Attachment ACF to the Memorandum of Understanding LIGO-M970077-00 between the German/British Collaboration (GEO 600) for the Detection of Gravitational Waves (GEO600) and the Laser Interferometer Gravitational Wave Observatory (LIGO)

For The Period
August 15, 2008 - August 14, 2009

This Attachment ACF to the Memorandum of Understanding LIGO-M970077-00 defines the role of the German/British Collaboration (GEO 600) for the Detection of Gravitational Waves (GEO600) as a 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 described in this Attachment is from August 15, 2008 - August 14, 2009.

1. Collaboration

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. MOU Attachment ACF defines the role and responsibilities of workgroups participating in this development group.

2. Participation

During the period August 15, 2008 - August 14, 2009, the members of GEO600 will participate in the ADCDG in the following areas:

a. Interferometer Configurations

At Glasgow experiments with the diffractively-coupled, suspended optical cavity shall conclude, and the results shall be disseminated. A design study into an experimental test of radiation pressure, currently underway, shall be completed. The outcome shall determine the design of a controls test in a radiation-pressure dominated cavity, as a precursor to low-noise experiments in Hannover.

b. Squeezed Light Generation

In Birmingham, work will continue to coordinate the GEO Simulation group and to model optical configurations for second generation detectors, focusing on im-
proving the detectors' performance after the initial installation. This includes continuing the development of FINESSE, in particular towards implementing radiation pressure effects. Experimental work will be started on initial proof of principle demonstrations of displacement noise free interferometry. Birmingham contributes to future GEO upgrades, especially with investigations of control systems for the injection of squeezed vacuum.

In Hannover a squeezed light source for a high-frequency upgrade of GEO600 will be commissioned. The experimental work on Kerr media in laser interferometers will be continued. High-reflection mirrors with single coating layers will be experimentally characterized as cavity couplers.

In Hannover and Golm theoretical and modelling work will continue. Simulations and calculations will be related to the development of Advanced LIGO and the prototype facility in Hannover. Considerations of potential QND schemes for 3rd generation detectors will be continued.

c. Other Contributions

At Hannover, with input from Glasgow, a low-noise interferometer prototype facility shall be constructed and commissioned: during the period of this attachment work shall focus on vacuum system commissioning and detailed design and procurement of the isolation system.

3. 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. 2, as indicated below.

a. Research accommodations for GEO600 group members while on LIGO research assignment at any LIGO Laboratory site.

   *Not Applicable*

b. Access to LIGO data through established LSC channels in support of this work.

   *Not Applicable*

4. Coordination and Reporting

GEO600 will perform this research within the structures established by the LIGO Laboratory and the LSC where appropriate.

In particular, activities described in Item 2 will be carried out within the Advanced Detector Configurations Development Group of the LSC.

This includes keeping the Group leaders informed of activities and plans, reporting to the group at meetings and telecons, and through technical documents submitted to the LIGO Document Control Center.

In addition, an annual report will be submitted with the update to this Attachment, giving a summary status on research by topic as indicated in Item No. 2, 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. This Attachment will be updated at least annually with a plan of activities for the succeeding one-year period. These documents will be due one month before the close of the period of performance under this Attachment.

5. Computer Code

All computer code delivered to the LSC under this Attachment must be developed in consultation with the LSC Data Analysis Software Working Group (DASWG) and archived, documented and reviewed as determined by that group.

Jay Marx
LIGO Laboratory Director

Karsten Danzmann
Principal Investigator(s)
GEO600

David Reitze
LSC Spokesperson
Attachment DAT to the
Memorandum of Understanding LIGO-M970077-00
between the German/British Collaboration (GEO 600) for the
Detection of Gravitational Waves (GEO600)
and the
Laser Interferometer Gravitational Wave Observatory (LIGO)
For The Period
August 15, 2008 - August 14, 2009

This Attachment DAT to the Memorandum of Understanding LIGO-M970077-00 defines the role of
the German/British Collaboration (GEO 600) for the Detection of Gravitational Waves (GEO600) as a Member of the LIGO Scientific Collaboration (LSC). In particular, it addresses data analysis activities in support of the initial LIGO interferometers. The period of performance for the activities in this Attachment is from August 15, 2008 - August 14, 2009.

1. Collaboration

Together, the LIGO Laboratory and the LIGO Scientific Collaboration (LSC) are responsible for implementing and exploiting the initial LIGO detector through its science data runs. The LSC has organized the data analysis effort into search groups which coordinate analysis, review, and publication on behalf of the collaboration. LSC groups are encouraged to participate in one or more of these groups.

MOU Attachment DAT defines the contributions of each participating group to the data analysis development groups.

2. Participation

During the period August 15, 2008 - August 14, 2009, the members of GEO600 will participate in the analysis of initial LIGO data in the following areas:

a. Binary Inspirals

Cardiff University:

(a) Finish S5 low-mass search [Fairhurst, Cokelaer, Harry, McKechan, Van Den Broeck]
Finish the analysis of second year of S5 data with the new infrastructure developed by Cokelaer and Fairhurst
(b) Conclude S5 high-mass search [Sathyaprakash, Robinson, Predio]
Strengthen the high-mass search so that the astrophysics result from the search is interesting and conclude the search
(c) Develop inspiral-merger-ringdown search with EOBNR [Sathyaprakash, Robinson, Fairhurst, New postdoc 1]
Test the new filtering code developed over the past six months to look for the inspiral and merger parts of the signal using the effective-one-body signals that are matched to numerical relativity simulations

(d) Prepare the ground for S6 analysis [Fairhurst, Harry, McKechan, New postdoc 1, 2]
Set the science goals, prioritize and identify the available and missing infrastructure for S6. Assign people to work on road blocks

(e) Assess the importance of harmonics in parameter estimation [McKechan, Van Den Broeck, Sathyaprakash]
It is well known that harmonics of the inspiral signal other than the one that is currently used in our searches improve parameter estimation. Carry out a detailed study of the improvement in real detector noise by using software/hardware injections.

(f) Search for Gamma-ray bursts in S5 data [Pathak, Clark, Fairhurst, Harry]
Identify *all* S5 gamma-ray bursts that are potentially compact binary mergers and search for them using inspiral matched filters.

(g) Study the effect of spin effects in parameter estimation [Harry, Van Den Broeck, Fairhurst, Sathyaprakash]
Estimate how well spin effects can be helpful in improving estimation of parameters, in particular directionality.

(h) Einstein Telescope science case and trade-offs [Sathyaprakash, Van Den Broeck, New postdoc 1]
The ET design study will begin in the summer of 2008. Contribute to the ET science case coming from binary inspiral sources.

Albert Einstein Institute:

Members:


Note:

Reports and plans are given separately for the Hannover and the Golm divisions. However there is extensive exchange between these two divisions and you will see Golm staff on the Hannover reports/plans and vice versa or similar contributions listed under both divisions with different names.

Golm:
• Continue development of software infrastructure to enable injections of numerical relativity waveforms in inspiral pipeline (Krishnan, Santamaria).
• Run 2 months of high mass search and also contribute to any software development and other tasks that might be required for this search. (Santamaria, Husa)
• Continue running 1 month of S5 low mass search and contribute to any necessary pipeline development work. (Santamaria)
• Implement the inspiral-merger-ringdown search using phenomenological waveforms based on matching numerical relativity and PN results (Krishnan, Husa, Santamaria, Whelan).
• Investigate the systematic errors in IMRI parameter estimation due to the use of waveform templates that are accurate only to leading order in the mass ratio of the binary. (Drasco, with Cutler and Vallisneri)

Hannover:

• further development of Bayesian follow-up code, extension to coherent analysis (C. Röver).
• Development of inspiral+merger+ring down waveform injection pipeline for (non-precessing) spinning black holes (A. Parameswaran).
• IMR injection pipeline with waveforms containing higher harmonics from non-spinning black-hole binaries (A. Parameswaran).
• Development of a template bank for the non-spinning binary black-hole phenomenological waveforms (A. Parameswaran).

Birmingham CBC Group (J Veitch & A Vecchio):

We will complete the development of the model-selection code with the goal of making it available in the pipeline for follow-ups and signal-based vetoes/coherent analysis. As part of this activity we will:

• Evaluate the performance of the code/method (and compare with alternative approaches) using 2PN SPA waveforms for the low-mass analysis.
• Evaluate the performance of the code/method (and compare with alternative approaches) using other approximants (such as EOB, EOBNR and IMR) for the high-mass search.
• Evaluate the possible use of this code/method in triggered (such as GRB) searches.
• Evaluate the possible use of this code/method to aid and complement MCMC parameter estimation approaches (in collaboration with NUGWAG, AEI and CCRG).

b. Bursts

Glasgow University:

We will contribute waveform reconstruction code towards the Omega pipeline for Burst analysis.

Cardiff University:
(a) Finish S5 LIGO-only and S5-VSR1 LIGO-Virgo GRB searches [Jones, Sutton]
(b) Rapid-response triggered search for GRBs in S6 data [Jones, Sutton] Use reviewed X-Pipeline package for automated, low-latency analysis of all GRBs.
(c) Coherent follow-up of candidate events in S6 [Edwards (PhD student), Sutton] Implement coherent follow-up in the Omega pipeline all-sky, low-latency search. Will study performance of the follow-up for source position reconstruction and background rejection.
(d) Improved background/foreground separation [Sutton, Jones] Apply multi-variate analysis methods (such as neural networks or decision trees) to triggers from coherent analysis, and quantify usefulness.
(e) Studying astrophysics that can be obtained from triggered and directed GW searches [Sutton, Jones, Edwards] Emphasis on the science results that can be obtained from burst detections or strong upper limits, and developing the science case for joint observations external collaborations.
(f) Census of GWB sources [Grindley (undergraduate)] Review of the literature to conduct a census of possible GWB sources and their properties (especially time-frequency signature) to inform burst searches.

AEI, Hannover:

Continue collaborating with the Florida group in customising the Coherent Waveburst algorithm with spinning/higher harmonics waveform injections (A. Parameswaran).

c. Stochastic

AEI, Golm:

• Complete isotropic search using LSC and Virgo data [Robinson, Whelan]
• Development and implementation of a search pipeline for a specific class of non-Gaussian stochastic background produced by bursts from cosmic strings. (Drasco (with Siemens and Regimbau))

University of Birmingham (E. Robinson & A. Vecchio):

• We will continue the S5 LIGO-VIRGO(-GEO) analysis with the aim of placing an upper-limit on the isotropic contribution of a stochastic background in the frequency range above \( \sim 600 \) Hz.
• We will continue the development of a Bayesian approach to search for isotropic stochastic backgrounds of arbitrary spectrum using multiple interferometers, by systematically running on software/hardware injections. We will then evaluate possible changes to the analysis pipeline, based on the results from this study.

d. Continuous

University of Glasgow:

[Clark (until October 2008), Gill (from October 2008) Heng, Pitkin, Woan, A.N. Other (from November 2008)]
(a) We will develop the targeted pulsar code so that it can include glitch change-points routinely.
(b) We will publish the S5 targeted pulsar paper.
(c) We will perform a thorough investigation of the noise environment close to the Crab frequency to see whether additional sensitivity can be achieved by using more sophisticated noise management schemes.
(d) We will contribute to the development of local area search techniques for pulsars of uncertain frequency and for r-mode emission.
(e) We will run the evidence-based code a follow-up to matched filter ring-down search.
(f) We will investigate ways of extracting glitch waveforms.
(g) We will have preliminary results of ring-down search from a Vela glitch in S5.

**Albert Einstein Institute:**

**Members:**


**Note:**

Reports and plans are given separately for the Hannover and the Golm divisions. However there is extensive exchange between these two divisions and you will see Golm staff on the Hannover reports/plans and vice versa or similar contributions listed under both divisions with different names.

**Golm:**

- Continue development of cross-correlation search and apply it to full S5 data set (Krishnan, Whelan)
- Extend the cross-correlation search to look for CW signal from binary systems (Whelan, Krishnan)
- Use Hierarchical hough code to search for CW signals from the galactic center (Behnke, Krishnan, Peralta)
- Investigate the feasibility of a galactic center search for transient CW signals lasting days or weeks. (Behnke, Krishnan, Peralta)
- Development and completion of the post processing of the E@H S5R2 and R3 results (Papa, Leaci)
- Set up and run of a new Einstein@Home search on S5-data (S5R4) (Krishnan, Papa, Sintes)

**Hannover:**
• Einstein@Home S5R1 postprocessing (H. Pletsch, B. Machenschalk, O. Bock)
• Einstein@Home project maintenance (B. Allen, B. Machenschalk, O. Bock)
• Einstein@Home application support and improvement (B. Allen, B. Machenschalk, R. Prix, O. Bock)
• Einstein@Home development of a radio pulsar search (C. Messenger, B. Allen, H. Pletsch, R. Prix)
• prepare paper on random template-banks and relaxed lattices (C. Messenger, R. Prix, MA Papa)
• prepare paper on flat-metric approximation for CW searches (R. Prix) prepare paper on parameter-space correlations of the optimal detection statistic (H. Pletsch)
• study optimization of Hierarchical search algorithms (R. Prix)
• study detection statistic for “transient” (lasting few days) CW signals (R. Prix)
• Implement and develop the "sideband" search for low-mass X-Ray binaries (C. Messenger)
• Apply the RXTE Sco X-1 search to other X-Ray sources (C. Messenger, R. Prix)
• Prepare paper on the RXTE Low-mass X-Ray binary searches (C. Messenger)
• Implement an XML format for reading/writing intermediate and final CW search results, including full history trails (R. Prix, O. Bock)
• Set up and run a new Einstein@Home search on S5-data (S5R4) (B. Allen, B. Machenschalk, R. Prix. O. Bock)
• Development of a generalized Einstein@Home/BOINC workunit-generator in order to simplify setting up new BOINC projects (O. Bock, R. Prix)
• Search for a CW signal from Cas A with Karl Wette and Ben Owen (C. Messenger, MA Papa, R. Prix)

e. Other Contributions

Cardiff University:

• Hardware/Support [Gerald Davies]
  (a) Maintain and operate the Explorer and Coma clusters strengthening the code base. In particular, upgrade the OS on our systems.
  (b) With the view to increase usage, install the necessary grid tools on Coma so that the cluster is more easily suitable for LSC searches.
  (c) Explore the possibility of moving data on our spinning media to tape storage on the new ARCCA HPC facility.
  (d) Keep up-to-date GEO astrowatch data and prepare hardware for LIGO S6 strain data at Cardiff. Also explore transferring data from Virgo during S6.

• Committees
  (a) Steve Fairhurst: Co-chair of the inspiral search group, LSC Council
  (b) B.S. Sathyaprakash: Coordinator of the WP4 of Einstein Telescope Design Study, LSC Council, GEO Exec Comm
  (c) Patrick Sutton: ExtTrig co-ordinator, burst review committee, LSC-PP, GEO Exec. Comm

AEI, Golm:
• Computing
  Continue reported activities
• Management and service
  Continue reported activities

AEI, Hannover:

• Computing
  – Operating and extension ATLAS cluster (5400 cores) (H. Fehrmann, B. Allen, C. Aulbert)
  – Data management for AEI/Hannover (C. Aulbert, O. Bock, H. Fehrmann)
  – Computing support for Einstein@Home postprocessing and future searches (B. Allen, C. Aulbert, H. Fehrmann, O. Bock, B. Machenschalk)

• Hardware
  – Continued operation and possibly expansion of current resources (C. Aulbert, H. Fehrmann, B. Allen)
  – Taking over some GEO data duty from Steffen Grunewald (C. Aulbert, H. Fehrmann, M. Hewitson)

• Other
  – Improvement of DASWG development process and version control scheme (O. Bock, R. Prix)
  – Maintenance and improvement of Twiki system for CW group and other groups (O. Bock, R. Prix)
  – GEO600 calibration, data collection and movement (M. Hewitson)

University of Birmingham:

D Stops

We will continue the support of our 210 CPU Beowulf cluster (Tsunami) and make it available to the LSC for data analysis exploratory work.

3. 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. 2, as indicated below.

a. Research accommodations for GEO600 group members while on LIGO research assignment at any LIGO Laboratory site.

   Not Applicable

b. Access to LIGO data through established LSC channels in support of this work.

   Not Applicable
4. Coordination and Reporting

GEO600 will perform research within the structures established by the LIGO Laboratory and the LSC where appropriate.
In particular, with reference to activities described above:

2a will be carried out within the LSC Inspiral Search Group.
2b will be carried out within the LSC Burst Search Group.
2c will be carried out within the LSC Stochastic Search Group.
2d will be carried out within the LSC Continuous Waves search Group.

This includes keeping the Group leaders informed of activities and plans, reporting to the group at meetings and telecons, and through technical documents submitted to the LIGO Document Control Center.
In addition, an annual report will be submitted with the update to this Attachment, giving a summary status on research by topic as indicated in Item No. 2, 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.
This Attachment will be updated at least annually with a plan of activities for the succeeding one-year period. These documents will be due one month before the close of the period of performance under this Attachment.

5. Computer Code

All computer code delivered to the LSC under this Attachment must be developed in consultation with the LSC Data Analysis Software Working Group (DASWG) and archived, documented and reviewed as determined by that group.
Jay Marx
LIGO Laboratory Director

Karsten Danzmann
Principal Investigator(s)
GEO600

David Reitze
LSC Spokesperson
Attachment LAS to the Memorandum of Understanding LIGO-M970077-00 between the German/British Collaboration (GEO 600) for the Detection of Gravitational Waves (GEO600) and the Laser Interferometer Gravitational Wave Observatory (LIGO)

For The Period
August 15, 2008 - August 14, 2009

This Attachment LAS to the Memorandum of Understanding LIGO-M970077-00 defines the role of the German/British Collaboration (GEO 600) for the Detection of Gravitational Waves (GEO600) as a Member of the LIGO Scientific Collaboration (LSC), and a member of the Lasers Development Group (LDG). The period of performance for the activities in this Attachment is from August 15, 2008 - August 14, 2009.

1. Collaboration

The Lasers Development Group (LDG) is the scientific collaboration for defining and developing future high power lasers for use in advanced subsystems for the initial LIGO interferometers or in entirely new advanced interferometers. MOU Attachment LAS defines the roles and responsibilities of groups in this development group.

2. Participation

During the period August 15, 2008 - August 14, 2009, the members of GEO600 will participate in LDG in the following areas:

a. Laser Development

The GEO laser group is developing and will fabricate the Advanced LIGO pre-stabilized laser system (PSL). This includes the laser development and fabrication at the Laser Zentrum Hannover (LZH) as well as the development of the power and frequency stabilization feedback control loops, the spatial control of the beam profile and the interfacing to the AdvLIGO computer control and data acquisition system.

Furthermore the GEO laser group is responsible for maintenance and upgrades of the PSL at the GEO600 detector and at the AEI 10m prototype. A small effort of this group is devoted to R&D towards laser systems and their stabilization for third generation gravitational wave detectors.
During the period July 15, 2008 to July 15, 2009, the GEO600 laser group will work on the following tasks:

200W laser
We will continue to optimize the high power resonator layout of the 200W laser with the main goals being to find a robust operation point, to increase the range of the length actuator for long-duration injection locking stretches and to reduce the free-running power fluctuations.
Furthermore experiments will be performed to investigate if a higher doping concentration of the laser crystals would be advantageous, which is more commonly used by industry and which can be produced with less crystal-to-crystal fluctuations.
We will fabricate, assemble and commission the next iteration of the high power stage, namely the engineering prototype. The spare #1 35W front end laser (to be produced as well during this MOU phase) will be used for this prototype. (The engineering PT front end cannot be used as it is at Caltech.) Once this laser is in operation we will characterize its performance, in particular the free running fluctuations and the available actuators for stabilization loops.
We will continue to fabricate the 35W front end laser (observatory #3, spare #1, spare #2). Furthermore the fabrication of the AdvLIGO diagnostic breadboards will continue.

AdvLIGO PSL integrated test
The integrated PSL test at the AEI will continue with the reference system 35W laser. We plan to install and operate all PSL stabilization loops at the same time and measure their performance as well as the frequency dependent couplings between the different loops. Lockacquisition, drift compensations and long term monitoring will be performed using the EPICS RT control system. The required interfaces (field boxes) will be designed and fabricated.

GEO-HF pre-stabilized laser
After the test of squeezing techniques at the GEO600 detector an upgrade of the laser to a power of 35W is planned. During this MOU period we will fabricate and prepare the laser and its stabilization components for the installation at the GEO site.

R&D
We will continue fundamental investigations to reduce the limit to which power fluctuations can be sensed and we will continue investigations devoted to laser sources for third generation gravitational wave detectors.

b. Other Contributions
The GEO laser group will prepare and hold the preliminary design review for the AdvLIGO PSL.
Benno Willke will serve as the PSL subsystem leader and as the chair of the LSC lasers working group.
3. 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. 2, as indicated below.

a. Research accommodations for GEO600 group members while on LIGO research assignment at any LIGO Laboratory site.

   Not Applicable

b. Access to LIGO data through established LSC channels in support of this work.

   Not Applicable

4. Coordination and Reporting

GEO600 will perform research within the structures established by the LIGO Laboratory and the LSC where appropriate. In particular, activities described in Item 2 will be carried out within the Lasers Development Working Group of the LSC. This includes keeping the Group leaders informed of activities and plans, reporting to the group at meetings and telecons, and through technical documents submitted to the LIGO Document Control Center.

In addition, an annual report will be submitted with the update to this Attachment, giving a summary status on research by topic as indicated in Item No. 2, 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.

This Attachment will be updated at least annually with a plan of activities for the succeeding one-year period. These documents will be due one month before the close of the period of performance under this Attachment.

5. Computer Code

All computer code delivered to the LSC under this Attachment must be developed in consultation with the LSC Data Analysis Software Working Group (DASWG) and archived, documented and reviewed as determined by that group.
Attachment OPS to the Memorandum of Understanding LIGO-M970077-00 between the German/British Collaboration (GEO 600) for the Detection of Gravitational Waves (GEO600) and the Laser Interferometer Gravitational Wave Observatory (LIGO)

For The Period
August 15, 2008 - August 14, 2009

This Attachment OPS to the Memorandum of Understanding LIGO-M970077-00 defines the role of the German/British Collaboration (GEO 600) for the Detection of Gravitational Waves (GEO600) as a Member of the LIGO Scientific Collaboration (LSC) in the areas of detector commissioning, detector characterization, and operations support in the initial LIGO interferometers. The period of performance for the activities in this Attachment is from August 15, 2008 - August 14, 2009.

1. Collaboration

Together, the LIGO Laboratory and the LIGO Scientific Collaboration (LSC) are responsible for implementing and exploiting the initial LIGO detector through its science data runs. LSC groups are encouraged to contribute to the commissioning, characterization, and operation of the LIGO detectors, as members of working groups established by the LIGO Laboratory and the LSC.

2. Participation

During the period August 15, 2008 - August 14, 2009, the members of GEO600 will participate in the initial LIGO detector research program in the following areas:

a. Detector Commissioning

   Not Applicable

b. Detector Characterization

   Not Applicable

c. Detector Operations

   The astrowatch mode will continue throughout 2008 and early 2009. During this time we will continue the preparation for GEO upgrades and investigation of noise sources. With the end of the astrowatch program when Enhanced Ligo detectors will start acquiring science data GEO600 will start to undergo a number of sequential upgrades, labelled as the ‘GEO-HF’ program. Likely then around spring
2009 (depending on LSC-wide consensus when astrowatch will end) we will install a new vacuum chamber for the OMC and a new Faraday isolator. Together with this, we will implement a squeezed vacuum source for application at the anti-symmetric port of GEO. When shot-noise limited performance is reached, we will try to increase the injected laser power. Upgrades of the input modecleaner optics and of the laser are foreseen for this purpose, and may follow throughout 2009 or later.

d. Other Contributions

   Not Applicable

3. 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. 2, as indicated below.

   a. Research accommodations for GEO600 group members while on LIGO research assignment at any LIGO Laboratory site.

      Not Applicable

   b. Access to LIGO data through established LSC channels in support of this work.

      Not Applicable

4. Coordination and Reporting

GEO600 will perform research within the structures established by the LIGO Laboratory and the LSC where appropriate.

In particular, with reference to activities described above:

2a will be carried out in coordination with the LIGO Laboratory Commissioning Leader.

2b will be carried out within the Detector Characterization Working Group of the LSC.

2c will be carried out in coordination with the LHO or LLO Site Head.

This includes keeping the Group leaders informed of activities and plans, reporting to the group at meetings and telecons, and through technical documents submitted to the LIGO Document Control Center.

In addition, an annual report will be submitted with the update to this Attachment, giving a summary status on research by topic as indicated in Item No. 2, 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.
This Attachment will be updated at least annually with a plan of activities for the succeeding one-year period. These documents will be due one month before the close of the period of performance under this Attachment.

5. Computer Code

All computer code delivered to the LSC under this Attachment must be developed in consultation with the LSC Data Analysis Software Working Group (DASWG) and archived, documented and reviewed as determined by that group.

Jay Marx
LIGO Laboratory Director

Karsten Danzmann
Principal Investigator(s)
GEO600

David Reitze
LSC Spokesperson
Attachment OPT to the Memorandum of Understanding LIGO-M970077-00 between the German/British Collaboration (GEO 600) for the Detection of Gravitational Waves (GEO600) and the Laser Interferometer Gravitational Wave Observatory (LIGO) For The Period August 15, 2008 - August 14, 2009

This Attachment OPT to the Memorandum of Understanding LIGO-M970077-00 defines the role of the German/British Collaboration (GEO 600) for the Detection of Gravitational Waves (GEO600) as a Member of the LIGO Scientific Collaboration (LSC), and a member of the Optics Development Group (LDG). The period of performance for the activities in this Attachment is from August 15, 2008 - August 14, 2009.

1. Collaboration

The Optics Development Group (ODG) is the scientific collaboration for defining and developing instruments in optics for use in advanced subsystems for the initial LIGO interferometers, or in entirely new advanced interferometers. MOU Attachment OPT defines the roles and responsibilities of groups in this development group.

2. Participation

During the period August 15, 2008 - August 14, 2009, the members of GEO600 will participate in ODG in the following areas:

a. Optics Characterization

Coating Losses for Advanced LIGO and beyond

a.1.) Measurements of multi-layer coatings applied to fused silica substrates (Bassiri, Murray, Rowan, Hough & I. MacLaren)

Reduction of the mechanical loss associated with the addition of coatings to substrates and associated thermal noise remains an important research area for Advanced LIGO and is vital for the success of any future detectors that aim to have sensitivities better than Advanced LIGO.

We propose to thus continue studies with our LSC colleagues at Stanford University, Syracuse University, MIT, Embry-Riddle Aeronautical University and Hobart and William Smith Colleges on the level of excess mechanical losses associated
with adding dielectric coatings to test mass substrates, as part of the ongoing LSC coating research program. We will investigate the suitability of multilayer coatings of silica-hafnia and silica-doped hafnia (doped with silica) from a thermal noise point-of-view. We also plan to study the material properties, e.g. Young's modulus and refractive index, of multi-layer and single-layer coatings using Atomic Force microscopy and ellipsometry.

**a.2.) Mechanical loss associated with coatings for diffractive optics**
(Cumming, Heptonstall, Rowan & Hough)
We propose to investigate the mechanical loss of silicon substrates with diffractive coatings applied, in collaboration with colleagues in Hanover and Jena. We will contact appropriate vendors for the supply of diffractive components.

**a.3.) Coating loss measurements using thin cantilever substrates**
(Martin, Chalkley, Bassiri, Reid, Rowan, Hough & I. MacLaren)
We will continue to investigate the effects of heat treatment on the mechanical dissipation in thin-film tantala, with particular focus on possible alterations on the observed low temperature dissipation peak. Samples with tantala coatings have undergone annealing temperatures in the range of 300 to 800°C and will be studied. We plan to procure comparable thin-film silica coatings to also be studied as a function of annealing temperature. Studies of the microscopic structure of these coatings using electron microscopy may help identify any crystalline structure [using Selected Area Diffraction (SAD) and Convergent Beam Electron Diffraction (CBED)] and to identify short-range order using Reduced Density Function analysis to identify amorphous structure, and possibly help relate this to our macroscopic mechanical loss measurements.

**b. Other Contributions**

**Studies of the use of non-Gaussian beams**
(Miller, Strain & Robertson)
Experimental tests and theoretical development of the optics for mesa beam interferometry are carried out at Caltech. We will continue to provide input to this through the effort of John Miller (visiting Caltech). This work is supervised from Glasgow (Strain, Robertson) and Caltech (DeSalvo, Robertson).

**3. 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. 2, as indicated below.

**a. Research accommodations for GEO600 group members while on LIGO research assignment at any LIGO Laboratory site.**

Not Applicable

**b. Access to LIGO data through established LSC channels in support of this work.**
4. Coordination and Reporting

GEO600 will perform research within the structures established by the LIGO Laboratory and the LSC where appropriate. In particular, activities described in Item 2 will be carried out within the Optics Development Working Group of the LSC. This includes keeping the Group leaders informed of activities and plans, reporting to the group at meetings and telecons, and through technical documents submitted to the LIGO Document Control Center. In addition, an annual report will be submitted with the update to this Attachment, giving a summary status on research by topic as indicated in Item No. 2, 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. This Attachment will be updated at least annually with a plan of activities for the succeeding one-year period. These documents will be due one month before the close of the period of performance under this Attachment.

5. Computer Code

All computer code delivered to the LSC under this Attachment must be developed in consultation with the LSC Data Analysis Software Working Group (DASWG) and archived, documented and reviewed as determined by that group.

Jay Marx
LIGO Laboratory Director

Karsten Danzmann
Principal Investigator(s)
GEO600

David Reitze
LSC Spokesperson
This Attachment OUT to the Memorandum of Understanding LIGO-M970077-00 defines the role of the German/British Collaboration (GEO 600) for the Detection of Gravitational Waves (GEO600) as a Member of the LIGO Scientific Collaboration (LSC) in support of Education and Outreach to the broader community. The period of performance for the activities in this Attachment is from August 15, 2008 - August 14, 2009.

1. Education and Outreach

As a frontier physics effort, LIGO offers a unique opportunity to inspire interest in science among students and to educate the broader community. The LIGO Laboratory supports a broad program of education and outreach to take advantage of these opportunities. Activities to attract and educate visitors take place at both Observatories, as well as the development of educational materials for use there and elsewhere.

The LIGO Laboratory is building a Science Education Center at the Livingston Observatory, and is participating with local partners to make it a vehicle for science education throughout the region. LSC groups are invited to participate in these activities, and to suggest others, with the goal of leveraging activities to make a greater impact.

This MOU Attachments defines the role and responsibilities of groups in this development group.

2. Participation

During the period August 15, 2008 - August 14, 2009, the members of GEO600 will participate in LDG in the following areas:

a. Educational Materials Developed

   (a) A dedicated, modern and attractive Gravitational Wave Astronomy outreach website will be developed. This will highlight current and future detectors, data analysis and numerical simulation research as well as the fundamentals of the science. A multimedia database will also be provided. The site will link...
to all detectors and research institutes. Target date for completion of the web-
site is November 2008.

(b) We will also work closely with other members of the EPO Working Group to
develop a web portal (with the proposed name www.gravitycentral.org) that
will describe general relativity to the general public. This website will link to
gravitational wave-specific sites including that described in item (1) above,
and the LSC outreach webpages.

(c) The YouTube interview series on black holes will be completed. A further se-
ries may also be developed, depending on funding availability.

(d) In Glasgow, Hendry plans to develop the Einsteins Universe series of public
lectures as an online resource, with multimedia content to be made available
for use across the LSC.

(e) In Cardiff Sathyaprakash plans to write up an article describing the develop-
ment of the Black Hole Hunter game, for publication in a popular science/physics
journal.

(f) In Cardiff Sathyaprakash and Wendy Sadler (Director of Science Made Sim-
ple) have funds from the Science and Technology Facilities Council to develop
further Sathyaprakashs Open Day lecture, and to deliver it under the banner
Gravity Beyond the Apple. The multimedia lecture will comprise video, audio,
interviews, pamphlets and posters and will showcase the online version of the
Black Hole Hunter game.

b. Other Contributions

(a) Milde Marketing will continue to carry out regular professional press work on
behalf of all GEO institutions.

(b) The UK and German GEO institutions will participate in a number of national
and international activities for IYA2009, including:

- The AEI, together with other institutes in Berlin and Potsdam, will orga-
nize the national opening in Berlin, in January 2009. The AEI plans to
develop an exhibition entitled From Galileo Galilei to Gravitational Waves,
which will showcase what astronomers see with the different astronomi-
cal methods that have been developed so far, and how gravitational wave
astronomy will expand our knowledge about the universe.

- The AEI will contribute to a series of articles in the German popular as-
tronomy magazine Sterne und Weltraum. This series of 7 articles will be
accompanied by tailor-made material for schools and will afterwards be
distributed to schools as a special issue.

- Glasgow will organize public lectures at the Glasgow Science Centre, and
plan to develop an interactive interferometer exhibit (similar to that built for
the RS Summer Science Exhibition) for the concourse of the GSC Plane-
tarium.

(c) The AEI will participate in the German adaptation of an American science
series for children.

(d) The AEI will participate in the Science Express train project in Germany.
(e) Hendry, together with other members of the EPO Working Group, plans to visit the Gravity Discovery Centre, in Perth Australia, to strengthen links and coordination of outreach activities across the LSC.

(f) We will assist the EPO Working Group in the development and delivery of the proposed World Science Festival activities on gravitational wave science, in New York City, May 2009.

3. 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. 2, as indicated below.

a. Research accommodations for GEO600 group members while on LIGO research assignment at any LIGO Laboratory site.

   Not Applicable

b. Access to LIGO data through established LSC channels in support of this work.

   Not Applicable

4. Coordination and Reporting

GEO600 will perform research within the structures established by the LIGO Laboratory and the LSC where appropriate. In particular, activities described in Item 2 will be carried out with the LIGO Observatories Educational and Outreach Leaders.

This includes keeping the Group leaders informed of activities and plans, reporting to the group at meetings and telecons, and through technical documents submitted to the LIGO Document Control Center.

In addition, an annual report will be submitted with the update to this Attachment, giving a summary status on research by topic as indicated in Item No. 2, 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.

This Attachment will be updated at least annually with a plan of activities for the succeeding one-year period. These documents will be due one month before the close of the period of performance under this Attachment.

5. Computer Code

All computer code delivered to the LSC under this Attachment must be developed in consultation with the LSC Data Analysis Software Working Group (DASWG) and archived, documented and reviewed as determined by that group.
Attachment SUS to the Memorandum of Understanding LIGO-M970077-00 between the German/British Collaboration (GEO 600) for the Detection of Gravitational Waves (GEO600) and the Laser Interferometer Gravitational Wave Observatory (LIGO) For The Period August 15, 2008 - August 14, 2009

This Attachment SUS to the Memorandum of Understanding LIGO-M970077-00 defines the role of the German/British Collaboration (GEO 600) for the Detection of Gravitational Waves (GEO600) as a 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 August 15, 2008 - August 14, 2009.

1. Collaboration

The Isolation/Suspension/Thermal Noise Development Group (ISTNDG) is the scientific collaboration for defining and developing instruments in optics for use in advanced subsystems for the initial LIGO interferometers or in entirely new advanced interferometers. MOU Attachment SUS defines the roles and responsibilities of workgroups in this development group.

2. Participation

During the period August 15, 2008 - August 14, 2009, the members of GEO600 will participate in ISTNDG in the following areas:

a. Coating Losses

See under Optics Characterization in Attachment OPT.

b. Suspension Design for Advanced LIGO

References to WP1-WP4 below are to work packages of the UK Advanced LIGO Project. See the Advanced LIGO UK (Glasgow) website: http://www.physics.gla.ac.uk/igr/advligo/

[Personnel for items b.1. - b.3.: K A Strain, R Jones, K Tokmakov, M van Veggel, G Hammond, S Rowan, J Hough]

b.1.) WP1 Project management

(RAL + Glasgow/GEO600 + UK Advanced LIGO Project Team)
Continue oversight of all of the work packages within the UK Advanced LIGO Project. Manage the continuing OJEU procurement process.

**b.2.) WP2 Main Suspension Science**
Continue scientific input to the suspensions for Advanced LIGO. This work will now concentrate on refinements to the designs currently under test at LASTI, in particular the prism material and ear design will be reviewed. In parallel provide for procurement of the production masses, ears, and prisms.

**b.3.) WP3 Main Suspension Systems: development of the final mechanical designs for the main suspension systems**
(RAL + Glasgow/GEO600 + UK Advanced LIGO Project Team)
Continue to support LASTI in the testing of the prototypes, and also assemble a production prototype quad suspension to ensure correct fit and function of final production parts. Complete procurement of the final suspensions.

[Personnel for items b.4. - b.6.: S M Aston, M Cruise, R Cutler, A Freise, D Hoyland, N Lockerbie, D Lodhia, A Page, C C Speake, A Vecchio + ALUK Project Team and US/SUS]

**b.4.) WP4 Electronics for Advanced LIGO**
Our work is fully defined by the scope and schedule of the ALUK project, within the larger Advanced LIGO project.

- Final production of the OSEMs is underway and these will be delivered to the US throughout the next 12 month period.
- A pre-production cycle for the Coil Drive Electronics will be carried out and we aim to deliver “Test Stand” units to the US. Work towards the optimization of the performance will continue.
- Testing and production of the Coil Drive Electronics and Electro-Static Drive units will be conducted and units delivered to the US.

**b.5.) WP4 Violin mode damping of silica ribbons for Advanced LIGO**
Four units are scheduled to be delivered to LASTI over the coming months and the need for dampers will be determined.

**b.6.) Compact interferometric sensor for Advanced LIGO**
We will continue to develop the compact interferometric sensor and consider potential applications in LIGO where the high sensitivity and larger working range it offers would be advantageous.

**c. Other Contributions**

**c.1.) Investigations of charge mitigation techniques**
[S Reid, I Martin, S Rowan, J Hough & W Cunningham]
We propose to develop the current deposition technique for SnO coatings in order to produce more uniform coatings in an attempt to minimise the degradation in the breaking stress of conductive silica fibres. We will contact coating vendors regarding the possibility of acquiring commercial coatings (SnO, SnO2 or ITO) to assess
their suitability for Advanced LIGO.

c.2.) Improved suspension techniques development for bulk mechanical loss measurements
[E Chalkley, P Murray, A Cumming, J Faller, J Hough & S Rowan]
Modifications will be applied our current nodal support set up to compensate for the differential expansion between the test mass and the clamping structure.

c.3.) Measurements of silicon ribbon flexures
[S Reid, I Martin, W Cunningham, S Rowan & J Hough]
We will continue our studies of the mechanical loss of silicon cantilevers (which is both of intrinsic interest regarding their possible use as suspension elements in future detectors as well as of immediate relevance for their use as substrates for the study of the temperature mechanical loss factors of dielectric coating materials).

c.4.) Silicate bonding
[M van Veggel, S Reid, I Martin, P Murray, W Cunningham, J Scott, S Rowan & J Hough]
Investigations of the dependence of the thickness of the silicate bonds on volume and chemistry of bonding solution used will continue. Silica (Suprasil 311 and 3001) and silicon test masses of diameter 65 mm and lengths 50 mm and 70 mm will be fabricated and bonded to investigate the level of excess mechanical dissipation resulting from the bond material. New bonded silicon samples, optimised for thermal conductivity studies, will be sent to the University of Florence to investigate the dependence of the thermal conductivity of silicate bonds on volume and chemistry of bonding solution also. Bending and shear strength tests will be carried out on silica silica bonds in addition to developing a test bed for carrying out bending tests at low temperature on silicon-silicon samples.

3. 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. 2, as indicated below.

a. Research accommodations for GEO600 group members while on LIGO research assignment at any LIGO Laboratory site.

Not Applicable

b. Access to LIGO data through established LSC channels in support of this work.

Not Applicable

4. Coordination and Reporting

GEO600 will perform research within the structures established by the LIGO Laboratory and the LSC where appropriate. In particular, activities described in Item 2 will be carried out within the Isolation/Suspension/Thermal Noise Development Group of the LSC.
This includes keeping the Group leaders informed of activities and plans, reporting to the group at meetings and telecons, and through technical documents submitted to the LIGO Document Control Center.

In addition, an annual report will be submitted with the update to this Attachment, giving a summary status on research by topic as indicated in Item No. 2, 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.

This Attachment will be updated at least annually with a plan of activities for the succeeding one-year period. These documents will be due one month before the close of the period of performance under this Attachment.

5. Computer Code

All computer code delivered to the LSC under this Attachment must be developed in consultation with the LSC Data Analysis Software Working Group (DASWG) and archived, documented and reviewed as determined by that group.

Jay Marx
LIGO Laboratory Director

Karsten Danzmann
Principal Investigator(s)
GEO600

David Reitze
LSC Spokesperson
Attachment Z to the Memorandum of Understanding LIGO-M970077-00 between the German/British Collaboration (GEO 600) for the Detection of Gravitational Waves (GEO600) and the Laser Interferometer Gravitational Wave Observatory (LIGO) For The Period August 15, 2008 - August 14, 2009

This Attachment Z to the Memorandum of Understanding LIGO-M970077-00 lists the members of German/British Collaboration (GEO 600) for the Detection of Gravitational Waves (GEO600) participating in LIGO Scientific Collaboration (LSC) development group activities in support of the initial LIGO interferometers. The period of performance for these activities is from August 15, 2008 - August 14, 2009.

Faculty:

The Faculty category includes all “faculty rank” LSC members. This includes professorial appointments, research faculty appointments, teaching faculty appointments, lecturer and reader appointments, and similar appointments in all these categories.

Name: Allen, Bruce
Phone:
Voice: 49 511 762 17148
Fax:
Email:
@LIGO.Org: bruce.allen@LIGO.Org
Forwarding: ballen@gravity.phys.uwm.edu
Postal Address:
Albert Einstein Institute
Callinstrasse 38
City: Hannover
State: Germany
Postal Code: 30167
Country: DEU

Name: Aufmuth, Peter
Phone:
Voice: 49 511 762 2396
Fax: 49 511 762 2784
Email:
@LIGO.Org: peter.aufmuth@LIGO.Org
Forwarding: pea@mpq.mpg.de
Postal Address:
Institut fur Gravitationsphysik
Universitat Hannover
City: Callinstrasse 38
State: Hannover
Postal Code: 30167
Country: DEU
<table>
<thead>
<tr>
<th>Name</th>
<th>Postal Address</th>
<th>Email</th>
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</tr>
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<tbody>
<tr>
<td>Chen, Yanbei</td>
<td>Max Planck Institute for Gravitational Physics</td>
<td><a href="mailto:yanbei.chen@LIGO.Org">yanbei.chen@LIGO.Org</a></td>
<td>DEU</td>
</tr>
<tr>
<td></td>
<td>Max Planck Institute for Gravitational Physics</td>
<td><a href="mailto:Yanbei.Chen@aei.mpg.de">Yanbei.Chen@aei.mpg.de</a></td>
<td></td>
</tr>
<tr>
<td>Cruise, Mike</td>
<td>The University of Birmingham</td>
<td><a href="mailto:mike.cruise@LIGO.Org">mike.cruise@LIGO.Org</a></td>
<td>GBR</td>
</tr>
<tr>
<td></td>
<td>School of Physics and Astronomy</td>
<td><a href="mailto:a.m.cruise@bham.ac.uk">a.m.cruise@bham.ac.uk</a></td>
<td></td>
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<tr>
<td>Danzmann, Karsten</td>
<td>Institut fur Gravitationsphysik</td>
<td><a href="mailto:karsten.danzmann@LIGO.Org">karsten.danzmann@LIGO.Org</a></td>
<td>DEU</td>
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<tr>
<td></td>
<td>Universitat Hannover</td>
<td><a href="mailto:karsten.danzmann@aei.mpg.de">karsten.danzmann@aei.mpg.de</a></td>
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</tr>
<tr>
<td>Daw, Edward</td>
<td>Physics and Astronomy</td>
<td><a href="mailto:edward.daw@LIGO.Org">edward.daw@LIGO.Org</a></td>
<td>GBR</td>
</tr>
<tr>
<td></td>
<td>Hicks Building</td>
<td><a href="mailto:e.daw@sheffield.ac.uk">e.daw@sheffield.ac.uk</a></td>
<td></td>
</tr>
<tr>
<td>Fairhurst, Stephen</td>
<td>Cardiff University</td>
<td><a href="mailto:stephen.fairhurst@LIGO.Org">stephen.fairhurst@LIGO.Org</a></td>
<td>GBR</td>
</tr>
<tr>
<td></td>
<td>Queens Building</td>
<td><a href="mailto:Stephen.Fairhurst@astro.cf.ac.uk">Stephen.Fairhurst@astro.cf.ac.uk</a></td>
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</table>
Name: Freise, Andreas
Phone:
Voice: 44 121 414 3565
Fax: 44 121 414 3722
Email: @LIGO.Org: andreas.freise@LIGO.Org
Forwarding: adf@star.sr.bham.ac.uk
Postal Address: The University of Birmingham
School of Physics and Astronomy
City: Edgbaston
State: Birmingham
Postal Code: B15 2TT
Country: GBR

Name: Friedrich, Daniel
Phone:
Voice: 49 511 762 19556
Fax: 49 511 762 2784
Email: @LIGO.Org: daniel.friedrich@LIGO.Org
Forwarding: daniel.friedrich@aei.mpg.de
Postal Address: Callinstr. 38
City: Hannover
State: Germany
Postal Code: 30167
Country: DEU

Name: Gholami, Iraj
Phone:
Voice:
Fax:
Email: @LIGO.Org: iraj.gholami@LIGO.Org
Forwarding: Iraj.Gholami@aei.mpg.de
Postal Address:
City:
State:
Postal Code:
Country: DEU

Name: Gossler, Stefan
Phone:
Voice: 49 511 762 19133
Fax: 49 511 762 49
Email: @LIGO.Org: stefan.gossler@LIGO.Org
Forwarding: stefan.gossler@aei.mpg.de
Postal Address: Max-Planck-Institut fuer Gravitationsphysik
Callinstrasse 22
City: Hannover
State: Lower Saxony
Postal Code: 30167
Country: DEU

Name: Grant, Alastair
Phone:
Voice:
Fax: 44 141 330 6834
Email: @LIGO.Org: alastair.grant@LIGO.Org
Forwarding: a.grant@physics.gla.ac.uk
Postal Address: Physics and Astronomy
Kelvin Building
City:
State: Glasgow
Postal Code: G12 8QQ
Country: GBR
Name: Greenhalgh, Justin
Postal Address: Building R34
City: Chilton
State: Didcot
Postal Code: OX11 0QX
Country: GBR
Phone: Voice: 44 1235 44 5297
Fax: 44 1235 44 5843
Email: justin.greenhalgh@LIGO.Org
Forwarding: j.greenhalgh@rl.ac.uk

Name: Grote, Hartmut
Postal Address: Universitat Hannover
City: Hannover
State: Lower Saxony
Postal Code: 30167
Country: DEU
Phone: Voice: 49 511 762 2210
Fax: 49 511 762 2784
Email: hartmut.grote@LIGO.Org
Forwarding: hartmut.grote@aei.mpg.de

Name: Grunewald, Steffen
Postal Address: Albert Einstein Institute
City: Golm
State: BRB
Postal Code: D-14476
Country: DEU
Phone: Voice: 49 331 567 7233
Fax: 49 331 567 7298
Email: steffen.grunewald@LIGO.Org
Forwarding: steffen.grunewald@aei.mpg.de

Name: Hammond, Giles
Postal Address: University of Glasgow
City: Glasgow
State: UK
Postal Code: G12 8QQ
Country: GBR
Phone: Voice: 44 141 330 3340
Fax:
Email: giles.hammond@LIGO.Org
Forwarding: g.hammond@physics.gla.ac.uk

Name: Heinzel, Gerhard
Postal Address: Universitat Hannover
City: Callinstrasse 38
State: Hannover
Postal Code: 30167
Country: DEU
Phone: Voice: 49 511 762 2210
Fax: 49 511 762 2784
Email: gerhard.heinzel@LIGO.Org
Forwarding: gerhard.heinzel@mpq.mpg.de
<table>
<thead>
<tr>
<th>Name</th>
<th>Postal Address</th>
<th>Email</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hendry, Martin</td>
<td>Department of Physics and Astronomy, University of Glasgow</td>
<td><a href="mailto:martin.hendry@LIGO.Org">martin.hendry@LIGO.Org</a></td>
</tr>
<tr>
<td>Heng, Ik Siong</td>
<td>Physics and Astronomy, Kelvin Building</td>
<td><a href="mailto:siong.heng@LIGO.Org">siong.heng@LIGO.Org</a></td>
</tr>
<tr>
<td>Hewitson, Martin</td>
<td>Institut fur Gravitationsphysik, Universitat Hannover</td>
<td><a href="mailto:martin.hewitson@LIGO.Org">martin.hewitson@LIGO.Org</a></td>
</tr>
<tr>
<td>Hough, James</td>
<td>Physics and Astronomy, Kelvin Building</td>
<td><a href="mailto:james.hough@LIGO.Org">james.hough@LIGO.Org</a></td>
</tr>
<tr>
<td>Husa, Sascha</td>
<td>AEI, Am Muehlenberg 1</td>
<td><a href="mailto:sascha.husa@LIGO.Org">sascha.husa@LIGO.Org</a></td>
</tr>
</tbody>
</table>
Name: Jones, Ian  
Phone:  
Voice: 44 23 8059 4829  
Fax: 44 23 8059 5147  
Email:  
@LIGO.Org: ian.jones@LIGO.Org  
Forwarding: d.i.jones@soton.ac.uk

Postal Address:  
School of Mathematics  
University of Southampton  
Highfield  
City: Southampton  
State: England  
Postal Code: SO17 1BJ  
Country: GBR

Name: Lockerbie, Nick  
Phone:  
Voice: 44 141 5483360  
Fax: 44 121 414 3722  
Email:  
@LIGO.Org: nick.lockerbie@LIGO.Org  
Forwarding: n.lockerbie@phys.strath.ac.uk

Postal Address:  
University of Strathclyde  
107 Rottenrow  
City:  
State: Glasgow  
Postal Code: G4 0NG  
Country: GBR

Name: Lueck, Harald  
Phone:  
Voice: 49 511 762 2229  
Fax: 49 511 762 2784  
Email:  
@LIGO.Org: harald.lueck@LIGO.Org  
Forwarding: harald.lueck@aei.mpg.de

Postal Address:  
Institut fuer Gravitationsphysik  
Leibniz Universitaet Hannover  
Callinstrasse 38  
City: Hannover  
State: Germany  
Postal Code: 30167  
Country: DEU

Name: Mossavi, Kasem  
Phone:  
Voice: 49 511 762 2229  
Fax: 49 511 762 2784  
Email:  
@LIGO.Org: kasem.mossavi@LIGO.Org  
Forwarding: ksm@mpq.mpg.de

Postal Address:  
Institut fur Gravitationsphysik  
Universitat Hannover  
Callinstrasse 38  
City: Hannover  
State: Hannover  
Postal Code: 30167  
Country: DEU

Name: Newton, Gavin  
Phone:  
Voice: 44 141 330 4196  
Fax: 44 141 330 6833  
Email:  
@LIGO.Org: gavin.newton@LIGO.Org  
Forwarding: G.Newton@physics.gla.ac.uk

Postal Address:  
Physics and Astronomy  
Kelvin Building  
City: Glasgow  
State: Scotland  
Postal Code: G12 8QQ  
Country: GBR
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<tr>
<td>Papa, Maria Alessandra</td>
<td>Albert Einstein Institute. Am Muehlenberg 5</td>
<td>D-14476</td>
<td>DEU</td>
<td><a href="mailto:maria.papa@LIGO.Org">maria.papa@LIGO.Org</a></td>
<td><a href="mailto:papa@aei.mpg.de">papa@aei.mpg.de</a></td>
<td></td>
</tr>
<tr>
<td>Prix, Reinhard</td>
<td>Albert-Einstein-Institut Hannover</td>
<td>Hannover</td>
<td>Niedersachsen</td>
<td><a href="mailto:reinhard.prix@LIGO.Org">reinhard.prix@LIGO.Org</a></td>
<td><a href="mailto:Reinhard.Prix@aei.mpg.de">Reinhard.Prix@aei.mpg.de</a></td>
<td>DEU</td>
</tr>
<tr>
<td>Roever, Christian</td>
<td>Max-Planck-Institut fuer Gravitationsphysik</td>
<td>Hannover</td>
<td>-</td>
<td><a href="mailto:christian.roever@LIGO.Org">christian.roever@LIGO.Org</a></td>
<td><a href="mailto:christian.roever@aei.mpg.de">christian.roever@aei.mpg.de</a></td>
<td>DEU</td>
</tr>
<tr>
<td>Rowan, Sheila</td>
<td>Physics and Astronomy</td>
<td>Glasgow</td>
<td>GBR</td>
<td><a href="mailto:sheila.rowan@LIGO.Org">sheila.rowan@LIGO.Org</a></td>
<td><a href="mailto:s.rowan@physics.gla.ac.uk">s.rowan@physics.gla.ac.uk</a></td>
<td></td>
</tr>
<tr>
<td>Ruediger, Albrecht</td>
<td>Institut fur Gravitationsphysik</td>
<td>Hannover</td>
<td>Niedersachsen</td>
<td><a href="mailto:albrecht.ruediger@LIGO.Org">albrecht.ruediger@LIGO.Org</a></td>
<td><a href="mailto:albrecht.ruediger@aei.mpg.de">albrecht.ruediger@aei.mpg.de</a></td>
<td>DEU</td>
</tr>
</tbody>
</table>
Name: Sathyaprakash, B  
Postal Address: Cardiff University  
City: Cardiff  
State: Cardiff  
Postal Code: CF24 3AA  
Country: GBR

Phone:  
Voice: 44 29 2087 6962  
Fax: 44 29 2087 4056

Email:  
@LIGO.Org: b.sathyaprakash@LIGO.Org  
Forwarding: B.Sathyaprakash@astro.cf.ac.uk

Name: Schilling, Roland  
Postal Address: Institut fur Gravitationsphysik  
Albert-Einstein-Institut  
Callinstrasse 38  
City: Hannover  
State: Germany  
Postal Code: 30167  
Country: DEU

Phone:  
Voice: 49 89 3292 9670  
Fax: 49 511 762 5861

Email:  
@LIGO.Org: roland.schilling@LIGO.Org  
Forwarding: ros@rzg.mpg.de

Name: Schnabel, Roman  
Postal Address: Institut fur Gravitationsphysik  
Universitat Hannover  
Callinstrasse 38  
City: Hannover  
State: Hannover  
Postal Code: 30167  
Country: DEU

Phone:  
Voice: 49 511 762 19169  
Fax: 49 511 762 2784

Email:  
@LIGO.Org: roman.schnabel@LIGO.Org  
Forwarding: roman.schnabel@aei.mpg.de

Name: Schutz, Bernard  
Postal Address: Albert Einstein Institute. Am Muehlenberg 5  
City: Golm  
State: Golm  
Postal Code: D-14476  
Country: DEU

Phone:  
Voice: 49 331 567 7218  
Fax: 49 331 567 7298

Email:  
@LIGO.Org: bernard.schutz@LIGO.Org  
Forwarding: bernard.schutz@aei.mpg.de

Name: Speake, Clive  
Postal Address: The University of Birmingham  
School of Physics and Astronomy  
City: Edgbaston  
State: Birmingham  
Postal Code: B15 2TT  
Country: GBR

Phone:  
Voice: 44 121 414 4679  
Fax: 44 121 414 3722

Email:  
@LIGO.Org: clive.speake@LIGO.Org  
Forwarding: c.c.speake@bham.ac.uk
Name: Strain, Ken
Postal Address: Physics and Astronomy
Voice: 44 141 330 5884 Kelvin Building
Fax: 44 141 330 6833
City: Glasgow
State: Scotland
Postal Code: G12 8QQ
Country: GBR
Email: @LIGO.Org: ken.strain@LIGO.Org
Forwarding: k.strain@physics.gla.ac.uk

Name: Sutton, Patrick J.
Postal Address: School of Physics and Astronomy
Voice: 44 029 2087 4649 Cardiff University
Fax: 44 029 2087 4056 5 The Parade
City: Cardiff
State: Wales
Postal Code: CF24 3AA
Country: GBR
Email: @LIGO.Org: patrick.sutton@LIGO.Org
Forwarding: patrick.sutton@astro.cf.ac.uk

Name: Vecchio, Alberto
Postal Address: The University of Birmingham
Voice: 44 121 414 6447 School of Physics and Astronomy
Fax: 44 121 414 3722
City: Edgbaston
State: Birmingham
Postal Code: B15 2TT
Country: GBR
Email: @LIGO.Org: alberto.vecchio@LIGO.Org
Forwarding: av@star.sr.bham.ac.uk

Name: Ward, Harry
Postal Address: Department of Physics and Astronomy
Voice: 44 141 330 4705 Kelvin Building
Fax: 44 141 330 6833
City: Glasgow
State: Scotland
Postal Code: G12 8QQ
Country: GBR
Email: @LIGO.Org: harry.ward@LIGO.Org
Forwarding: h.ward@physics.gla.ac.uk

Name: Westphal, Tobias
Postal Address: Callinstrasse 38
Voice: 49 511 762 17190 City: Hannover
Fax: 49 511 762 49
State: Niedersachsen
Postal Code: 30167
Country: DEU
Email: @LIGO.Org: tobias.westphal@LIGO.Org
Forwarding: tobias.westphal@aei.mpg.de
Name: Willke, Benno  
Postal Address: Institut fur Gravitationsphysik
Universitat Hannover
City: Callinstrasse 38
State: Hannover
Postal Code: 30167
Country: DEU

Name: Winkler, Walter  
Postal Address: Institut fur Gravitationsphysik
Universitat Hannover
City: Callinstrasse 38
State: Hannover
Postal Code: 30167
Country: DEU

Name: Woan, Graham  
Postal Address: Physics and Astronomy
Kelvin Building
University of Glasgow
City: Glasgow
State: UK
Postal Code: G12 8QQ
Country: GBR

Name: Yamamoto, Kazuhiro  
Postal Address: Callinstrasse 38
City: Hannover
State: Niedersachsen
Postal Code: D-30167
Country: DEU

Technical Staff:

The Technical Staff category includes all non-PI LSC members with scientist, engineer, computer systems administrator or programmer, technician, and similar appointments, and visiting appointments in all these categories.
Name: Aulbert, Carsten
Postal Address: Max Planck Institute for Gravitational Physics
Albert Einstein Institute
Callinstrasse 38
City: Hannover
State: NDS
Postal Code: D-30167
Country: DEU
Phone: 49 511 762 17185
Voice: 49 511 762 17193
Email: 
@LIGO.Org: carsten.aulbert@LIGO.Org
Forwarding: carsten.aulbert@aei.mpg.de

Name: Bock, Oliver
Postal Address: Max-Planck-Institute for Gravitational Physics
Albert-Einstein-Institute
Callinstrasse 38
City: Hannover
State: Niedersachsen
Postal Code: 30167
Country: DEU
Phone: 49 511 762 17165
Voice: 49 511 762 49
Email: 
@LIGO.Org: oliver.bock@LIGO.Org
Forwarding: oliver.bock@aei.mpg.de

Name: Brinkmann, Marc
Postal Address: Institut fur Gravitationsphysik
Universitat Hannover
Callinstrasse 38
City: Hannover
State: Hannover
Postal Code: 30167
Country: DEU
Phone: 49 511 762 6138
Voice: 49 511 762 2784
Email: 
@LIGO.Org: marc.brinkmann@LIGO.Org
Forwarding: marc.brinkmann@aei.mpg.de

Name: Degallaix, Jerome
Postal Address: Albert Einstein Institute
Callinstrasse 38
City: Hannover
State: NS
Postal Code: 30167
Country: DEU
Phone: 49 511 762 17150
Voice: 49 511 762 2784
Email: 
@LIGO.Org: jerome.degallaix@LIGO.Org
Forwarding: jerome.degallaix@aei.mpg.de

Name: Fehrmann, Henning
Postal Address: AEI
Callinstrasse 38
City: Hannover
State: germany
Postal Code: 30167
Country: DEU
Phone: 49 511 762 17145
Voice: 49 511 762 49
Email: 
@LIGO.Org: henning.fehrmann@LIGO.Org
Forwarding: henning.fehrmann@aei.mpg.de
Name: Kringel, Volker
Postal Address: Albert-Einstein-Institut
Voice: 49 511 762 6151 Callinstr. 38
Fax: 49 511 762 2784
City: Hannover
Email: volker.kringel@aei.mpg.de
State: Germany
Postal Code: 30167
Country: DEU

Name: Page, Anthony
Postal Address: School of Physics and Astronomy
Voice: 44 121 415 8424 University of Birmingham
Fax: 44 121 414 3722 Edgbaston
Email: anthony.page@LIGO.Org
City: Birmingham
State: B15 2TT
Postal Code: B15 2TT
Country: GBR

Name: Weinert, Michael
Postal Address: Institut fur Gravitationsphysik
Voice: 49 511 762 6139 Universitat Hannover
Fax: 49 511 762 2784 Callinstrasse 38
Email: michael.weinert@LIGO.Org
City: Hannover
State: DEU
Postal Code: 30167
Country: DEU

Name: Breyer, Jens
Postal Address: Callinstr. 38
Voice: 49 0511 762 17104 City: Hannover
Fax: 49 0511 762 17194 State: Niedersachsen
Email: jens.breyer@aei.mpg.de
Postal Code: 30167
Country: DEU

Name: Cutler, Ron
Postal Address: The University of Birmingham
Voice: 44 121 414 3722 School of Physics and Astronomy
Fax: rmc@star.sr.bham.ac.uk
City: Birmingham
State: UK
Postal Code: B15 2TT
Country: GBR
Name: Davies, Gerald
Postal Address: Cardiff University
Phone: Voice: 44 29 2087 5120
Fax: 44 29 2087 5120
Email: @LIGO.Org: gerald.davies@LIGO.Org
Forwarding: gerald.davies@astro.cf.ac.uk
City: Cardiff
State: Cardiff
Postal Code: CF24 3AA
Country: GBR

Name: Hayler, Tim
Postal Address: Rutherford Appleton Lab
Phone: Voice: 44 1235 44 6458
Fax: 44 1235 446863
Email: @LIGO.Org: tim.hayler@LIGO.Org
Forwarding: t.m.hayler@rl.ac.uk
City: Didcot
State: Oxon
Postal Code: OX11 0QX
Country: GBR

Name: Hoyland, David
Postal Address: The University of Birmingham
Phone: Voice: 44 121 414 6466
Fax: 44 121 414 3722
Email: @LIGO.Org: david.hoyland@LIGO.Org
Forwarding: dh@star.sr.bham.ac.uk
City: Edgbaston
State: Birmingham
Postal Code: B15 2TT
Country: GBR

Name: Jones, Russell
Postal Address: Department of Physics and Astronomy
Phone: Voice: 44 141 330 3376
Fax: 44 141 330 6833
Email: @LIGO.Org: russell.jones@LIGO.Org
Forwarding: r.jones@physics.gla.ac.uk
City: Glasgow
State: Glasgow
Postal Code: G12 8QQ
Country: GBR

Name: Kuehn, Gerrit
Postal Address: Max-Planck-Institut fuer Gravitationsphysik
Phone: Voice: 49 511 762 2785
Fax: 49 511 762 49
Email: @LIGO.Org: gerrit.kuehn@LIGO.Org
Forwarding: gerrit.kuehn@aei.mpg.de
City: Hannover
State: Niedersachsen
Postal Code: 30167
Country: DEU
Name: Mors, Konrad
Postal Address: Institut fur Gravitationsphysik
Universitat Hannover
City: Callinstrasse 38
State: Hannover
Postal Code: 30167
Country: DEU

Name: Odell, Joseph
Postal Address: STFC
Chilton
City: Didcot
State: Oxon
Postal Code: OX11 8JL
Country: GBR

Name: Pickenpack, Michaela
Postal Address: Max-Planck-Institut fuer Gravitationsphysik und
Universitaet Hannover
Callinstr. 38
City: Hannover
State: Niedersachsen
Postal Code: 30167
Country: DEU

Name: Robertson, Norna
Postal Address: Institute for Gravitational Research
Department of Physics and Astronomy
University of Glasgow
City: Glasgow
State: -
Postal Code: G12 8QQ
Country: GBR

Name: Scott, Jamie
Postal Address: Department of Physics and Astronomy
University of Glasgow
City: Glasgow
State: UK
Postal Code: G128QQ
Country: GBR
Name: Weidner, Andreas
Phone:
Voice: 49 893 2905 267
Fax: 49 511 762 2784
Email:
@LIGO.Org: andreas.weidner@LIGO.Org
Forwarding: andreas.weidner@aei.mpg.de
Postal Address:
Institut fur Gravitationsphysik
Universitat Hannover
City: Callinstrasse 38
State: Hannover
Postal Code: 30167
Country: DEU

Name: Wilmut, Ian
Phone:
Voice: 44 1235 821900
Fax: 44 1235 44 6836
Email:
@LIGO.Org: ian.wilmut@LIGO.Org
Forwarding: i.wilmut@rl.ac.uk
Postal Address:
Building R66
Rutherford Appleton Lab
City: Chilton
State: Didcot
Postal Code: OX11 0QX
Country: GBR

Name: zur Muehlen, Heiko
Phone:
Voice: 49 511 762 2229
Fax: 49 511 762 2784
Email:
@LIGO.Org: heiko.zurmuehlen@LIGO.Org
Forwarding: Heiko.zurMuehlen@aei.mpg.de
Postal Address:
Institut fur Gravitationsphysik
Universitat Hannover
City: Callinstrasse 38
State: Hannover
Postal Code: 30167
Country: DEU

Postdoctoral Scholars:

Name: Babak, Stanislav
Phone:
Voice: 49 331 567 7329
Fax:
Email:
@LIGO.Org: stanislav.babak@LIGO.Org
Forwarding: Stanislav.Babak@aei.mpg.de
Postal Address:
Albert Einstein Institute. Am Muehlenberg 5
City:
State: Golm
Postal Code: D-14476
Country: DEU

Name: Barr, Bryan
Phone:
Voice: 44 141 330 2517
Fax: 44 141 330 6833
Email:
@LIGO.Org: bryan.barr@LIGO.Org
Forwarding: b.barr@physics.gla.ac.uk
Postal Address:
Physics and Astronomy
Kelvin Building
City: Glasgow
State: Glasgow
Postal Code: G12 8QQ
Country: GBR
**Name:** Born, Michael  
**Postal Address:** Institut fuer Gravitationsphysik  
Callinstrasse 36  
City: Hannover  
State:  
Postal Code: 30167  
Country: DEU

**Name:** Chelkowski, Simon  
**Postal Address:** University of Birmingham  
School of Physics and Astronomy  
Physics West  
City: Birmingham  
State: -  
Postal Code: B15 2TT  
Country: GBR

**Name:** Clark, James  
**Postal Address:** Room 465  
Kelvin Building  
City: Glasgow  
State: Scotland  
Postal Code: G12 8QQ  
Country: GBR

**Name:** Cunningham, Liam  
**Postal Address:** Department of Physics and Astronomy  
University of Glasgow  
City: Glasgow  
State: UK  
Postal Code: G128qq  
Country: GBR

**Name:** Engel, Robert  
**Postal Address:** Albert Einstein Institute  
Am Muehlenberg 1  
City: Golm  
State: Brandenburg  
Postal Code: 14476  
Country: DEU
Name: Harms, Jan
Phone:
Voice: 49 511 762 17127
Fax: 49 511 762 2784
Email:
@LIGO.Org: jan.harms@LIGO.Org
Forwarding: jan.harms@aei.mpg.de
Post Office Address: Institut fur Gravitationsphysik
Callinstrasse 38
City: Hannover
State: Lower Saxony
Postal Code: 30167
Country: DEU

Name: Hild, Stefan
Phone:
Voice: 44 121 41 58309
Fax: 44 121 41 43722
Email:
@LIGO.Org: stefan.hild@LIGO.Org
Forwarding: hild@star.sr.bham.ac.uk
Post Office Address: School of Physics and Astronomy
University of Birmingham
Edgbaston
City: Birmingham
State: England
Postal Code: B15 2TT
Country: GBR

Name: Huttner, Sabina
Phone:
Voice: 44 141 330 3376
Fax: 44 141 330 6833
Email:
@LIGO.Org: sabina.huttner@LIGO.Org
Forwarding: s.huttner@physics.gla.ac.uk
Post Office Address: Physics and Astronomy
Kelvin Building
City: Glasgow
State: Glasgow
Postal Code: G12 8QQ
Country: GBR

Name: Jones, Gareth
Phone:
Voice: 44 29 2087 6460
Fax: 44 29 20874056
Email:
@LIGO.Org: gareth.jones@LIGO.Org
Forwarding: Gareth.Jones@astro.cf.ac.uk
Post Office Address: Cardiff University
Queens Building
City: Cardiff
State: Cardiff
Postal Code: CF24 3AA
Country: GBR

Name: Kim, Hyunjoo
Phone:
Voice: 49 511 762 17114
Fax: 49 511 762 49
Email:
@LIGO.Org: hyunjoo.kim@LIGO.Org
Forwarding: hyunjoo.kim@aei.mpg.de
Post Office Address: Callinstr. 38
City: Hannover
State: Niedersaechsischen
Postal Code: 30167
Country: DEU
Name: Krishnan, Badri
Phone:
Voice: 49 331 567 7323
Fax: 49 331 567 7298
Email:
@LIGO.Org: badri.krishnan@LIGO.Org
Forwarding: badkri@aei.mpg.de

Postal Address:
Max Planck Institut fuer Gravitationsphysik
Albert Einstein Institute
Am Muehlenberg 1
City: Golm
State:
Postal Code: D-14476
Country: DEU

Name: Leaci, Paola
Phone:
Voice: 49 511 762 2522
Fax:
Email:
@LIGO.Org: paola.leaci@LIGO.Org
Forwarding: paola.leaci@aei.mpg.de

Postal Address:
Max Planck Institut fuer Gravitationsphysik. Callinstrasse 38
Callinstrasse 38
City: Hannover
State: Germany
Postal Code: 30167
Country: DEU

Name: Machenschalk, Bernd
Phone:
Voice: 49 511 762 17145
Fax: 49 511 762 2784
Email:
@LIGO.Org: bernd.machenschalk@LIGO.Org
Forwarding: Bernd.Machenschalk@aei.mpg.de

Postal Address:
Max-Planck-Institut for Gravitational Physics
Albert Einstein Institute
Callinstr. 38
City: Hannover
State:
Postal Code: D-30167
Country: DEU

Name: Messenger, Chris
Phone:
Voice: 49 511 762 19922
Fax: 49 511 762 2784
Email:
@LIGO.Org: chris.messenger@LIGO.Org
Forwarding: c.messenger@physics.gla.ac.uk

Postal Address:
Albert Einstein Institut
38 Callinstr
City: Hannover
State: Neidersachsen
Postal Code: 30167
Country: DEU

Name: Murray, Peter
Phone:
Voice: 44 141 330 0097
Fax: 44 141 330 6833
Email:
@LIGO.Org: peter.murray@LIGO.Org
Forwarding: p.murray@physics.gla.ac.uk

Postal Address:
Physics and Astronomy
Kelvin Building
City:
State: Glasgow
Postal Code: G12 8QQ
Country: GBR
Name: Newrodt, Ronnie  
Postal Address: Institute for Gravitational Research  
Voice: 44 141 330 3340  
Email: r.newrodt@physics.gla.ac.uk  
Country: GBR

Name: Pai, Archana  
Postal Address: Albert Einstein Institute. Am Muehlenberg 5  
Voice: 49 331 567 7115  
Email: archana.pai@LIGO.Org  
Country: DEU

Name: Pitkin, Matthew  
Postal Address: Physics and Astronomy  
Voice: 44 141 330 2298  
Email: matthew.pitkin@LIGO.Org  
Country: GBR

Name: Plissi, Mike  
Postal Address: Physics and Astronomy  
Voice: 44 141 330 4196  
Email: mike.plissi@LIGO.Org  
Country: GBR

Name: Radke, Thomas  
Postal Address: Albert Einstein Institute  
Voice: 49 331 567 7194  
Email: thomas.radke@aei.mpg.de  
Country: DEU
<table>
<thead>
<tr>
<th>Name:</th>
<th>Reid, Stuart</th>
<th>Postal Address:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Phone:</td>
<td>Voice: 44 141 330 0097</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Fax: 44 141 330 6833</td>
<td></td>
</tr>
<tr>
<td>Email:</td>
<td>@LIGO.Org: <a href="mailto:stuart.reid@LIGO.Org">stuart.reid@LIGO.Org</a></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Forwarding: <a href="mailto:s.reid@physics.gla.ac.uk">s.reid@physics.gla.ac.uk</a></td>
<td></td>
</tr>
<tr>
<td>City:</td>
<td>Glasgow</td>
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</tr>
<tr>
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<td>G12 8QQ</td>
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</tr>
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<td>GBR</td>
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</tr>
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<table>
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<tr>
<th>Name:</th>
<th>Robinson, Craig</th>
<th>Postal Address:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Phone:</td>
<td>Voice: 44 29 2087 6460</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Fax: 44 29 20874056</td>
<td></td>
</tr>
<tr>
<td>Email:</td>
<td>@LIGO.Org: <a href="mailto:craig.robinson@LIGO.Org">craig.robinson@LIGO.Org</a></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Forwarding: <a href="mailto:Craig.Robinson@astro.cf.ac.uk">Craig.Robinson@astro.cf.ac.uk</a></td>
<td></td>
</tr>
<tr>
<td>City:</td>
<td>Cardiff</td>
<td></td>
</tr>
<tr>
<td>State:</td>
<td>CF24 3AA</td>
<td></td>
</tr>
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</tr>
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<table>
<thead>
<tr>
<th>Name:</th>
<th>Sorazu, Borja</th>
<th>Postal Address:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Phone:</td>
<td>Voice: 44 141 330 6435</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Fax: 44 141 330 6833</td>
<td></td>
</tr>
<tr>
<td>Email:</td>
<td>@LIGO.Org: <a href="mailto:borja.sorazu@LIGO.Org">borja.sorazu@LIGO.Org</a></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Forwarding: <a href="mailto:B.Sorazu@physics.gla.ac.uk">B.Sorazu@physics.gla.ac.uk</a></td>
<td></td>
</tr>
<tr>
<td>City:</td>
<td>Glasgow</td>
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</tr>
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</tr>
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<tr>
<th>Name:</th>
<th>Speirits, Fiona</th>
<th>Postal Address:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Phone:</td>
<td>Voice: 44 141 3303340</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Fax: 44 141 3305299</td>
<td></td>
</tr>
<tr>
<td>Email:</td>
<td>@LIGO.Org: <a href="mailto:fiona.speirits@LIGO.Org">fiona.speirits@LIGO.Org</a></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Forwarding: <a href="mailto:fionas@astro.gla.ac.uk">fionas@astro.gla.ac.uk</a></td>
<td></td>
</tr>
<tr>
<td>City:</td>
<td>Glasgow</td>
<td></td>
</tr>
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</tr>
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<th>Taylor, Robert</th>
<th>Postal Address:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Phone:</td>
<td>Voice: 49 511 76217195</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Fax: 49 511 7622784</td>
<td></td>
</tr>
<tr>
<td>Email:</td>
<td>@LIGO.Org: <a href="mailto:robert.taylor@LIGO.Org">robert.taylor@LIGO.Org</a></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Forwarding: <a href="mailto:bob.taylor@aei.mpg.de">bob.taylor@aei.mpg.de</a></td>
<td></td>
</tr>
<tr>
<td>City:</td>
<td>Hannover</td>
<td></td>
</tr>
<tr>
<td>State:</td>
<td>30167</td>
<td></td>
</tr>
<tr>
<td>Country:</td>
<td>DEU</td>
<td></td>
</tr>
</tbody>
</table>
Name: Tokmakov, Kirill
Phone: 
Voice: 44 141 330 6435
Fax: 44 141 330 6833
Email: 
@LIGO.Org: kirill.tokmakov@LIGO.Org
Forwarding: k.tokmakov@physics.gla.ac.uk
Postal Address: 
Rm 351 Kelvin building
Department of Physics and Astronomy
University of Glasgow
City: Glasgow
State: UK
Postal Code: G12 8QQ
Country: GBR

Name: Torrie, Calum
Phone: 
Voice: 44 141 330 8237
Fax: 44 141 330 6833
Email: 
@LIGO.Org: calum.torrie@LIGO.Org
Forwarding: c.torrie@physics.gla.ac.uk
Postal Address: 
Physics and Astronomy
Room 230b
Kelvin Building
City: Glasgow
State: Scotland
Postal Code: G12 8QQ
Country: GBR

Name: Veitch, John
Phone: 
Voice: 44 121 414 3020
Fax: 44 121 414 3722
Email: 
@LIGO.Org: john.veitch@LIGO.Org
Forwarding: jveitch@star.sr.bham.ac.uk
Postal Address: 
School of Physics and Astronomy
Physics West Building
University of Birmingham
City: Birmingham
State: England
Postal Code: B15 2TT
Country: GBR

Name: Whelan, John
Phone: 
Voice: 49 331 567 7117
Fax: 49 331 567 7298
Email: 
@LIGO.Org: john.whelan@LIGO.Org
Forwarding: whelan@slack.net
Postal Address: 
Max-Planck-Institute for Gravitational Physics
Albert-Einstein-Institute
City: Potsdam
State: Brandenberg
Postal Code: D-14424
Country: DEU

Name: van Veggel, Mariel
Phone: 
Voice: 44 141 330 2258
Fax: 
Email: 
@LIGO.Org: mariel.vanveggel@LIGO.Org
Forwarding: m.veggel@physics.gla.ac.uk
Postal Address: 
Department of Physics and Astronomy
University of Glasgow
City: Glasgow
State: UK
Postal Code: G12 8QQ
Country: GBR

Graduate Students:
<table>
<thead>
<tr>
<th>Name</th>
<th>Institute</th>
<th>Phone</th>
<th>City</th>
<th>Email</th>
<th>State</th>
<th>Zip Code</th>
<th>Country</th>
</tr>
</thead>
<tbody>
<tr>
<td>Abernathy, Matthew</td>
<td>Institute for Gravitational Research</td>
<td>44 141 330 3340</td>
<td>Glasgow</td>
<td><a href="mailto:matthew.abernathy@LIGO.Org">matthew.abernathy@LIGO.Org</a></td>
<td></td>
<td>G12 8QQ</td>
<td>GBR</td>
</tr>
<tr>
<td>Aston, Stuart</td>
<td>The University of Birmingham</td>
<td>44 121 414 6452</td>
<td>Birmingham</td>
<td><a href="mailto:stuart.aston@LIGO.Org">stuart.aston@LIGO.Org</a></td>
<td></td>
<td>B15 2TT</td>
<td>GBR</td>
</tr>
<tr>
<td>Bassiri, Riccardo</td>
<td>Department of Physics and Astronomy</td>
<td>44 141 330 3340</td>
<td>Glasgow</td>
<td><a href="mailto:riccardo.bassiri@LIGO.Org">riccardo.bassiri@LIGO.Org</a></td>
<td></td>
<td>G12 8QQ</td>
<td>GBR</td>
</tr>
<tr>
<td>Bastarrika, Mikel</td>
<td>Physics and Astronomy</td>
<td></td>
<td>Glasgow</td>
<td><a href="mailto:mikel.bastarrika@LIGO.Org">mikel.bastarrika@LIGO.Org</a></td>
<td></td>
<td>G12 8QQ</td>
<td>GBR</td>
</tr>
<tr>
<td>Behnke, Berit</td>
<td>Am Muehlenberg 1</td>
<td>49 331 567 7305</td>
<td>Potsdam</td>
<td><a href="mailto:berit.behnke@LIGO.Org">berit.behnke@LIGO.Org</a></td>
<td></td>
<td>14476</td>
<td>DEU</td>
</tr>
<tr>
<td>Name</td>
<td>Institute</td>
<td>State</td>
<td>City</td>
<td>Postal Code</td>
<td>Country</td>
<td></td>
<td></td>
</tr>
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<td>-------------</td>
<td>---------</td>
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<td></td>
</tr>
<tr>
<td>Beverage, Nicola</td>
<td>Institute for Gravitational Research</td>
<td></td>
<td>Glasgow</td>
<td>G12 8QQ</td>
<td>GBR</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bloomer, Edward</td>
<td>Physics and Astronomy</td>
<td></td>
<td>Glasgow</td>
<td>G12 8QQ</td>
<td>GBR</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bogenstahl, Johanna</td>
<td>Physics and Astronomy</td>
<td></td>
<td>Glasgow</td>
<td>G12 8QQ</td>
<td>GBR</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Britzger, Michael</td>
<td>Max Planck Institut fuer Gravitationsphysik</td>
<td></td>
<td>Hannover</td>
<td>30449</td>
<td>DEU</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Burmeister, Oliver</td>
<td>Institut fur Gravitationsphysik</td>
<td></td>
<td>Hannover</td>
<td>30167</td>
<td>DEU</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Name: Campsie, Paul
Phone:
  Voice: 44 141 330 3340
Fax:
Email:
  @LIGO.Org: paul.campsie@LIGO.Org
Forwarding: p.campsie@physics.gla.ac.uk
Postal Address:
  Institute for Gravitational Research
  University of Glasgow
  City: Glasgow
  State:
  Postal Code: G12 8QQ
  Country: GBR

Name: Chalkley, Eleanor
Phone:
  Voice: 44 141 330 2000
Fax: 44 141 330 6833
Email:
  @LIGO.Org: eleanor.chalkley@LIGO.Org
Forwarding: e.chalkley@physics.gla.ac.uk
Postal Address:
  Physics and Astronomy
  Kelvin Building
  City: Glasgow
  State: Scotland
  Postal Code: G12 8QQ
  Country: GBR

Name: Cumming, Alan
Phone:
  Voice: 44 141 330 3340
Fax: 44 141 330 6833
Email:
  @LIGO.Org: alan.cumming@LIGO.Org
Forwarding: a.cumming@physics.gla.ac.uk
Postal Address:
  Physics and Astronomy
  Kelvin Building
  City: Glasgow
  State: Glasgow
  Postal Code: G12 8QQ
  Country: GBR

Name: Dahl, Katrin
Phone:
  Voice: 49 511 762 17195
Fax: 49 511 762 2784
Email:
  @LIGO.Org: katrin.dahl@LIGO.Org
Forwarding: katrin.dahl@aei.mpg.de
Postal Address:
  Albert-Einstein-Institut Hannover
  Callinstrasse 38
  City: Hannover
  State:
  Postal Code: 30167
  Country: DEU

Name: Devanka, Pathak
Phone:
  Voice: 44 29 20875120
Fax: 44 29 20874457
Email:
  @LIGO.Org: pathak.devanka@LIGO.Org
Forwarding: devanka.pathak@astro.cf.ac.uk
Postal Address:
  School of Physics and Astronomy
  Cardiff University
  The Parade
  City: Cardiff
  State:
  Postal Code: CF24 3AA
  Country: GBR
Name: DiGuglielmo, James
Phone:
Voice: 49 0511 76217088
Fax: 49 0511 7622784
Email:
@LIGO.Org: james.diguglielmo@LIGO.Org
Forwarding: james.diguglielmo@aei.mpg.de

Postal Address:
Callinstrasse 38
City: Hannover
State:
Postal Code: 30167
Country: DEU

Name: Dueck, Jessica
Phone:
Voice: 49 511 762 3437
Fax: 49 511 762 49
Email:
@LIGO.Org: jessica.dueck@LIGO.Org
Forwarding: jessica.dueck@aei.mpg.de

Postal Address:
Max-Planck-Institut fuer Gravitationsphysik
Albert-Einstein-Institut
Callinstrasse 38
City: Hannover
State: Niedersachsen
Postal Code: 30167
Country: DEU

Name: Edgar, Matthew
Phone:
Voice: 44 141 330 3340
Fax:
Email:
@LIGO.Org: matthew.edgar@LIGO.Org
Forwarding: m.edgar@physics.gla.ac.uk

Postal Address:
Department of Physics and Astronomy
University of Glasgow
City: Glasgow
State: UK
Postal Code: G128QQ
Country: GBR

Name: Edwards, Mark
Phone:
Voice: 44 29 20875120
Fax: 44 29 20874457
Email:
@LIGO.Org: mark.edwards@LIGO.Org
Forwarding: mark.edwards@astro.cf.ac.uk

Postal Address:
School of Physics and Astronomy
Cardiff University
The Parade
City: Cardiff
State:
Postal Code: CF24 3AA
Country: GBR

Name: Fulda, Paul
Phone:
Voice: 44 121 414 3721
Fax: 44 121 414 3722
Email:
@LIGO.Org: paul.fulda@LIGO.Org
Forwarding: pfulda@star.sr.bham.ac.uk

Postal Address:
School of Physics and Astronomy
University of Birmingham
Edgbaston
City: Birmingham
State:
Postal Code: B15 2TT
Country: GBR
Name: Gill, Colin
Phone: 
Voice: 44 141 0926  
Fax: 44 141 5183
Email: 
@LIGO.Org: colin.gill@LIGO.Org
Forwarding: c.gill@astro.gla.ac.uk
Postal Address: 
Department of Physics and Astronomy  
University of Glasgow  
City: Glasgow  
State: 
Postal Code: G128QQ 
Country: GBR

Name: Hage, Boris
Phone: 
Voice: 49 511 762 2522  
Fax: 49 511 762 2784
Email: 
@LIGO.Org: boris.hage@LIGO.Org
Forwarding: boris.hage@aei.mpg.de
Postal Address: 
Institut fur Gravitationsphysik  
Universitat Hannover  
City: Callinstrasse 38  
State: Hannover  
Postal Code: 30167  
Country: DEU

Name: Hallam, Jonathan
Phone: 
Voice: 44 121 414 3721  
Fax:
Email: 
@LIGO.Org: jonathan.hallam@LIGO.Org
Forwarding: jmh@star.sr.bham.ac.uk
Postal Address: 
The University of Birmingham  
School of Physics and Astronomy  
Edgbaston  
City: Birmingham  
State: UK  
Postal Code: B15 2TT  
Country: GBR

Name: Harry, Ian
Phone: 
Voice: 44 29 2087 6460  
Fax:
Email: 
@LIGO.Org: ian.harry@LIGO.Org
Forwarding: iwharry@googlemail.com
Postal Address: 
School of Physics and Astronomy  
Cardiff University  
City: Cardiff  
State: UK  
Postal Code: CF24 2AA  
Country: GBR

Name: Haughian, Karen
Phone: 
Voice: 44 141 330 3340  
Fax:
Email: 
@LIGO.Org: karen.haughian@LIGO.Org
Forwarding: k.haughian@physics.gla.ac.uk
Postal Address: 
Department of Physics and Astronomy  
University of Glasgow  
City: Glasgow  
State: UK  
Postal Code: G128QQ  
Country: GBR
Name: Kawazoe, Fumiko
Phone:
Voice: 81 422 34 3625
Fax: 81 422 34 3793
Email:
@LIGO.Org: fumiko.kawazoe@LIGO.Org
Forwarding: kawazoe@gravity.mtk.nao.ac.jp
Postal Address:
2-1-1 Otsuka
City: Bunkyo-ku
State: Tokyo
Postal Code: 112-8610
Country: JPN

Name: Khalaidovski, Alexander
Phone:
Voice: 49 511 762 17125
Fax: 46 511 762 2784
Email:
@LIGO.Org: alexander.khalaidovski@LIGO.Org
Forwarding: alexander.khalaidovski@aei.mpg.de
Postal Address:
Max Planck Institut fuer Gravitationsphysik
Albert Einstein Institut
Callinstrasse 38
City: Hannover
State: Niedersachsen
Postal Code: 30163
Country: DEU

Name: Kullmann, Joachim
Phone:
Voice: 49 511 762 2799
Fax: 49 511 762 49
Email:
@LIGO.Org: joachim.kullmann@LIGO.Org
Forwarding: joachim.kullmann@aei.mpg.de
Postal Address:
Callinstrasse 38
City: Hannover
State: Lower Saxony
Postal Code: 30167
Country: DEU

Name: Kwee, Patrick
Phone:
Voice: 49 511 762 17144
Fax: 49 511 762 2784
Email:
@LIGO.Org: patrick.kwee@LIGO.Org
Forwarding: Patrick.Kwee@aei.mpg.de
Postal Address:
Institut fur Gravitationsphysik
Universitat Hannover
City: Callinstrasse 38
State: Hannover
Postal Code: 30167
Country: DEU

Name: Lastzka, Nico
Phone:
Voice: 49 511 762 17089
Fax:
Email:
@LIGO.Org: nico.lastzka@LIGO.Org
Forwarding: nico.lastzka@aei.mpg.de
Postal Address:
Callinstrasse 38
City: Hannover
State:
Postal Code: D-30167
Country: DEU
Name: Lodhia, Deepali  
Postal Address: The University of Birmingham  
Voice: 44 121 414 3721  
Fax:  
Email: deepali.lodhia@LIGO.Org  
Forwarding: dl@star.bham.ac.uk  
City: Birmingham  
State: UK  
Postal Code: B15 2TT  
Country: GBR  

Name: Martin, Ian  
Postal Address: Physics and Astronomy  
Voice: 44 141 330 8484  
Fax: 44 141 330 6833  
Email: ian.martin@LIGO.Org  
Forwarding: I.martin@physics.gla.ac.uk  
City: Glasgow  
State: Scotland  
Postal Code: G12 8QQ  
Country: GBR  

Name: McKechan, David  
Postal Address: School of Physics  
Voice: 44 2920 20875 120  
Fax:  
Email: david.mckechan@LIGO.Org  
Forwarding: dja.mckechan@gmail.com  
City: CARDIFF  
State: Glamorgan  
Postal Code: CF10 5NF  
Country: GBR  

Name: Mehmet, Moritz  
Postal Address: Max-Planck-Institute for Gravitational Physics  
Voice: 49 511 762 17139  
Fax: 49 511 762 49  
Email: moritz.mehmet@LIGO.Org  
Forwarding: moritz.mehmet@aei.mpg.de  
City: Hannover  
State: Niedersachsen  
Postal Code: 30167  
Country: DEU  

Name: Meier, Tobias  
Postal Address: Max-Planck-Institut fur Gravitationsphysik  
Voice: 49 511 762 17170  
Fax: 49 511 762 2784  
Email: tobias.meier@aei.mpg.de  
Forwarding: tobias.meier@aei.mpg.de  
City: Hannover  
State: Niedersachsen  
Postal Code: 30167  
Country: DEU  

Name: McKechan, David  
Postal Address: School of Physics  
Voice: 44 2920 20875 120  
Fax:  
Email: david.mckechan@LIGO.Org  
Forwarding: dja.mckechan@gmail.com  
City: CARDIFF  
State: Glamorgan  
Postal Code: CF10 5NF  
Country: GBR  

Name: Meier, Tobias  
Postal Address: Max-Planck-Institut fur Gravitationsphysik  
Voice: 49 511 762 17170  
Fax: 49 511 762 2784  
Email: tobias.meier@aei.mpg.de  
Forwarding: tobias.meier@aei.mpg.de  
City: Hannover  
State: Niedersachsen  
Postal Code: 30167  
Country: DEU
Name: Miller, John
Phone:
Voice: 1 626 395 2079
Fax: 1 626 304 9834
Email:
@LIGO.Org: john.miller@LIGO.Org
Forwarding: j.miller@physics.gla.ac.uk

Postal Address:
LIGO Laboratory - Caltech
1200 E. California Blvd.
MC 18-34
City: Pasadena
State: CA
Postal Code: 91125
Country: USA

Name: Muller-Ebhardt, Helge
Phone:
Voice: 49 511 762 19466
Fax: 49 511 762 2784
Email:
@LIGO.Org: helge.muller-ebhardt@LIGO.Org
Forwarding: Helge.Mueller-Ebhardt@aei.mpg.de

Postal Address:
Institut fur Gravitationsphysik
Universitat Hannover
Callinstrasse 38
City: Hannover
State: Niedersaschen
Postal Code: 30167
Country: DEU

Name: Nelson, John
Phone:
Voice:
Fax: 44 141 330 6833
Email:
@LIGO.Org: john.nelson@LIGO.Org
Forwarding: J.Nelson@physics.gla.ac.uk

Postal Address:
Physics and Astronomy
Kelvin Building
City: Glasgow
State: UK
Postal Code: G12 8QQ
Country: GBR

Name: Parameswaran, Ajith
Phone:
Voice: 49 511 762 17120
Fax: 49 511 762 2784
Email:
@LIGO.Org: ajith.parameswaran@LIGO.Org
Forwarding: Ajith.Parameswaran@aei.mpg.de

Postal Address:
Max Planck Institute for Gravitational Physics
Albert Einstein Institute
Callinstrasse 38
City: Hannover
State: Niedersaschen
Postal Code: 30167
Country: DEU

Name: Perreca, Antonio
Phone:
Voice: 44 121 414 3721
Fax:
Email:
@LIGO.Org: antonio.perreca@LIGO.Org
Forwarding: perreca@star.bham.ac.uk

Postal Address:
The University of Birmingham
School of Physics and Astronomy
Edgbaston
City: Birmingham
State: UK
Postal Code: B15 2TT
Country: GBR
Name: Pletsch, Holger  
Postal Address: Albert-Einstein-Institut  
Max-Planck-Institut fuer Gravitationsphysik  
Callinstr. 38  
City: Hannover  
State: Niedersachsen  
Postal Code: 30167  
Country: DEU  
Email: holger.pletsch@aei.mpg.de

Name: Predoi, Valeriu  
Postal Address: School of Physics and Astronomy  
Cardiff University  
The Parade  
City: Cardiff  
State:  
Postal Code: CF24 3AA  
Country: GBR  
Email: valeriu.predoi@astro.cf.ac.uk

Name: Rehbein, Henning  
Postal Address: Institut fur Gravitationsphysik  
Universitat Hannover  
Callinstrasse 38  
City: Hannover  
State: Niedersachsen  
Postal Code: 30167  
Country: DEU  
Email: henning.rehbein@aei.mpg.de

Name: Robinson, Emma  
Postal Address: The University of Birmingham  
School of Physics and Astronomy  
City: Edgbaston  
State: Birmingham  
Postal Code: B15 2TT  
Country: GBR  
Email: elr@star.sr.bham.ac.uk

Name: Samblowski, Aiko  
Postal Address: Callinstr. 38  
City: Hannover  
State:  
Postal Code: 30167  
Country: DEU  
Email: aiko.samblowski@aei.mpg.de
Name: Santamaria Lara, Lucia  
Postal Address: 
Voice: 49 331 567 7181  
Fax: 49 331 567 7298  
Email: @LIGO.Org: lucia.santamaria@LIGO.Org  
Forwarding: lucia.santamaria@aei.mpg.de

Name: Santiago Prieto, Ricardo  
Postal Address: Institute for Gravitational Research  
University of Glasgow  
Voice: 44 141 330 3340  
Fax:  
Email: @LIGO.Org: ricardo.santiagoprieto@LIGO.Org  
Forwarding: r.santiagoprieto@physics.gla.ac.uk

Name: Seifert, Frank  
Postal Address: Institut fur Gravitationsphysik  
Universitat Hannover  
Voice: 49 511 762 4994  
Fax: 49 511 762 2784  
Email: @LIGO.Org: frank.seifert@LIGO.Org  
Forwarding: frs@aei.mpg.de

Name: Thuering, Andre  
Postal Address: Institut fur Gravitationsphysik  
Universitat Hannover  
Voice: 49 511 762 2522  
Fax: 49 511 762 2784  
Email: @LIGO.Org: andre.thuering@LIGO.Org  
Forwarding: andre.thuering@aei.mpg.de

Name: Toher, Jennifer  
Postal Address: Physics and Astronomy  
Kelvin Building  
Voice:  
Fax: 44 141 330 6833  
Email: @LIGO.Org: jennifer.toher@LIGO.Org  
Forwarding: j.toher@physics.gla.ac.uk
Name: Vahlbruch, Henning  
Postal Address: Institut für Gravitationsphysik 
Voice: 49 511 762 2522 Universității Hannover 
City: Callinstrasse 38 
State: Hannover 
Postal Code: 30167 
Country: DEU 
Email: henning.vahlbruch@LIGO.Org 
Forwarding: henning.vahlbruch@aei.mpg.de

Name: Wanner, Alexander  
Postal Address: Max-Planck-Institut für Gravitationsphysik 
Voice: 49 0511 762 5845 Leibniz Universităet Hannover 
City: Callinstr. 38 
State: Niedersachsen 
Postal Code: 30167 
Country: DEU 
Email: alexander.wanner@LIGO.Org 
Forwarding: alexander.wanner@aei.mpg.de

Name: van den Broeck, Chris  
Postal Address: Cardiff University 
Voice: 44 29 2087 5120 Queens Building 
City: Cardiff 
State: Cardiff 
Postal Code: CF24 3AA 
Country: GBR 
Email: chris.vandenbroeck@LIGO.Org 
Forwarding: Chris.van-den-Broeck@astro.cf.ac.uk

Undergraduate Students: 
Name: Eberle, Tobias  
Postal Address: Callinstr. 38 
Voice: 49 511 762 2522 
Fax: 49 511 762 2784 
Email: tobias.eberle@LIGO.Org 
Forwarding: tobias.eberle@aei.mpg.de

Name: Graef, Christian  
Postal Address: Max-Planck-Institut für Gravitationsphysik 
Voice: 49 511 762 2522 Albert-Einstein-Institut 
City: Callinstrasse 38 
State: Niedersachsen 
Postal Code: 30167 
Country: DEU 
Email: christian.graef@LIGO.Org 
Forwarding: christian.graef@aei.mpg.de
Name: Ryll, Henning
Postal Address: Max Planck Institut fuer Gravitationsphysik
Leibniz Universitaet Hannover
Callinstr 38
City: Hannover
State: Niedersachsen
Postal Code: 30167
Country: DEU
Phone: 49 511 762 17188
Voice: 49 511 762 17188
Fax: 49 511 762 17188
Email: henning.ryll@LIGO.Org
Forwarding: henning.ryll@aei.mpg.de

Name: Steinlechner, Sebastian
Postal Address: Institut fuer Gravitationsphysik Leibniz Universitaet Hannover und
Max-Planck-Institut fuer Gravitationsphysik Albert-Einstein-Institut
Callinstr. 38
City: Hannover
State: Niedersachsen
Postal Code: 30167
Country: DEU
Phone: 49 511 762 17076
Voice: 49 511 762 17076
Fax: 49 511 762 2783
Email: sebastian.steinlechner@LIGO.Org
Forwarding: sebastian.steinlechner@aei.mpg.de

Administrative Staff:
The Administrative Staff category allows the listing of administrative aides and other staff members who perform essential support services in or for LSC member groups, but are not involved in the LIGO Scientific Collaborations engineering or scientific work. Personnel who are involved in the LSC’s scientific or engineering work, including computer system administration and programming, should be listed under other categories. Personnel listed as Administrative Staff may be designated as a point of contact or proxy, but do not appear as authors on LSC publications, do not count toward a group’s council delegate allocation, may not serve as council delegates, and do not increase a group’s shift obligation.

Name: Milde, Susanne
Postal Address: Milde Marketing Science Communication
Merkurstr. 12
City: Potsdam
State: Brandenburg
Postal Code: 14482
Country: DEU
Phone: 49 331 583 9354
Voice: 49 331 583 9354
Fax: 49 331 583 9357
Email: susanne.milde@LIGO.Org
Forwarding: milde@mildemarketing.de

Name: Schlichting, Ute
Postal Address: Albert Einstein Institute
City: Potsdam
State: Brandenburg
Postal Code: 14424
Country: DEU
Phone: 49 331 567 7220
Voice: 49 331 567 7220
Fax: 49 331 567 7298
Email: ute.schlichting@LIGO.Org
Forwarding: ute.schlichting@aei.mpg.de
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Total FTE: 122.86

Roles:

**Principal Investigators:**
- Danzmann, Karsten
- Hough, James
- Schutz, Bernard

**Membership Point-Of-Contact:**
- Woan, Graham

**Group PIO/Press Coordinator:**
- Papa, Maria Alessandra
- Willke, Benno
- Woan, Graham

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