

Memorandum of Understanding (LIGO-M050315-00-M)
between the
Hobart & William Smith Colleges LIGO Group (HWSLG)
and the
Laser Interferometer Gravitational Wave Observatory (LIGO)
August 15, 2005

The purpose of this Memorandum of Understanding (MOU) is to establish and define a collaborative relationship between the Hobart & William Smith Colleges LIGO Group (HWSLG) 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 HWSLG will be a member group of the LIGO Scientific Collaboration.

1. The Hobart & William Smith Colleges LIGO Group (HWSLG) consists of Professor Steven Penn, who will serve as Principal Investigator for research in LIGO. While at any one time one or two undergraduate students do perform research with Professor Penn, the level of their work does not warrant full group membership. The focus of the work done by the Hobart & William Smith Colleges LIGO Group under this agreement will be the research and development of low thermal noise optical substrates and dielectric mirror coatings for use in Advanced LIGO, research and development of reduced thermal noise suspensions for large optics in Initial LIGO, and the development of a bicoherence data monitor for use in detecting bilinearity, non-Gaussianity and frequency/phase noise.
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 were 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 HWSLG 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 HWSLG 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 HWSLG.
 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. Steven Penn (HWSLG) will be responsible for interaction with the designated LSC Shift Organizer with respect to the HWSLG'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 HWSLG and to define any resources to be provided by the LIGO Laboratory to the HWSLG in support of those activities.
 9. HWSLG 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 HWSLG Group members will be updated at least every six months. HWSLG 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 HWSLG 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 HWSLG 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 HWSLG at LIGO facilities shall be owned by Hobart and William Smith Colleges, 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 HWSLG 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 HWSLG under this Attachment will be in accordance with the policies of Hobart and William Smith Colleges.

14. This MOU supersedes the previous MOU between the LIGO Laboratory and the HWSLG group (LIGO-M020307-00-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:

Barry Barish
LIGO Director

Steven Penn
Principal Investigator
Hobart and William Smith Colleges LIGO Group

Peter Saulson
LSC Spokesperson

Attachment OPS to the
Memorandum of Understanding (LIGO-M050315-00-M)
between the
Hobart and William Smith Colleges Group (HWSLG)
and the
Laser Interferometer Gravitational Wave Observatory (LIGO)
August 15, 2005

This Attachment OPS to the Memorandum of Understanding LIGO-M050315-00-M defines the role of the Hobart and William Smith Colleges Group (HWSLG) 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 Laboratory and the LSC.
2. During the period August 15, 2005 to August 15, 2006, the members of HWSLG will participate in the initial LIGO detector research program in the following areas:
 - a) *Detector Characterization* – HWSLG plans to complete development of the bicoherence monitor, BicoMon. This monitor is used to detect bilinear coupling, such as up-conversion, non-Gaussianity, and frequency/phase noise. Although work on the monitor has languished during the past year due to heavy teaching commitments, the work should be able to be completed this year while Penn is on research leave.
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 HWSLG members while on LIGO research assignment at any LIGO Laboratory site,
 - b) Access to LIGO data in support through established LSC channels in support of this work.
4. Coordination and Reporting – HWSLG 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 within the Detector Characterization 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. 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.
6. The research effort pursuant to this Attachment A will be coordinated by Steven Penn (HWSLG), Albert Lazzarini (LIGO Laboratory) and Keith Riles (LSC Detchar Leader).

Approved:

Barry Barish
LIGO Laboratory Director

Steven Penn
HWSLG Principal Investigator

Peter Saulson
LSC Spokesperson

Keith Riles
LSC Detector Characterization Leader

**Attachment OPT to the
Memorandum of Understanding (LIGO-M050315-00-M)
between the
Hobart and William Smith Colleges LIGO Group (HWSLG)
and the
Laser Interferometer Gravitational Wave Observatory (LIGO)
August 15, 2005**

This Attachment OPT to the Memorandum of Understanding LIGO-M050315-00-M defines the role of the Hobart and William Smith Colleges LIGO Group (HWSLG) 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 HWSLG will participate in ODG in the following areas:
 - a) *Optics Characterization* -- HWSLG will continue its studies of the mechanical loss in fused silica as a function of silica variety, surface treatment, S/V ratio, frequency, and internal stress (as altered by annealing). These studies will be conducted on flame polished rods and mechanically polished optics. The rod samples allow us to study the mechanical loss at a low resonant frequency and low S/V ratio without the losses associated with a polished surface. In comparison, the polished optic samples allow us to study the effect of the polished surface.
 - b) *Coating Characterization* – HWSLG will continue its research with the LIGO coating research group to find a suitable high refractive index, low mechanical loss material for use in the mirror coatings for Advanced LIGO. The HWS Lab provides a third measurement facility for coating samples in addition to the MIT and Glasgow facilities.
 - c) *Reduced Noise Initial LIGO Optic Suspension* – Penn will be applying to the LIGO visitors program in Fall 2005 in order to work at LASTI to help develop a nondestructive modification to the LIGO I optics suspension that will lower the thermal noise. The goal would be to make the modification as part of an interim upgrade to Initial LIGO.
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 HWSLG members while on LIGO research assignment at any LIGO Laboratory site,
 - b) Access to LIGO data in support through established LSC channels in support of this work.
 - c) Purchasing of some of the samples to be used in the fused silica research described in Section 2a.
 - d) Providing Coating samples as required by the coating research group as described in Section 2b.
4. Coordination and Reporting – HWSLG 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 Steven Penn (HWSLG) and the leader(s) of the ODG .

Approved:

Barry Barish
LIGO Laboratory Director

Steven Penn
HWSLG Principal Investigator

Peter Saulson
LSC Spokesperson

David Reitze
ODG Leader

**Attachment OUT to the
Memorandum of Understanding (LIGO-M050315-00-M)
between the
Hobart and William Smith Colleges Group (HWSLG)
and the
Laser Interferometer Gravitational Wave Observatory (LIGO)
August 15, 2005**

This Attachment OUT to the Memorandum of Understanding LIGO-M050315-00-M defines the role of the Hobart and William Smith Colleges Group (HWSLG) as a Member of the LIGO Scientific Collaboration (LSC) in support of Education and Outreach to the broader community. The period of performance for the activities in this Attachment is from August 15, 2005 to August 15, 2006.

1. Education and Outreach – As a frontier physics effort, LIGO offers a unique opportunity to inspire interest in science among students and to educate the broader community. The LIGO Laboratory supports a broad program of education and outreach to take advantage of these opportunities. Activities to attract and educate visitors take place at both Observatories, as well as the development of educational materials for use there and elsewhere. The LIGO Laboratory is building a Science Education Center at the Livingston Observatory, and is participating with local partners to make it a vehicle for science education throughout the region. LSC groups are invited to participate in these activities, and to suggest others, with the goal of leveraging activities to make a greater impact. MOU Attachments define the roles and responsibilities of groups participating in these activities.
2. During the period August 15, 2005 to August 15, 2006, the members of HWSLG will participate in Education and Outreach in the following areas:
 - a) *K-12 Educational Activities* – HWSLG will be continuing its support of the Geneva (NY) high school LIGO program. This year we plan to create two new interactive experiments with the students: a small interferometer and a vibration isolation system. We have also received donations of a few computers that we plan to use for data analysis using the bicoherence monitor developed by HWSLG. We are exploring the possibility of arranging to have some subset of the students be able to visit one of the LIGO laboratory sites.
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 HWSLG members while on LIGO assignment at any LIGO Laboratory site,
 - b) Access to LIGO data in support through established LSC channels in support of this work.

4. Coordination and Reporting – HWSLG 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 in coordination with the LIGO Observatories Education and Outreach Leaders. Coordination will include keeping these leaders informed of activities and plans, reporting to them 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 B will be coordinated by Steven Penn (HWSLG) and John Thacker LLO Education and Outreach Leader.

Approved:

Barry Barish
LIGO Laboratory Director

Steven Penn
HWSLG Principal Investigator

Peter Saulson
LSC Spokesperson

John Thacker
LLO Education and Outreach Leader

**Attachment Number Z to the
Memorandum of Understanding (LIGO-M050315-00-M)
between the
Hobart & William Smith Colleges LIGO Group (HWSLG)
and the
Laser Interferometer Gravitational Wave Observatory (LIGO) Laboratory
August 15, 2005**

This Attachment to the Memorandum of Understanding LIGO-M050315-00-M lists the coordinates of members of the Hobart & William Smith Colleges LIGO Group (HWSLG) 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 August 15, 2006**. This period may be modified by agreement to a revision of this Attachment.

| Name | Address | E-Mail | Phone Nos. | Begin Date | End Date |
|--|---|---------------|--|-------------------|-----------------|
| Penn, Steven 100% LIGO I 20% AdLIGO 80% Faculty | Hobart & William Smith Colleges Dept. of Physics, Eaton Hall Geneva, NY 14456 | penn@hws.edu | 315-781-3759 (office/lab) 315-383-0069 (cell) Fax: 315-781-3860 | Aug. 15, 2005 | Aug. 15, 2006 |

Scientific Collaboration Council Delegate: Steven Penn

Approved:

Barry Barish
LIGO Laboratory Director

Steven Penn
Principal Investigator
Hobart & William Smith Colleges LIGO Group

Peter Saulson
LSC Spokesperson