

Attachment Number A to the
Memorandum of Understanding (LIGO-M970058-00-M)
between the
Pennsylvania State University Relativity Group (PSURG)
and the
Laser Interferometer Gravitational Wave Observatory (LIGO) Laboratory
August 15, 2002

This Attachment to the Memorandum of Understanding LIGO-M970058-00-M covers the role of Pennsylvania State University Relativity Group (PSURG) as a Charter Member of the LIGO Scientific Collaboration (LSC) and a member of the LIGO I Development Group (LIDG). The period of performance for the activities in this Attachment is from August 15, 2002 to February 15, 2003. 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, physics publications, and talks announcing new 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. 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 Pennsylvania State University Relativity Group (PSURG) and the LIGO Laboratory concerning the activities of PSURG as a Collaborating Institution in the LIGO Scientific Collaboration (LSC) and in the LIGO I Development Group (LIDG), and as indicated in Items No. 8 and No. 9.
4. LIGO I Development Group - The LIGO I Development Group is the scientific collaboration for implementing and exploiting the initial LIGO detector and physics through the initial science data run. Only groups who establish a specific Attachment approved by the LIGO Laboratory, which defines a sufficient contribution and participation in LIGO I development,

implementation or data analysis will be part of this initial LIGO data run and science. Participation in future data runs and science that follow LIGO I will be possible for other groups, with guidelines to be determined by the LIGO Scientific Collaboration. It is anticipated that LIGO I data will only be made available, during the first two years following its collection, through formal collaboration within the LIGO I Development Group.

The general guideline for institutional membership in the LIGO I Development Group is that the contribution per collaborator of any new group to the design, construction, and implementation of the initial LIGO detector and to the first data run be comparable to that of the LIGO Laboratory scientists.

5. Report of Progress - PSURG 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. 9 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 coordinates of PSURG members are included in Attachment Z to the Memorandum of Understanding LIGO-M970058-00-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. LAL Software Conventions - It is necessary that any delivered code conforms to the LAL style as laid out in the LAL specification T990030. This includes: 1) coding style, headers, etc.; 2) use of function calls, etc.; 3) organization of software in the directory structures indicated in the document; 4) inclusion of test codes and validation tests to enable users to verify successful installation of implementation; and 5) documentation and users manuals (html or pdf) to enable users to understand and adopt code.
9. The work planned by PSURG during the period August 15, 2002 to February 15, 2003, is as follows:

LIGO I Data Analysis

- a) Tools for studying the stationarity of LIGO data: Zaleski (undergraduate), supervised by Finn, will use Matlab tools developed in last 6 month period to study the stationarity of the S1 data set.
- b) Kalman filter for violin mode line removal: Rotthoff (undergraduate), supervised by Finn, will complete the implementation, testing, characterization and documentation of

the Kalman filter actions for violin mode line removal in the datacondAPI.

- c) Detector sensitivity monitor: Schlaufman (undergraduate), supervised by Finn and Sutton, will maintain and improve the dmt monitor that evaluates the sensitivity of the LIGO data by computing the instantaneous volume that the detector is sensitive to inspiraling binary neutron stars within. A functioning monitor with web, trend, and dmtviewer reporting has been completed for S1; the current goal (for Feb 15 2003) is to improve the dynamical tracking of interferometer calibration, and to write a technical report on the monitor.
- d) Hepler (undergraduate) will develop a data analysis pipeline that uses the wavelet tools she has developed to do a dyadic band analysis of LIGO data. Each band will be separately analyzed by the LDAS slope event trigger generator. The pipeline will be applied to the S1 data set and the distribution of events in each band studied.
- e) Block-normal analysis for bursts: Stuver (graduate student), supervised by Finn, will complete the development of a prototype of the block-normal method for searching for gravitational wave bursts, based on the identification of change points in stationary data. Tibbits (undergraduate), also supervised by Finn, will continue to do the LAL development work on the block-normal DSO. This DSO will be used in the analysis of S2 data.
- f) Identifying high-order moment correlations: Summerscales (graduate student), will apply the Matlab test code for high-order correlations to the S1 data set. The Matlab test code will be packaged as a Matlab tool box and made generally available to the collaboration, together with a technical report describing its use. A short report describing the test and its uses will also be prepared for submission to Astroparticle Journal.
- g) Continuous wave search code: Berukoff (graduate student) will continue debugging and maintaining the demodulation code in the LAL pulsar package as needed by the Pulsar Upper Limits group.
- h) Ramsunder (graduate student), supervised by Finn, will perform benchmarks on the performance of LDAS for data analysis on several different computer configurations. A matrix of configuration possibilities involving the interconnect and the compute nodes controlled by the wrapperAPI will be studied. On the network axis we are interested in three possibilities: fast ethernet, gigabit and dophin gigabit (assuming that dophin operates behind system calls and does not require any modifications to the ldas build). On the compute node axis we are interested in single processor nodes vs. dual processor nodes. The information we want to collect is time to complete the analysis of the data set we have identified for testing purposes. The analysis will be on a representative job mix drawn from our (LIGO's) most recent analysis effort. The final product is a technical report describing the throughput (which we define here to be the reciprocal of the time to complete analysis) per cpu (*not* node). This work will form the basis for a set of recommendations to the LSC for the configuration of the PSU LSC tier 2 center.

- i) 'Rayleigh' Monitor: Sutton (Postdoc) has completed a GUI interface to the Rayleigh monitor and demonstrated its use at LHO. His immediate goal (for Feb 15 2003) is to write a technical report describing the monitor, its functioning, the interpretation of its output, and examples of its use for the LIGO DCC.
 - j) LIGO/SWIFT Collaboration: Finn (faculty) will represent LIGO on the SWIFT Science Team. Working with Krishnan and Sutton (postdocs), he has developed a figure of merit that characterizes the sensitivity of the LIGO/SWIFT instrument pair to gravitational waves from gamma-ray bursts for different Swift pointings relative to LIGO's orientation. The immediate goal (for Feb 15 2003) is to complete a manuscript describing the figure of merit and develop a module that the SWIFT team can use in the optimization process for determining satellite pointing.
 - k) Matched filtering search for precessing binaries: Owen (faculty) will estimate the computational costs of matched filtering searches for the inspirals of precessing compact binaries, using two families of approximate waveforms in the existing literature (Apostolatos 1996, Grandclement and Kalogera 200). This work is done in collaboration with Alberto Vecchio at the University of Birmingham in England (covered under the GEO600 MoU). The goal is to submit, before the March 2003 LSC meeting, a paper that computes the parameter-space metrics of both sets of waveforms, estimates costs of searches of various regions of parameter space, and proposes regions of low cost and high reward to be targeted by LIGO I.
 - l) Matched filtering search for binary black holes: Owen (faculty) will code into LAL a set of waveform generators for the various approximations to the end of inspiral, appropriate for binary black holes in the LIGO I band, catalogued in the literature (Buonanno, Chen, and Vallisneri 2002). These will form the basis of future searches for binary black holes by the Inspiral Upper Limits group, which is currently focused on neutron star binaries.
 - m) Administration
 - a. Finn will continue to serve on the LSC executive committee.
 - b. Finn will continue to serve as the GWIC executive secretary
 - c. Finn will continue to serve as co-Chair of the unmodeled source analysis group.
 - d. Finn will continue to represent the PSU tier 2 center on the LSC Comp Coord Comm.
 - e. Finn will supervise the development of the PSU tier 2 center and participate in the iVDGL collaboration as co-Chair of the applications task group.
 - f. Finn will continue to serve on the LIGO Software Coordination Committee (this committee has not met in the most recent reporting period but has not been dissolved).
 - g. Finn will supervise and participate in all the work described in this Attachment, with particular emphasis on those projects where a student is involved.
10. During the period August 15, 2002 to February 15, 2003, the LIGO Laboratory will share, as requested and appropriate, LIGO data of relevance to the research focus in Item No. 8.

11. The research effort pursuant to this Attachment A will be coordinated by Lee Samuel Finn and Albert Lazzarini on behalf of PSURG and the LIGO Laboratory, respectively.
12. 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. 9, as indicated below.
 - a) Accommodations for PSURG investigators while on LIGO research assignment at Caltech, and/or LIGO sites.

Approved:

Barry Barish
Barry Barish
LIGO Laboratory Director
14 April 04
Date

Lee Samuel Finn
Lee Samuel Finn
ERG Principal Investigator
20 April 2004
Date

Albert Lazzarini
Albert Lazzarini
LIGO Laboratory Data and Computing
Group Leader
21 March 2003
Date