# Attachment DAT to the

# Memorandum of Understanding (LIGO-M 050266 -00-M)

# between the

# Michigan Gravitational Wave Group ( MGWG )

# and the

# Laser Interferometer Gravitational Wave Observatory (LIGO)

# August 15, 2006

This Attachment DAT to the Memorandum of Understanding LIGO-M 050266 -00-M defines the role of the Michigan Gravitational Wave Group as a Member of the LIGO Scientific Collaboration (LSC), in particular, its activities in data analysis in support of the initial LIGO interferometers. The period of performance for the activities in this Attachment is from August 15, 2006 to August 15, 2007.

1. 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 the analyses, perform detailed reviews, and prepare publications on behalf of the collaboration. LSC groups are encouraged to participate in one or more of these groups. MOU Attachments define the contributions of each participating group to the data analysis groups.

2. During the period August 15, 2006 to August 15, 2007, the members of MGWG will participate in the analysis of initial LIGO data in the following areas:

b) Bursts

1) Riles will continue participating in review of WaveBurst searches (incoherent and coherent).

d) Continous

1) Dergachev and Riles will continue a broadband, S5 all-sky search for continuous–wave gravitational sources using Dergachev's PowerFlux analysis pipeline, based on incoherent averaging of power spectra with noise and antenna-pattern weighting.

2) An article presenting PowerFlux and other incoherent search (StackSlide & Hough) results from the S4 run will be completed and submitted for publication.

3) We will continue analyzing the S5 data on a regular basis during the run and will write an article for publication using the results of the first year of S5 running.

4) Refinements and optimizations of the PowerFlux pipeline will be carried out.

e) 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 **MGWG** group members while on LIGO research assignment at any LIGO Laboratory site,
b) Access to LIGO data through established LSC channels in support of this work.

c) Not Applicable

4. Coordination and Reporting -

**MGWG** will perform this research within the structures established by the LIGO Laboratory and the LSC where appropriate. In particular activities described in Item 2a) will be carried out within the LSC Inspiral Search Group, Item 2b) will be carried out within the LSC Burst Search Group, Item 2c) will be carried out within the LSC Stochastic Search Group and Item 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 on-year period. These documents will be due one month before the close of the period of performance under this Attachment.

5. 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.

Approved:

Jay Marx
LIGO Laboratory Director

Peter Saulson
LSC Spokesperson

**Keith Riles**
Principal Investigator
**Michigan Gravitational Wave Group**

# Attachment OPS to the

# Memorandum of Understanding (LIGO-M 050266 -00-M)

# between the

# Michigan Gravitational Wave Group ( MGWG )

# and the

# Laser Interferometer Gravitational Wave Observatory (LIGO)

# August 15, 2006

This Attachment OPS to the Memorandum of Understanding LIGO-M 050266 -00-M defines the role of the Michigan Gravitational Wave Group 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, 2006 to August 15, 2007.

1. 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 Laboratroy and the LSC.

2. During the period August 15, 2006 to August 15, 2007, the members of MGWG will participate in the initial LIGO detector research program in the following areas:

a) Detector Commissioning

1) Gustafson will continue to investigate and remove systemic noise in the LHO 4K and 2K interferometers working to extend IFO sensitivity, robustness, and reliability beyond the presently achieved SRD level performance.

2) Gustafson will further refine the Recycling Cavity Analyzer System, with production of electronic demodulation modules, with the goal of further shakedown and studies in the S5 - S6 break.

3) Gustafson will continue to study the recycling cavity, pursuing noise reduction and stability enhancement. Consequences of the non perfect match of the recycling cavity free spectral
range ( fsr ) to the mode cleaner fsr tune, particularly to the AS-I problem will be tested ( S5 - S6 break ); remedies will be devised and explored.

4) Gustafson, with Kawabe and student David Levitan will further pursue Output Mode Cleaner (OMC ) issues in simulation; small and large ( 6-meter ) units of three and four mirrors are being studied. Gustafson is gathering optics for an optical table test of a folded ( to 1 meter ) 6-meter, 3-mirror unit. Assembly of a folded table-top prototype suitable for will be tried if results are encouraging.

5) Goetz (graduate student) will continue residence at LHO, working on calibration, detector characterization (see below), and commissioning.

b) Detector Characterization

1) Riles will continue to chair the LSC Detector Characterization Committee, coordinating the efforts of detector characterization working groups and working with LIGO Laboratory physicists, primarily John Zweizig, to improve online detector characterization by LSC members. He will also continue contributing directly to software algorithms for the on-site Data Monitor Tool (DMT).

2) Riles will maintain the DMT operational state condition software package.

3) Riles will maintain the LockLoss DMT monitor.

4) Goetz will maintain and improve the PlaneMon DMT monitor and compile S5 data quality flag intervals based on its output.

5) Armen (undergraduate) will complete a DMT monitor class based on the LAL code of Xavier Siemens of UWM for producing h(t) for general use by DMT monitors. An online DMT monitor based on this class will be written for real-time calibration diagnostics.

6) Dergachev (graduate student) will continue maintaining the ligo_viewer program for viewing LIGO data trends at the observatory sites remotely from unix/linux and Windows computers.

7) Dergachev will maintain the SpectrumFold DMT monitor to track combs of harmonic lines in real time.

8) Dergachev, Riles and Gustafson will continue contributing to cataloguing known instrumental lines in the gravitational wave channel.

9) Armen will continue maintaining the StrainBandsMon DMT monitor.

10) Zhang (graduate student) will complete the SixtyHertzMon DMT monitor for measuring effects of upconversion associated with 60 Hz power mains.

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c) Detector Operations

1) Riles will continue organizing staffing and duty assignments of scientific monitoring shifts and maintaining the S5 web site, in conjunction with S5 run coordinators.

2) Riles will continue maintaining data quality segment repositories for the S5 and earlier science data runs.

3) Gustafson and Goetz will assist in LIGO Hanford operations during S5 by helping with repairs, investigations and other necessary tasks arising.

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 **MGWG** group members while on LIGO research assignment at any LIGO Laboratory site,
b) Access to LIGO data through established LSC channels in support of this work.

c) Not Applicable

4. Coordination and Reporting -

**MGWG** will perform this research within the structures established by the LIGO Laboratory and the LSC where appropriate. In particular activities described in Item 2a) will be carried out in coordination with the LIGO Laboratory Commissioning Leader, Item 2b) will be carried out within the Detector Characterization Working Group of the LSC, and Item 2c) will be carried out in coordination with the LHO {or LLO} Site Head. Coordination will include 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 on-year period. These documents will be due one month before the close of the period of performance under this Attachment.

5. 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.

Approved:

Jay Marx
LIGO Laboratory Director

**Keith Riles**
Principal Investigator
**Michigan Gravitational Wave Group**

Peter Saulson
LSC Spokesperson

# Attachment OUT to the

# Memorandum of Understanding (LIGO-M 050266 -00-M)

# between the

# Michigan Gravitational Wave Group ( MGWG )

# and the

# Laser Interferometer Gravitational Wave Observatory (LIGO)

# August 15, 2006

This Attachment OUT to the Memorandum of Understanding LIGO-M 050266 -00-M defines the role of the Michigan Gravitational Wave Group as a Member of the LIGO Scientific Collaboration (LSC) in support of Educational and Outreach to the broader community. The period of performance for the activities in this Attachment is from August 15, 2006 to August 15, 2007.

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. MOU Attachments define the roles and responsibilities of groups in this development group.

2. During the period August 15, 2006 to August 15, 2007, the members of MGWG will participate in Education and Outreach in the following areas:

b) Other Contributions

1) MGWG members will complete a refined prototype Michelson Interferometer exhibit for the Ann Arbor Hands-On Museum, along with supporting educational material concerning interferometry, gravitational waves and LIGO.

2) We expect to submit a joint proposal with the Museum to obtain funding for a final "hardened" interferometer exhibit.

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 **MGWG** group members while on LIGO research assignment at any LIGO Laboratory site,
b) Access to LIGO data through established LSC channels in support of this work.

c) Not Applicable

4. Coordination and Reporting -

**MGWG** 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 with the LIGO Observatories Educational and Outreach Leaders. Coordination will include 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 on-year period. These documents will be due one month before the close of the period of performance under this Attachment.

5. 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.

Approved:

Jay Marx
LIGO Laboratory Director

**Keith Riles**
Principal Investigator
**Michigan Gravitational Wave Group**

Peter Saulson
LSC Spokesperson

# Attachment Number Z to the Memorandum of Understanding (LIGO-M **050266** -00-M) between the **Michigan Gravitational Wave Group** ( **MGWG** ) and the Laser Interferometer Gravitational Wave Observatory (LIGO) Laboratory

This Attachment to the Memorandum of Understanding LIGO-M **050266** -00-M lists the coordinates of members of the **Michigan Gravitational Wave Group** who will participate in the LIGO Scientific Collaboration (LSC) as members of LIGO Development Groups. The period of performance for the activities in this Attachment is from August 15, 2006 to August 15, 2007. This period may be modified by agreement to a revision of this Attachment. This list may be extended by agreement to a revision of this Attachment.

**Principal Investigator**


First Name: **Keith** Last Name: **Riles**

Affiliation: **University of Michigan**

Address: **450 Church Street**

City: **Ann Arbor** State: **MI** Zip Code: **48109-1040**

Country: **United States** Primary Email: **kriles@umich.edu**

Job Title: **Professor** Secondary Email:

Phone Number: **734 764 4652** Fax Number: **734 936 6529**


Begin Date: **Aug 15, 2006** End Date: **Aug 15, 2007**

Research FTE: **90** % LIGO FTE: **100** % AdvLIGO FTE: **0** %

Author on LSC papers: ☒ LSC Council Delegate? ☒

**Member #2**

☐ Select this box if the contact information of this member is the same as that of the Principal Investigator.

First Name: **Dick** Last Name: **Gustafson**

Affiliation: **University of Michigan**

Address: **450 Church Street**

City: **Richland** State: **WA** Zip Code: **99352**

Country: **United States** Primary Email: **gustafso@ligo-wa.caltech.edu**

Job Title: **Research Scientist** Secondary Email:

Phone Number: **509 372 8300** Fax Number:

Begin Date: **Aug 15, 2006** End Date: **Aug 15, 2007**

Research FTE **100** % LIGO FTE **90** % AdvLIGO FTE **0** %

Author on LSC papers: ☒ LSC Council Delegate? ☐

**Member #3**

☒ Select this box if the contact information of this member is the same as that of the Principal Investigator.

First Name: **Vladimir** Last Name: **Dergachev**

Affiliation: **University of Michigan**

Address: **450 Church Street**

City: **Ann Arbor** State: **MI** Zip Code: **48109-1040**

Country: **United States** Primary Email: **volodya@umich.edu**

Job Title: **Graduate student** Secondary Email:

Phone Number: **734 764 5146** Fax Number: **734 936 6529**

Begin Date: **Aug 15, 2006** End Date: **Aug 15, 2007**

Research FTE **20** % LIGO FTE **100** % AdvLIGO FTE **0** %

Author on LSC papers: ☒ LSC Council Delegate? ☐

**Member #4**

☐ Select this box if the contact information of this member is the same as that of the Principal Investigator.

First Name: **Evan** Last Name: **Goetz**

Affiliation:

Address: **450 Church Street**

City: **Richland** State: **WA** Zip Code: **99352**

Country: **United States** Primary Email: **egoetz@umich.edu**

Job Title: **Graduate student** Secondary Email:

Phone Number: **509 372 8300** Fax Number:

Begin Date: **August 15, 2006** End Date: **August 15, 2007**

Research FTE **100** % LIGO FTE **100** % AdvLIGO FTE **0** %

Author on LSC papers: ☒ LSC Council Delegate? ☐

**Member #5**

☒ Select this box if the contact information of this member is the same as that of the Principal Investigator.

First Name: **Junyi** Last Name: **Zhang**

Affiliation: **University of Michigan**

Address: **450 Church Street**

City: **Ann Arbor** State: **MI** Zip Code: **48109-1040**

Country: **United States** Primary Email: **jyzhang@umich.edu**

Job Title: **Graduate student** Secondary Email:

Phone Number: **734 764 5146** Fax Number: **734 936 6529**

Begin Date: **Aug 15, 2006** End Date: **Aug 15, 2007**

Research FTE **25** % LIGO FTE **100** % AdvLIGO FTE **0** %

Author on LSC papers: ☐ LSC Council Delegate? ☐

**Member #6**

☒ Select this box if the contact information of this member is the same as that of the Principal Investigator.

First Name: **Peter** Last Name: **Troyan**

Affiliation: **University of Michigan**

Address: **450 Church Street**

City: **Ann Arbor** State: **MI** Zip Code: **48109-1040**

Country: **United States** Primary Email: **ptroyan@umich.edu**

Job Title: **Undergraduate** Secondary Email:

Phone Number: **734 764 4652** Fax Number: **734 936 6529**

Begin Date: **Aug 15, 2006** End Date: **Aug 15, 2007**

Research FTE **20** % LIGO FTE **100** % AdvLIGO FTE **0** %

Author on LSC papers: ☐ LSC Council Delegate? ☐

**Member #7**

☒ Select this box if the contact information of this member is the same as that of the Principal Investigator.

First Name: **Ramon** Last Name: **Armen**

Affiliation: **University of Michigan**

Address: **450 Church Street**

City: **Ann Arbor** State: **MI** Zip Code: **48109-1040**

Country: **United States** Primary Email: **rarmen@umich.edu**

Job Title: **Undergraduate** Secondary Email:

Phone Number: **734 764 5146** Fax Number: **734 936 6529**

Begin Date: **Aug 15, 2006** End Date: **Aug 15, 2007**

Research FTE **20** % LIGO FTE **100** % AdvLIGO FTE **0** %

Author on LSC papers: ☐ LSC Council Delegate? ☐

**Member #8**

☒ Select this box if the contact information of this member is the same as that of the Principal Investigator.

First Name: **Courtney** Last Name: **Jarman**

Affiliation: **University of Michigan**

Address: **450 Church Street**

City: **Ann Arbor** State: **MI** Zip Code: **48109-1040**

Country: **United States** Primary Email: **cjarman@umich.edu**

Job Title: **Undergraduate** Secondary Email:

Phone Number: **734 764 5146** Fax Number: **734 936 6529**

Begin Date: **Aug 15, 2006** End Date: **Aug 15, 2007**

Research FTE **20** % LIGO FTE **100** % AdvLIGO FTE **0** %

Author on LSC papers: ☐ LSC Council Delegate? ☐

**Member #9**

☐ Select this box if the contact information of this member is the same as that of the Principal Investigator.

First Name: Last Name:

Affiliation:

Address: **450 Church Street**

City: State: Zip Code:

Country: Primary Email:

Job Title: Secondary Email:

Phone Number: Fax Number:

Begin Date: End Date:

Research FTE % LIGO FTE % AdvLIGO FTE %

Author on LSC papers: ☐ LSC Council Delegate? ☐

**Member #10**

☐ Select this box if the contact information of this member is the same as that of the Principal Investigator.

First Name: Last Name:

Affiliation:

Address: **450 Church Street**

City: State: Zip Code:

Country: Primary Email:

Job Title: Secondary Email:

Phone Number: Fax Number:

Begin Date: End Date:

Research FTE % LIGO FTE % AdvLIGO FTE %

Author on LSC papers: ☐ LSC Council Delegate? ☐

**Authorship:**

**Riles**

**Gustafson**

**Dergachev**

**Goetz**

**Scientific Collaboration Council Delegate(s):**

**Riles**

Approved:

Jay Marx

LIGO Laboratory Director

Principal Investigator(s)

**Michigan Gravitational Wave Group**

Peter Saulson

LSC Spokesperson