E7

Lessons Learned

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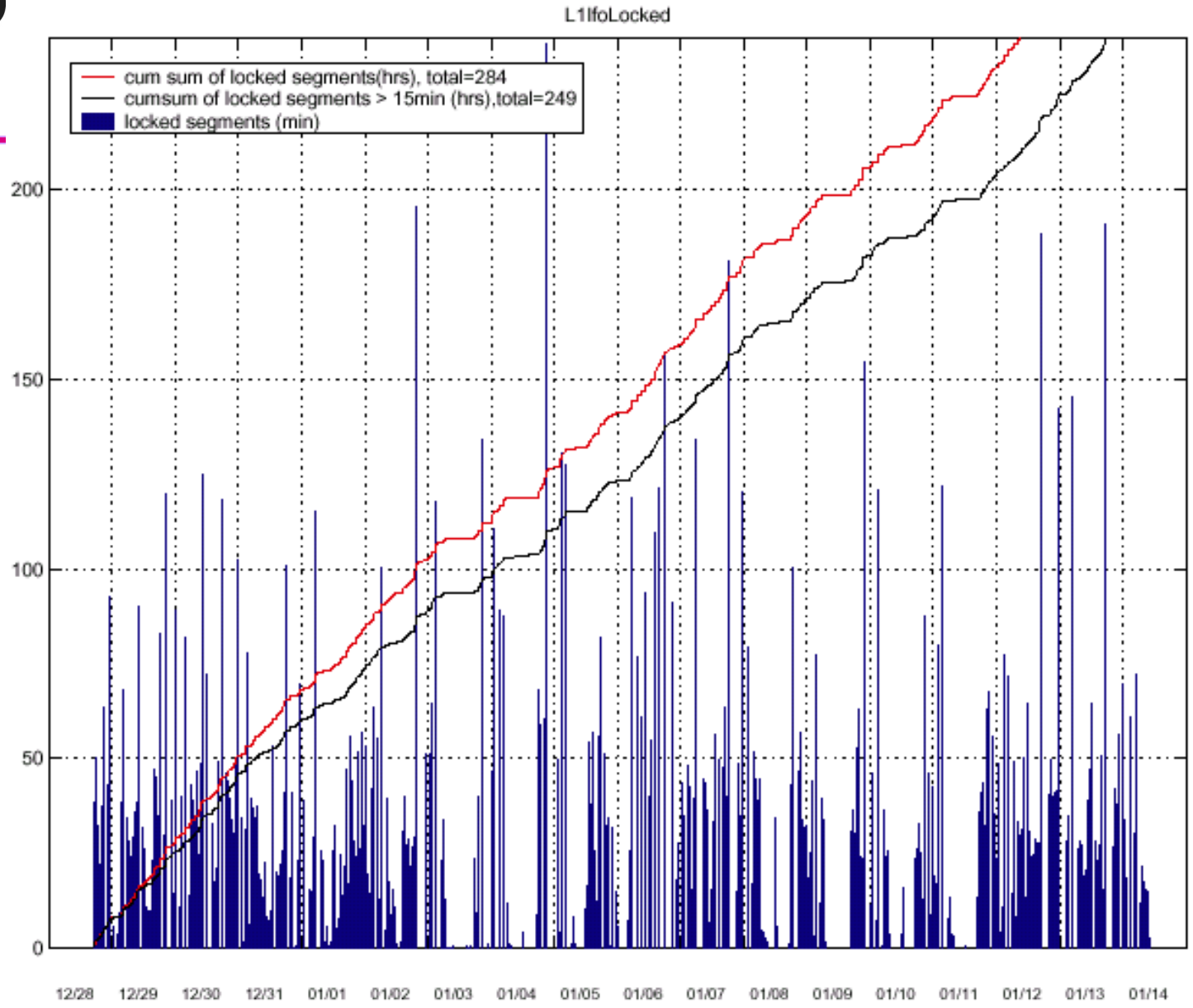
G020009-00-L

Run Statistics Summary

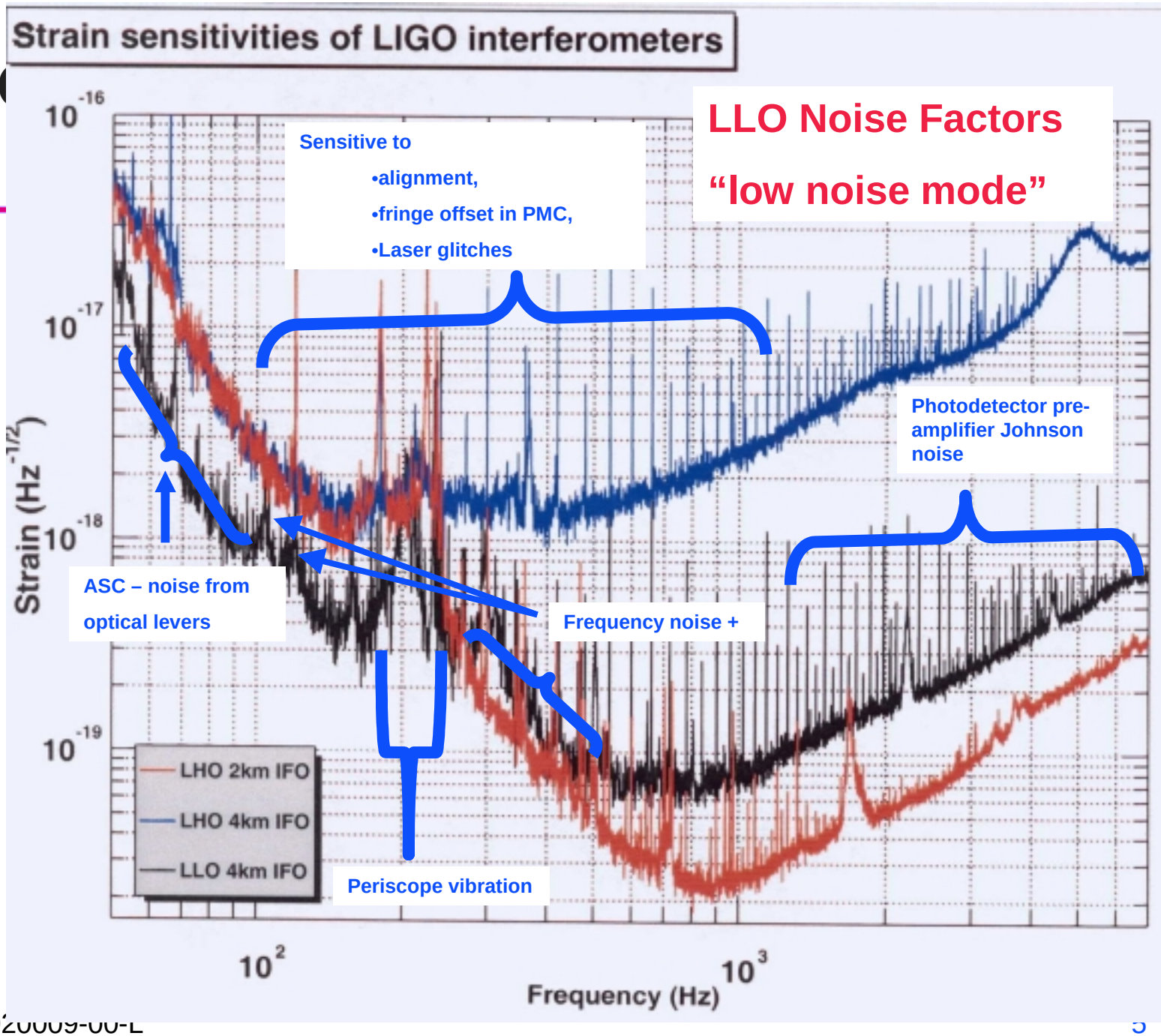
	LLO-4K	LHO-4K	LHO-2K	All three together
Total lock time	284 hours	294 hours	214 hours	140 hours
Duty cycle	71%	72%	53%	35%
Total time locked > 15 min	249 hours	231 hours	157 hours	72 hours
Long lock duty cycle	62%	57%	39%	18%

Cumulative statistics at LLO



Run time distribution at LLO

Run Category	Per cent of total run time
Long locks	~62%
Intermittent locking (<15 min)	~9%
Seismic interference	~25%
Time server and calibrations	~5%


Strain sensitivities of LIGO interferometers
LLO Noise Factors
"low noise mode"
Sensitive to
•alignment,
•fringe offset in PMC,
•Laser glitches
Photodetector pre-amplifier Johnson noise
ASC – noise from optical levers
Frequency noise +
Periscope vibration
LHO 2km IFO
LHO 4km IFO
LLO 4km IFO
Strain (Hz^-1/2)
Frequency (Hz)
10^-16
10^-17
10^-18
10^-19
10^2
10^3

What did we learn…

- That will improve the conduct of the next run?
- That will aid in completion of commissioning?
- That will help LIGO to attain reliable full-time operation as a scientific observatory

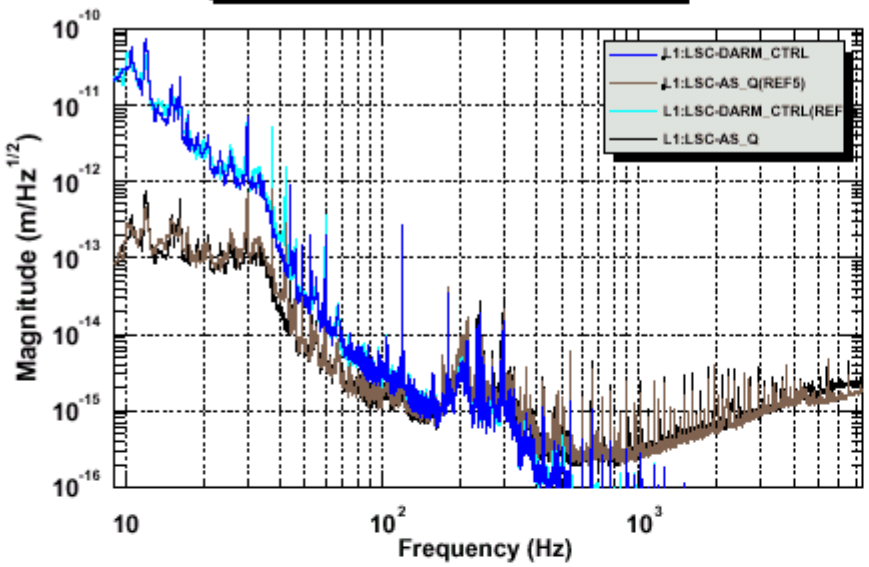
Topics:

- Detector stationarity and stability
- Hardware performance: reliability, robustness
- Software and controls: reliability, performance, ease of use
- Operations procedures: calibrations, check lists, shift duties, shift lengths, staffing numbers, other human factors, etc.
- Inter-site planning and coordination

Detector Performance

- **Noise stationarity**
  - » **We made and archived spectra 3-10 times per day throughout the run (usually 3 per shift when locked), more than 100 archived spectra during run**
  - » **“Canonical” comparison format for data – between times of day and between interferometers is very helpful**
    - – **We decided on a particular way of doing this during E7.**
    - – **Based on E7 experience, we should establish a standard for future science runs to represent calibrated sensitivity so ALL detectors participating will have compatible plots for easy comparison**
  - » **Need to tell difference between spectrum changing and calibrations changing – need to think about how to optimize this for future runs**

Differential Arm Noise Spectrum



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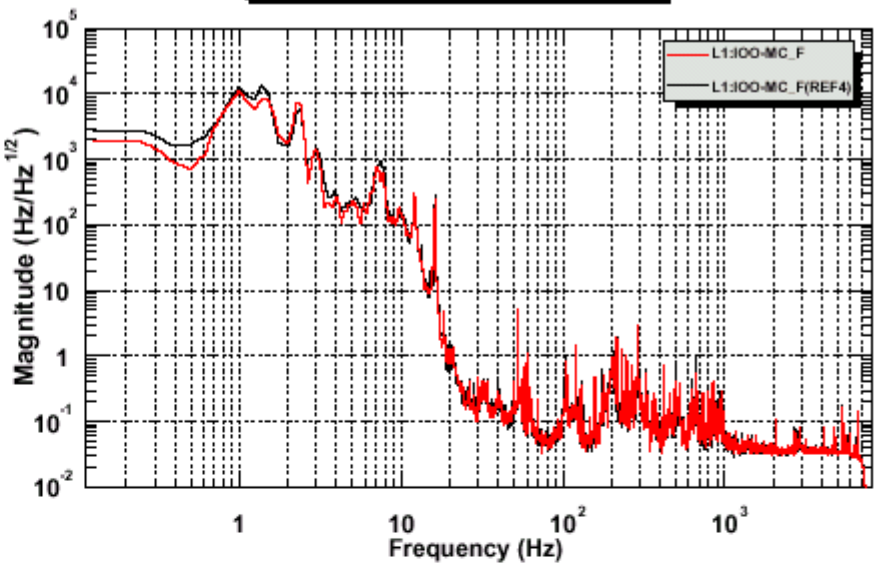
Mode Cleaner Noise Spectrum



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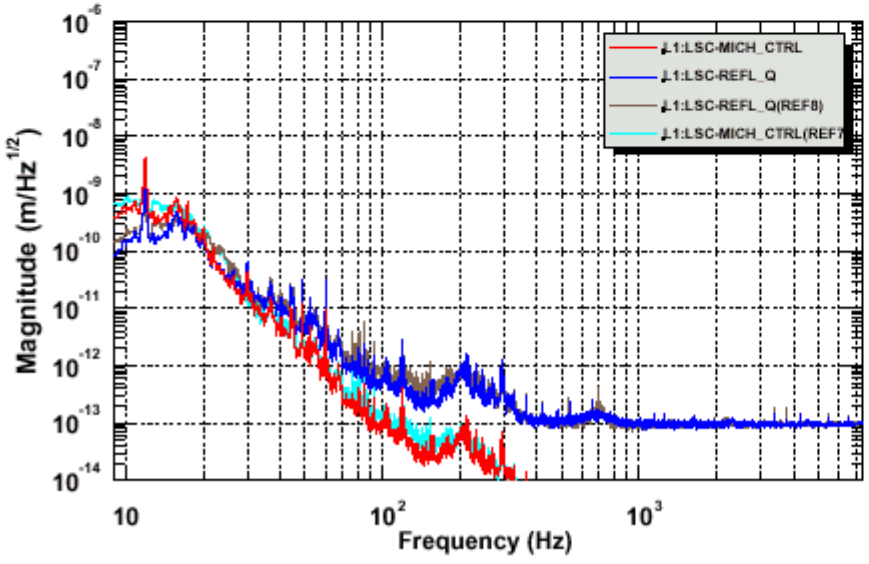
Michelson Noise Spectrum



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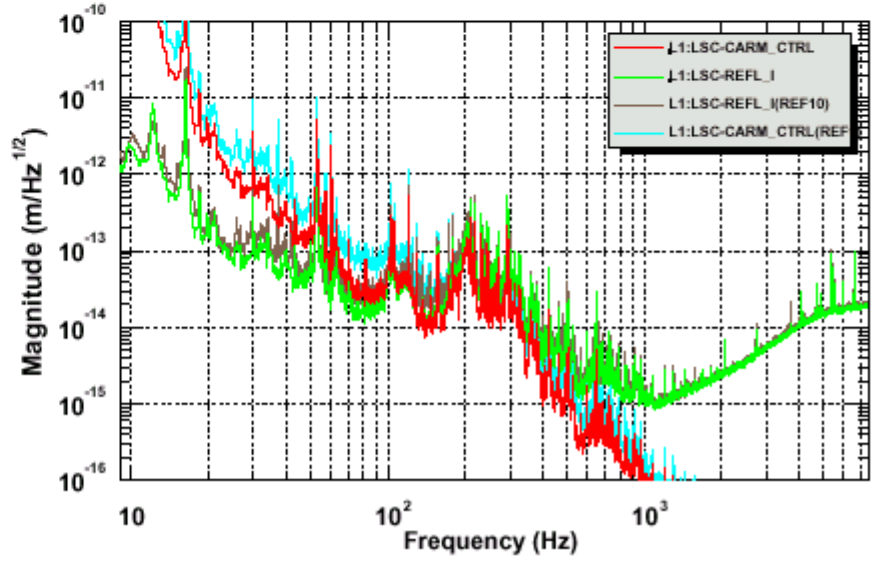
Common Mode Arm Noise Spectrum



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Calibration

- Updates made three times during run
- Calibrations synchronized between sites
- CARM and DARM control signals stable within about ~5%
- AS_Q and REFL_I &Q signal varied by perhaps ~20-30% over the run due to alignment and offset drifts (calibration uncertainty determination in progress)
- Indicates there are slow changes in noise spectrum that occur during long locked stretches- due to e.g. tidal shifts at LLO (tidal feedback servo not yet implemented at LLO)
- How frequently should we calibrate in order to maximize ability to analyze data?
- A standard procedure for calibration that is automated as much as possible would be very welcome in future runs. Present method is time consuming and requires several hours of precious “prime time”

LLO Calibration Stability

PRELIMINARY – UNCERTAINTIES NOT YET ESTABLISHED

	12/31	1/6	1/14
CARM_CTRL	0.86e-9	0.85e-9	0.83e-9
DARM_CTRL	0.86e-9	0.85e-9	0.83e-9
MICH_CTRL	9.47e-9	9.1e-9	9.4e-9
AS_Q	1.63e-14	1.4e-14	1.22e-14
REFL_I	5.63e-14	5.0e-14	4.75e-14
REFL_Q	8660e-14	7400e-14	6970e-14

Hardware Reliability

- **Microseismic feed forward worked very well except in 2 cases where shape of microseismic peak changed significantly. Ability to adapt filters to accommodate other shapes is needed.**
- **Hardware failures during run were minor:**
  - **GDS clock True Time server Y2K+2 fault promptly fixed by setting up alternate time server on UNIX workstation.**
  - **One disc on RAID system for frame builder failed for 1 sec frames (but without harm since RAID)**
  - **Cold weather was a cause for concern in air compressor system due to residual water. Added to operator watch list**
- **Need to have operator visibility into data logging process:**
  - **EPICS screen of frame builder diagnostics with web interface developed during run (Chethan). Added to operator checklist for future runs.**
- **Updated on-line operator check list seemed to work well, insuring that even obscure sub-systems are looked at regularly.**
- **When seismic noise was too high to maintain lock (typically weekdays) we operated with a single arm locked.**
  - **Is this useful?**

Software Reliability

- CDS software was robust
- DCU's operated without reboot, and very limited problems in general with data acquisition
- Except for GDS Time Server Y2K+2 problem, operation was smooth and almost trouble free

Realtime Data Monitoring Suggestions:

- Realtime lock statistics are nice to have as a monitor of shift performance
- More data monitors that display realtime data in a way that is helpful to the on-shift staff for hardware monitoring and data quality
  - » AS_Q BLRMS monitor created (by Ed Daw) during run to look at time evolution of AS_Q signal in particular frequency bands is a good example of a useful monitor
  - » LIGO could create a list of DMT monitor items that the project would like to have the LSC provide.
  - » Use Data Viewer to display trends of data monitors
  - » Develop standards for interface and display of DM variables
- Tedious to compare spectra which use different calibration files - an easy way to overlay data from different calibrations would be helpful

More realtime suggestions…

- **Some additional live data quality factors for noise performance during run will be helpful for future runs. Example:**
  - **Live spectrograms using spectrum analyzer (last day of run) => easy to see burst noise**
  - **Enhancements to data quality monitor such as trigger rates, histograms of time between triggers, trend lock length vs time of day**
  - **Monitor injected cw signal long term as a realtime measure of spectral quality and calibration (in progress – Sergei Klimenko)**
  - **R0 and integrated R**3 (enhancement of Sam Finn's binary inspiral model and BENCH program to work with realtime data), etc.**
  - **Probability distributions of the signals/signatures to look for. Ability to discriminate non-Gaussian behavior is critical.**

Environmental Couplings

- Operation over New Year's holiday was a good choice seismically for LLO. That, plus rain two days, reduced logging and other outdoor activity which contribute to overall seismic environment.
- Auto traffic on-site across cattle guard couples pretty strongly into AS_Q, REFL_I, and REFL_Q signals. We should remove cattle guard since it is no longer needed (and investigate whether the one close to the highway degrades the data too.)

Human Factors

- **Shift lengths**
  - 10 hour shifts seemed to work very well. Operator feedback uniformly positive.
  - Operator shifts: 7am – 5pm, 4 pm – 2 am, and 10 pm – 8 am so that there is a big crew during prime operating time – very helpful for calibrations and house keeping chores
  - Only one operator on day shift Mon-Fri.
    - This should be changed – too stressful with one because of the amount of day time activity that comes through the control room, really need two people
  - Scientist shifts were 12 hours. Some positive feedback but lots of negative feedback that this was too long and people were too tired for there to be much effective overlap.
  - Albert Lazzarini has raised the issue of beds on site for driving safety
- **Operator responsibilities**
  - Uniform positive response from scientific staff regarding quality of operator support to maintain operation, fill out check lists, etc.
  - Operator shift check list worked well, but a bit tedious. It ensures that someone looks at the operational status of a large number of systems at least three times per day, but automated alarms can replace some of this in the future.

Human Factors…

- **Scientist responsibilities**
  - » **Less well defined, but there is a very wide spectrum of operating experience of scientists on shift. Strong operator support makes this issue less pressing at present, but we should think about how to make this a more effective role for the scientists on shift to act as representatives of the LSC to "QC" the data during future science runs**
    - – **Strengthen intellectual coupling of scientists to the operational activities**
    - – **Task lists evolved during the run, continue to think about how to use these effectively**
    - – **Most scientists were very conscientious in carrying out shift responsibilities**
    - – **Hard to quantify how to actively check for problems *in addition to what's on the list,* but more guidance for future runs will be helpful**

Human Factors…

- One of the biggest benefits of E7 is that it got a large number of people to look at the data and consequently unanticipated instrumental signatures were identified in the data. This is a very good start to a role we want to foster for scientific shift taking
- Suggestions
  - LSC operations bootcamp preparatory to S1
  - Feedback that more discretionary time while at site would be useful to give visitors chance to work on analysis software and other related projects rather than just be on shift all the time – another motivation for shorter shifts

Human factors…

- **Coordination between LIGO sites and GEO, ALLEGRO**
  - » **Continue to evolve master run schedule list**
    - – **Examples: Calibrations periods, signal injections, planned operational status of LSU bar, scheduled disruptions, etc.**
    - – **Some of this was done for E7, but we can enhance for next time**
    - – **Coordination with ALLEGRO needs to improve**
  - » **Enhance usefulness of daily run coordination calls**
    - – **It's a valuable resource, how do we make the most use of it?**
    - – **Review of structured information such as daily run summaries, planned schedule changes, other?**
    - – **Informal telephone calls between control rooms worked very well for quick communication of status information**

Human factors…

- **Continue to develop operator documentation:**
  - **We had procedures for how to put IFO in robust mode, low noise mode, single arm lock – but they got revised a lot during the run.**
  - **Need to continue adding to and updating this documentation.**
  - **More and better on-screen help files on control screens. E7 run helps focus attention on this need.**
    - **What we have is very helpful, but we need to add to it**
    - **More details, standard formatting to improve readability, add names of experts, etc.**

Final suggestions

- **Auto files are great, need more utilization – but need to be carefully implemented**
  - BURT files to change operating mode but: *need to update filters after BURT*
  - AUTOLOCK script for acquire of lock in recombined mode was very helpful
  - Expand these tools for the next run.
- **More system level documentation. What we have already available has proven very useful - especially helpful for quick access to system level information and to those less familiar with system as a quick learning tool.**
  - block diagrams of optical configuration, control topologies, CDS architecture
  - Additional diagrams such as filter topology, etc., would be helpful
- **Greater organization of e-log to find important information**
  - Reference spectra
  - Procedures and operating instructions
  - Configuration changes
- **Time to begin implementing Systems Identification concepts?**
  - Quantitative methods for determining when to recalibrate
  - Generalization of micro-seismic feed forward filters?
  - Identification of recalibration points?

Make sure both sites benefit from each other's experience!