LIGO Status Report

David Shoemaker

LIGO Project

G960073-00-D

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Organization of talk: From the outside in

- sites
- beam tubes
- buildings
- vacuum equipment
- detector, supporting research
- systems
- people
- plans

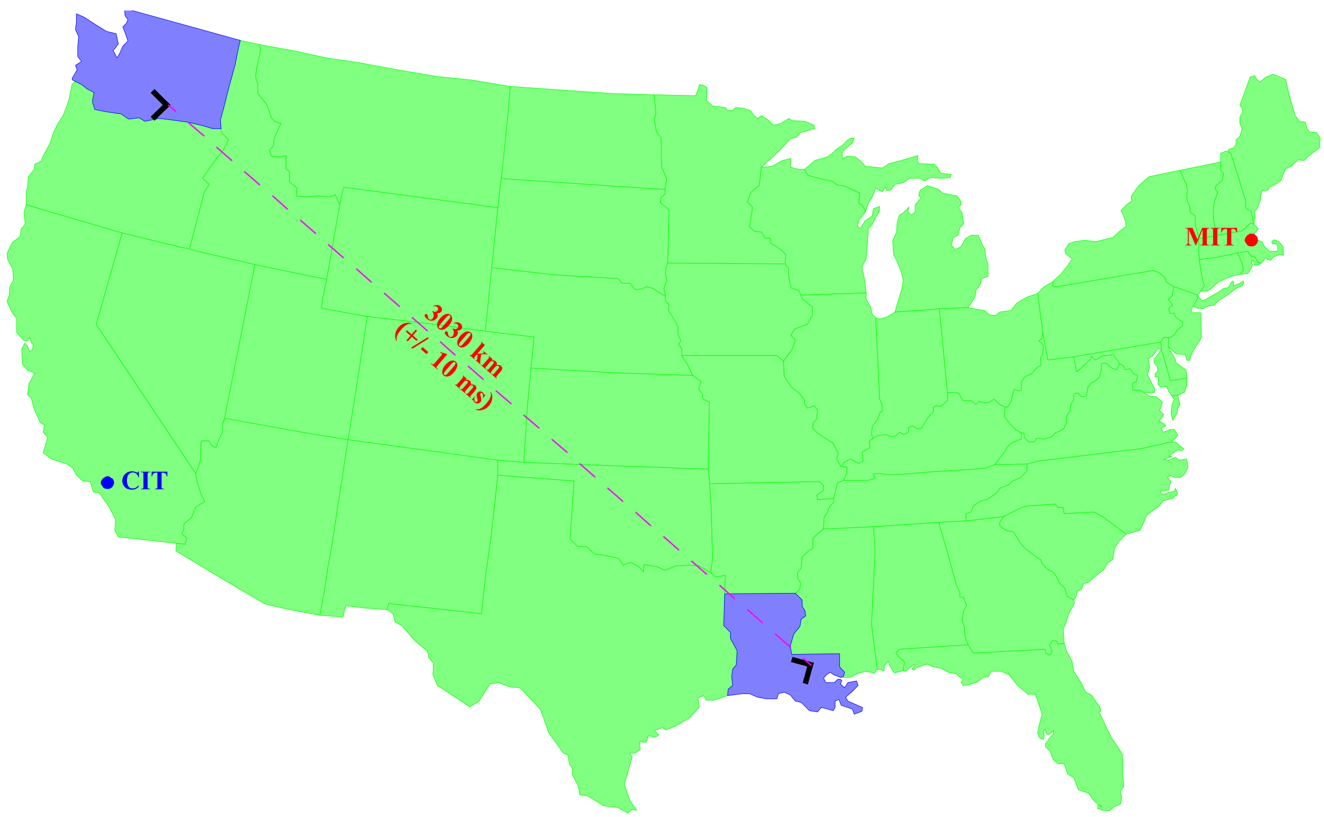
LIGO Sites

Hanford, WA

- 25 km from Richland, WA
- cleared, graded, and settling
- seismic noise survey completed

Livingston, LA

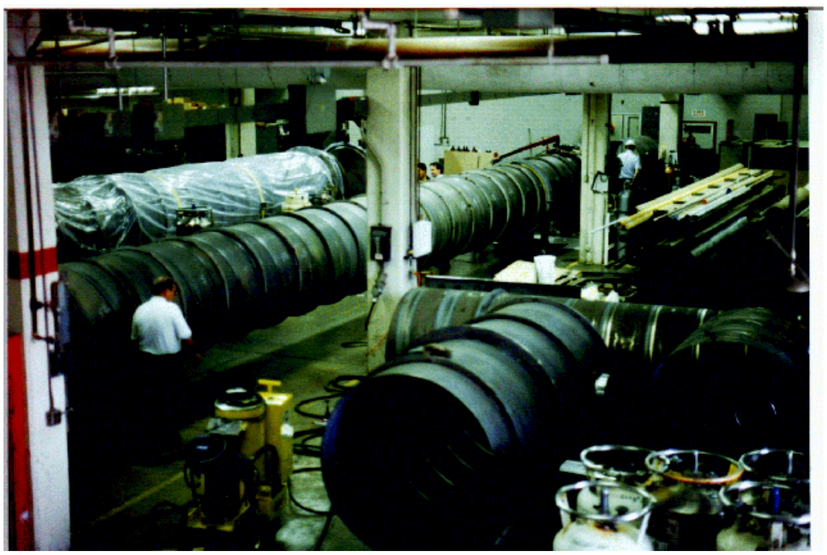
- 50km from Baton Rouge, LA
- dedication 6 July 95
- cleared; rough grading started



Beam Tube

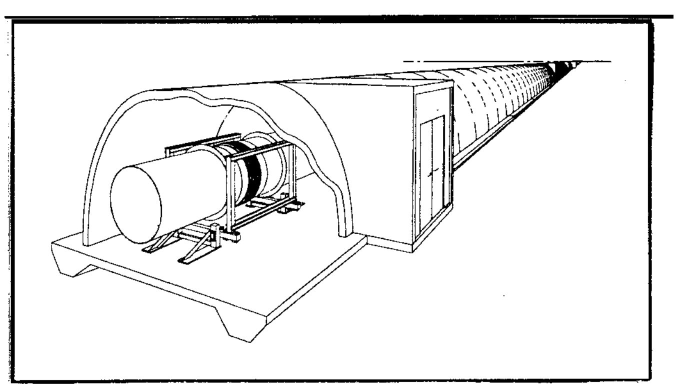
Beam Tube Chicago Bridge and Iron

- total of 16 km of 1.2 m diameter high vacuum
- tests of fabrication, cleaning, vacuum performed



Beam Tube Enclosure RM Parsons

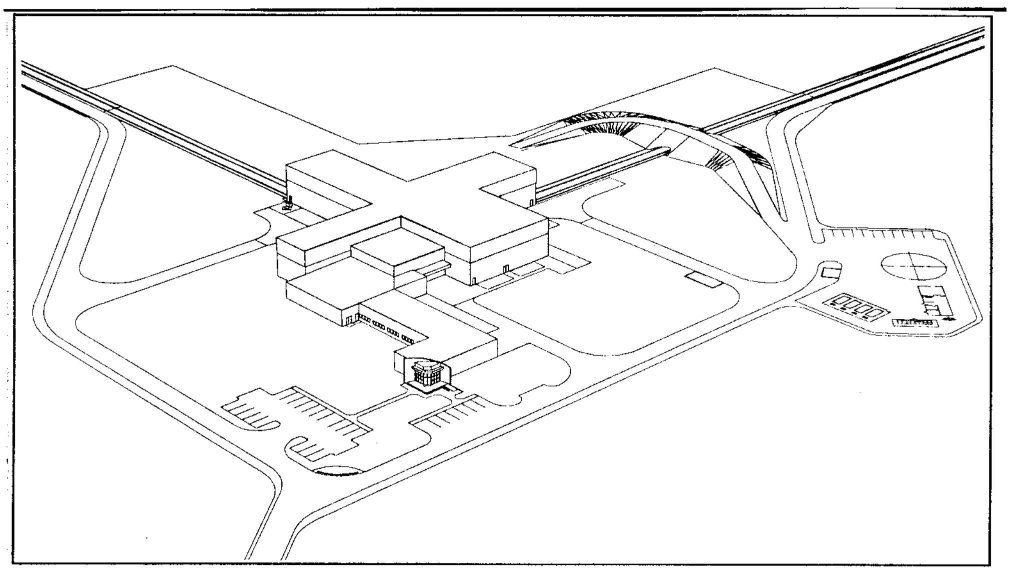
- supports and aligns Beam Tube, protects (from bullets!)
- final design, Oct 95



Buildings

Civil construction contract RM Parsons

- clean, quiet, temperature regulated environment
- work over requirements, realization from Dec 94 - Nov 95
- Preliminary Design Review in Nov 95

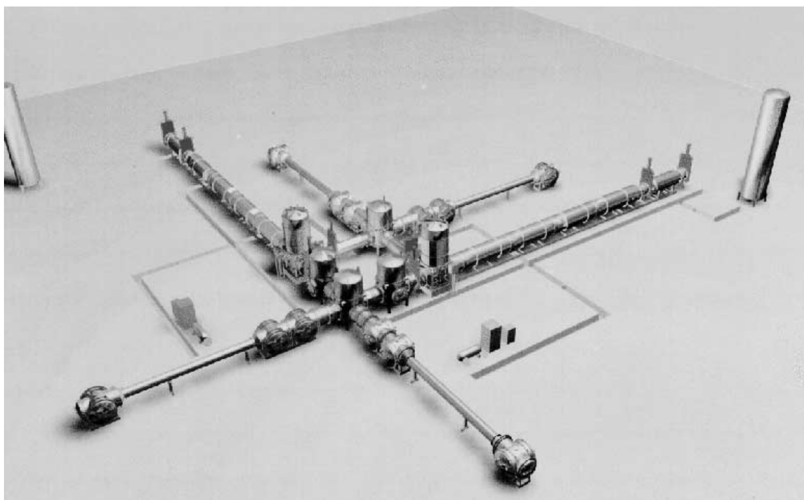


- WA: 2 full length or 1 full length, one half-length
- LA: 2 full length interferometers
- room to expand for additional interferometers

Vacuum equipment

Contractor selected

- Process Systems International
- provides flexible envelope for interferometer components
- allows isolation of elements, mechanical and electrical interface



- Preliminary Design Review in October, 95
- basic design of system, components well advanced

Detector: Laser

LIGO baseline was Argon Ion laser

- workhorse since 70’s
- well established control technology
- dated technology, obsolete in 2000

Solid State laser adopted as new baseline

- Nd:YAG or equivalent
- 1064 nm, near infrared wavelength

Advantages

- allows adiabatic increase in power—no mirror changes
- relaxed mirror surface requirements (longer yardstick)
- some better optical components available (modulators...)
- common with other GW efforts, industry momentum

Disadvantages

- reworking of (advanced) laser system, control design

Nd:YAG development effort

- contract for commercial development (early stages)
- internal effort to transfer technology
- incorporation into high-sensitivity instruments (5m, 40m)

Detector: Optics

Suspended Mode Cleaner

- 12m model of LIGO system
- control tests (locking, manual alignment)
- performance tests (beam jitter, passing of modulation)

LIGO Optics Pathfinder

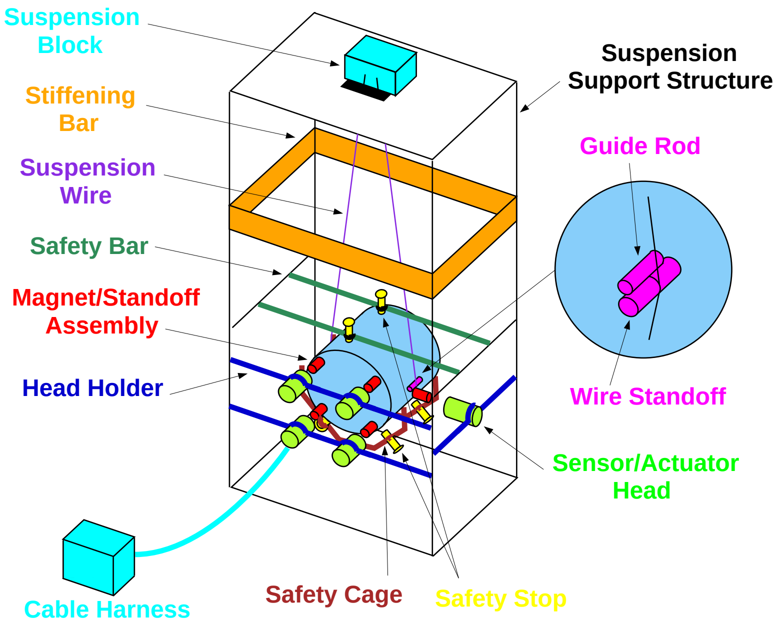
- to find path for industrial fabrication of LIGO optics
- substrates (Corning at present)
- polishing (several contractors)
- metrology (with help from NIST)
- coating (REO)

Coating: real progress

- development of requirements (FFT and analytic modeling)
- development of implications for coating (modeling: 0.1% uniformity required over ~10cm diameter)
- development of masking techniques for coating
- comparison of transmission, AR coating reflectivity measurements
- looks feasible!

Detector: Suspensions

Refinement of single sling suspension



- techniques for maintaining high substrate '*Q*' used
- refined versions of coil-magnet motor, LED-PD sensor
- version for 40m in preparation, soon to be installed
- designs for LIGO to follow

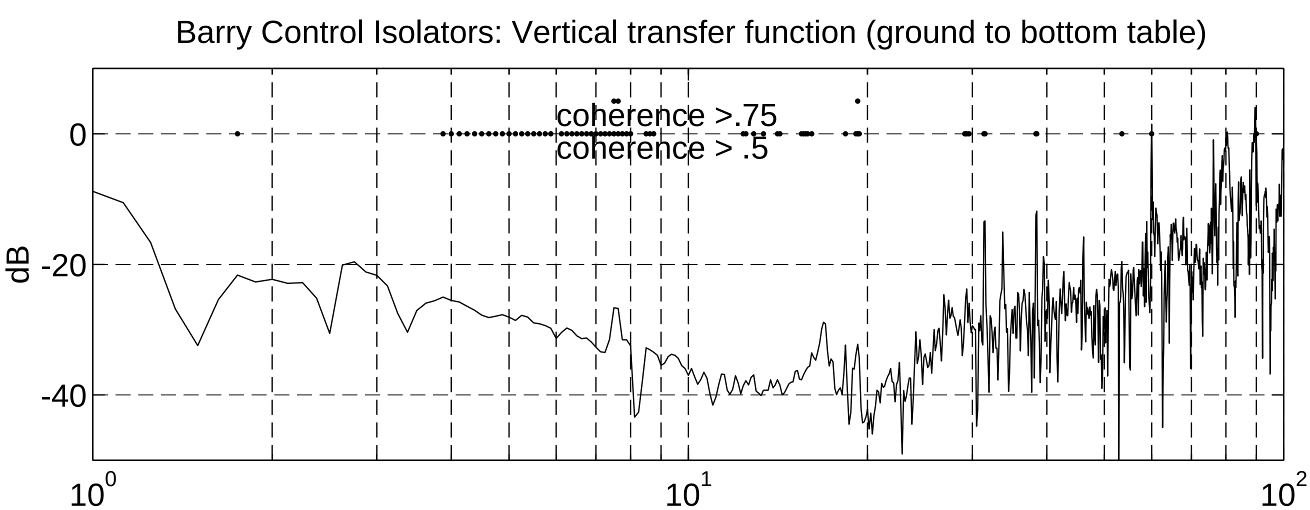
Measurement of *Q* for full-size mass underway

- electrostatic excitation
- study of sling, attachments
- no results yet

Detector: Isolation

Test of Commercial active vibration-isolation system

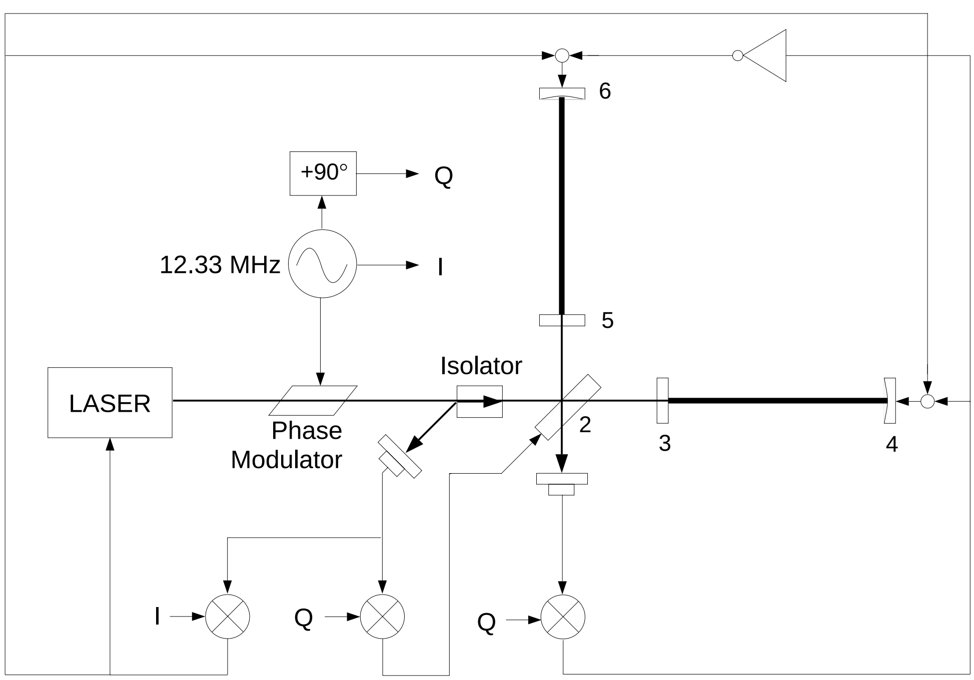
- ‘beta’ test of commercial system
  - › active servo system, measures ground noise, feedback
  - › six degrees of freedom
  - › at MIT, suppresses local non-stationary noise (trucks, subways...)
  - › for LIGO, can reduce controller dynamic range, up-conversion
- system functional
  - › required collaborative work between Barry, Inc. and LIGO staff
  - › significant reduction in noise: factor 100 in vertical, 2-30 Hz
  - › still short of prediction in horizontal, but
  - › makes qualitative difference in seismic environment



Detector: Length sensing/control

Recombined-Beam 40m interferometer configuration

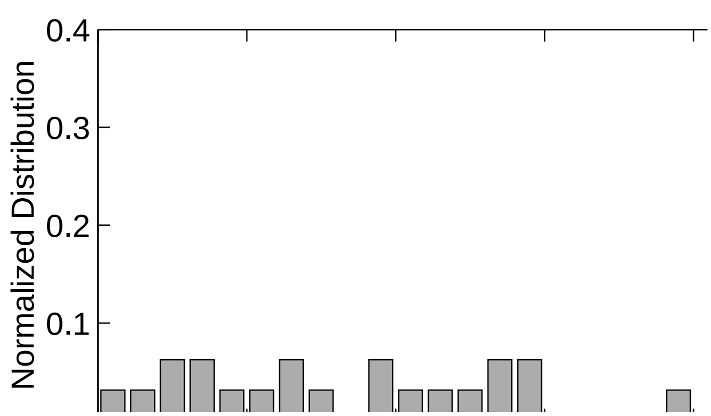
- Objective: give tests of models for dynamics of length control
  - › linear model (time constants similar to LIGO)
  - › acquisition (pendulum suspensions, correct D.O.F.)
- Requires optical configuration of LIGO
  - › recombination of beams from the two arms
  - › addition of recycling mirror
- Significant construction project finished
  - › modifications to in-vacuum components
  - › arms asymmetrized for modulation technique
  - › new modulation and control system



Detector: Lock Acquisition

Guided Lock Acquisition

- traditional brute-force method for acquiring ‘lock’ of cavity
  - system moves very quickly through resonance - non-adiabatic
  - very wide-bandwidth, high-force servo control
  - short effective duty-cycle
- better idea: reduce test-mass velocity
  - analyze signal output in time domain of unlocked system
  - calculate relative velocity of test masses
  - apply force X duration to ‘brake’ masses
  - THEN acquire lock
- success
  - considerably reduced locking time
  - valuable information for locking strategies
  - good technical experience for hardware/software



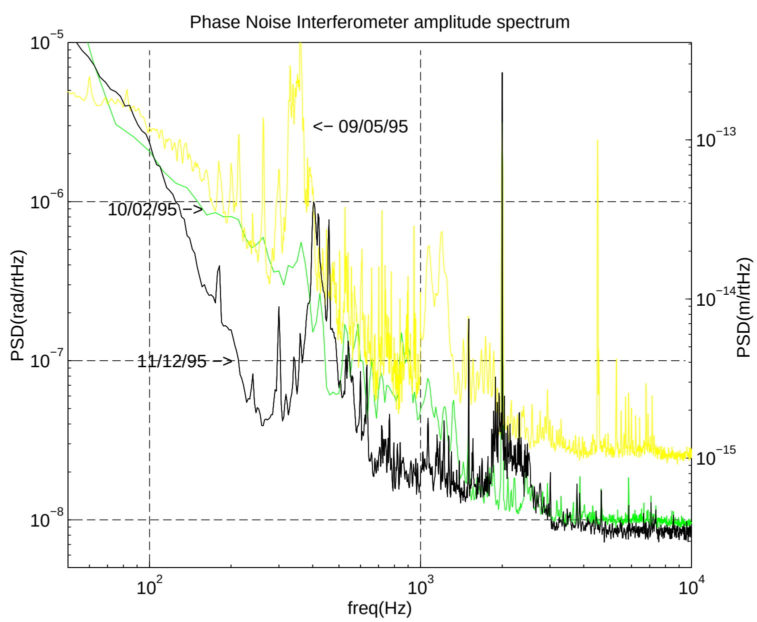
Detector: Phase Noise sensitivity

OBJECTIVES:

- demonstrate the initial LIGO phase sensitivity ($\sim 10^{-10}\,\mathrm{rad}/\sqrt{\mathrm{Hz}}$)
- develop the sensors, electronics, scattering control needed

Activity in '95 dominated by construction

- re-commissioning of vacuum system
- fabrication of seismic isolation system
- design, production of optic suspensions
- replication of the Argon pre-stabilized laser
- control and monitor systems
- recycled Michelson now being commissioned



Detector: And...

Alignment research

- detailed design of wavefront sensing system
- construction of complete tabletop model
- fully digital servo and control system
- system requirements, subsystem specifications for LIGO

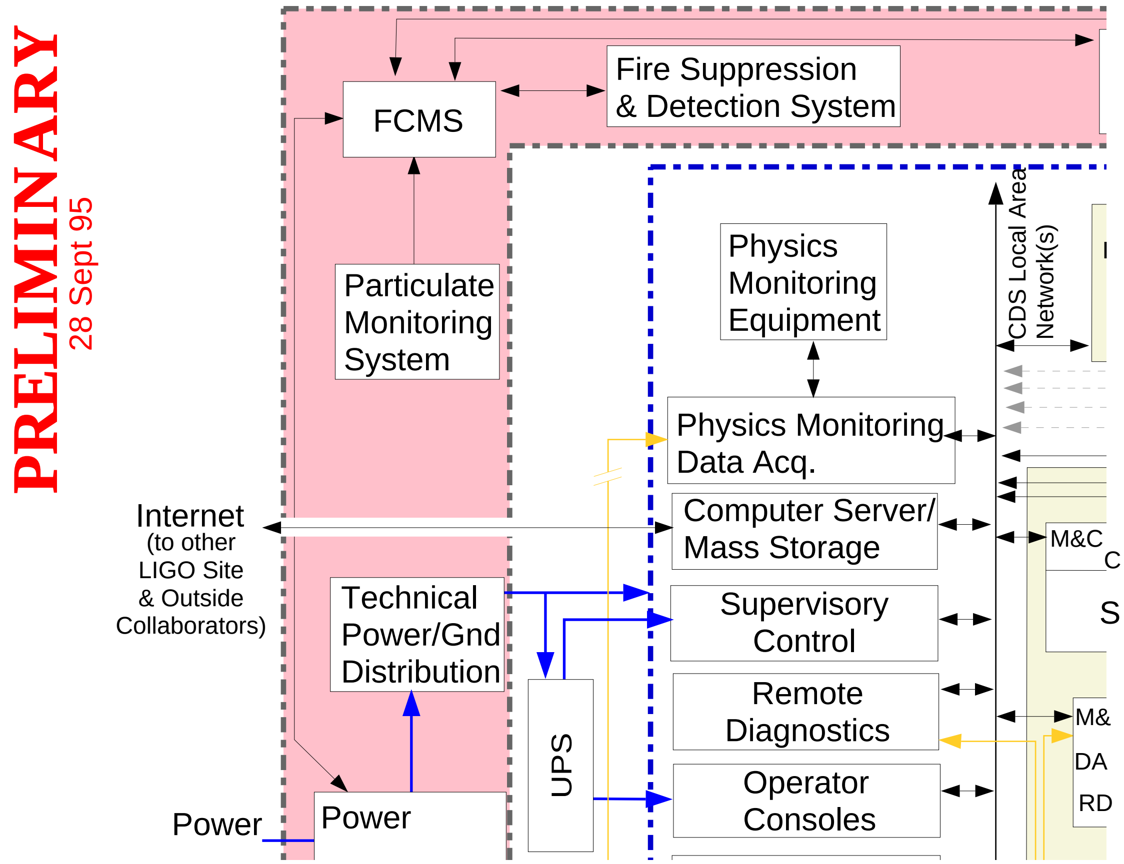
Modeling (and joint with System Integration, or SysInt alone)

- FFT model: optimizing, automating, propagating
- also, dual-recycling FFT model, real optics (in process)
- dynamics of coupled cavities, means to generalize
- data analysis of 40m
- end-to-end noise modeling, housekeeping

...etc.

System Integration

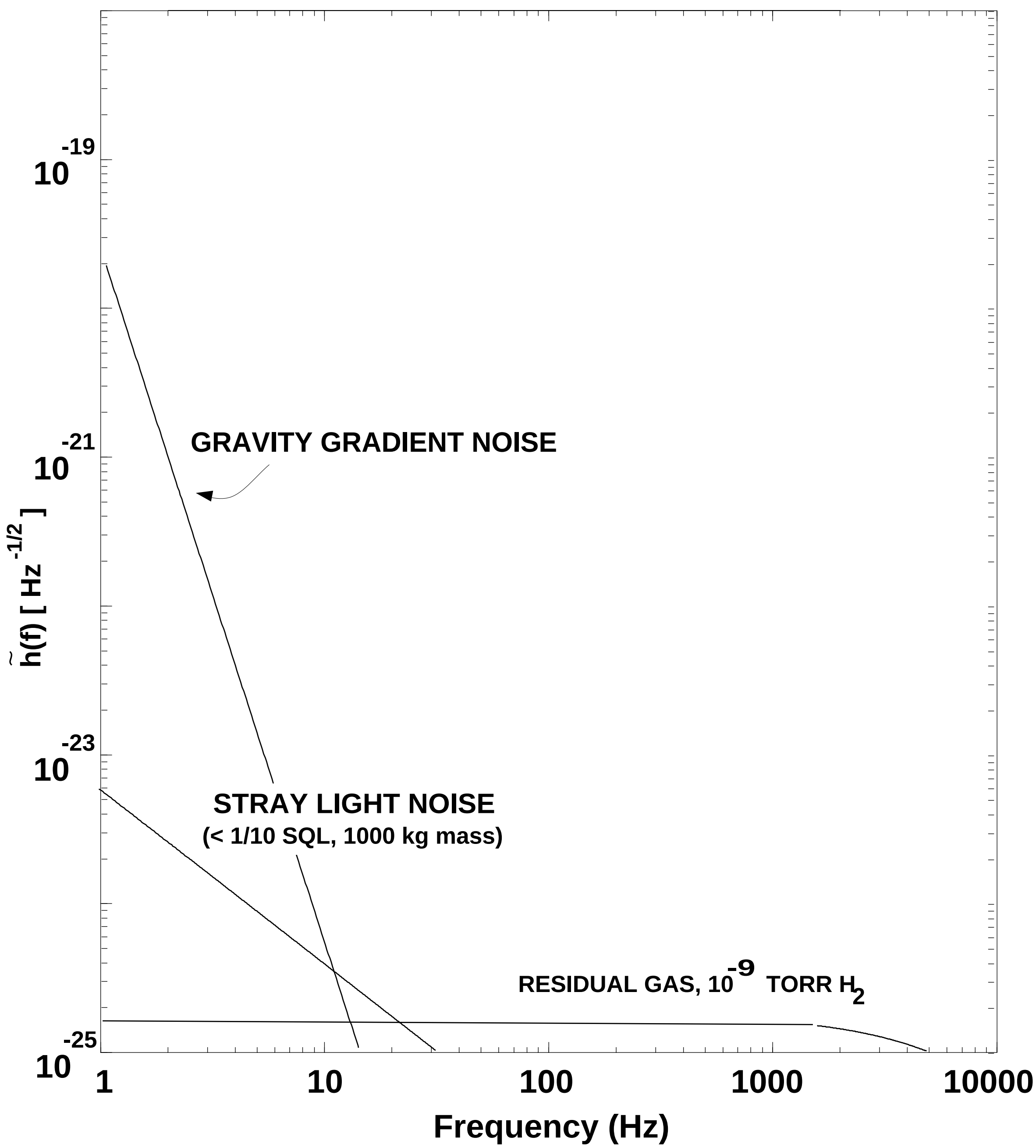
Interfaces, top-level requirements, and everything else



Interface Control Documents

- example: Vacuum Equipment/Beam Tube - Civil Construction

System Integration: Facility Limits



Structure of LIGO

The heart of the project: People

- 85 people, 29 new in ‘95
- several more in ‘96
- Visitors (B. Allen, D. Gustafson, P. Saulson, K. Sliwa)

Organizational

- Detector and R&D groups brought together (S. Whitcomb)
- Site directors named (F. Raab, M. Coles)
- LRC born and moved out (S. Finn)

Milestones (WA, LA)

- Initiate Beam Tube Fabrication: imminent
- Initiate building construction: 6/96, 1/97
- Accept beam tube and cover: 3/98, 9/98
- Accept buildings, became equipment: 3/98, 9/98
- Initiate interferometer installation: 7/98, 1/99
- **Begin coincidence tests: 07/00**