

**Attachment Number B to the  
Memorandum of Understanding (LIGO-M970077-00-M)  
between the  
German/British Collaboration for the Detection of Gravitational Waves  
(GEO 600)  
and the  
Laser Interferometer Gravitational Wave Observatory (LIGO) Laboratory  
February 15, 2004**

This Attachment to the Memorandum of Understanding LIGO-M970077-00-M covers the role of GEO 600 as a Charter Member of the LIGO Scientific Collaboration (LSC) and a member of the Isolation/Suspension/Thermal Noise Development Group (ISTNDG). The period of performance for the activities in this Attachment is from February 15, 2004 to August 15, 2004. 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 German/British Collaboration for the Detection of Gravitational Waves (GEO 600) and the LIGO Laboratory concerning the activities of GEO 600 as a Collaborating Institution in the LIGO Scientific Collaboration (LSC) and in the Isolation/Suspension/Thermal Noise Development Group (ISTNDG), and as indicated in Item No. 8.

4. Isolation/Suspension/Thermal Noise Development Group - The Isolation/Suspension/Thermal Noise Development Group (ISTNDG) is the scientific collaboration for defining and developing future isolation and suspension improvements for use in advanced sub-systems for the initial LIGO interferometers or in entirely new advanced interferometers. 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.
5. Report of Progress – GEO 600 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.
7. For the coordinates of GEO 600 personnel who will participate in the ISTNDG activities in Item No. 8 below, see Attachment Z to Memorandum of Understanding LIGO-M970077-00-M and the attached GEO LSC Contribution for LSC Period February 15, 2004 to August 15, 2004.
8. During the period February 15, 2004 to August 15, 2004 the GEO 600 team will work on suspension developments as follows:
  - a) Mechanical and suspension control developments by the GEO 600 team relevant to Advanced LIGO including the relevant work packages within the UK Advanced LIGO Project:
    - 1) Continuing development of mechanical aspects of detailed design of recycling mirror triple and test mass quadruple suspensions for controls and noise prototypes for LASTI. Includes continuing work on suspension and support structure design, cantilever blade design and adjustment, blade clamps/blade wire clamps and design of mass catcher/assembly jig with earthquake stops for silica/sapphire stage assembly. General assistance will also be provided using Solidworks software for drawings and assemblies of parts. (Cantley, Jones, Perreur-Lloyd, Cagnoli, Plissi, N Robertson (Stanford), Torrie et al (Caltech) + Rutherford Appleton Laboratory).
    - 2) Continued investigation of the potential application of penultimate mass silica blades for vertical isolation and improved thermal noise at low frequencies. This will include investigation of the application of low dissipation protective coatings such as sapphire for improved blade performance. (Cagnoli, Cantley, Heptonstall, Crooks).

- 3) Continuing work on the suitability of silica ribbons for suspension of 40 kg test masses, including loading tests, violin and pendulum  $Q$  measurements, finite element analysis and investigation of welding and bonding issues (Cagnoli, Heptonstall, Rowan, Hough, Elliffe, Cantley, Crooks, Jones).
- 4) Continuing development of eddy current damping for application in Advanced LIGO suspensions including optimization of design of the eddy current damping units with respect to performance and size/mass. Comparison with alternative low noise damping techniques. (Plissi, Cantley, Strain, Perreux-Lloyd, Grant with Torrie (Caltech) and N. Robertson (Stanford/Glasgow)).
- 5) Continuing research into improved control algorithms for local damping (Strain, Cantley, Plissi with Torrie (Caltech) and N. Robertson (Stanford/Glasgow)).
- 6) Continuing work on fabrication of electronic and associated parts for local control systems and design and fabrication of electrostatic drives for global control for prototypes at Caltech and LASTI. Continuing development of lower noise sensors/actuators for local control (Strain, Ward, D Robertson with UK Advanced LIGO project team and Caltech).
- 7) *Activities forming WP1 of UK Advanced LIGO Project – Project Management.*  
Continuing provision of project management and oversight of all work packages within the UK Advanced LIGO Project. For further details refer to UK proposal “Exploring the Dark Side of the Universe: Proposal for UK Involvement in Advanced LIGO”, Issue 2, November 2002 online at:  
[http://www.physics.gla.ac.uk/gwg/Proposal\\_for\\_Advanced\\_LIGO.htm](http://www.physics.gla.ac.uk/gwg/Proposal_for_Advanced_LIGO.htm)  
(Greenhalgh (Rutherford Appleton Lab) + UK Advanced LIGO Project Team)
- 8) *Activities forming WP2 of UK Advanced LIGO Project – Main Suspension Science*  
Continuing scientific input to the suspensions for Advanced LIGO based on the development of triple suspension systems for GEO 600. For further details refer to UK proposal “Exploring the Dark Side of the Universe: Proposal for UK Involvement in Advanced LIGO”, Issue 2, November 2002 online at:  
[http://www.physics.gla.ac.uk/gwg/Proposal\\_for\\_Advanced\\_LIGO.htm](http://www.physics.gla.ac.uk/gwg/Proposal_for_Advanced_LIGO.htm)  
(Glasgow/GEO600 + UK Advanced LIGO Project Team)
- 9) *Activities forming WP3 of UK Advanced LIGO Project – Main Suspension Systems*  
Continuing development of final mechanical designs for the suspensions working from the prototype designs as a basis. Manufacture of prototypes and final articles for delivery to the LIGO Lab. For further details refer to UK proposal “Exploring the Dark Side of the Universe: Proposal for UK Involvement in Advanced LIGO”, Issue 2, November 2002 online at:  
[http://www.physics.gla.ac.uk/gwg/Proposal\\_for\\_Advanced\\_LIGO.htm](http://www.physics.gla.ac.uk/gwg/Proposal_for_Advanced_LIGO.htm)  
(Greenhalgh (Rutherford Appleton Lab) + UK Advanced LIGO Project Team)
- 10) *Activities forming WP5 of UK Advanced LIGO Project – Optical Material*  
Continuing development towards provision of four blanks (sapphire or silica) each of 40 kg for one interferometer (work relevant to polishing and coating the blanks is excluded

from this package). For further details refer to UK proposal “Exploring the Dark Side of the Universe: Proposal for UK Involvement in Advanced LIGO”, Issue 2, November 2002 online at: [http://www.physics.gla.ac.uk/gwg/Proposal\\_for\\_Advanced\\_LIGO.htm](http://www.physics.gla.ac.uk/gwg/Proposal_for_Advanced_LIGO.htm) (Glasgow/GEO600 + UK Advanced LIGO Project Team)

b) Materials research relevant to Advanced LIGO and beyond

- 1) Development of an automated ribbon/fiber pulling and welding machine using high power CO<sub>2</sub> laser heating. (Cagnoli, Cantley, Crooks, Jones).
- 2) Continuation of investigation of losses associated with dielectric coatings on silica and sapphire test masses in collaboration with other LSC groups. Coatings of single layers of materials, coatings containing doped or structurally modified Ta<sub>2</sub>O<sub>5</sub> and coatings based on other high index materials such as HfO<sub>2</sub> will be investigated. (Rowan, Sneddon, Crooks, Murray, Reid, Cagnoli and Hough).
- 3) Ongoing investigation of ribbon strengths and quality factors and effects of welding to silicate bonded attachments, in collaboration with Caltech (Heptonstall, Cagnoli, Hough, Rowan, Cantley, Jones with Willems).
- 4) Ongoing investigation of hydroxy-catalysis bonding of silica to crystalline materials, in collaboration with Caltech. Also further investigation of bonding of silica to heavy glasses that could be used for penultimate mass in multiple pendulums. (Rowan, Elliffe, Hough with Armandula).
- 5) Continued evaluation of design of silica ears of suitable design to allow the jointing of ribbons in collaboration with Caltech (Cagnoli, Cantley, Hough, Rowan with Willems).
- 6) The construction of a fabricated heavy glass mass of 25 cm diameter suitable as a pre-prototype intermediate mass for Advanced LIGO (Elliffe, Hough, Cagnoli, Heptonstall and Rowan).
- 7) The preliminary testing of large sapphire mass, 25 cm diameter by 10 cm deep (Sneddon, Crooks, Hough, Rowan and Cagnoli).
- 8) The hanging of the sapphire mass from the heavy glass mass by silica ribbons connected to the sapphire and heavy glass by means of bonded ears (Heptonstall, Cagnoli and Hough).
- 9) The preliminary testing of the bonded configuration (Heptonstall, Cagnoli, Hough, Elliffe etc).
- 10) Continued investigation of charge mitigation in silica and sapphire (Elliffe, Sneddon, Rowan, Murray, Reid, Hough).

11) Further work on finite element modeling of the fused silica bonded test masses installed in GEO 600 (Murray, Crooks, Rowan, Hough).

12) Complete construction of a second apparatus for measuring mechanical loss factors, capable of handling larger test samples than can be studied in our current system. (Sneddon, Rowan, Hough).

c) Other relevant research

The experiment in Hannover to allow direct measurement of the off-resonant thermal noise of the pendulum mode of a suspended silica mirror will continue using a system of two coupled cavities with one common mirror that is currently being developed. (Ribichini, Lueck, Danzmann)

9. During the period February 15, 2004 to August 15, 2004, the LIGO Laboratory will share, as requested and appropriate, LIGO data of relevance to the planned research in Item No. 8.
10. The research effort pursuant to this Attachment B will be coordinated by Caroline Cantley and David Shoemaker on behalf of GEO 600 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) Accommodations for GEO 600 investigators while on LIGO research assignment at Caltech, and/or at LIGO sites.

Approved:

*Barry C. Barish*

Barry Barish  
LIGO Laboratory Director

Date June 17, 2004

*Karsten Danzmann*

Karsten Danzmann  
GEO 600 Principal Investigator

Date 22.6.04

*James Hough*

James Hough  
GEO 600 Principal Investigator

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*Bernard Schutz*

Bernard Schutz  
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Date