

**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, 2002**

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, 2002 to August 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, 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 indicated in Item No. 8.

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, systems 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 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, 2002 to August 15, 2003, the following CaRT personnel will contribute to Advanced LIGO LSC-related research: professor Kip S. Thorne; postdoctoral fellow Alessandra Buonanno; and graduate students Yanbei Chen, Richard O'Shaughnessy, and Yi Pan. The work plan for this period will focus on R&D for the LIGO Facilities and Advanced Detectors as follows:
 - a) K. Thorne and R. O'Shaughnessy, in collaboration with LIGO-Lab scientist E. d'Ambrosio and MSURG scientists S. Strigin and S. Vyatchanin, will complete their analyses of advanced LIGO with flattened mirrors and flat topped beams (including their effectiveness in reducing thermoelastic noise and their sensitivity to mirror tilt,

displacement, and figure errors), and based on their analyses, they will make recommendations to the LSC about further research on and implementation of flat-topped beams.

b) K. Thorne (with V. Braginsky, M. Gorodetsky, F. Khalili and S. Vyatchanin of MSURG and A. Matsko of Texas A&M) will publish their analysis showing that the quantum mechanical properties of the test masses will NEVER have any influence on the noise in any LIGO interferometer.

c) A. Buonanno and Y. Chen will continue their theoretical studies of the baseline optical topology for advanced LIGO's signal recycling interferometers.

d) A. Buonanno and Y. Chen will continue their collaboration with N. Mavalvala on a fully quantum mechanical optimization of the readout system for AdLIGO.

e) A. Buonanno and Y. Chen will embark on developing a master-equation-based, fully quantum analysis of the feedback system for controlling the recycling-mirror-induced dynamical instability in AdLIGO, so as to make sure that quantum noise introduced by the photodiode need not compromise the interferometer performance.

f) A. Buonanno and Y. Chen will carry out theoretical studies on injection of squeezed vacuum into the dark port of the advanced LIGO interferometers.

g) Y. Chen, with P. Purdue (now moved to Colorado College) will complete and submit for publication their manuscript on practical versions of speedmeter QND interferometers that are candidates for advanced detector configurations. Y. Chen has conceived ideas for a Sagnac-type speedmeter QND configuration, which he will analyze.

h) Y. Chen will carry out experimental work related to possible advanced LIGO QND interferometers, under the supervision of S. Whitcomb (LIGO Lab) and D. McClelland (ACIGA) in McClelland's laboratory at ANU. This will be valuable for Chen's future LIGO related research.

9. During the period August 15, 2002 to August 15, 2003, the LIGO Laboratory will share, as requested and appropriate, LIGO data of relevance to the research topics in Item No. 8.

10. The research effort pursuant to this Attachment D will be coordinated by K. Thorne and Gary Sanders on behalf of CaRT and the 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

a) Provide accommodations for CaRT investigators while on LIGO research assignment at LIGO sites.

b) Contribute funding for MSURG's collaboration in support of LIGO. The 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.

Approved:

Barry C Barish

Barry Barish
LIGO Laboratory Director

11-Jan-04
Date

Kip S Thorne

Kip S. Thorne
CaRT Principal Investigator

31 Jan 2004
Date