functions to support the overall effort in achieving high detector sensitivity and high data quality. In particular, each LSC group is expected to assist in the staffing of scientific monitoring shifts during organized data runs. The staffing of these shifts is notable for both its importance and the travel burden it places on

scientists. This burden makes an equitable shift allocation mechanism necessary.

A nominal guideline is that each LSC group should staff a fraction of the shifts comparable to its FTE fraction devoted to LSC activities. Robert L. Byer (SAGWI Group) will be responsible for interaction with the designated LSC Shift Organizer with respect to the SAGWI Group's Service Function commitments.

Groups making extensive contributions to the LSC in other service efforts that involve a substantial travel burden may request a reduction in their nominal share of shift staffing. Those efforts can include:

- Commissioning and instrument improvement
- Participation in on-site detector characterization investigations
- Development/operation of analysis software/hardware infrastructure and validation of analysis software that requires travel away from the home institution.

7. Each party to this agreement continues to be responsible for all support of its staff including travel costs associated with the activities under this agreement. Exceptional support of travel by the other institution may be allowed for travel requested by that institution.

8. Attachments to this MOU will be prepared annually to define the specific activities and responsibilities of the SAGWI Group and to define any resources to be provided by the LIGO Laboratory to the SAGWI Group in support of those activities.

9. SAGWI Group will provide an annual status report on its activities in support of LIGO. The report will consist of a summary status on research by topic as indicated in the Attachments for that period 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 by each member of the group. The report will be due one month before the close of the period of performance under the Attachments in question.

10. The LSC will review the progress report against the Attachments from the previous year and assess the Attachments for the up-coming year annually, under its established procedure, and recommend acceptance or rejection of each Attachment by the LIGO Director and the LSC Spokesperson.

11. A list of SAGWI Group members will be updated at least every six months. SAGWI Group members and appropriate contact information will be provided in electronic form as Attachment Z to this Memorandum of Understanding. In cases where individuals who leave the group have had access to LIGO data and this access should be terminated, the SAGWI Group Principal Investigator is responsible for timely notification to the Directorate and to the computing committee so access may be revoked.

12. The LIGO Laboratory is responsible for obtaining NSF approval of collaborative

Memoranda of Understanding where required. All Memoranda of Understanding will be provided to NSF for their information.

13. The rights to intellectual property developed under this Attachment using LIGO Laboratory resources will be subject to the National Science Foundation Grant Policy as indicated in Section 730, Intellectual Property.

    A. In the event a patentable invention is conceived or first actually reduced to practice during the work of a member(s) of the SAGWI Group at LIGO Laboratory facilities, he/she will:
        i) make prompt disclosure of the invention to the Director of the LIGO Laboratory; and
        ii) cooperate with LIGO Laboratory and supply all information and execute all papers including invention reports, records of invention, patent applications and powers of attorney, necessary and proper to fulfill the obligations of the LIGO Laboratory to the U.S. Government sponsor.
    B. The ownership of inventions conceived solely by members of the SAGWI Group at LIGO facilities shall be owned by Stanford University, although the LIGO Laboratory shall be granted a license to use such invention for noncommercial research purposes at LIGO facilities. Inventions that are conceived by both members of the SAGWI Group and LIGO Laboratory staff as part of the LIGO project shall be jointly owned and any income from commercial licensing shall be shared in proportion to the number of joint inventors from each institution.

    In all other regards, the rights to intellectual property developed by members of the SAGWI Group under this Attachment will be in accordance with the policies of Stanford University.

14. This MOU supersedes the previous MOU between the LIGO Laboratory and the SAGWI Group (LIGO-M950060-A-M) and its amendments and attachments. This MOU will remain in force until the parties mutually agree to terminate it, or until it is terminated in accordance with LSC procedures.

Approved:

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Barry Barish
LIGO Director

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Robert L. Byer
Principal Investigator
Stanford Advanced Gravitational Wave Interferometry Group

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Peter Saulson
LSC Spokesperson

Attachment ACF to the
Memorandum of Understanding (LIGO- M050297-00-M)
between the
Stanford Advanced Gravitational Wave Interferometry (SAGWI) Group
and the
Laser Interferometer Gravitational Wave Observatory (LIGO)
August 15, 2005

This Attachment ACF to the Memorandum of Understanding LIGO-M050297-00-M defines the role of the Stanford Advanced Gravitational Wave Interferometry Group (SAGWI) as a Member of the LIGO Scientific Collaboration (LSC) and a member of the Advanced Detector Configurations Development Group (ADCDG). The period of performance for the activities in this Attachment is from August 15, 2005 to August 15, 2006.

1. Advanced Detector Configurations Development Group - The Advanced Detector Configurations Development Group (ADCDG) is the scientific collaboration for defining and developing entirely new advanced interferometers. It is expected that this development group will pursue research in dual recycling, resonant sideband extraction, Sagnac interferometers, systems with non-transmitting optics and other advanced configurations. MOU Attachments define the roles and responsibilities of groups in this development group.

2. During the period August 15, 2005 to August 15, 2006, the members of SAGWI Group will participate in the ACF (Advanced Detector Configurations Development Group) in the following areas:

   <u>Advanced Configurations</u>

   (R. Byer, M. Fejer, E. Gustafson, P. Beyersdorf, K-X. Sun, A. Bullington, S. Sinha , S. Zappe)

   a) Study all-reflective topologies and gratings for application to future ground-based detectors;

   b) Investigate the relationship between transverse displacement noise of gratings and the phase noise it produces for various interferometer configurations. This will be used to specify an additional constraint on suspension system designs that would be used for suspending diffractive optics.

   c) Construct a quantum-noise test-bed to simulate the effects of shot noise and radiation pressure noise on suspended mass interferometers in the regime where both effects are of comparable magnitude. This test-bed will be used to explore the effects on the quantum noise caused by having multiple carrier frequencies injected into an interferometer. Externally induced amplitude and phase noise will simulate quantum noise, but with much larger amplitude to ease the challenge of observation. The goal is to develop an RF readout scheme that can have a frequency dependent readout phase to take advantage of

squeezed light, while avoiding the "non-stationary" shot noise that typically accompanies configurations with RF readout.

d) Measure the thermal distortion of an existing mode-cleaner with high circulating powers (incident powers of over 20 W); This will involve measuring the mode structure of the mode-cleaner output with increasing incident power. The results can then be compared with MELODY's theoretical predictions of the mode-cleaner's expected behavior.

3. Resource Sharing: The 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. 2, as indicated below.

   a) Research accommodations for SAGWI group members while on LIGO research assignment at any LIGO Laboratory site,
   b) Access to LIGO data through established LSC channels in support of this work.

4. Coordination and Reporting – SAGWI Group will perform this research within the structures established by the LIGO Laboratory and the LSC where appropriate. In particular activities described in Item 2 will be carried out within the Advanced Detector Configurations Development Group of the LSC. Coordination will include keeping the Group leaders informed of activities and plans, reporting to the group at meetings and telecons, and through technical documents submitted to the LIGO Document Control Center.

   In addition, an annual report will be submitted with the update to this Attachment, giving a summary status on research by topic as indicated in Item No. 2, 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. This Attachment will be updated at least annually with a plan of activities for the succeeding on-year period. These documents will be due one month before the close of the period of performance under this Attachment.

Approved:

Barry Barish LIGO Laboratory Director	Robert L. Byer SAGWI Principal Investigator
Peter Saulson LSC Spokesperson	Ken Strain ADCDG Leader

Attachment LAS to the

Memorandum of Understanding (LIGO-M050297-00-M)

between the

Stanford Advanced Gravitational Wave Interferometry (SAGWI) Group and the

Laser Interferometer Gravitational Wave Observatory (LIGO)

August 15, 2005

This Attachment LAS to the Memorandum of Understanding LIGO-M050297-00-M defines the role of the Stanford Advanced Gravitational Wave Interferometry Group (SAGWI) as a Member of the LIGO Scientific Collaboration (LSC) and a member of the Lasers Development Group (LDG). The period of performance for the activities in this Attachment is from August 15, 2005 to August 15, 2006.

1. Lasers Development Group - The Lasers Development Group (LDG) is the scientific collaboration for defining and developing future high power lasers for use in advanced subsystems for the initial LIGO interferometers or in entirely new advanced interferometers. MOU Attachments define the roles and responsibilities of groups in this development group.

2. During the period August 15, 2005 to August 15, 2006, the members of SAGWI Group will participate in the LAS (Lasers and Detectors Development Group) in the following areas:

   Power-scaling of MOPA laser systems

   (R. Byer, K. Urbanek, P. Lu)

   a) Scale the Nd:YAG slab MOPA laser system to higher powers; We have increased the reliability of our system in this period at the expense of output power. In the coming period, we will attempt to scale to the 200 W level by optimizing the alignment of the second slab, and investigate the possible use of Gaussian to super-Gaussian convertors to improve extraction efficiencies from the end-pumped slab. We will determine the fidelity to which we can convert the super-Gaussian from the output back into a TEM_{00} Gaussian beam. We will investigate the use of silicate bonding to bond dielectric coated YAG pieces for use in parasitic mode suppression to improve the small signal gain of the end-pumped slab.

   Development of fiber laser systems

   (R.L. Byer, S. Sinha)

   b) Scale fiber MOPA to 160 W;

      We will work to scale the fiber MOPA output to the 160 W level with a single stage of amplification with good beam quality and acceptable polarization extinction ratio. We hope to demonstrate over 50% optical-to-optical efficiency with respect to incident pump power. We will continue to modify the design of our fiber fixtures to increase the

reliability of the system. We will order a more reliable 400 W fiber-coupled pump diode stack that will allow us to scale the output power to the 200 W level.

c) Characterize fiber MOPA output;

We will characterize the intensity noise, phase noise and pointing stability of this system at the maximum operating power. We will measure the TEM_{00} mode content by locking the output to a mode cleaner and we will characterize mode content fluctuations over time. We also plan to characterize the reliability of the system by running the system continuously for a week to determine if either catastrophic failure or a gradual reduction in performance is observed (for example from fiber photo-darkening).

d) Investigate phosphate fibers for possible applications in Advanced LIGO;

Using primarily ARO (Army Research Office) support, we are planning to build a single frequency fiber MOPA in highly doped phosphate fibers. Phosphate fibers promise a lower noise contribution from spontaneous Brillouin scattering noise (compared to silicates) due to shorter fiber lengths. We plan to obtain double-clad Yb:phosphate fibers through a collaboration with NP Photonics that will be suitable for generating output powers > 10 W. We will characterize this system to determine if these fibers can be used for creating extremely compact LIGO pre-amplifiers and/or scaled to over 100 W for use as power amplifiers.

Development of high-power photodiodes
(D. Jackrel, Z Rao, J. Harris, M. Fejer)

e) Continue the development of high power photodiodes.

Photodiode development for the next twelve month period will be focused on fabricating both InGaAs and GaInNAs(Sb) rear-illuminated devices with higher efficiencies, lower dark currents and high temperature packages compatible with other Advanced LIGO research activities. In addition, segmented detectors which have the ability to handle higher power levels and provide pointing and spatial mode information, may be investigated. In order to reach external quantum efficiencies approaching 90%, the substrate must be thinned to less than 10 μm. Attempts to achieve these ultra-thin structures, where the substrate is completely removed, have failed, however, due to an ineffective etch-stop layer (the function of which is to protect the device layers from the etchant used for substrate removal). In the future, the epitaxial growth procedure will be redesigned to accommodate a more effective etch-stop layer, which will in turn enable the fabrication of 80% to 90% efficient devices. The dilute nitride and nitride-antimonide materials will continue to be developed in the hopes that a high efficiency, low dark current device will be the result. Materials characterization of these structures is critical in the determination of the causes of device deficiencies. The epitaxial structures will therefore be characterized using x-ray diffraction, photoluminescence (PL), deep-level transient spectroscopy (DLTS), spectral cathodoluminescence (CL) imaging and other techniques. Finally, devices will be wire-bonded and packaged in high temperature packages and sent to MIT and GEO 600 to be characterized for properties such as electronic noise and spatial uniformity. They may potentially become integrated into Advanced LIGO test systems such as the high-power laser intensity stabilization system under development at GEO 600.

3. Resource Sharing: The 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. 2, as indicated below.

   a) Research accommodations for SAGWI group members while on LIGO research assignment at any LIGO Laboratory site,
   b) Access to LIGO data through established LSC channels in support of this work.

4. Coordination and Reporting – SAGWI Group will perform this research within the structures established by the LIGO Laboratory and the LSC where appropriate. In particular activities described in Item 2 will be carried out within the Lasers Development Working Group of the LSC. Coordination will include keeping the Group leaders informed of activities and plans, reporting to the group at meetings and telecons, and through technical documents submitted to the LIGO Document Control Center.

   In addition, an annual report will be submitted with the update to this Attachment, giving a summary status on research by topic as indicated in Item No. 2, 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. This Attachment will be updated at least annually with a plan of activities for the succeeding on-year period. These documents will be due one month before the close of the period of performance under this Attachment.

Approved:

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Barry Barish LIGO Laboratory Director	Robert L. Byer SAGWI Principal Investigator
_____	_____
Peter Saulson LSC Spokesperson	Benno Wilke LDG Leader

Attachment OPS to the
Memorandum of Understanding (LIGO- M050297-00-M)
between the
Stanford Advanced Gravitational Wave Interferometry (SAGWI) Group
and the
Laser Interferometer Gravitational Wave Observatory (LIGO)
August 15, 2005

This Attachment OPS to the Memorandum of Understanding LIGO-M050297-00-M defines the role of the Stanford Advanced Gravitational Wave Interferometry Group (SAGWI) as a Member of the LIGO Scientific Collaboration (LSC) in the areas of detector commissioning, detector characterization, and operations in support of the initial LIGO interferometers. The period of performance for the activities in this Attachment is from August 15, 2005 to August 15, 2006.

1. Together, the LIGO Laboratory and the LIGO Scientific Collaboration (LSC) are responsible for implementing and exploiting the initial LIGO detector through its science data runs. LSC groups are encouraged to contribute to the commissioning, characterization, and operation of the LIGO detectors, as members of working groups established by the LIGO Laboratroy and the LSC.

2. During the period August 15, 2005 to August 15, 2006, the members of SAGWI Group will participate in the initial LIGO detector research program in the following areas:

   a) *HEPI support* – Brian Lantz will work with LIGO to support the Hydraulic External Pre-Isolator (HEPI) that has been installed at LASTI and the LIGO Livingston Observatory (LLO) to ameliorate the consequences of ground motion.

   b) *Scientific Monitors* – Stanford will continue to provide scientific monitors for the science runs, according to the relevant rules of the LIGO Science Collaboration.

   c) *30 W laser* – We will continue our discussions with the LIGO lab about the applicability of the 30 W laser amplifier for use in the Interim Upgrade. We will work with the LIGO Lab on measurements of the amplifier in our lab if these prove useful for the upgrade process.

   (*note*: Discussion of the work on coaxial double pendulums for a possible Interim Upgrade has been moved to the SUS attachment.)

3. Resource Sharing: The 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. 2, as indicated below.

   a) Research accommodations for SAGWI group members while on LIGO research assignment at any LIGO Laboratory site,

b) Access to LIGO data through established LSC channels in support of this work.

4. Coordination and Reporting – SAGWI Group will perform this research within the structures established by the LIGO Laboratory and the LSC where appropriate. In particular activities described in Item 2a) will be carried out in coordination with the ISTNDG leader, Item 2b) will be carried out within the Detector Characterization Working Group of the LSC, and Item 2c) will be carried out in coordination with the LIGO Laboratory Commissioning Leader. Coordination will include keeping the Group leaders informed of activities and plans, reporting to the group at meetings and telecons, and through technical documents submitted to the LIGO Document Control Center.

   In addition, an annual report will be submitted with the update to this Attachment, giving a summary status on research by topic as indicated in Item No. 2, 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. This Attachment will be updated at least annually with a plan of activities for the succeeding on-year period. These documents will be due one month before the close of the period of performance under this Attachment.

5. All computer code delivered to the LSC under this Attachment must be developed in consultation with the LSC Data Analysis Software Working Group (DASWG) and archived, documented and reviewed as determined by that group.

Approved:

Barry Barish LIGO Laboratory Director	Robert L. Byer SAGWI Principal Investigator
Peter Saulson LSC Spokesperson	Keith Riles LSC Detector Characterization Leader

Joe Giaime ISTNDG Leader	Peter Fritschel LIGO Laboratory Commissioning Leader

Attachment OPT to the
Memorandum of Understanding (LIGO- M050297-00-M)
between the
Stanford Advanced Gravitational Wave Interferometry (SAGWI) Group
and the
Laser Interferometer Gravitational Wave Observatory (LIGO)
August 15, 2005

This Attachment OPT to the Memorandum of Understanding LIGO-M050297-00-M defines the role of the Stanford Advanced Gravitational Wave Interferometry Group (SAGWI) as a Member of the LIGO Scientific Collaboration (LSC) and a member of the Optics Development Group (ODG). The period of performance for the activities in this Attachment is from August 15, 2005 to August 15, 2006.

1. Optics Development Group – The Optics Development Group (ODG) is the scientific collaboration for defining and developing improvements in optics for use in advanced subsystems for the initial LIGO interferometers or in entirely new advanced interferometers. MOU Attachments define the roles and responsibilities of groups in this development group.

2. During the period August 15, 2005 to August 15, 2006, the members of SAGWI Group will participate in OPT (Optics Development Group) in the following areas:

   <u>Development of optical materials</u>
   (V. Kondilenko, A. Alexandrovski, R. Route, M. Fejer)

   a) Continue vacuum heat-treatment processing and photo-thermal common-path interferometry (PCI) measurements of absorption losses in sapphire optical elements;

      With the recent adoption of fused silica for the Advanced LIGO test mass material, the need for near-term study of large size sapphire optics has diminished. However, for future gravitational wave detectors, it remains desirable to continue heat-treatment studies on sapphire. The focus will be to identify post-growth processing conditions that reduce optical absorption losses from as-grown levels of 40-60 ppm/cm to the range of 10 ppm/cm. This will be done on sapphire windows 37 mm dia. by 25 mm high, using an existing rf-induction-heated (~ 1800 °C) high-vacuum furnace and a new tungsten-mesh-heated vacuum furnace with larger capacity that was purchased with other sources of funding. The study will elucidate the effects of high-temperature, high-vacuum heat-treatment on absorption losses in Crystal Systems, Inc. (CSI) sapphire, aiming to determine if the levels of 12.5 ppm/cm achieved previously on smaller size optics can be demonstrated on larger size optics. To do this, we will focus on investigating the kinetics of the process to predict if large-size sapphire boules could be vacuum heat-treated at

high temperatures in reasonable amounts of time. We will also study the homogeneity of the heat-treated samples.

b) Continue the measurement of optical absorption losses in coated fused silica optics in a collaborative study with LIGO aimed at optimizing coating deposition, heat-treatment parameters and associated cleaning and handling procedures.

3. Resource Sharing: The 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. 2, as indicated below.

   a) Research accommodations for SAGWI group members while on LIGO research assignment at any LIGO Laboratory site,
   b) Access to LIGO data through established LSC channels in support of this work.

4. Coordination and Reporting – SAGWI Group will perform this research within the structures established by the LIGO Laboratory and the LSC where appropriate. In particular activities described in Item 2 will be carried out within the Optics Development Working Group of the LSC. Coordination will include keeping the Group leaders informed of activities and plans, reporting to the group at meetings and telecons, and through technical documents submitted to the LIGO Document Control Center.

   In addition, an annual report will be submitted with the update to this Attachment, giving a summary status on research by topic as indicated in Item No. 2, 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. This Attachment will be updated at least annually with a plan of activities for the succeeding on-year period. These documents will be due one month before the close of the period of performance under this Attachment.

5. The research effort pursuant to this Attachment A will be coordinated by Robert L. Byer (SAGWI Group) and the leader(s) of the ODG .

Approved:

Barry Barish LIGO Laboratory Director	Robert L. Byer SAGWI Principal Investigator
Peter Saulson LSC Spokesperson	David Reitze ODG Leader

Attachment SUS to the
Memorandum of Understanding (LIGO-M050297-00-M)
between the
Stanford Advanced Gravitational Wave Interferometry (SAGWI) Group
and the
Laser Interferometer Gravitational Wave Observatory (LIGO)
August 15, 2005

This Attachment SUS to the Memorandum of Understanding LIGO-M050297-00-M defines the role of the Stanford Advanced Gravitational Wave Interferometry Group (SAGWI) as a 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 August 15, 2005 to August 15, 2006.

1. 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 initial LIGO interferometers or in entirely new advanced interferometers. MOU Attachments define the roles and responsibilities of groups in this development group.

2. During the period August 15, 2005 to August 15, 2006, the members of SAGWI Group will participate in the SUS (Isolation/Suspensions/Thermal Noise Development Group) in the following areas:

   Materials and Thermal Noise

   (M. Fejer, R. Route, S Zappe)

   a) Investigations into the level of excess loss introduced by dielectric mirror coatings applied to test-mass substrates;

      Reduction of the mechanical loss associated with coatings applied to substrates and associated thermal noise remains an important research area for Advanced LIGO and is vital for the success of any future detectors with sensitivities better than Advanced LIGO.

      We will evaluate in collaboration with Glasgow the usefulness of silicon cantilevers with deposited dielectric thin films for the estimation of dielectric mirror coating mechanical losses.

      In collaboration with Glasgow, MIT, Syracuse and Hobart and William Smith Colleges, we will continue our studies of coated substrate materials to investigate and reduce the mechanical losses of coatings.

   b) Participation as required in modeling efforts on the effects of inhomogeneous mechanical losses on the expected thermal noise from a finite sized test mass;

c) Design and fabrication, using Stanford's extensive MEMS technology, of custom flexures from doped and non-doped single crystal silicon for evaluation as suspension elements for test masses;

This work will be carried out in collaboration with Glasgow.

d) Continued optical and Q measurements on crystalline materials;

In collaboration with Glasgow we will continue our investigations of the optical and Q factors of samples of single crystal silicon with varying dopants and cut along different crystallographic axes.

Contingent on initial measurements by Glasgow, more cantilevers for the measurement of bulk-dominated loss effects will be fabricated. The quality of the silicon nitride masking layer and the cleanliness of surfaces in the case of silicon fusion bonding, respectively, will be improved.

Active Alignment, Isolation, Control and Suspension Design

(D. DeBra, M. DeGree, W. East, B. Lantz, N. Robertson, M. Thielvoldt)

Norna Robertson will continue to serve as Cognizant Scientist for the Suspensions subsystem (SUS) in Advanced LIGO, as chair of the LASTI Technical Advisory Committee, as chair of the LSC Nominating Committee, and as a member of the LSC restructuring committee. She will also serve on the MOU review panel in August 2005.

We will carry out further development of the design of suspension systems for controls and noise prototypes at LASTI and for Advanced LIGO, and we will carry out further design and development of the seismic isolation systems at the ETF, at LASTI, and for Advanced LIGO in general. We will:

e) Work with other members of the SUS team on general design issues as they arise, and in particular on aspects of;
   i) the testing and characterization of the ETM controls prototype at Caltech and subsequently at LASTI,
   ii) the design of the noise prototype ETM/ITM, including implementing lessons learned from the controls prototype,
   iii) the design of other BSC and HAM suspensions as required.

f) Participate in upcoming SUS and SEI design reviews and planning meetings for BSC and HAM optics;

g) Work with SUS and SEI colleagues on issues of integration of suspension and isolation systems, and on issues of integration with other subsystems. This will include collaborating on tests of the proposed SUS support structure attached to the ETF Technology Demonstrator at Stanford;

h) Continue efforts to improve the isolation performance of the ETF Technology Demonstrator at 1 Hz and at 10 Hz;

j) Improve the sensor performance of the GS-13 to improve the performance of the ETF Technology Demonstrator;

k) Continue to develop methods and transfer knowledge to speed up the implementation of control techniques at LASTI and for Advanced LIGO;

m) Work in collaboration with the LIGO Lab and LASTI to complete the ASI contract;

n) Work with the LASTI lab to develop implementation and testing plans for the BSC prototype isolation and alignment system and support the installation and testing of this system at LASTI;

o) Help develop requirements for the HAM isolation and alignment for Advanced LIGO;

p) Work with the LIGO lab and outside vendors to develop a mechanical system for a HAM isolation and alignment system;

q) Devise a control scheme to use with a HAM isolation and alignment system;

r) Study the design for a coaxial double-pendulum, which uses the Initial LIGO optics, for possible use in an Interim Upgrade to Initial LIGO;

s) Pursue, in consultation with the SWG, given sufficient time and additional manpower:

i) Temperature monitoring of the actuators in the ETF Technology Demonstrator,

ii) Control re-allocation and global control studies of the ETF technology demonstrator, using a capacitive displacement sensor located between the second stage and the support structure,

iii) Feed-forward isolation of the first stage of the ETF Technology Demonstrator to reduce the motion around 10 Hz from tip and tilt, using vertical seismometers.

All of the above will be carried out in collaboration with colleagues in the LSC.

3. Resource Sharing: The 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. 2, as indicated below.

a) Research accommodations for SAGWI group members while on LIGO research assignment at any LIGO Laboratory site,
b) Access to LIGO data through established LSC channels in support of this work.

4. Coordination and Reporting – SAGWI Group will perform this research within the structures established by the LIGO Laboratory and the LSC where appropriate. In particular activities described in Item 2 will be carried out within Isolation/Suspension/Thermal Noise Development Group of the LSC. Coordination will include keeping the Group leaders informed of activities and plans, reporting to the group at meetings and telecons, and through technical documents submitted to the LIGO Document Control Center.

In addition, an annual report will be submitted with the update to this Attachment, giving a summary status on research by topic as indicated in Item No. 2, 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. This Attachment will be updated at least annually with a plan of activities for the succeeding on-year period. These documents will be due one month before the close of the period of performance under this Attachment.

Approved:

_____	_____
Barry Barish LIGO Laboratory Director	Robert L. Byer SAGWI Principal Investigator
_____	_____
Peter Saulson LSC Spokesperson	Joseph Giaime ISTNDG Leader

Attachment Z to the
Memorandum of Understanding (LIGO-M050297-00-M)
between the
Stanford Advanced Gravitational Wave Interferometry (SAGWI) Group
and the
Laser Interferometer Gravitational Wave Observatory (LIGO) Laboratory
August 15, 2005

This Attachment to the Memorandum of Understanding LIGO-M050297-00-M lists the coordinates of the members of the Stanford Advanced Gravitational Wave Interferometry Group (SAGWIG) who will participate in the LIGO Scientific Collaboration (LSC) as members of LIGO Development Groups. The period of performance for the activities in this Attachment is from **August 15, 2005 to February 15, 2006**. This period may be modified by agreement to a revision of this Attachment.

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Scientific Collaboration Council Delegates: Martin Fejer, Brian Lantz and Norna Robertson.

Approved:

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