Attachment Number A to the Memorandum of Understanding (LIGO-M000125-00-M) between the Carleton College Relativity Group (CCRG) and the Laser Interferometer Gravitational Wave Observatory (LIGO) Laboratory

August 15, 2001

This Attachment A to the Memorandum of Understanding LIGO-M0000125-00-M covers the role of the Carleton College Relativity Group (CCRG) as a Charter Member of the LIGO Scientific Collaboration (LSC) and a member of the LIGO I Development Group (L1DG). The period of performance for the activities in this Attachment is from August 15, 2001 to February 15, 2002. This period may be modified by agreement to a revision of this Attachment.

1. LIGO Scientific Collaboration - The LIGO Scientific Collaboration (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 semi-annual 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 and approved, as appropriate, 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 Carleton College Relativity Group (CCRG) and the LIGO Laboratory concerning the activities of CCRG as a Collaborating Institution in the LIGO Scientific Collaboration (LSC) and in the LIGO I Development Group (L1DG), and as indicated in Items No. 8 and 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 Labo-

ratory, 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 - CCRG 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 Items No. 8 and 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 CCRG members are included in the Attachment Z to the Memorandum of Understanding LIGO-M000125-00-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. During the period August 15, 2001 to February 15, 2002, Professor Nelson Christensen and up to three undergraduate students will conduct research in the areas of data analysis algorithm development and coding, and R&D related to the LIGO facilities. The following are CCRG's research goals for the six month period under this agreement:

a) LIGO I Data Analysis, Statistics and Parameter Estimation for Binary Inspiral Searches

1. Carleton is participating in the LSC group that hopes to set upper limits of the rate of inspiral of binary compact objects. Christensen is leading the detector characterization sub-group, and is also participating in the multiple interferometer and statistics sub-groups.

2. Carleton College will continue to work on the LAL implementation of the binary inspiral signal detection and parameter estimation code. This will be an extension of Carleton's MCMC work.

3. The code being developed for LAL is a Metropolis-Hastings algorithm. We are modifying Duncan Brown's (UW-M) findchirp program to suite our needs. However, we are writing the program in a general fashion so that we may use more complicated templates, including those with compact object spin, final plunge, and black hole formation and ringing.

4. Presently, the parameter space for coalescing binaries is being extended to include compact object spin. The seven-parameter problem will be studied in detail. This is being done with Christensen's software. Once the technique has been demonstrated the goal will be to implement the scheme in LAL.

5. We will continue work outlined in Attachments A for previous LSC periods.

6. In parallel we are working on the multiple detector problem. Christensen will coordinate this work with other members of the LSC who are also researching this topic. The goal for members of the Carleton team will be to demonstrate whether a MCMC appr oach may prove advantageous for parameter estimation. In addition to the parameters describing the compact binary system, the analysis will also include the parameters corresponding to the location of the source in the sky and the gravity wave polarization. We will start by modifying and adapting the LAL software developed by Sukanta Bose. A network of interferometers will be treated as a single system.

b) Detector Characterization and Engineering Data Analysis for Commissioning

1. Engineering Run Analysis

Carleton will continue its participation in the detector characterization program. Christensen is leading the sub-group that is looking for correlations in interferometer and environmental channels. This is currently being done with E5 data, and will continue with E6. The correlation sub-group also includes Adrian Ottewill (University College Dublin) and Steve Penn (Syracuse University). Christensen and Ottewill will use the DMT tool CorrMon to catalog and study correlations between interferometer and mode-cleaner channels, and channels from physical and environmental monitors (PEM).

2. Christensen will also extend the ability of the DMT tool NonMon in order to effectively search for correlated glitches. Reed College undergraduate Jacob Fenton initially developed NonMon. The Carleton group will modify NonMon in order to expand its capabilities and usefulness for use during engineering and scientific runs. It usefulness as a veto trigger for the burst and inspiral upper limit groups will be studied.

3. We will also be using higher order statistics, such as the bicoherence, to look for coherence between interferometer noise at different frequencies. Steve Penn has developed a DMT tool for measuring bicoherence. Christensen previously used the bicoherence (with MATLAB software) to examine interferometer and PEM channels. Christensen and Penn, as part of their correlation sub-group responsibilities, will coordinate their effort in order to examine interferometer, mode-cleaner and PEM channels.

4. For the next six-months the correlation sub-group will concentrate on E5 data; when available, the group will use E6 data. Results of tasks detailed above will be presented at the March 2002 LSC meeting, and a summary report will also be written and posted as a LIGO document.

5. An important task in the next 6 months will be in participating in the E6 run. Christensen (and possibly a student) will spend a week at one of the interferometer sites during the E6 run.

c) Inspiral Upper Limit Group

Carleton College will continue to contribute to the IUL effort. Christensen will continue to lead the detector characterization sub-group. The group's primary effort in the next few months will be in developing techniques to create veto triggers for the E6 run. We will be working on developing LDAS to search for chirps in PEM channels. We will be modifying the NonMon program in order to help us effectively veto glitches that appear simultaneously in PEM and interferometer channels.

d) Stochastic Background Upper Limit Group

Carleton is participating in the LSC group that hopes to set upper limits of the strength of the stochastic gravity wave background. Carleton is also participating in sub-groups that are looking for cross-correlations in the noise between various interferometer outputs, and line removal. We will continue to investigate correlated events in PEM channels between the two LIGO sites. We will be contributing to the effort of this sub-group (led by Mike Landry, LHO).

10. During the period August 15, 2001 to February 15, 2002, the LIGO Laboratory will provide, as requested and necessary, 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 Nelson Christensen and Albert Lazzarini on behalf of CCRG 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. These resources will be in addition to the coordination effort and data to be made available per Item No. 10 above.

    a) Accommodations for CCRG investigators while on LIGO research assignment at Caltech, and /or LIGO sites.

Approved:

Barry Barish
LIGO Laboratory Director

Oct 18, 2001
Date

Nelson Christensen
CCRG Principal Investigator

10-24-01
Date

Albert Lazzarini
LIGO Laboratory Data and Computing
Group Leader

19 Sept 2001
Date