Global Diagnostics and Detector Characterization

9th Marcel Grossmann Meeting

Daniel Sigg, LIGO Hanford Observatory

Organization

- ❑ **Detector Characterization Working Group**
  - ➤ Leader: Keith Riles
  - ➤ Part of the LIGO Science Collaboration
  - ➤ Development of software algorithms
    - ➤ Transient analysis
    - ➤ Performance characterization
    - ➤ Data set simulation
    - ➤ Reduced data sets

- ❑ **Global Diagnostics Subsystem**
  - ➤ John Zweizig, Daniel Sigg
  - ➤ Hardware and software infrastructure

Diagnostics Tasks

□ **Detector Characterization**

  ➢ Calibration

  ➢ Detector response, inter-system dependencies & cross-couplings

  ➢ Machine artifacts

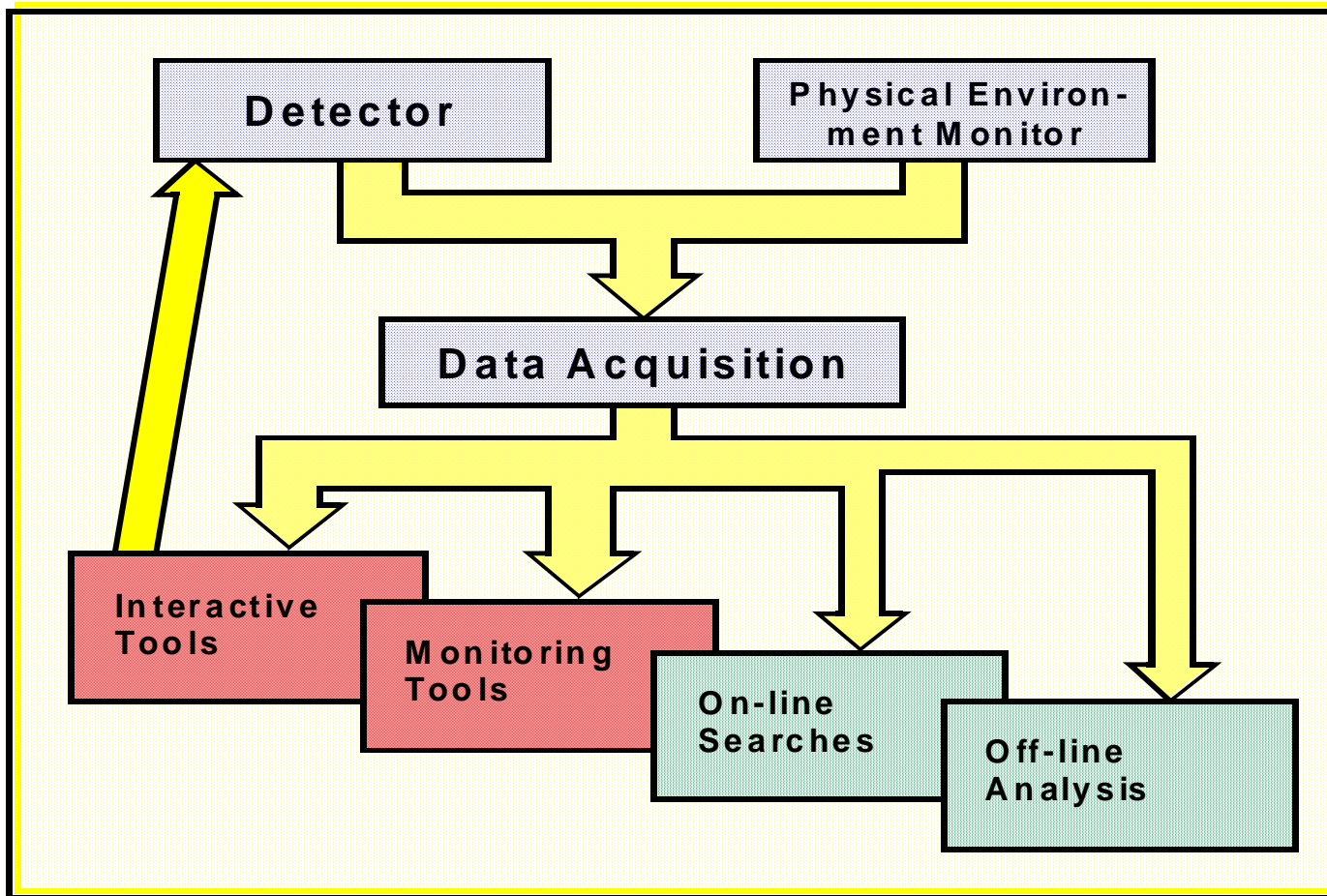□ **Maintain Performance**

  ➢ System identification (Feedback control)

  ➢ Continuous operation monitoring

□ **Detection Confidence**

  ➢ Understand the physical environment

  ➢ Understand the auxiliary degrees-of-freedom

$\Rightarrow$ GW signal $\therefore$ 1% of data rate (3MB/s/ifo)

System Overview

Basic Approach

❑ **Diagnostics Test Tool**

  ➢ Emulates a measurement instrument

  ➢ Interactive graphical user interface

  ➢ Stimulus-response tests

❑ **Data Monitoring Tool**

  ➢ Maximum flexibility

  ➢ Interactive command line interface & background processing

  ➢ Simultaneously look at all channels

Diagnostics Test Tool

❑ **Supported tests**

  ➢ Fourier tools: power spectra estimates, coherence, etc.

  ➢ Swept sine measurements

  ➢ Multiple sine response measurements

  ➢ Triggered time series measurements

❑ **Supports many excitations & measurement channels**

❑ **Site-wide & GPS/UTC synchronized**

❑ **Interfaces digital feedback controllers**

❑ **Off-line capabilities**

Setup

Plot

Data Monitoring Tool

- ❑ Multi-processor SUN workstations
- ❑ Input:
  - ➤ High bandwidth distribution of on-line data (1000baseSX broadcast)
  - ➤ Alternatively: Frame files from disk
  - ➤ Shared memory partitions (~10 sec of data)
- ❑ Output:
  - ➤ Triggers/veto to event database
  - ➤ Alarms to control room
  - ➤ Trend channel recording
- ❑ C++ class library
  - ➤ Container objects for time and frequency series, etc.
  - ➤ Signal processing library: FFT, etc.
  - ➤ Interactive environment & graphics based on ROOT

Micro-Seismic Monitoring

LHO Microseism Signal with Calibrations, 11/99 to 2/00, from Gladstone High School

Channel Statistics
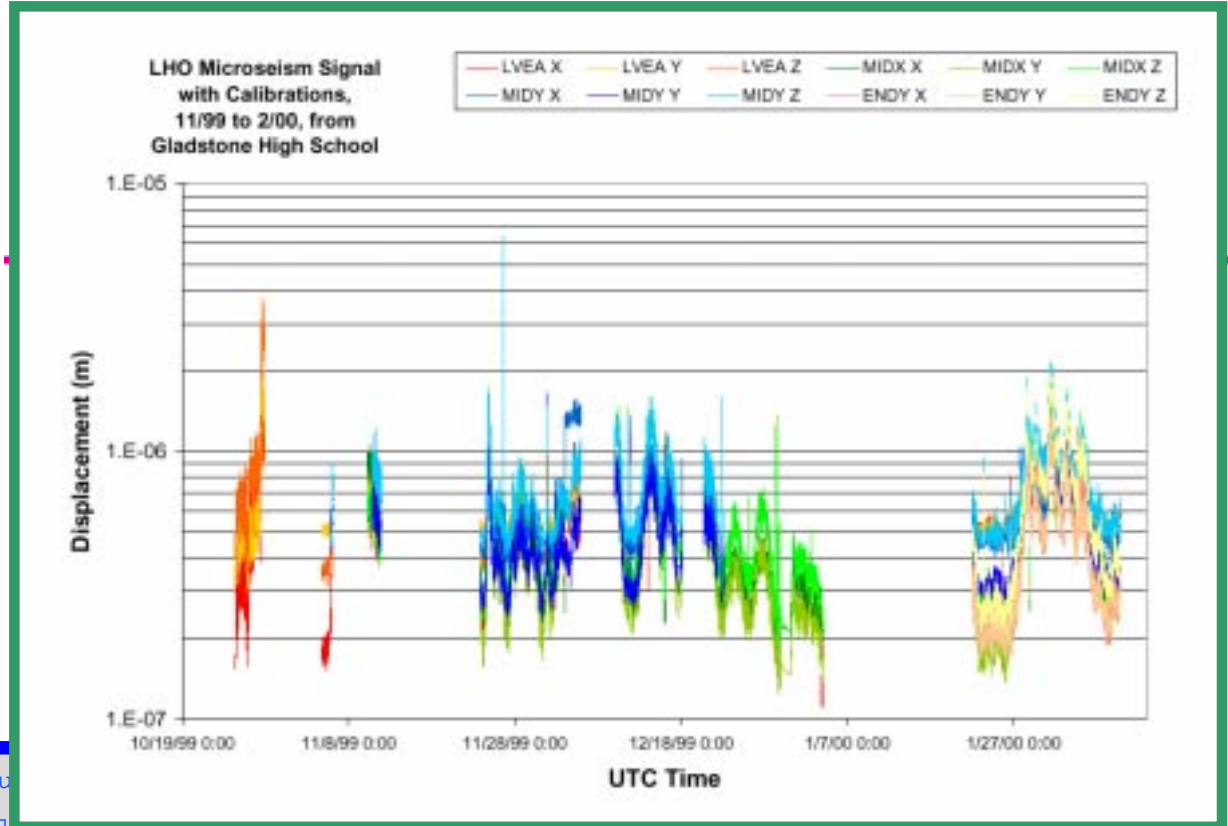
```
Report produced for 28793 seconds to Ju
=============================  Channel Statistics
Flag Channel                       Frames   On    Off   Repeat    Avg       Sigma     Minimum    Maximum
     H0:PEM-MX_TILTT               28793 1000 ee00      19     4319.97     19.04        4298       4383
     H0:PEM-MX_SEISZ               28793 0000 0000       9      -97.57     46.52       -1117        939
     H0:PEM-MX_SEISY               28793 0000 0000       7     -106.64     32.65        -737        481
     H0:PEM-MX_SEISX               28793 0000 0000       7     -257.45     62.06       -1717       1225
     H0:PEM-MX_TILTY               28793 0800 f400      30     2478.16     67.30        2199       2971
     H0:PEM-MX_TILTX               28793 c000 0000      28    -8842.84     70.82       -9563      -7929
     H0:PEM-MY_TILTT               28793 0000 e000      17     4012.75     36.57        3967       4107
```
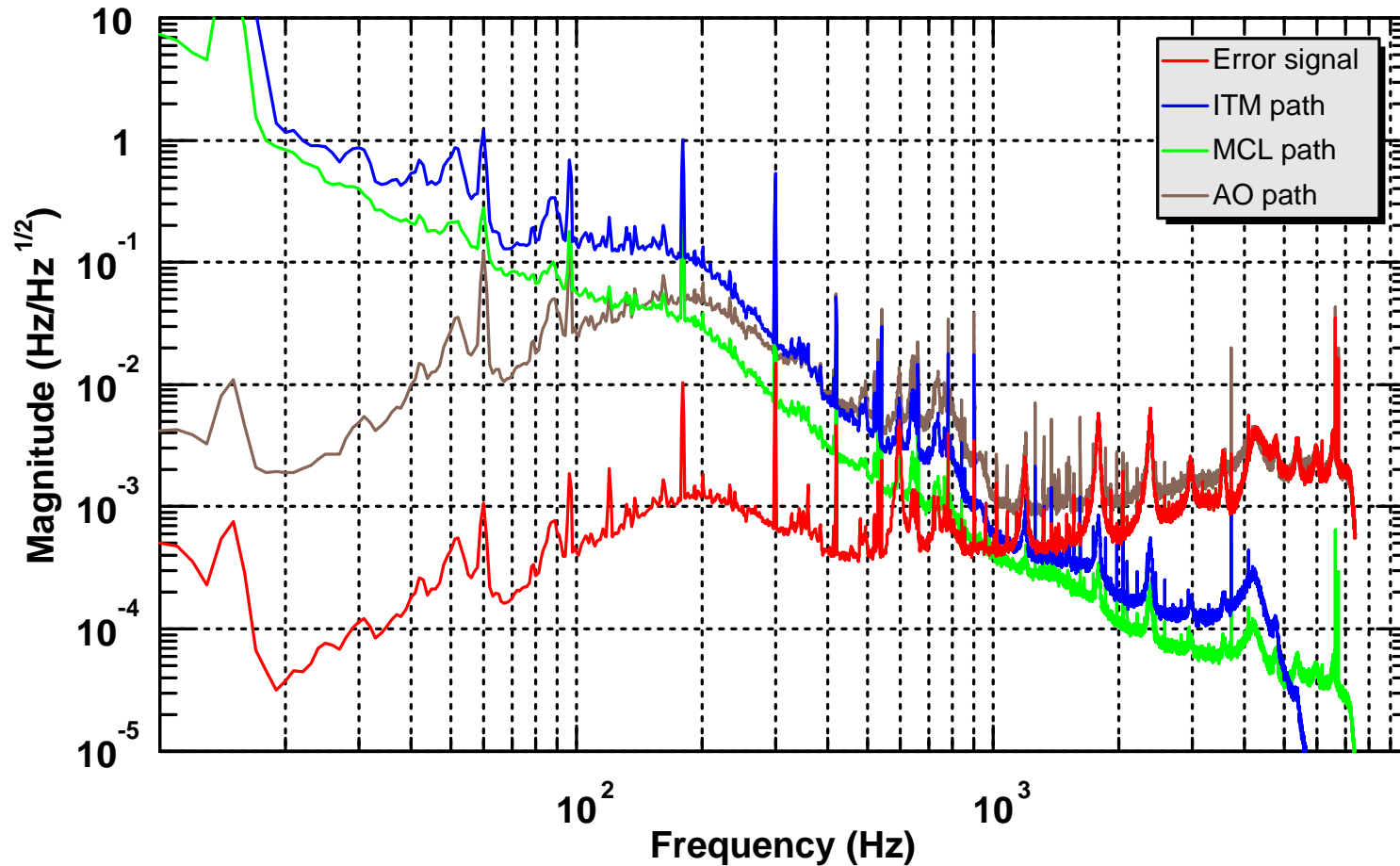
Time Frequency Analysis
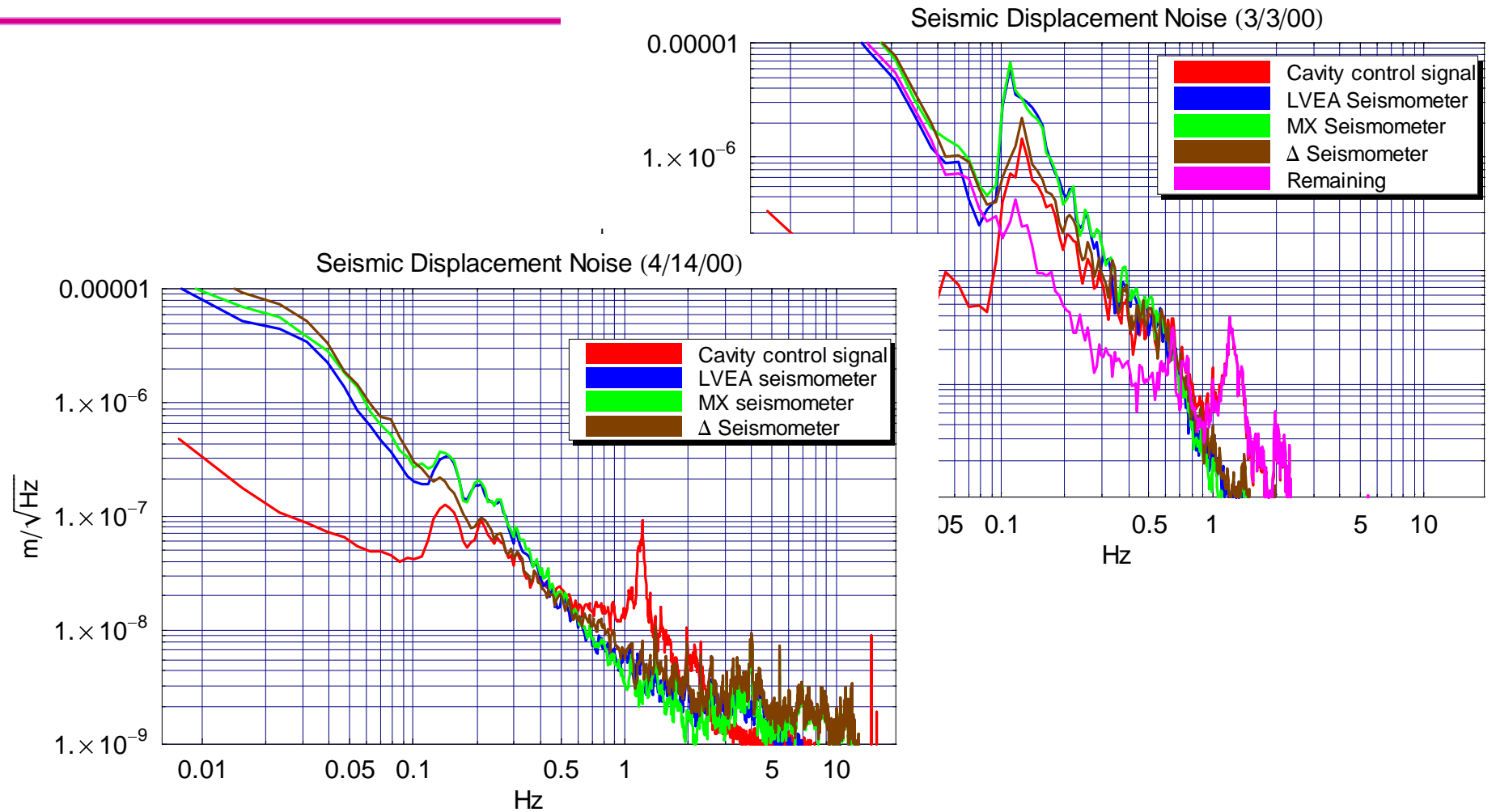
LIGO I
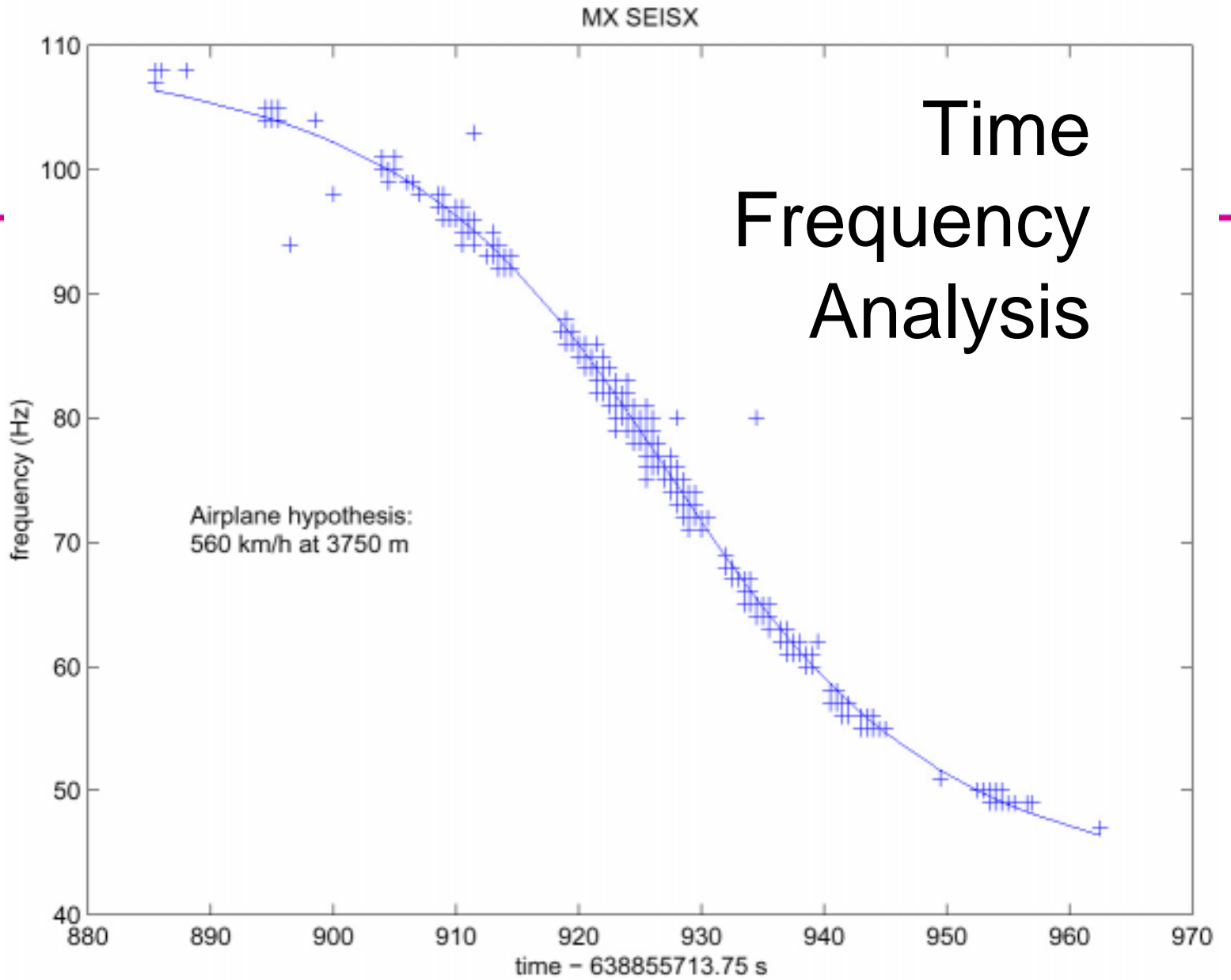
Power spectrum estimate: Frequency Noise

T0=14/04/2000 03:30:00   **Avg=100**   **BW=1.49999**

Seismic Displacement

Seismic Displacement Noise (3/3/00)

Legend:
- Cavity control signal
- LVEA Seismometer
- MX Seismometer
- Δ Seismometer
- Remaining

Seismic Displacement Noise (4/14/00)

Legend:
- Cavity control signal
- LVEA seismometer
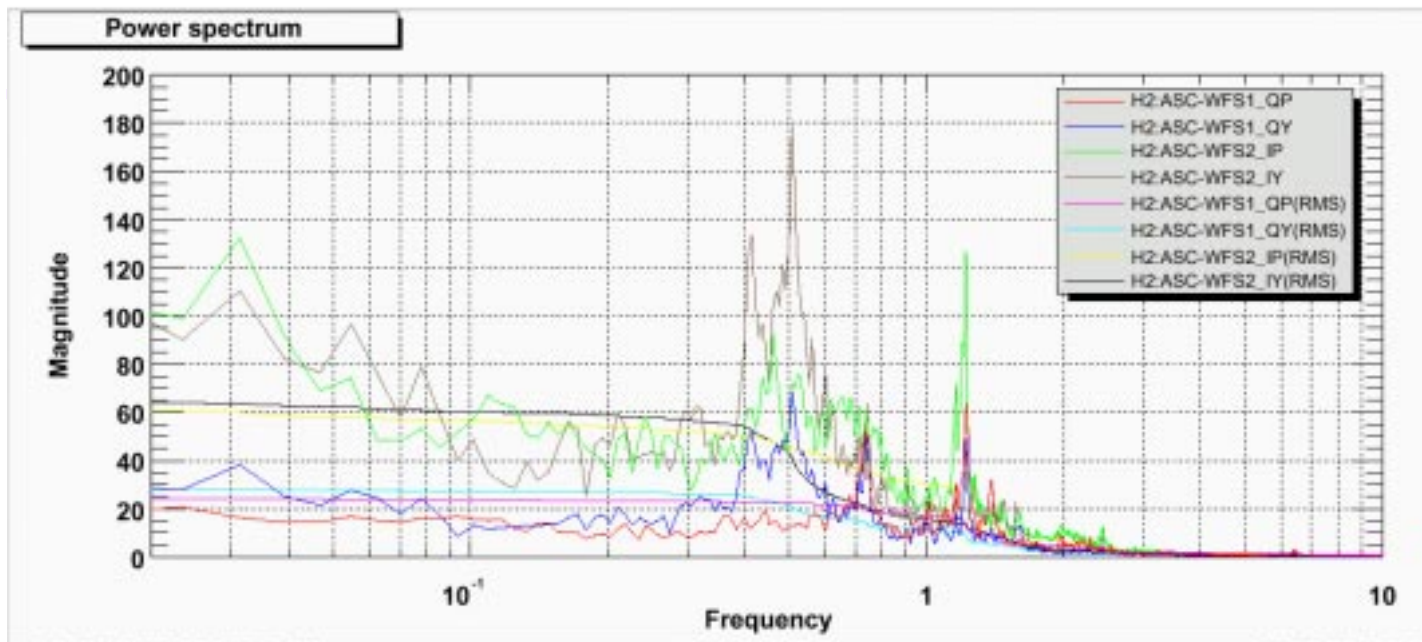- MX seismometer
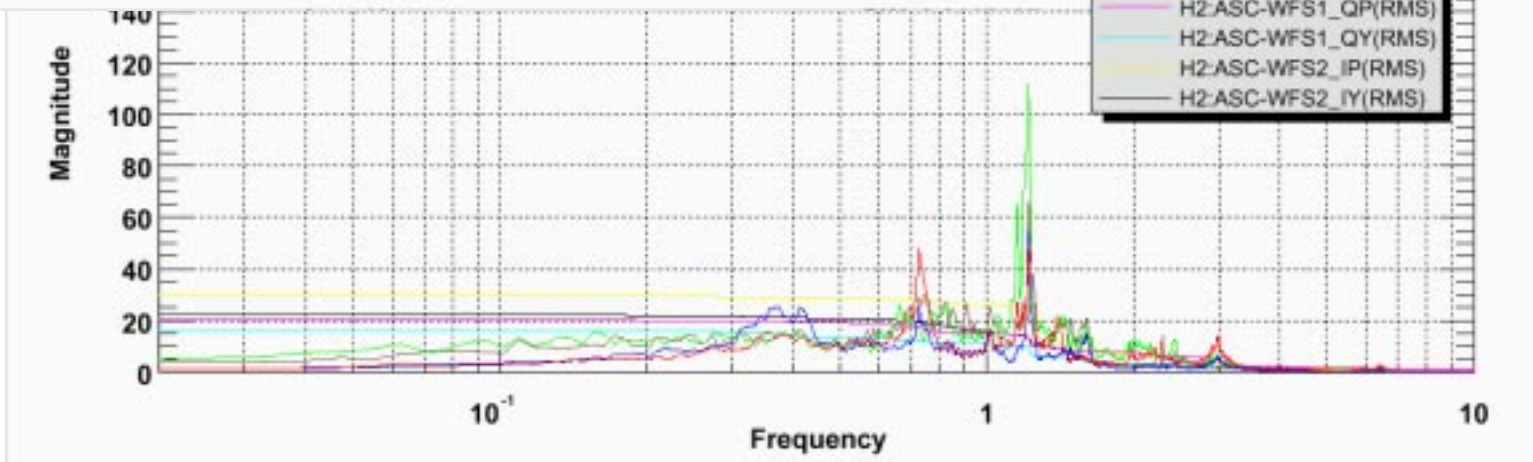- Δ Seismometer

Axes: $m/\sqrt{Hz}$ vs Hz
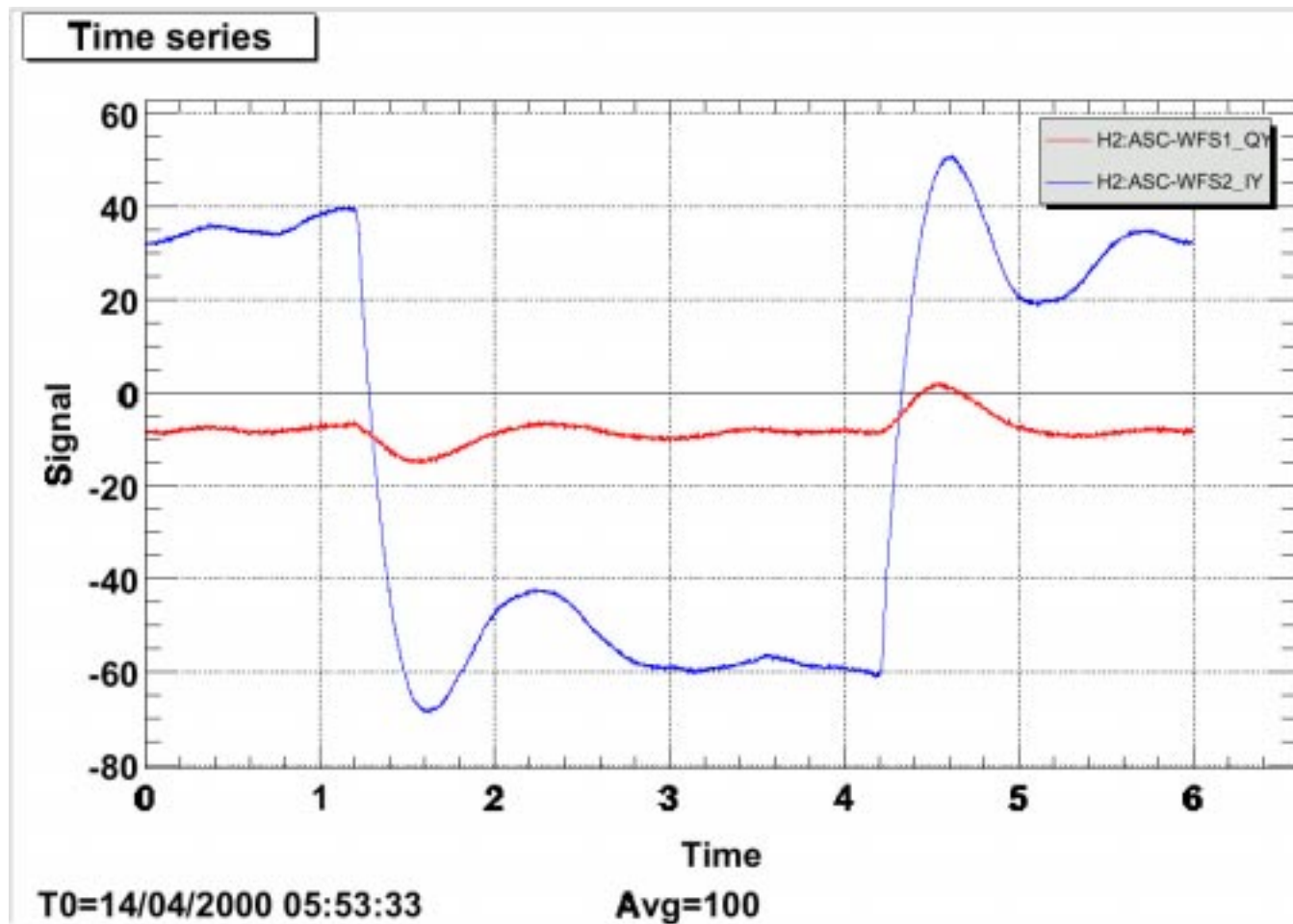
Alignment Fluctuations

before

after

Auto-Alignment: Step Response

Conclusions

Combination of

- ➢ High performance data acquisition system
- ➢ 24 hour disk cache
- ➢ New software and analysis tools

has enabled

- ➢ Fast learning curve
- ➢ Emphasis on analysis rather than data gathering
- ➢ Greatly enhanced remote diagnostics