

**Attachment Number A to the
Memorandum of Understanding (LIGO-M950019-00-M)
between the
Caltech Relativity Group (CaRT)
and the
Laser Interferometer Gravitational Wave Observatory (LIGO) Laboratory
August 15, 1997**

This Attachment to the Memorandum of Understanding LIGO-L950019-00-M covers the role of the Caltech Relativity Group (CaRT) 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, 1997 to February 15, 1998. This period may be modified by agreement to a revision of this Attachment.

1. LIGO Scientific Collaboration - The LIGO Scientific Collaboration will be organized as a separate organization from the LIGO Laboratory. It will include scientists from the LIGO Laboratory, and those from collaborating institutions, and will have 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 will commence on March 1, 1997 and will end following the first full meeting of the Collaboration at which the Collaboration Council will assume its role. We expect that this transition will occur within six months. Membership in the Collaboration during this charter period will be initiated by proposal to the LIGO Laboratory Directorate.

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 Caltech Relativity Group (CaRT) and the LIGO Laboratory concerning the activities noted below, under provision 8, of CaRT as a Collaborating Institution in the LIGO Scientific Collaboration (LSC) and in the LIGO I Development Group (L1DG).

4. LIGO I Development Group - The LIGO I Development Group will be 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 - CaRT will provide a summary report of progress, monthly, by e-mail to the Collaboration Council and to the LIGO Laboratory Director. CaRT will submit a complete report on its activities every six months, supply an updated List of Collaborators, and a plan of activities for the next six months. This report should be submitted one month before the updated attachment will take effect.
6. Term of Membership - Membership will be renewed every six months upon evidence of satisfactory performance of agreed upon duties.
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. During the period August 15, 1997 - February 15, 1998, CaRT, led by Prof. Kip S. Thorne, will include as collaborators the following people: Patrick Brady, Jolien Creighton, Teviet Creighton, Scott Hughes, Yuri Levin, Ben Owen, and Kip Thorne. Alan Wiseman will be included from Aug. 15, 1997 - Nov. 1, 1997.

The work of CaRT will be in the areas of R&D for data analysis algorithms, interfacing with the theoretical astrophysics and theoretical relativity communities, and R&D for selected aspects of LIGO facilities and of advanced detectors. The work plan for the next six months is as follows; much of this work is already in progress, and much is likely to require twelve months rather than six.

A. R&D for Data Analysis

a.) Develop methods for stacked and hierarchical searches for narrow-band waves from pulsars, and scope out their computational requirements [Patrick Brady and Teviet Creighton; partly in collaboration with Tom Prince and Stewart Anderson of Caltech's SRL].

- b.) Write up and perhaps extend exploratory studies of hierarchical methods of searching for waves from inspiraling binaries [Ben Owen and Kip Thorne].
- c.) Develop and implement algorithms for constructing discrete grids of 2PN search templates for inspiraling binaries [Ben Owen; with B.S. Sathyaprakash of GEO600].
- d.) Carry out a search for coalescing binaries in 40m prototype data using 2PN search templates [Patrick Brady, Jolien Creighton, Teviet Creighton, Scott Hughes, Ben Owen, Alan Wiseman; in collaboration with Bruce Allen of UWM].
- e.) Explore information extraction from observed waves produced by binary black hole mergers [Scott Hughes; with Eanna Flanagan, Cornell].
- f.) Develop methods for searching for the waves from black-hole ringdown [Jolien Creighton].
- g.) Do a preliminary exploration of methods to jointly optimize the optical configurations and data analysis techniques for advanced detectors, for the task of extracting nuclear equation of state information from neutron-star merger waves [Scott Hughes and Kip Thorne].

B. Interface with Research on Source Modeling and Waveform Computation

A significant portion of CaRT's research will deal with the modeling of gravitational-wave sources and computations of waveforms; this work will be performed outside the LSC.

Thorne and other CaRT members will continue to serve as an interface between this type of non-LSC research by the theoretical astrophysics and theoretical relativity communities, and LSC research, with the goal of optimizing the contributions of these theory communities to LIGO.

C. R&D for LIGO Facilities and Advanced Detectors

- a. Analyze the limits on advanced detector sensitivity due to gravity gradient noise produced by:
 - i. ambient seismic waves in the earth beneath the detector [Scott Hughes and Kip Thorne];
 - ii. human motion [Kip Thorne; with Carolee Winstein, USC];
 - iii. atmospheric inhomogeneities [new project; participants not yet determined].
- b. Write a series of papers on light scattering noise in the LIGO beam tube and the geometric design of the baffles that control it [Kip Thorne, with Eanna Flanagan; also, for some aspects, Scott Hughes and Alan Wiseman]. ^(Cornell U.)
- c. Write up a new method for analyzing internal thermal noise in LIGO test masses, and its

warnings about the failure of the standard normal-mode-decomposition method when losses are inhomogeneously distributed [Yuri Levin].

d. Analyze the coherent superposition and interference of suspension thermal noise associated with violin modes and with the pendulum mode [Yuri Levin].

e. Explore the use of LIGO to search for narrow-band gravitational waves at 37kHz (1/round trip travel time of light in the arms) and its harmonics [Yuri Levin].

f. Devise, and explore theoretically, new optical configurations that can beat the standard quantum limit (SQL) and/or achieve near-SQL sensitivities with light powers lower than standard configurations require [Yuri Levin and Kip Thorne; in collaboration with Vladimir Braginsky and his MSU group].

Approved:

Barry Barish

Barry Barish
LIGO Laboratory Director

Kip S. Thorne

Kip S. Thorne
CaRT Principal Investigator

Aug 15, 1997

Date

Aug 15, 1997

Date