

**Attachment Number D 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, 1999

This Attachment to the Memorandum of Understanding LIGO-M950019-00-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 Advanced Detector Configurations Development Group (ADCDG). 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 Caltech Relativity Group (CaRT) and the LIGO Laboratory concerning the activities of CaRT as a Collaborating Institution in the LIGO Scientific Collaboration (LSC) and in the Advanced Detector Configurations Development Group (ADCDG), and as noted in Item No. 8 below.
4. Advanced Detector Configurations Development Group - The Advanced Detector Configurations Development Group (ADCDG) is the scientific collaboration for defining and developing entirely new advanced interferometers. It is expected that this development group will pursue research in dual recycling, resonant sideband extraction, Sagnac interferometers, sys-

tems with non-transmitting optics and other advanced configurations. A specific Attachment will define the roles and responsibilities of groups in this development group. Members of this group will normally be authors on publications reporting the work of the group and will normally be eligible to participate in data runs and science beyond the LIGO I data run.

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 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.8 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 CaRT members are included in the Attachment Z to the Memorandum of Understanding LIGO-M950019-00-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. During the period August 15, 1999 to February 15, 2000, the CaRT leadership will continue to train a new group of graduate students and postdoctoral fellows in the LIGO-related research. The contributions to LIGO will be made by the following people:

Experienced personnel - Kip Thorne, Lee Lindblom (a senior scientist in CaRT), Teviet Creighton (graduate student, will complete Ph.D. and move to Milwaukee in September), Yuri Levin (completed his Ph.D. in May; will be a postdoctoral fellow in CaRT until September, then move to Berkeley).

New personnel as of this past year - Yuk Tung Liu (graduate student), Patricia Purdue (graduate student) and Michelle Vallisneri (graduate student).

New personnel arriving in September - Scott Hughes (postdoctoral fellow) and Alessandra Buonanno (postdoctoral fellow).

The work plan for the period August 15, 1999 to February 15, 2000 will focus on R&D for the LIGO Facilities and Advanced Detectors as follows:

a. Optical configurations that can beat the Standard Quantum Limit

Y. Levin, P. Purdue and K. Thorne, in collaboration with V. Braginsky and other MSURG collaborators at Moscow State University, will continue to devise, and explore theoretically, new optical configurations that can beat the SQL and/or achieve near-SQL sensitivities with light powers lower than standard configurations require. This work will include the following sub-projects:

a.1. V. Braginsky, Michail Gorodetsky and Farid Khalili of MSURG, and K. Thorne will complete a manuscript on the theory, predicted performance, and experimental prospects for the microwave-frequency Dual-Resonator "speed-meter" for possible use as an internal read-out device in LIGO-III.

a.2. P. Purdue and K. Thorne will carry out a careful and full analysis of the performance of the speed-meter-type interferometer for possible use in LIGO-III.

a.3. Jeff Kimble of Caltech Atomic/Molecular/Optical Physics group, K. Thorne, Y. Levin, Andrey Matsko of Texas A&M, and S. Vyatchanin of MSURG will write a manuscript on analysis of schemes to convert conventional interferometers into QND interferometers by modifying their input and/or output optics.

a.4. K. Thorne and others will initiate a search for a viable LIGO-III QND design that produces squeezed vacuum ponderomotively and (in effect) injects it into the interferometer dark port; such a design would avoid having to use nonlinear crystals to produce squeezing.

a.5. All the above QND schemes for LIGO entail high light power. K. Thorne, with V. Braginsky and colleagues of MSURG and possibly others, will redouble efforts to find viable schemes that can operate with much lower power.

b. Y. Levin, possibly with Vladimir Braginsky and Sergey Vyatchanin of MSURG, will continue the conceptual development of new methods for controlling suspension thermal noise.

c. P. Purdue, K. Thorne and possibly S. Hughes will provide advice to the CAPS of Louisiana Tech University and UOERG of University of Oregon about their seismic surveys at Livingston and Hanford, and use their measurements to begin improving the Hughes/Thorne estimates of LIGO's seismic gravity gradient noise.

d. T. Creighton will complete work on estimating the gravity gradient noise produced by atmospheric inhomogeneities and by tumbleweeds.

e. Y. Levin, possibly with Vladimir Braginsky and Sergey Vyatchanin of MSURG, will continue the conceptual development of new methods for controlling suspension thermal noise.

9. 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. 8 above.

10. The research effort pursuant to this Attachment D will be coordinated by K. Thorne and Syd Meshkov on behalf of CaRT and LIGO Laboratory respectively.
11. 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. 8, as indicated below. These resources will be in addition to the coordination effort and data to be made available per Item No. 9 above.
 - a. Provide accommodations for investigators from other institutions in Item No. 8 above while on research assignment on LIGO at Caltech.
 - b. Contribute funding for MSURG's collaboration in support of LIGO. Funding is provided under a subcontract between the Caltech and US Civilian Research and Development Foundation (USRDF). The funding authority is National Science Foundation (NSF) Grant No. 9800097.

Approved:

Barry C Barish
Barry Barish
LIGO Laboratory Director

Kip S. Thorne
Kip S. Thorne
CaRT Principal Investigator

12-27-99
Date

1-6-00
Date