LIGO In-Vacuum Sensors

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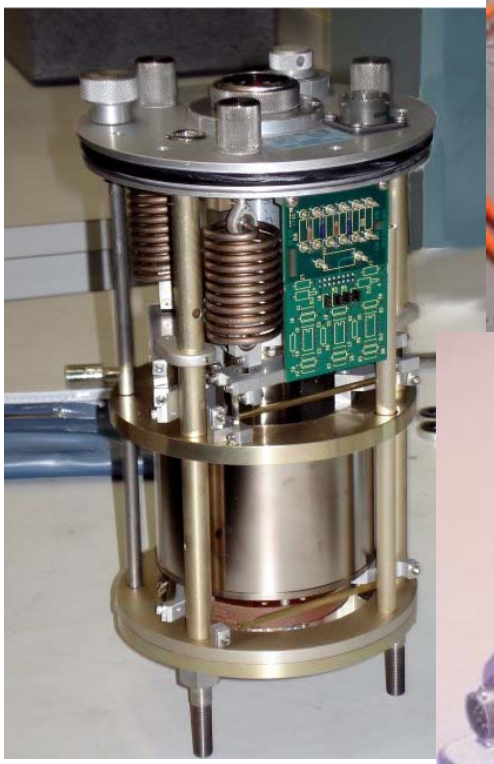
Outline

- Overview of types of geophones
- How LIGO uses its geophones
- LIGO's assembly, testing and problems for each type
- Future solutions
- Summary

Types of Geophones

- GS-13
  - 1-D Seismomter
  - Suspended cylindrical proof mass
  - Resonance: 1 Hz
  - Requires mass locking
- STS-2
  - 3-D Seismometer
  - 3 identical suspended mases
  - Resonace: 0.08Hz (or 1Hz)
  - Requires mass locking
- L-4C
  - 1-D Seismometer
  - Suspended cylindrical proof mass
  - Resonance: 1 or 2 Hz
  - Does not require mass locking



LIGO System Uses
In vacuum pods

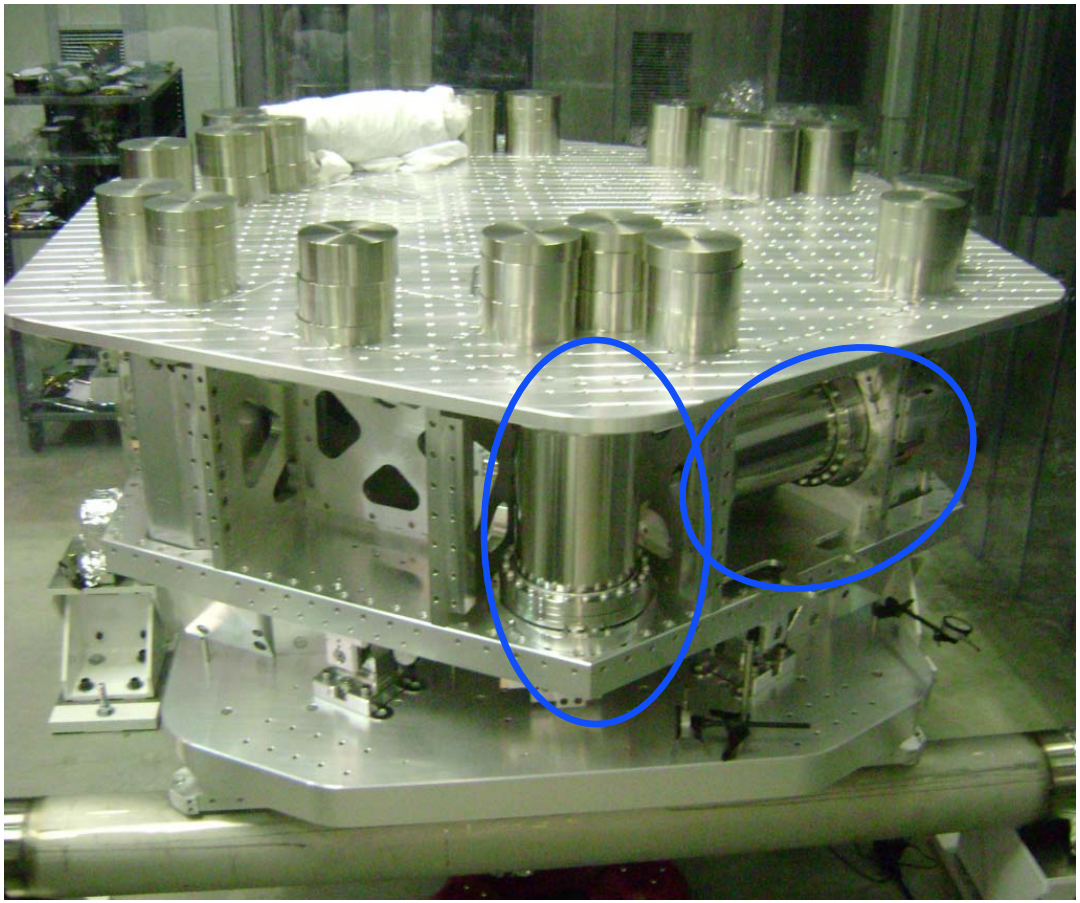
Instruments in vacuum pods

- Dirty seismometers need to go in clean vacuum systems
- Solution: Instruments are mounted to a base-plate, then enclosed inside a vacuum-sealed pod.
- Assembled pod mass
  - GS-13: 71 lbs.
  - STS-2: 110 lbs.
  - L-4C: 18 lbs.
- GS-13 and STS-2 need to be locked and unlocked once in vacuum, one has to do this remotely.

LIGO System Uses
HAM ISI

- Single Stage seismic isolation platform

- Needs (HAM-ISI):
  - 6 GS-13 pods per HAM ISI (108 total!)
  - Additional 6 if a LASTI HAM-ISI is built

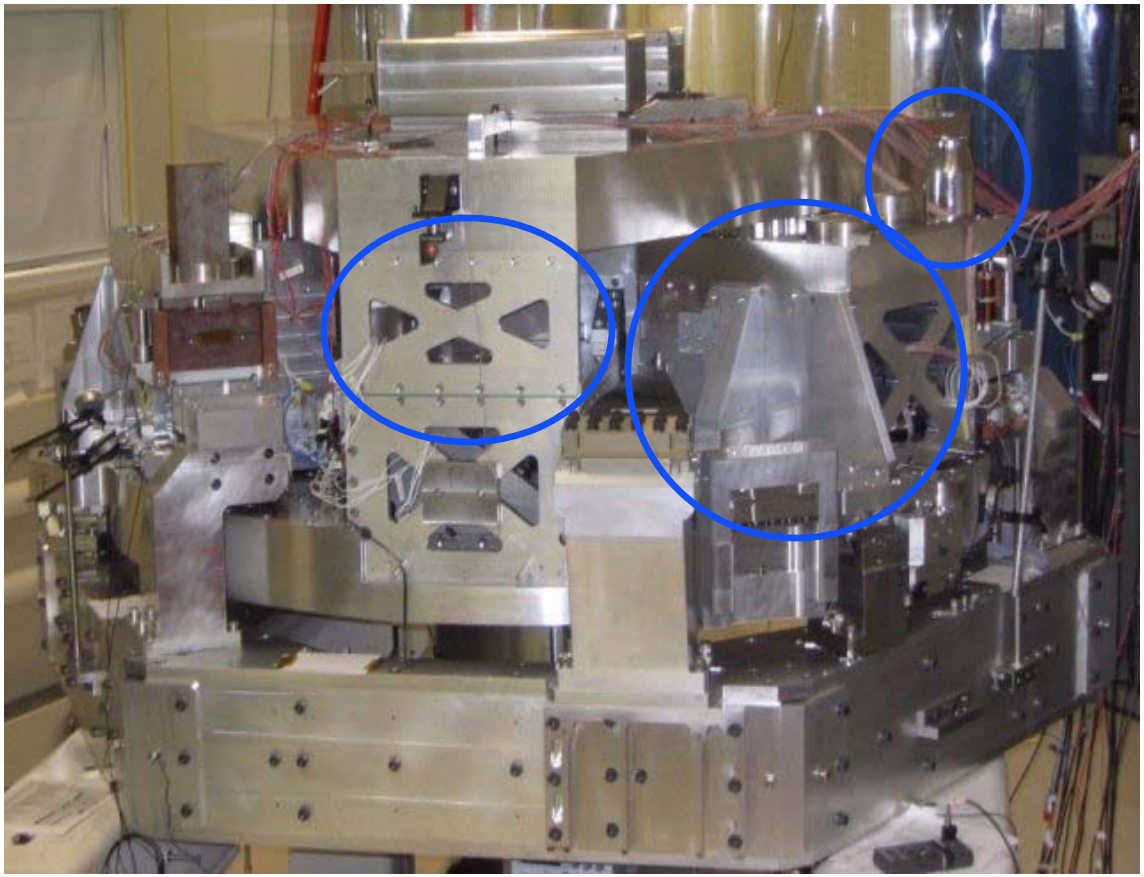


The HAM ISI mid-assembly

LIGO System Uses BSC ISI

- Double Stage suspended seismic isolation platform
- Needs (per BSC ISI):
  - 6 GS-13 pods (96 total)
  - 3 STS-2 pods (48 total)
  - 6 L-4C Pods per BSC ISI (96 total)

Advanced LIGO needs 354 in-vacuum seismometers if we include prototypes.



The BSC ISI mid-assembly at LASTI

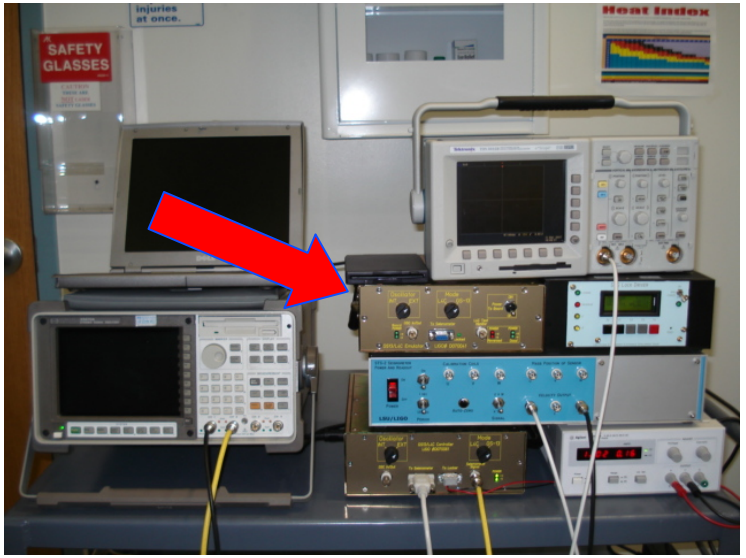
The LIGO GS-13
Assembly / Modifications

- Secure calibration coil using RTV and better chamfered set screws
- Modify locking mechanism to include electronically controlled 12V motor
- Replace internal circuit board with LIGO fabricated Pre-Amp board that includes
- Add bushing to top plate where locking rod exits to prevent precision of locking rod

The LIGO GS-13
Testing

- **Emulator**
  - Electronics box meant to simulate a podded GS-13
  - Used to test all cabling up to the point where it is connected to the pod to prevent incorrect pinning

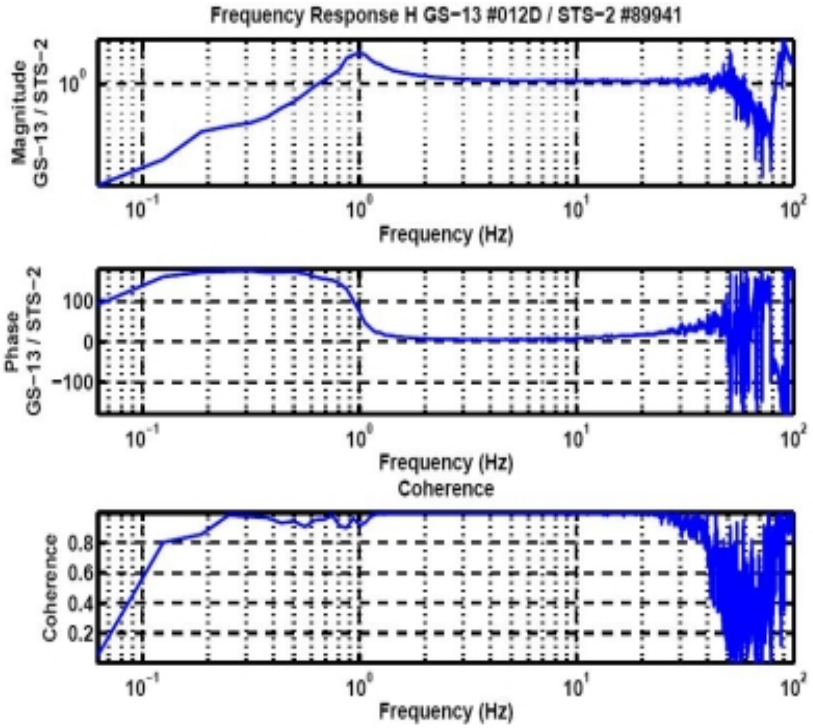
Red arrow points at emulator



Counter mechanism

- **Locking-Unlocking Cycle test**
  - Locking mechanism cycled 10+ times
  - Counted using multi-directional rotational counter mounted to locking rod

The LIGO GS-13
Testing



- **Huddle Test**
  - Frequency response taken against STS-2, including power spectra of both
  - Taken on 3x4 ft. level granite block
  - Taken before and after podding
- **Rigorous visual inspection**
- **Document all results in "Inspection Checklist," in seismic log, in IFO iLog, and travelers**
- **After all this testing (and and a few repairs) we still see problems at LLO**

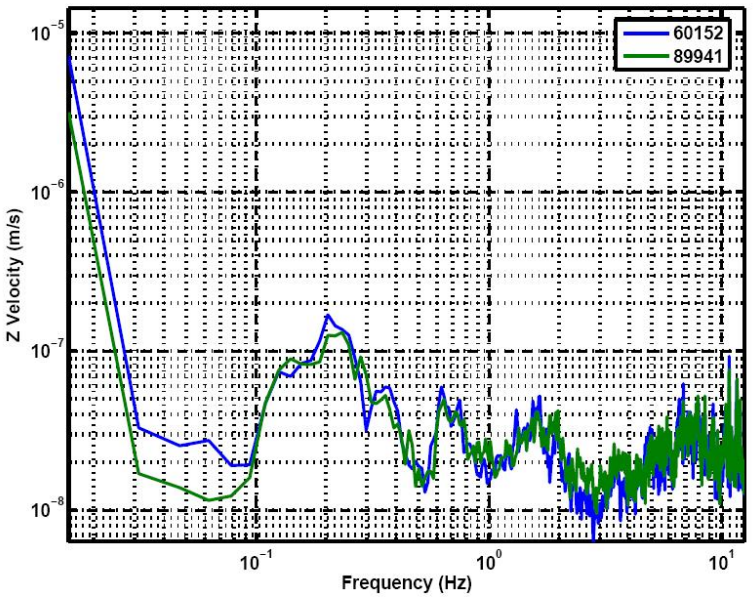
The LIGO GS-13
Problems

- **Mass does not unlocked because mechanism is jammed but double locking or too high of a voltage signal**
- **Mass does not unlock because not enough voltage reaches motor from cable from to racks**
- **Locking mechanism disengages, but mass remains frozen in container ring or falls too far**
  - GS-13 is not level because of baseplate mounting mechanism or sheered skeleton (i.e. shoddy craftsmanship)
- **Spectra looks like signal is not getting out**
- **Mass is slow to "fall off" container ring**

FAILURE RATE: 3 of the 14 eLIGO GS-13s have been deemed "unusable until further investigation."

The LIGO STS-2
Assembly / Modifications

- No major modifications, just locking motor system and readout cable
- Testing regime similar to GS-13 (includes huddle test and motor cycle test)
- No need for internal visual inspection



The LIGO STS-2
Problems

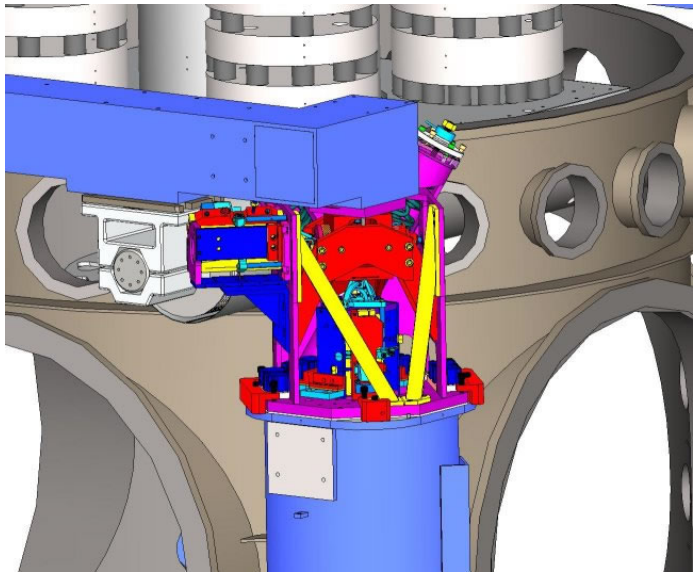
- Frozen or sticky locking screws maybe do to “gunk” from opening shield
- Internal moisture contamination, and defective electrolytic capacitors known to be problems do to age
- Those used for HEPI have had troubles as well, may be due to power outages on site
- Permanently railed velocity signal from initial cabling issues

FAILURE RATE: 6 of 17 STS-2 in LIGO have been sent to Quanterra for repair

The LIGO L4-C

Assembly / Testing

- Assembly / Modifications
  - No modifications to speak of other than insertion into vacuum pod
- Testing
  - No rigorous testing up to date, but 72 L-4Cs were used on L1's HEPI, and we have not seen any failures in 3+ years
- Problems
  - Some initial teething problems, but have worked nominally for 3+ years on HEPI



Future Work

- Modifying GS-13 structure to relieve locking necessity
  - Stanford group is looking into materials, shapes, and configurations that might provide this rigidity
- Is there a non-locking alternative? How important is the noise performance for the HAM? Should we ask around?
- Modify baseplate and chamber so one can see proof mass bubble through feedthrough.
- Need to discuss quality control with the vendor.
- Trillium 240
  - Being tested at ETF.
  - No Mass Locking ("withstands 20 G half sine loading")
  - Vendor is responsive.

Summary

- Three types of instruments with which LIGO has had years of experience
- We've seen many different problems varying in severity in all three types. GS-13s seem the worst.
- aLIGO needs over *300 more*! At least 1 person-year of labor.
- Rigorous and well documented testing procedure is in development
  - Should consider mounting instruments on a shaker table to better characterize response.
- Looking into entirely new and improving current seismometers to increase reliability and longevity of seismic subsystems of LIGO
- We should not lock ourselves in to a design which is not robust.