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aLIGO PEM system upgrade

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1 Introduction

While major changes to the PEM (physical environment monitoring) system are not a part of the advanced LIGO grant, the PEM system must be taken apart for aLIGO installation, affording an opportunity for redistribution of the sensors, upgrades, and channel renaming based on lessons learned in initial LIGO.

The initial LIGO PEM system is described in the Final Design Document, LIGO-T970112-00. Many of the experiences with, and uses of the initial LIGO PEM system are documented in ilog and other links on R. Schofield's web page, including the sources of environmental signals, coupling levels to the interferometer, and uses of the PEM system in vetoing astrophysical candidates: <http://www.ligo-wa.caltech.edu/~robert.schofield/iLIGOenvironmentalInfluences.htm>. Note that the ilogs are now archived, so only the reader/readonly user and password will work.

2 Changes from the initial LIGO PEM system

1) No H2. Many sensors were used for both interferometers but H2 sensors that are freed up will be used for H1.

2) Vacuum chamber accelerometers will be moved from support tubes to chamber walls. The vacuum chamber accelerometers are now redundant at their iLIGO locations because of coverage from HPI and ISI vibration sensors. The plan is to mount them on the chamber walls where they could detect motions that could modulate light scattered off of the chamber walls. The accelerometers will be attached to either flat blank-off flanges on the chambers or else directly to the wall using 5 minute epoxy. The epoxy and the required cabling have been OK'd by John Worden and Richard McCarthy.

2b) The different axes of vacuum chamber accelerometers will not be co-located. Instead, each axis will be located at a position where motion in that direction is large and could produce coupling through backscattering. Thus, the Z-axis will be located on the bottom of the chamber to detect chamber floor motion, and the X and Y axes will be located on the sides of the chamber that face those directions.

3) Accelerometers on beam tubes. There will also be accelerometers monitoring selected sites on beam tubes (e.g. new input tube) to monitor modulation of reflected light.

4) One-axis accelerometer on optical tables that have beams during power up, but are beam-free during science mode (e.g. ISCT1). This is to help with commissioning and with power up problems and acquisition of science mode.

5) One-axis accelerometers on test mass optical levers. In case we use these for servos early on.

6) Electronics racks magnetometers. In initial LIGO an important coupling site for magnetic fields was the electronics racks. Relatively large magnetic fields are generated by the equipment in the racks and these fields can couple to components, cables and, mainly, connectors in the racks. In addition, magnetometers can detect DC power supply ripple and currents associated with cyclical processes that may produce line artifacts in the gravitational wave channel. Magnetometers have been useful even when the coupling was not through magnetic fields – the magnetic fields produced by the cyclical process are used to narrow down the location of the source even though the magnetic fields are too small to produce the artifact.

7) Electronics bay accelerometers. In addition to microphones, we will have an accelerometer on the floor of each E-BAY in order to detect vibrational coupling to the electronics boards and to monitor the E-BAY as a seismic source.

8) LVEA/VEA floor accelerometers. One of the uses of the PEM system is to track down sources that are producing features in DARM. We will have a number of accelerometers mounted on the floor to help us locate vibration sources through propagation delays and amplitude differences.

9) Extra PSL table accelerometers. The PSL table was the most important vibrational coupling site in S6. An accelerometer will be added to the top of the periscope to monitor periscope-induced beam jitter. Two accelerometers will be added to the table to help determine coupling sites on the table.

10) Reduce the frequency of the magnetometer sigmoid filter. The iLIGO magnetometer filter box gives a gain of 10 at high frequencies and a gain of 0.01 at DC. The filter should be modified to produce a flat response above 1 Hz instead of above 10 Hz, which is now in-band.

11) Mid-station beam tube accelerometers at LHO to monitor scattering modulation from the most constricted part of the beam tube. Seismometers and microphones will also be kept at the mid stations for help determining source directions and airplane flight paths.

12) Rigid tripods for fluxgate magnetometers at LHO. LLO already has such tripods, though the mounting scheme may be improved. Non-rigid tripods lead to increased crosstalk between floor vibrations and the magnetometer signal as the magnetometer vibrates in the earth's magnetic field with large amplitude at the tripod resonances.

13) Infrasound microphones. Our microphones do not detect ambient sound levels below about

10 Hz. The Eotvos group has designed and built a prototype infrasound mic, which detected low frequency correlations between pressure and DARM_CTRL during S6. They will supply one microphone for each of the six buildings.

14) New naming scheme. The iLIGO naming scheme required a knowledge of the BSC numbering system, which differed between LHO and LLO, in order to determine which building an accelerometer was in. This led to many interpretation problems. In addition, it was difficult to select all sensors of a particular type in a building, because the sensors were organized by specific location, and the user would have to search under each location to see if there was a sensor of a particular type at that sub-location. The new naming scheme is designed to avoid these problems:

site:system-building_sensor_location_descriptor(_axis, units)('BLRMS' _band)

Examples:

H1:PEM-CS_ACC_HAM2_PRM1_X

H1:PEM-CS_ACC_HAM2_PRM1_Y

H1:PEM-CS_ACC_HAM2_PRM1_Z

H1:PEM-CS_ACC_LVEA_FLOORHAM1_Z

H1:PEM-CS_ACC_PSL_PERISCOPE_X

H1:PEM-CS_ACC_PSL_TABLE1_Z

H1:PEM-CS_DUST_BAKE1_300NM_PCF

H1:PEM-CS_DUST_BAKE1_500NM_PCF

H1:PEM-CS_MIC_PSL_CENTER

H1:PEM-CS_RELHUM_BAKE1_DUSTMON

H1:PEM-EX_SEIS_VEA_FLOOR_X

H1:PEM-EX_SEIS_VEA_FLOOR_Y

H1:PEM-EX_SEIS_VEA_FLOOR_Z

H1:PEM-EX_TILT_VEA_FLOOR_TEMP

H1:PEM-EY_ACC_BSC10_ETMX_X

H1:PEM-EY_ACC_BSC10_ETMX_Y

H1:PEM-EY_ACC_BSC10_ETMX_Z

H1:PEM-EY_WIND_ROOF_WEATHER_DIR

H1:PEM-EY_WIND_ROOF_WEATHER_MPH

H1:PEM-EY_WIND_ROOF_WEATHER_MPS

L1:PEM-CS_ACC_IOT1_MCCNTRL_Y

L1:PEM-CS_MAG_EBAY_LSCRACK_X
 L1:PEM-CS_MAG_EBAY_LSCRACK_Y
 L1:PEM-CS_MAG_EBAY_LSCRACK_Z
 L1:PEM-CS_RADIO_ROOF_45MHZ
 L1:PEM-CS_RADIO_ROOF_9MHZ
 L1:PEM-CS_SEIS_LVEA_FLOOR_X
 L1:PEM-CS_SEIS_LVEA_FLOOR_Y
 L1:PEM-CS_SEIS_LVEA_FLOOR_Z

Naming scheme for weather stations and dust monitors:

(H0|L0):PEM-(CS|MX|MY|EX|EY)_RAIN_ROOF_WEATHER_MM
 (H0|L0):PEM-(CS|MX|MY|EX|EY)_WIND_ROOF_WEATHER_(MPH|MPS|DEG)
 (H0|L0):PEM-(CS|MX|MY|EX|EY)_RELHUM_(VEA|MSR|LVEA|EBAY|ROOF)_WEATHER
 (H0|L0):PEM-
 (CS|MX|MY|EX|EY)_TEMP_(VEA|MSR|LVEA|EBAY|ROOF)_WEATHER_(DEGF|DEGC)
 (H0|L0):PEM-(CS|MX|MY|EX|EY)_PRESS_(VEA|MSR|LVEA|EBAY)_WEATHER_(INHG|PA)
 (H0|L0):PEM-
 (CS|MX|MY|EX|EY)_DUST_(LVEA#|VEA#|BAKE|OPTLAB|VACPREP)_(300NM|500NM|700
 NM|1000NM|2000NM|5000NM)_RAW
 (H0|L0):PEM-
 (CS|MX|MY|EX|EY)_DUST_(LVEA#|VEA#|BAKE|OPTLAB|VACPREP)_(300NM|500NM|700
 NM|1000NM|2000NM|5000NM)_PCF
 (H0|L0):PEM-
 (CS|MX|MY|EX|EY)_TEMP_(LVEA#|VEA#|BAKE|OPTLAB|VACPREP)_DUSTMON_(DEGC|
 DEGF)
 (H0|L0):PEM-
 (CS|MX|MY|EX|EY)_(RELHUM|MODE|STAT|UNIXTIME|SAMPMIN|SAMPSEC|MODESTR|
 STATSTR|SAMPSTR|DATESTR|TIMESTR)_(LVEA#|VEA#|BAKE|OPTLAB|VACPREP)_DUS
 TMON

3 Expected coupling sites

1) **Vibration** (more or less in order of importance).

- a. PSL table (dominant in S6)
- b. OMC table in HAM6

- c. Optical levers if they are used in-loop early on.
- d. ISI tables at the forest of table resonances, unless resonances are damped.
- e. Vacuum enclosure walls reached by scattered light.

2) Magnetic field

- a. Electronics, particularly ISC
- b. OMC tip/tilt steering mirror magnets
- c. Large magnets on M0 and L1 of quads
- d. Magnets on PUM
- e. Faraday isolators

3) RF field

- a. Diodes, cables and connectors for MICH, PRC and SRC.

4 Maps of sensor locations

The maps also have summaries of desired sensors vs. owned sensors. Cost estimates for the extra accelerometers and magnetometers are given in section 5. Dust monitors and the desired additional upgrades of section 6 are not shown on the maps.

5 Proposal for additional magnetometers and accelerometers

The maps in section 4 include 6 extra magnetometers and 5 extra accelerometers that we think would significantly improve coverage. An estimate of the cost follows:

6 magnetometers:

| | |
|---------------------------------------|-----------------------|
| Bartington MAG-03MCESL70 magnetometer | 6 * \$4250 = \$25,500 |
| Bartington PSU1 power supply unit | 6 * \$980 = \$5880 |
| Bartington MAG-03MCESL 42M cable | 6 * \$390 = \$2340 |

5 accelerometers:

| | |
|---------------------------------|--------------------|
| Wilcoxon 731-207 accelerometers | 5 * \$515 = \$2575 |
| Wilcoxon R1-2-J93-100 cable | 5 * \$230 = \$1150 |
| | \$37,445 |

6 Additional upgrades and projects

1) Power meters for roof radio monitors that monitor RF in modulation frequency bands (e.g. 9MHz 45MHz) etc. A unit that could monitor six frequencies at once and output 6 analog signals proportional to the power is desired. We had only one power meter for iLIGO.

2) RF monitors at the main modulation frequencies for inside the LVEA. These would use signals from the RF distribution system as the local oscillators. They would be attached to lamda/2 antennas in the LVEA. Temporary electronics were used in iLIGO for this purpose.

3) An RF spectrum monitoring system that sweeps from a few kHz to a couple of GHz. It would be attached to one or two wide-band antennas and would output spectrograms showing the RF environment. The heart, of course, would be a spectrum analyzer along with a laptop. The motivation for this is to monitor wider bands than presently possible. For iLIGO we were only able to monitor small 100 kHz bands and had to use external observatories for validation of the big dog blind injection. High amplitude RF couples to the interferometer at a number of frequencies that were not monitored, e.g. the 10 MHz oscillator synchronization frequency. The heart of this system would be a programmable spectrum analyzer, a laptop and a couple of wide band antennas.

4) We would also like to monitor 1 Hz to 10,000 Hz RF with this system or a separate system - again the output would probably be a spectrogram but this one would also have a simple analog connection from the amplifier to the DAQ system. There were no external observatories in the United States that have public archives of this data. For the big dog validation we used observatories in Europe. The coil magnetometer in the vault may be sufficient hardware for this system, or, alternatively, a Marconi antenna connected to an audio amplifier.

- 5) **An electrostatic field monitor.** This would be connected to a dead-end wire that goes into the BSC and it would use the signal to quantitatively measure electrostatic fields inside the vacuum chamber.
- 6) **Coil magnetometers** to supplement our Bartingtons, which have only a 3kHz bandwidth, and our single coil magnetometer. For one in each building, we would need six. These would be custom built, reproducing our current sensors.
- 7) **A sky observation system.** At each station – SBIG Allsky 340 is about \$2,200.
- 8) **An upgraded cosmic-ray detection system.** To be provided by Oregon.
- 9) **Infrasound monitors.** To be provided by the Eotvos group.
- 10) **A few low-frequency accelerometers.** Our accelerometers measure ground motion down to just below 10 Hz. The wavelengths of Rayleigh surface waves are a few tens of meters at 10 Hz, so a single seismometer is not enough to cover the entire LVEA in the 3-10 Hz band.