

**Attachment Number A to the  
Memorandum of Understanding (LIGO-M950061-00-M)**

**between the**

**University of Wisconsin - Milwaukee Relativity Group (UWMRG)**

**and the**

**Laser Interferometer Gravitational Wave Observatory (LIGO) Laboratory**

**August 15, 1999**

This Attachment to the Memorandum of Understanding LIGO-M950061-00-M covers the role of UWMRG 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, 1999 to February 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 University of Wisconsin - Milwaukee Relativity Group (UWMRG) and the LIGO Laboratory concerning the activities of UWMRG as a Collaborating Institution in the LIGO Scientific Collaboration (LSC) and in the LIGO I Development Group (LIDG), and as noted in Item No. 9 below.
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 through formal collaboration within the LIGO I Development Group during the first two years following its collection.

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 - UWMRG 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 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 coordinates of UWMRG members are included in the Attachment Z to the Memorandum of Understanding LIGO-M950061-00-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. Notes - Software Deliverables for LIGO I

Note A: It is necessary that any delivered code conforms to the LLAL style as laid out in the LLAL 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 very successful installation of implementing; and 5) documentation to enable users to understand and adopt code.

Note B: The projects in Item No. 9 below are rated in order of priority from 1 to 3, the rating of 1 being assigned to LIGO I completion tasks and the ratings of 2 and 3 being assigned to best efforts commitments.

9. During the period August 15, 1999 to February 15, 2000, UWMRG will carry out the projects as indicated below.

## a) Matched-filter Veto Techniques / Rating 1

Patrick Brady and Adrian Ottewill will document their code which implements the parameter space veto using the time of arrival parameter, and insert it into GRASP. Teviet and Jolien Creighton will do the same for their version of the multi-template veto method. An improved version of the multi-template veto technique will be implemented, documented and included into GRASP. At the same time, the power of this method will be examined and compared with other veto techniques.

## b) Regression Analysis of Environmental Channels &amp; Matched Filtering / Rating 1

As PEM data becomes available from the LIGO sites, A. Ottewill will use the environmental correlation code in GRASP to gain insight into interactions between different elements of the LIGO interferometers. The environmental correlation code will be incorporated into the DMT as soon as that structure is made publicly available.

Bruce Allen and A. Ottewill will assist Anthony Rizzi and Michael Werda of LIGO-LA staff in using GRASP to identify chirp signals in PEM data, currently concentrating on seismic data.

## c) Robust Methods for Stochastic Background Detection / Rating 3

B. Allen and J. Creighton, with J. Romano of UT Brownsville, will continue to develop optimized algorithms for detecting stochastic gravitational waves in the presence of non-Gaussian detector noise. The method will be extended to colored noise, and a paper documenting the technique will be submitted for publication.

## d) LSC ASIS and DCSA Groups / Rating 1

The UWMRG will continue to participate in and help organize the work of the Astrophysical Source Identification and Signature (ASIS) and Detection Confidence and Statistical Analysis (DCSA) groups.

## e) Excess Power Statistic / Rating 2

Warren Anderson, Patrick Brady, J. Creighton, and E. Flanagan of Cornell University will submit a paper on excess power statistic method. P. Brady has implemented the algorithm discussed in the manuscript. In collaboration with the Cornell group, the code will be brought up to LLAL standard.

## f) Mock Coincidence Analysis Data Run on November 1994 Data Set / Rating 1

B. Allen, Alan Wiseman, J. Creighton and W. Anderson will participate in the continuing analysis of the November 1994 data set, in particular attempting to explain anomalous instrument behavior based on multi-channel analysis. Further analysis will also be carried out

searching for binary inspiral signals. Matched filtering, where the data has time delays inserted in order to mimic the situation of two separate instruments, will be used. The goal is to develop and test methods for inspiral searches in the two detector context. This will be done through a formal proposal to LSC.

g) GRASP Data Analysis Package / Frame Format Data / LLAL / Rating 1

B. Allen will continue to maintain the GRASP data analysis package. The package is now fairly complete and so this maintenance will be primarily fixing bugs, and improving the documentation.

B. Allen and J. Creighton will assist in developing the LIGO/LSC Algorithm Library. If it will be helpful for the LDAS system, B. Allen will organize and help in converting either the entire GRASP package or certain parts of it to conform to the requirements of LDAS. In addition, the UWMRG will keep abreast of any further changes in the frame library and will, if necessary, produce fresh translation tapes of the November 1994 old format data in the latest frame version.

Note: The LLAL style software development conventions in Note A, Item No. 8, will apply to the above conversion of the GRASP package.

h) Time/Freq and Blind Methods For Signal Detection / Rating 2

W. Anderson will work with Eric Chassande-Mottin from Potsdam, and R. Balasubramanian from Cardiff in the use of power reassignment in time-frequency distributions for blind searches and detector characterization.

Note: The LLAL style software development conventions in Note A, Item No. 8, will apply to the above code effort.

i) Binary Inspirial Chirp Template Generators / Rating 3

The binary chirp filter generators were some of the first software routines incorporated into the prototype data analysis package GRASP. A. Wiseman intends to see that these routines are brought into compliance with the LIGO Lab and LSC software standards. This will include shepherding the routines through the process of incorporation in the LIGO/LSC Analysis Library.

j) Continuous Wave Sources / Rating 3

P. Brady, T. Creighton, and Stuart Anderson of LIGO Laboratory staff will write and test code to search for isolated pulsars with known phase evolution in the LIGO data stream. This is part of the long term plan to provide LIGO documented (high-performance) code to search for continuous waves.

Note: The LLAL style software development conventions in Note A, Item No. 8, will apply to

the above code effort.

k) Seismic Monitoring / Rating 2

B. Allen will continue to provide, test, and maintain GRASP code to produce calibrated seismic noise power spectra from the on-site data stream.

l) LLAL Template / Rating 1

B. Allen and J. Creighton will develop the prototype code to be used as a model for LLAL software in accordance with the software development conventions in Note A, Item No. 8. They will complete the first milestone in the hierarchical search code: the master routine to meet their first ASIS milestone.

10. During the period August 15, 1999 to February 15, 2000, the LIGO Laboratory will share, as requested and appropriate, the LIGO data of relevance to the research topics in Item No. 9 above.

11. The research effort pursuant to this Attachment A will be coordinated by B. Allen and Albert Lazzarini on behalf of UWMRG and 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. These resources will be in addition to the coordination effort and data to be made available per Item No. 10 above.

a. Provide accommodations for investigators in Item No. 9 above while on research assignment at LIGO facilities.

Approved:

*Barry Barish*

Barry Barish  
LIGO Laboratory Director

*Jan 10, 2000*

Date

*Bruce Allen*

Bruce Allen  
UWMRG Principal Investigator

*2/3/00*

Date

*Albert Lazzarini*

Albert Lazzarini  
LIGO Staff

*21 Dec 1999*

Date