Oregon Proposal for LIGO Research

Jim Brau
Univ. of Oregon

MIT, PAC7
November 18, 1999

The emphasis of the Oregon research activities is <u>sustained</u> achievement of the ultimate performance of the LIGO interferometers needed for gravity wave physics, and a search for gravity waves associated with gamma ray bursts (GRBs).

LIGO-G990139-00-Z

Oregon Group working on LIGO

Faculty:

Jim Brau
Ray Frey
David Strom

Research associates:

Evan Mauceli
Robert Schofield
Nikolai Sinev

Graduate students:

Masahiro Ito
Rauha Rahkola

The Oregon group's effort includes the following goals:

Understand the environmental influences on the IFO signal
Use this knowledge to produce reduced data sets
Search for gravitational radiation associated with GRBs

<u>Environmental Monitoring</u>

- **Weather monitoring**
- **Magnetic field studies**
- **Seismic characterization**
- **Cosmic ray studies**
- **Gravity-gradient noise**

<u>Detector Characterization/ Data Analysis</u>

- **Data reduction**
- **Transient analysis**
- **Gamma Ray Burst studies**

We have established a significant presence at the Hanford site, and plan to work closely with the LIGO Lab and the LSC in an effective effort on <u>detector characterization</u> and <u>data analysis</u>

Environmental Monitoring

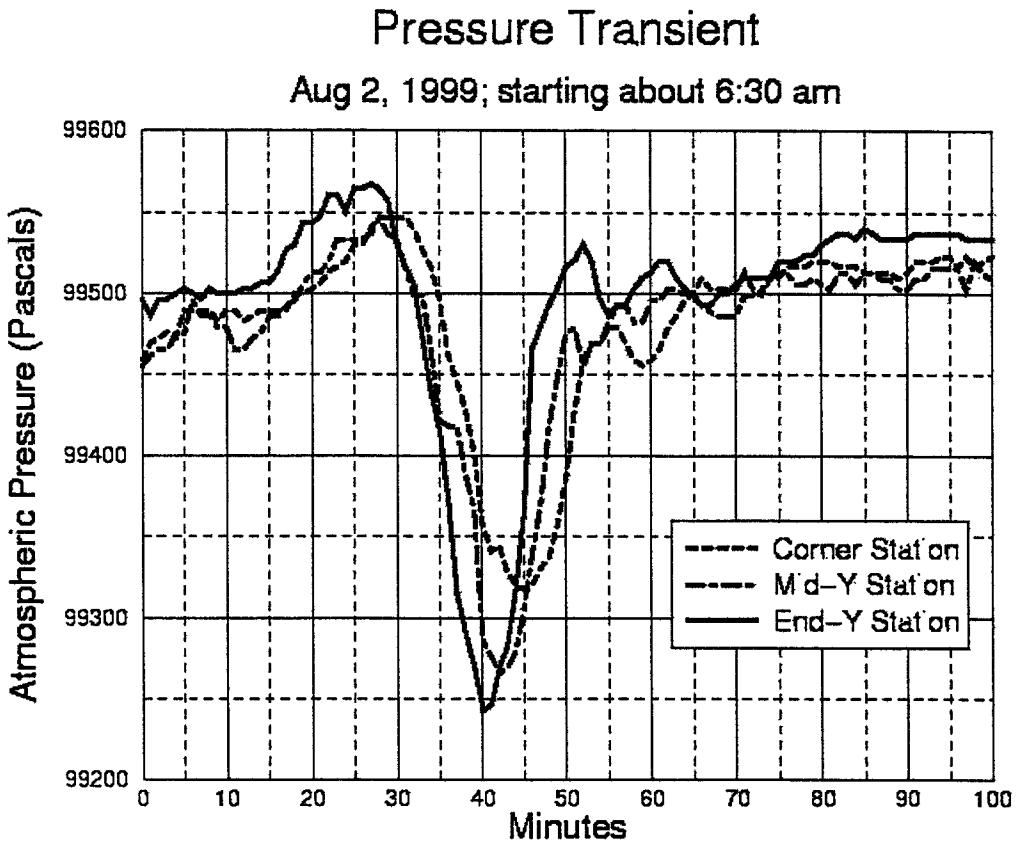
Weather monitoring
Magnetic field studies
Seismic characterization
Cosmic ray studies
Gravity-gradient noise

Environmental Monitoring - Weather

Variable weather conditions will alter LIGO performance

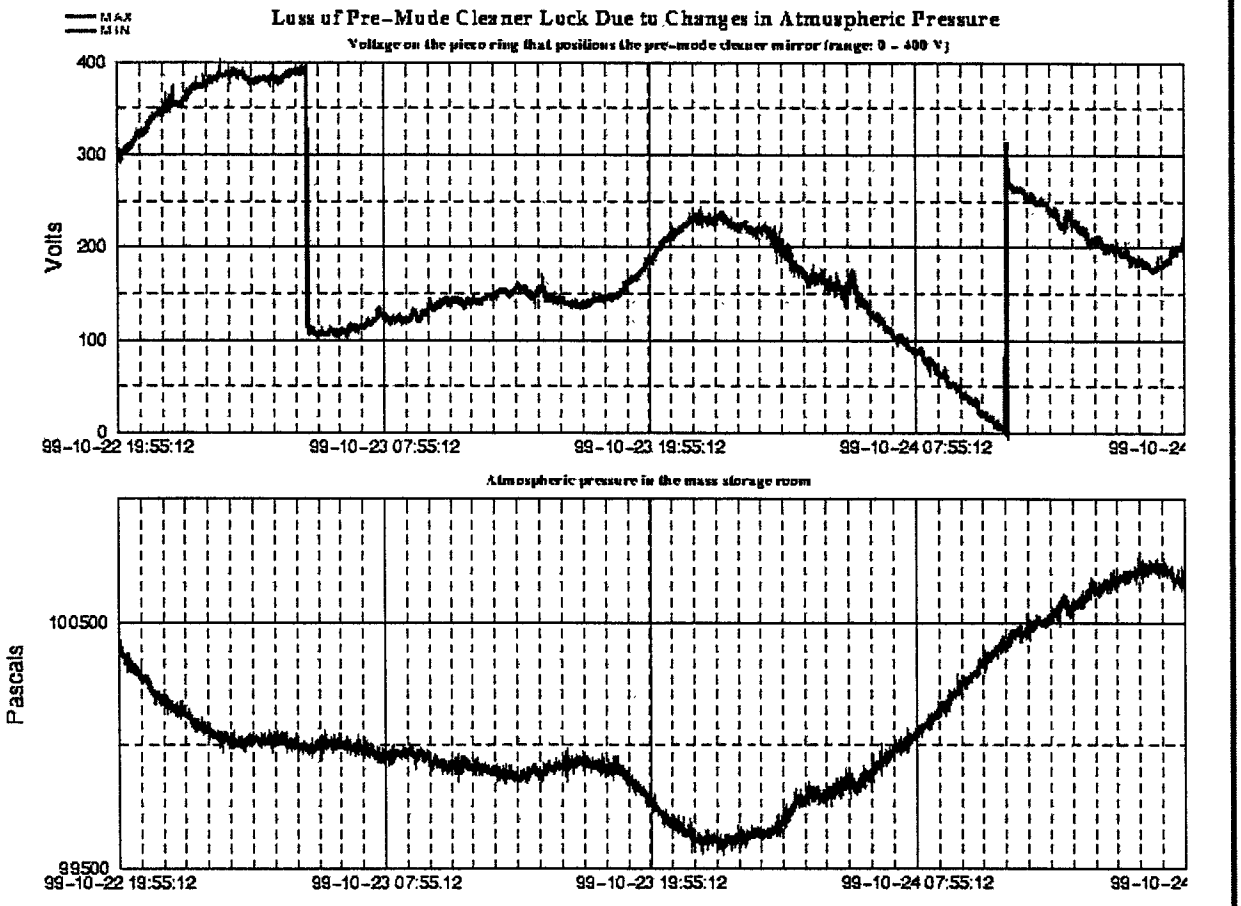
pressure changes	⇒	**tilts and laser alignment**
		optical path lengths (pre-mode cleaners)
wind gusts and rain	⇒	**vibration**
temp & rel. humidity	⇒	**signal drift**

We intend to study these interactions and understand the effects of weather on LIGO



Environmental Monitoring - Weather

Pre-mode cleaner loses lock due to changes in atmospheric pressure.



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MIT-PAC7, November 18, 1999

Environmental Monitoring - Weather

A summary of our contribution in weather monitoring follows.

1) helped set up the 5 weather stations

2) designed, manufactured and installed a circuit to boost the relative humidity signals, compensating for the long cable lengths

3) wrote the device driver code for the weather stations

4) wrote code to transfer the data to the EPICS data collection system and developed MEDM screens to display the data in the control room (a simple tabulation of current data is available within the LIGO Laboratory at http://ligo-wa.caltech.edu/pub/epics.ps)

5) have undertaken a calibration of the stations to improve on the factory calibration

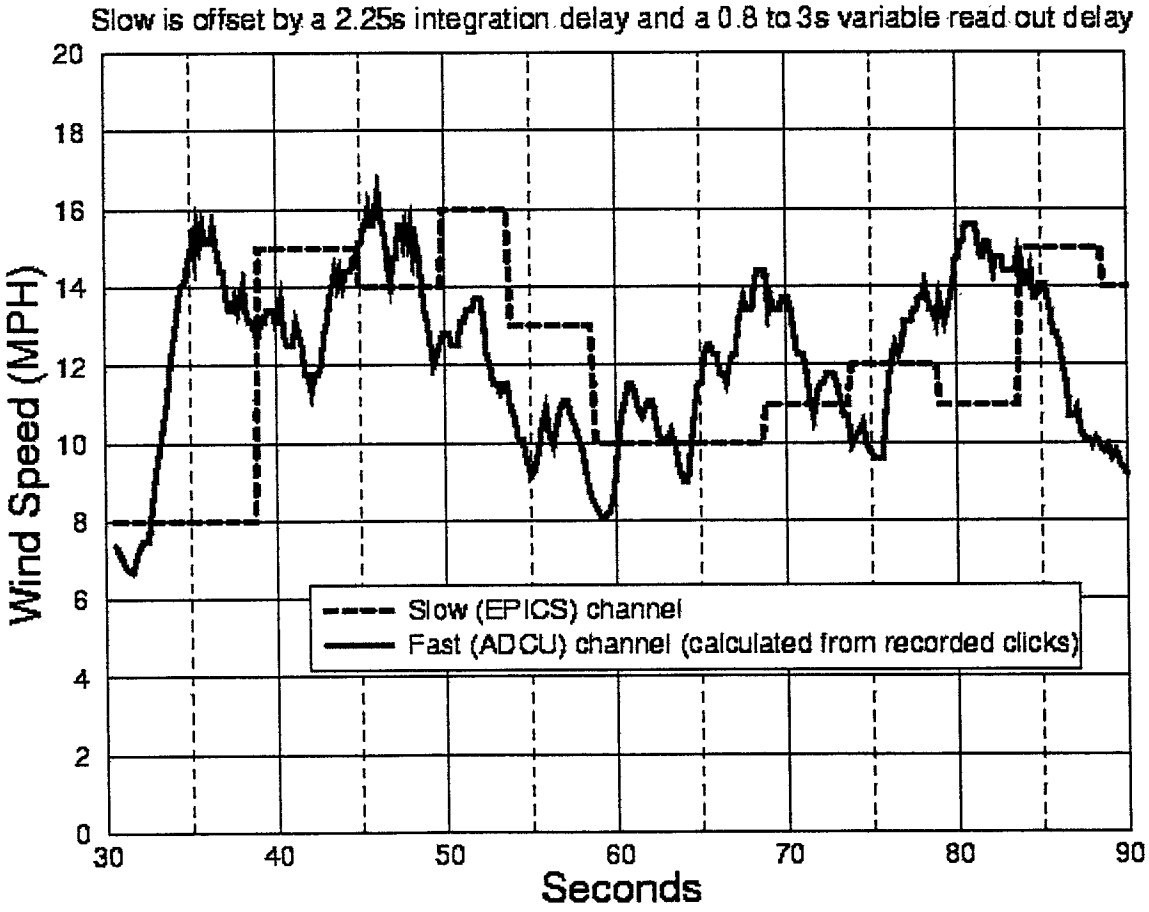
Environmental Monitoring - Weather

Wind Gust Monitoring

Perhaps more important than average wind speed

Modified anemometer read-out

Anemometer data – fast and slow channels



Environmental Monitoring - Magnetic Field Studies

Four studies of magnetic fields and effects:

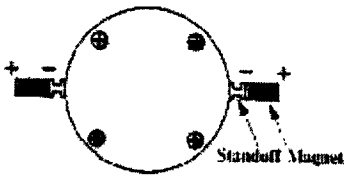
1. **Ambient fields inside and outside of BSC vacuum chambers**
2. **Development of diagnostic system to generate forces on the optics using external coils**
3. **Investigation of the transfer function from outside to inside of the chambers**
4. **Experimental measurements of the gradients produced by optic support structures**

Environmental Monitoring - Magnetic Field Studies

1. Ambient fields inside and outside of BSC vacuum chambers

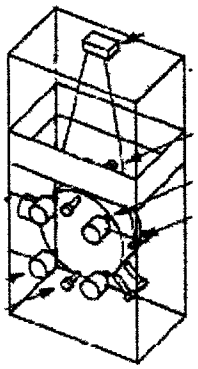
Why measurements of ambient fields ?

- Magnets on the optics may couple optic motion to time-varying ambient magnetic fields.



$$\vec{\tau} = \vec{\mu} \times \vec{B}$$

$$\vec{F} = (\vec{\mu} \cdot \vec{\nabla})\vec{B}$$



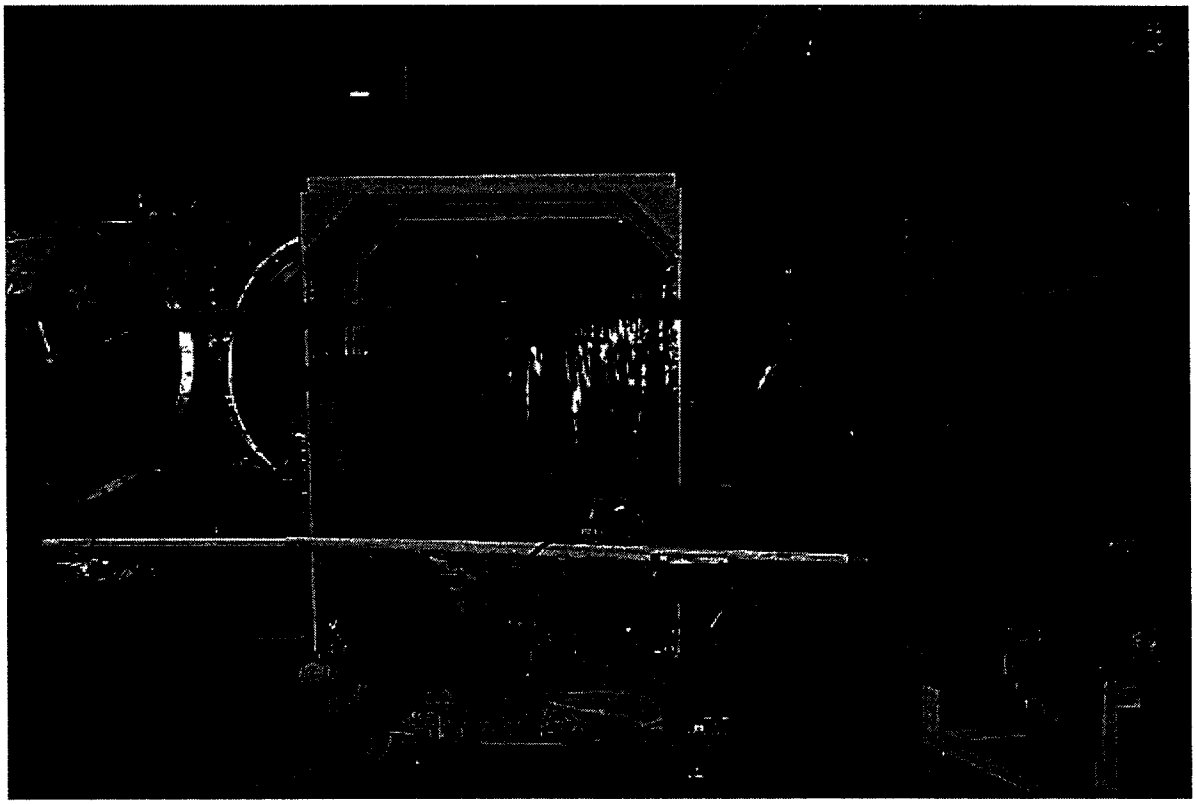
Why measurements of fields generated by external coils (diagnostic fields)?

- Obtain approximate transfer function from outside to inside of chamber.
- Map out field from standardized coil position for future shaking of optics.

From Schofield, Stanford LSC meeting transparencies, www.ligo.caltech.edu/LIGO_web/9907lsc/9907trans.html

Environmental Monitoring - Magnetic Field Studies

1. Ambient fields inside and outside of BSC vacuum chambers



Environmental Monitoring - Magnetic Field Studies

1. Ambient fields inside and outside of BSC vacuum chambers

Ambient magnetic fields in WBSC-7 & 8

Location	(nT)rms at 60 Hz	noise (pT/ sqrt Hz)rms at 50 Hz	n	instrument noise (pT/ sqrt Hz) at 50 Hz
7 locations in WBSC-7; 5/30/99	3.73 ± 0.22	9.6 ± 1.4	7	≤ 2.6
3 locations in WBSC-8; 3/2/99	1.64 ± 0.21	10	4	≤ 2.6

Ambient B field gradients in WBSC-7

Location	(nT/m)rms at 60 Hz	noise (pT/m sqrt Hz)rms at 50 Hz	n	instrument noise (pT/m sqrt Hz) at 50 Hz
7 locations in WBSC-7; 5/29/99	2.31 ± 0.92	≥ 9 ± 2 ≤ 20	7	≤ 11

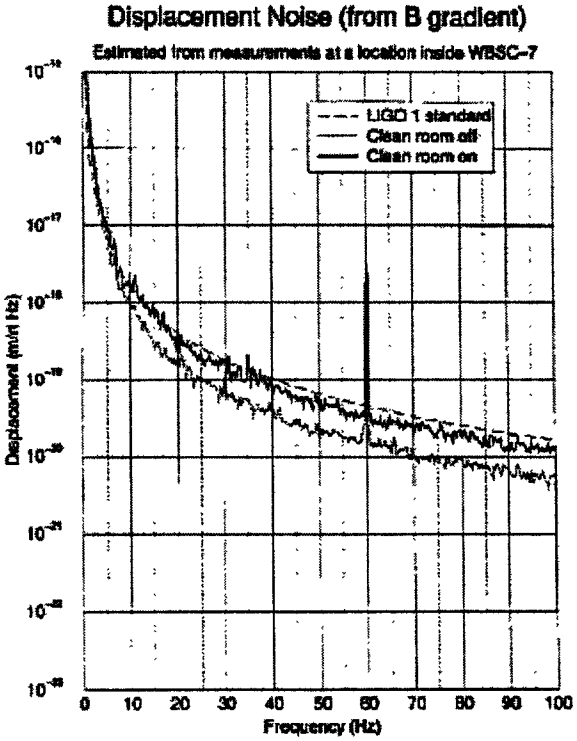
From Schofield, Stanford LSC meeting transparencies, www.ligo.caltech.edu/LIGO_web/9907lsc/9907trans.html

Environmental Monitoring - Magnetic Field Studies

1. Ambient fields inside and outside of BSC vacuum chambers

Conclusion: Simplified model of coupling between ambient fields and optic motion

$$noise < 2\times10^{-20}\, m/\sqrt{Hz}\ @\ 50Hz$$



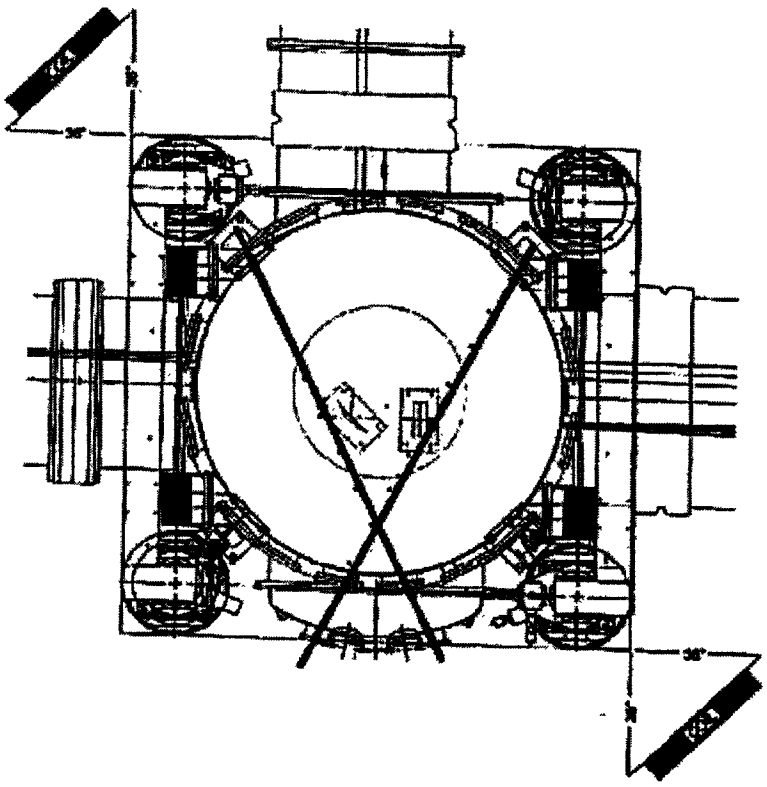
This is a factor 3 down from the LIGO I requirement

Continued investigations are warranted

Environmental Monitoring - Magnetic Field Studies

2. Development of diagnostic system to generate forces on the optics using external coils

Built two (2) 1 m diameter coils of 12 gauge varnished copper wire wound on plywood spools. Select 10, 30, 60, or 100 turns.



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Environmental Monitoring - Magnetic Field Studies

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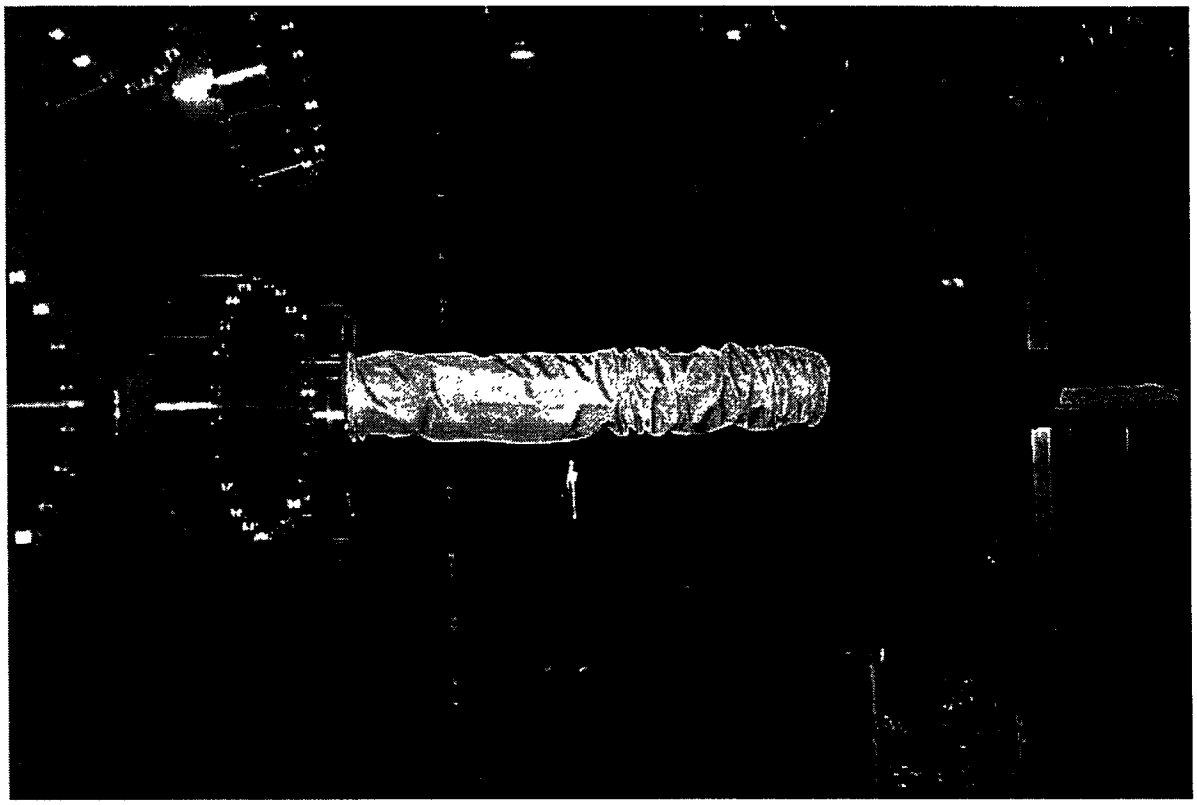


Environmental Monitoring - Magnetic Field Studies

2. Development of diagnostic system to generate forces on the optics using external coils

Fairly uniform field, or uniform gradient, can be produced in the central region of the vacuum chamber.

Model of expected field from Frey and Rahkola (LIGO-T990092-00-H)

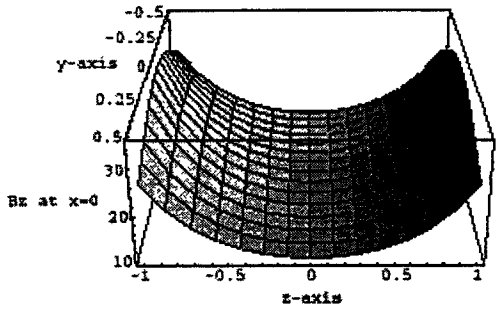


Figure 1: The axial field B_z as a function of (y, z) at $x = 0$ for the Helmholtz configuration with $N = 10^6$, $I = 3$ A. The coils are placed at $z = \pm 2$ m. The field is in units of 10^{-6} T.

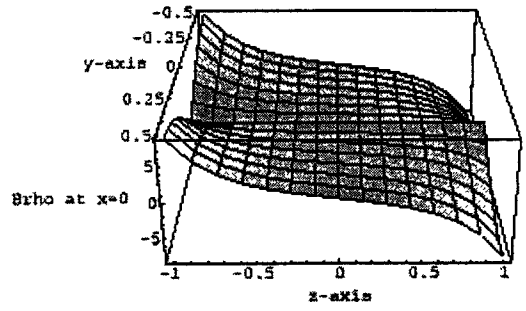
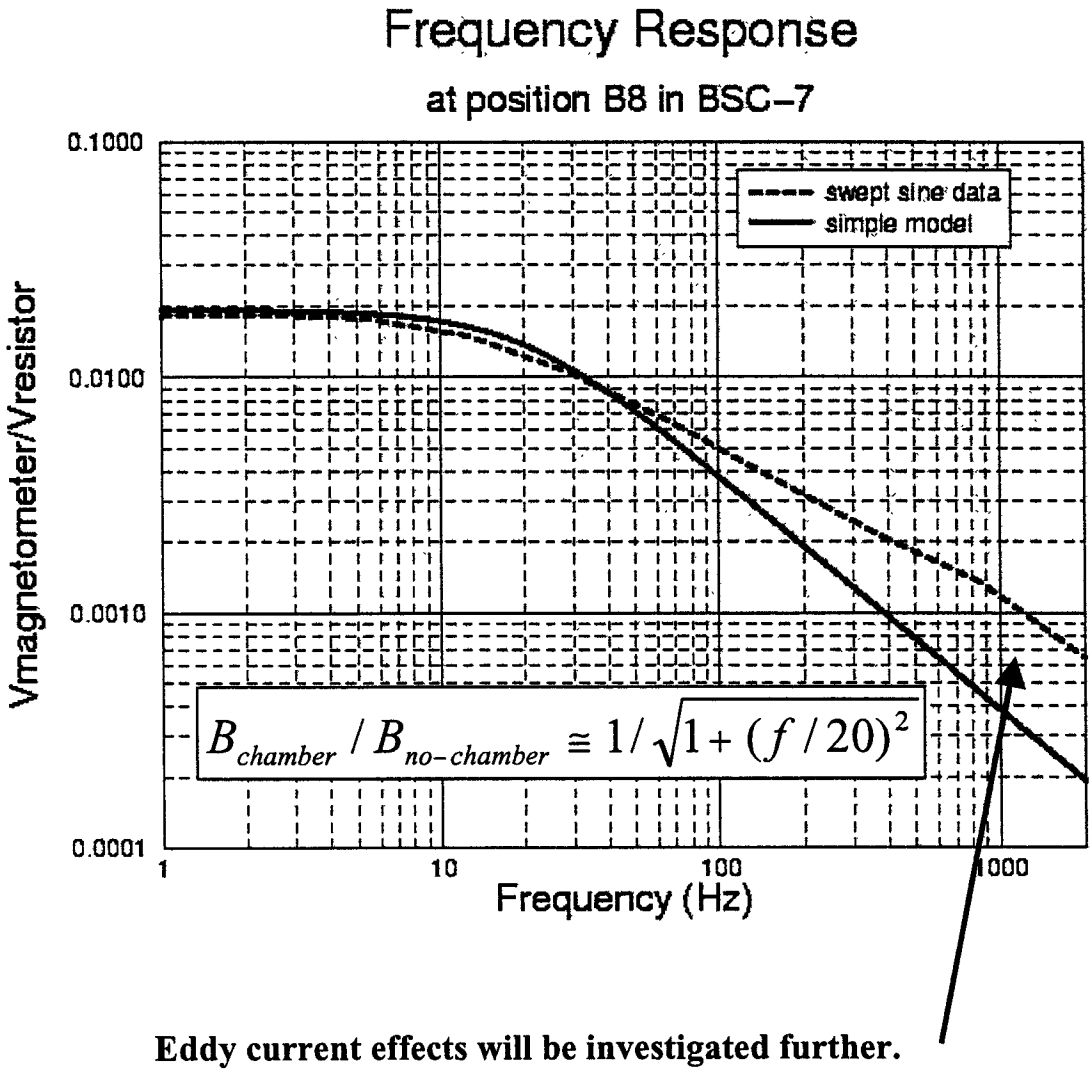


Figure 2: Same as previous figure but for the transverse field component, B_ρ.

Environmental Monitoring - Magnetic Field Studies

3. Investigation of the transfer function from outside to inside of the chambers



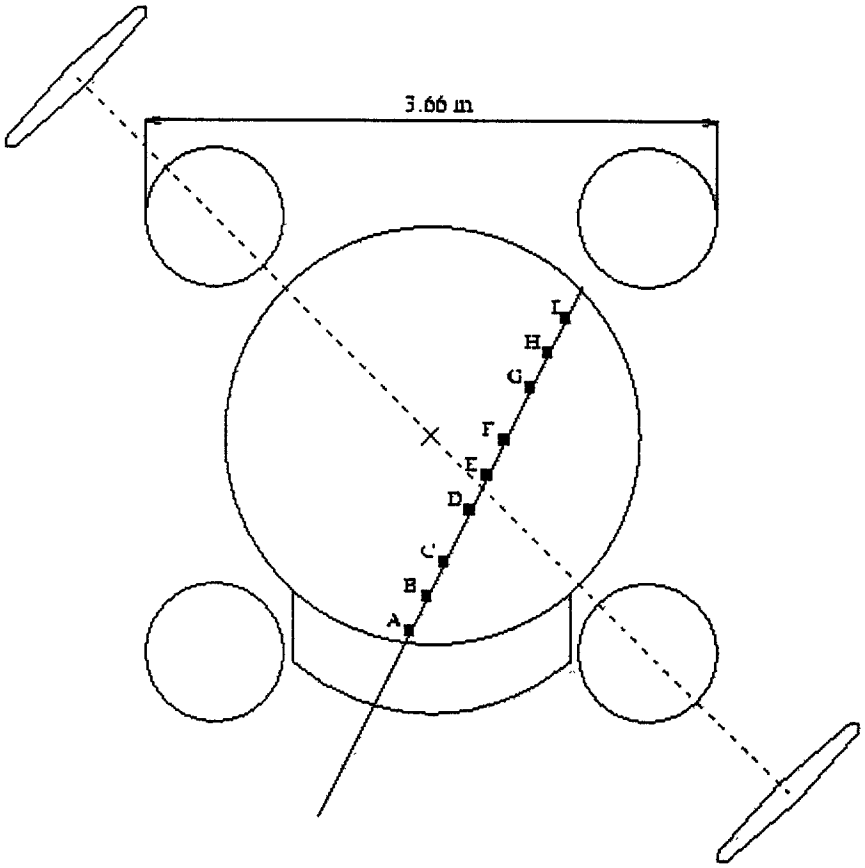
Eddy current effects will be investigated further.

Environmental Monitoring - Magnetic Field Studies

3. Investigation of the transfer function from outside to inside of the chambers

Eddy current effects are being investigated with the data from several positions along the tube.

BSC7 Plan View



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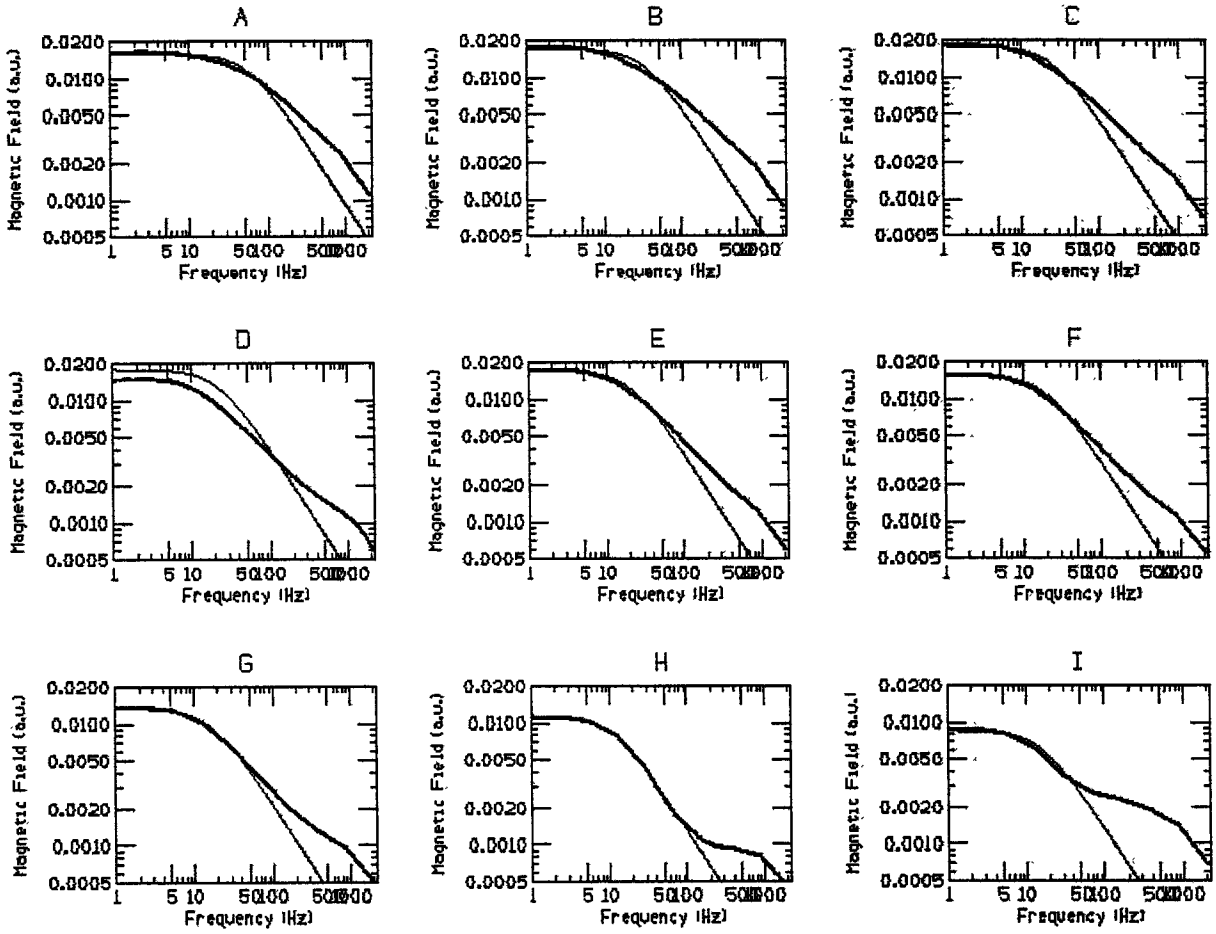
Environmental Monitoring - Magnetic Field Studies

3. Investigation of the transfer function from outside to inside of the chambers

Effect of eddy current depends significantly on distance to the wall



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Environmental Monitoring - Magnetic Field Studies

4. Experimental measurements of the gradients produced by optic support structures

Optic support structures were not in place for our measurements

Will measure gradients produced by an isolated optic support structure

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Also ⇒ Sources of Ambient Fields

Move wall mounted emergency light away from BSC-8 transformer is a large source

Seismic isolation piers are magnetized this may be a negligible effect, but we will check it further

Lightning strike noise

We plan to search for other sources

Environmental Monitoring - Seismic Characterization

Placed accelerometers on major pieces of equipment to identify characteristic frequencies identified office area air handler as the major source of noise

Schofield and Ito, LIGO-T990091-00-W

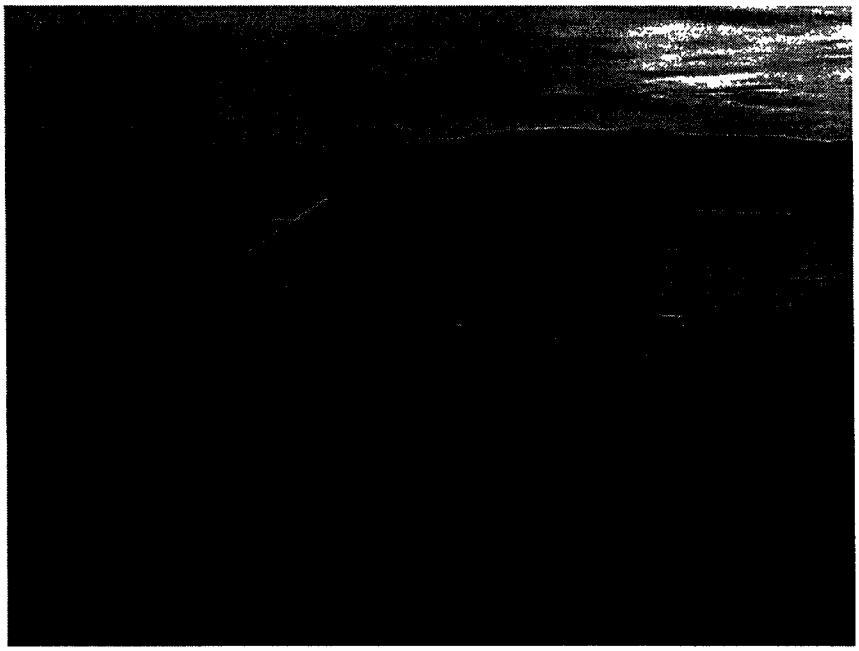
Road Traffic

highway 240 traffic ⇒ nm/√Hz at end stations

Two seismometer cross-correlation measurements

Environmental Monitoring - Seismic Characterization

Wannawish Dam (5 km from Y end-station)
comparable to road noise, but 5 km distance kills it



Environmental Monitoring - Cosmic Ray Studies

A very energetic cosmic ray shower incident on a test mass could, in principle, create a background to gravity wave searches.

The two mechanisms usually considered are
(1) the transfer of the particle momenta (impulse) to the test mass;
(2) the loss of particle energy resulting in internal-mode excitations within the test mass.

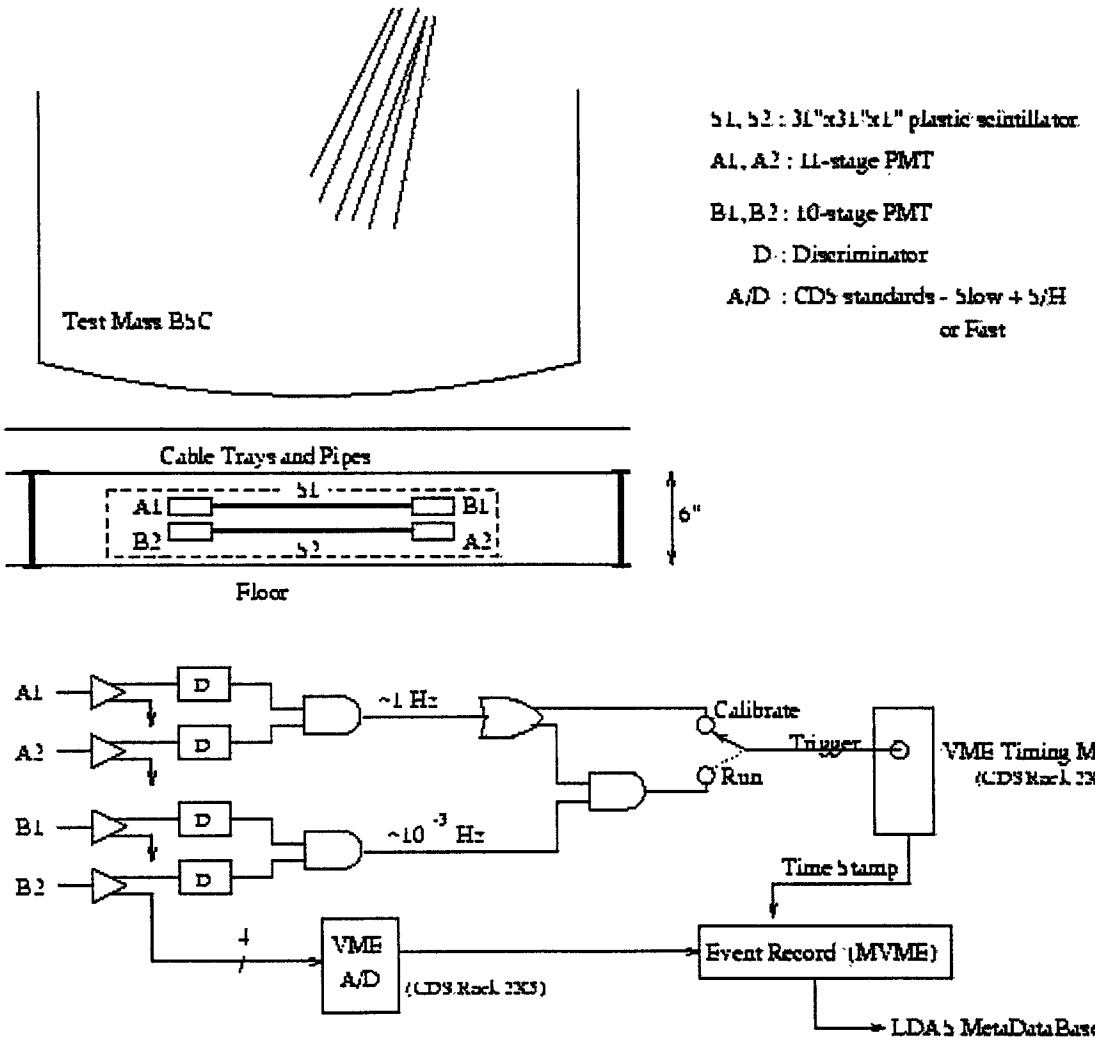
A. Marin, "Cosmic Muon Signature in LIGO," Second Workshop on Gravitational Wave Data Analysis, Orsay, 1997, Editions Frontieres, 1998.

Estimates place the effects of cosmic rays to be a few orders of magnitude below LIGO sensitivity.

Still, it is important to have an independent monitor
check estimates
confirm size for LIGO II

Environmental Monitoring - Cosmic Ray Studies

We are building a cosmic ray system
near test mass (under BSC?)
trigger - adjustable thresholds

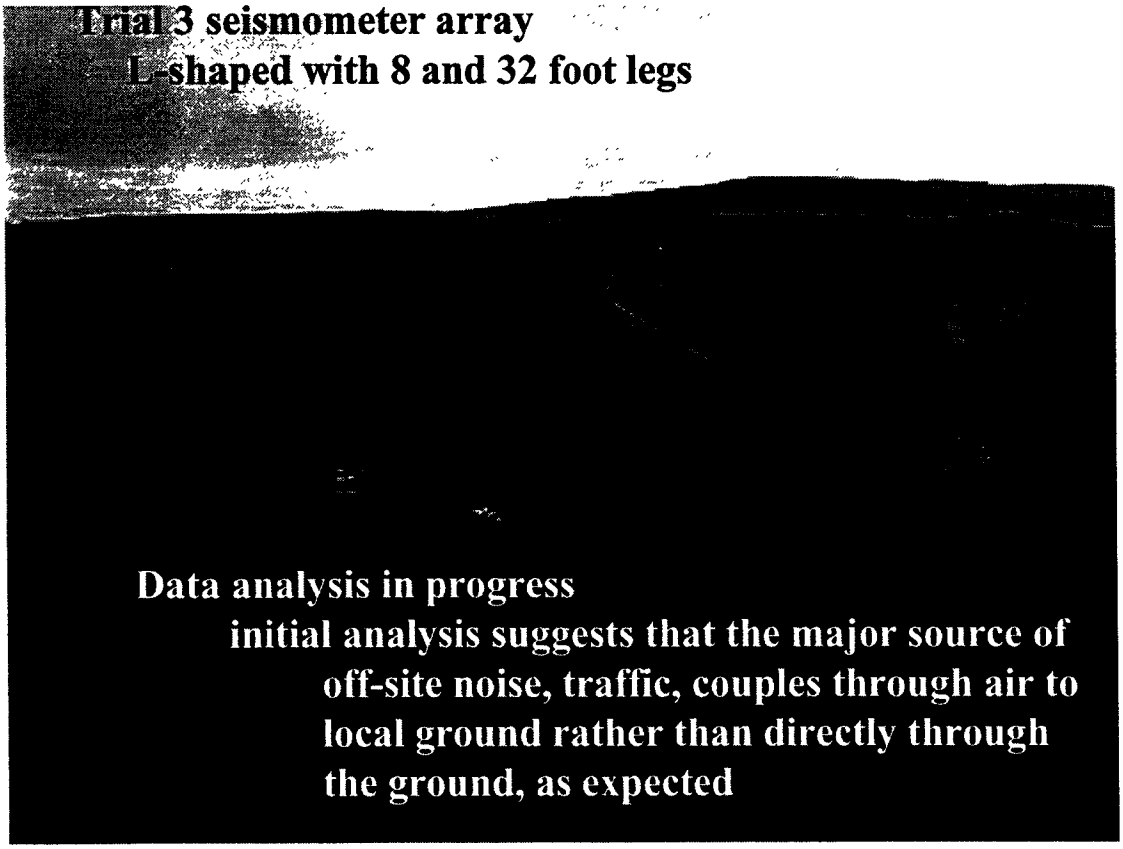


Environmental Monitoring - Gravity-gradient Noise

Gravity-gradient noise from seismic waves generated by uncontrollable sources may limit Advanced LIGO (Hughes and Thorne)

Early measurements by A. Rohay used to constrain effects
Next step ⇒ surface seismic arrays

Working with Group set-up by Thorne
Trial 3 seismometer array
L-shaped with 8 and 32 foot legs



Data analysis in progress
initial analysis suggests that the major source of off-site noise, traffic, couples through air to local ground rather than directly through the ground, as expected

Data Analysis

Data reduction
Transient analysis
Gamma Ray Burst studies

Data Analysis
- Data Set Reduction

The LIGO complex produces about 15 Gbyte/sec of data. LIGO plans to reduce the data through 3 steps:

Level 0 ⇒ Level 1 (10%)
Archived Reduced Data Set
all important IFO and PEM channels
stored in FRAME format

Level 1 ⇒ Level 2 (1% of Level 0)
IFO Strain plus Data Quality Channels
for detailed science analysis

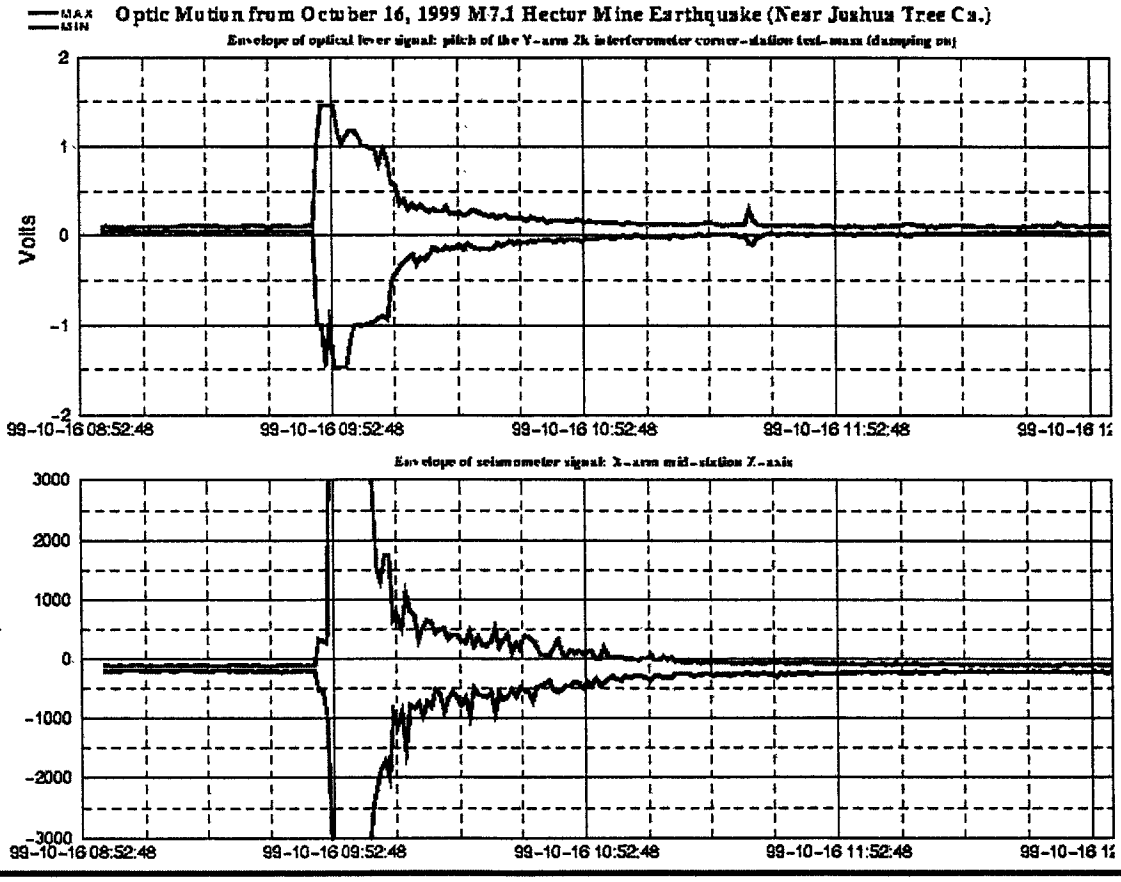
Level 2 ⇒ Level 3
Whitened GW Strain Data
2 year, 50% -> 200 GB

Mauceli and Schofield are at Hanford now exercising the LIGO data acquisition system and experimenting with reduced data sets.

Data Analysis - Transients

We are studying for instrument transients produced by the environment:

- **wind gusts**
- **lightning strikes**
- **cosmic ray showers**
- **earthquakes**



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Data Analysis
- Physics Analysis

We intend to work toward a study of correlations of LIGO response to Gamma Ray Bursts

Gamma Ray Bursts

- **BATSE events about 1/day**
- **More than 1 class?**
  - **Use space and time constraints to search for gravity waves associated with these events.**

We expect our experience with working directly on LIGO hardware will prepare us for effective searches for gravity waves.

Plan to collaborate closely with others in LSC (eg. theorists) on this effort.

Technical Notes

1. Documentations for Functions and Diagrams Describing 3 Coordinate Systems, Horak and Amasha, ORDOC 98-6, Jul 27, 1998

2. Documentation of All Tests Performed on GWSIM Function, Horak and Amasha, ORDOC 98-7, Aug 3, 1998

3. Ambient and Diagnostic Magnetic Fields Measured in and Around Hanford BSC's, Schofield , Rahkola, Frey, LIGO-G990104-00-W

4. Frequencies of Large Equipment Sources of Seismic Noise at LHO Corner Station, Schofield, Ito, LIGO-T990091-00-W

5. Generation of Diagnostic Magnetic Fields for Test Mass Chambers, Frey and Rahkola, LIGO-T990092-00-H

In progress and planned:

6. A Proposal for Gust-measuring System at LIGO, Rahkola, Schofield (in prog.)

7. LHO Weather Station Calibrations, Schofield, Rahkola, Frey (in prog.)

8. Progress in Seismic Characterization of the LIGO Site, Schofield, Ito (planned)

9. Commissioning the LHO Particle Detector System, Frey, Rahkola, Schofield (planned)

10. Search for Gamma Ray - GW Correlations with 40m Data, Ito, Brau (planned)

Other Detector Experience

R. Schofield is located at LHO and plans to continue gaining general experience with the detector in order to contribute to the understanding that will yield the ultimate LIGO performance.

Other members of the group (Mauceli, Frey, Strom, Brau, etc.) are primarily located in Eugene, but expect to be present at Hanford when needed.

So far, in addition to experience in the environmental monitoring areas mentioned above Robert has:

1) helped install seismic isolation systems in HAM-10, BSC-8, BSC-5 and BSC-4,

2) measured the changing tilt of the concrete slab as HAM - 7 was pumped down, (The difference in tilt was about 5 microradians; this tilt will affect laser alignment)

3) helped test chamber shakers and accelerometers,

4) helped install tilt meters and seismometers,

5) helped install and adjust the recycling mirror in HAM-9,

6) designed and tested an extension to monitor dust in vacuum chambers during installations,

7) written the device driver code, EPICS interface and control room screens for the dust monitoring system.

NSF Support

Joined LSC March, 1997

Awarded 2 years of NSF support
beginning Sept, 1998

1st year:	95k$
2nd year:	140k$

Proposal:

2000-2001:	268k$
2001-2002:	318k$
2002-2003:	331k$

This supports:

- 2 postdocs
- 2 grad students
- travel support to give us strong presence at the Hanford site
- modest computer enhancements

Summary

The Oregon group has initiated an effort in environmental monitoring and data analysis which will lead to effective searches for gravity waves with the LIGO data

<u>Environmental Monitoring</u>

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