Introduction to LIGO

Designed to help orient NSF folk as we start with procurements

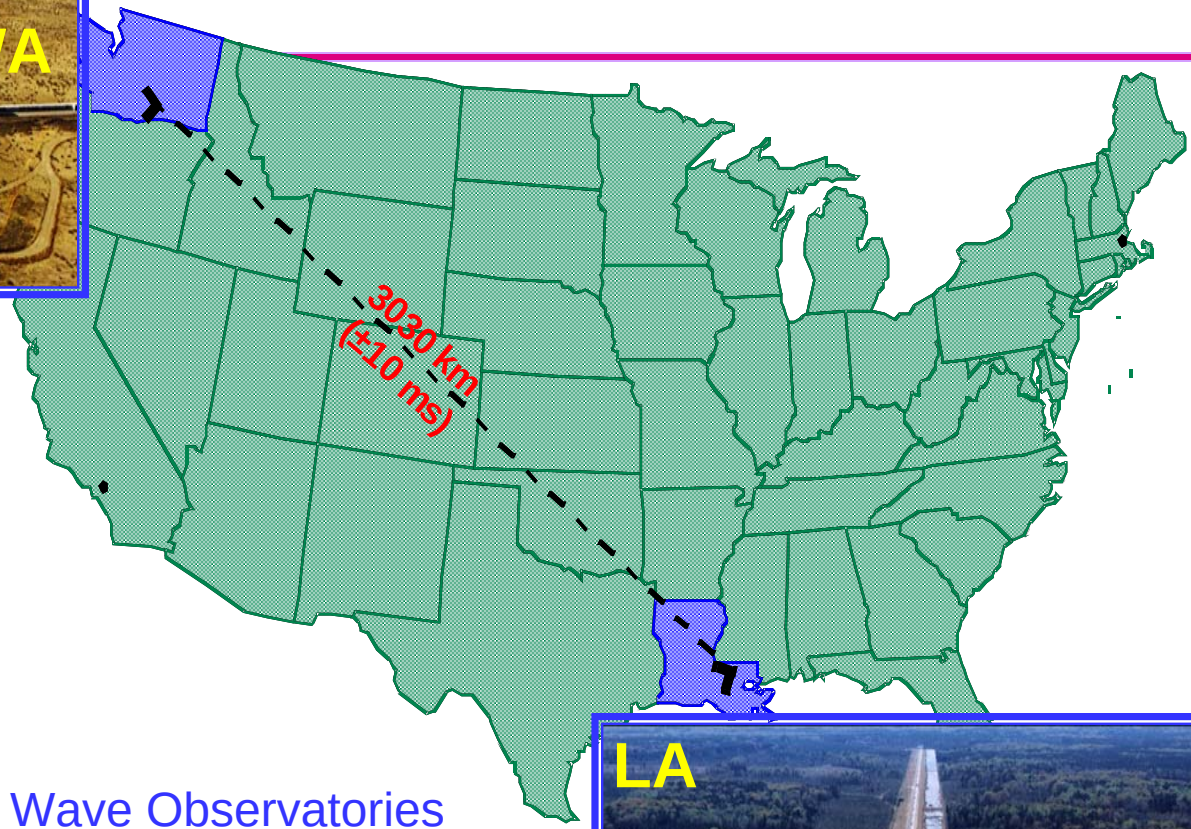
First few give a sense of how LIGO works

Most slides are for later reference

David Shoemaker, MIT 28 May 2008

LIGO

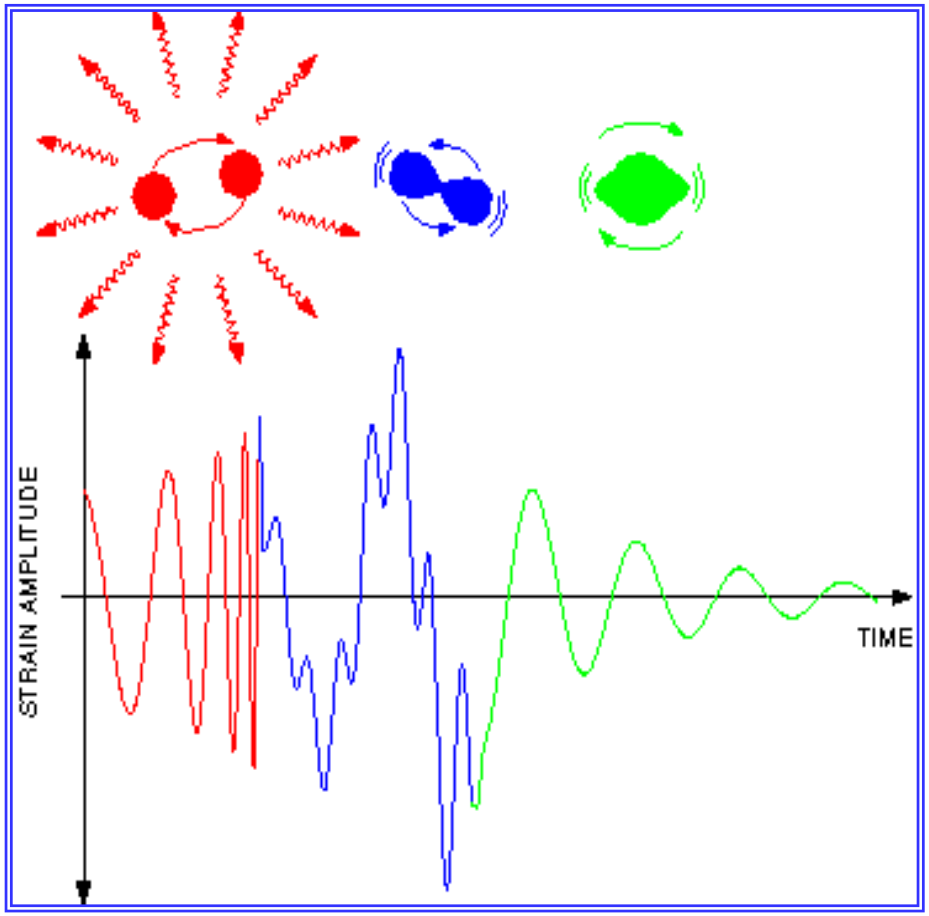
4 km, 2.5 miles



- NSF-funded Gravitational Wave Observatories
- Two sites: Hanford, WA; Livingston, LA
- MIT-Caltech collaboration
- 600 person, 40 institution international community

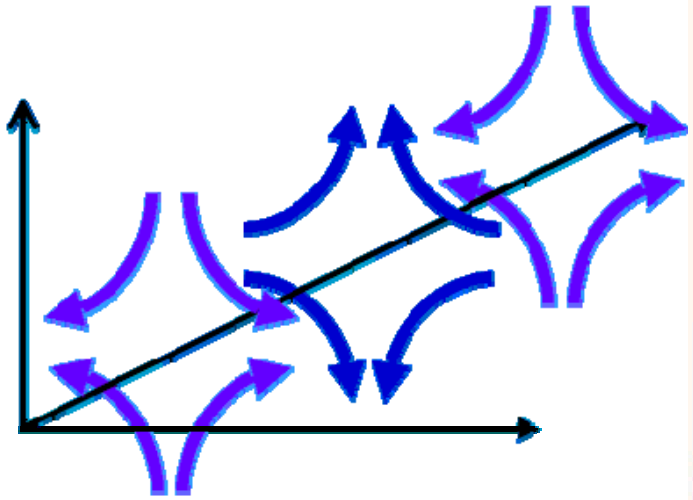
What are gravitational waves?

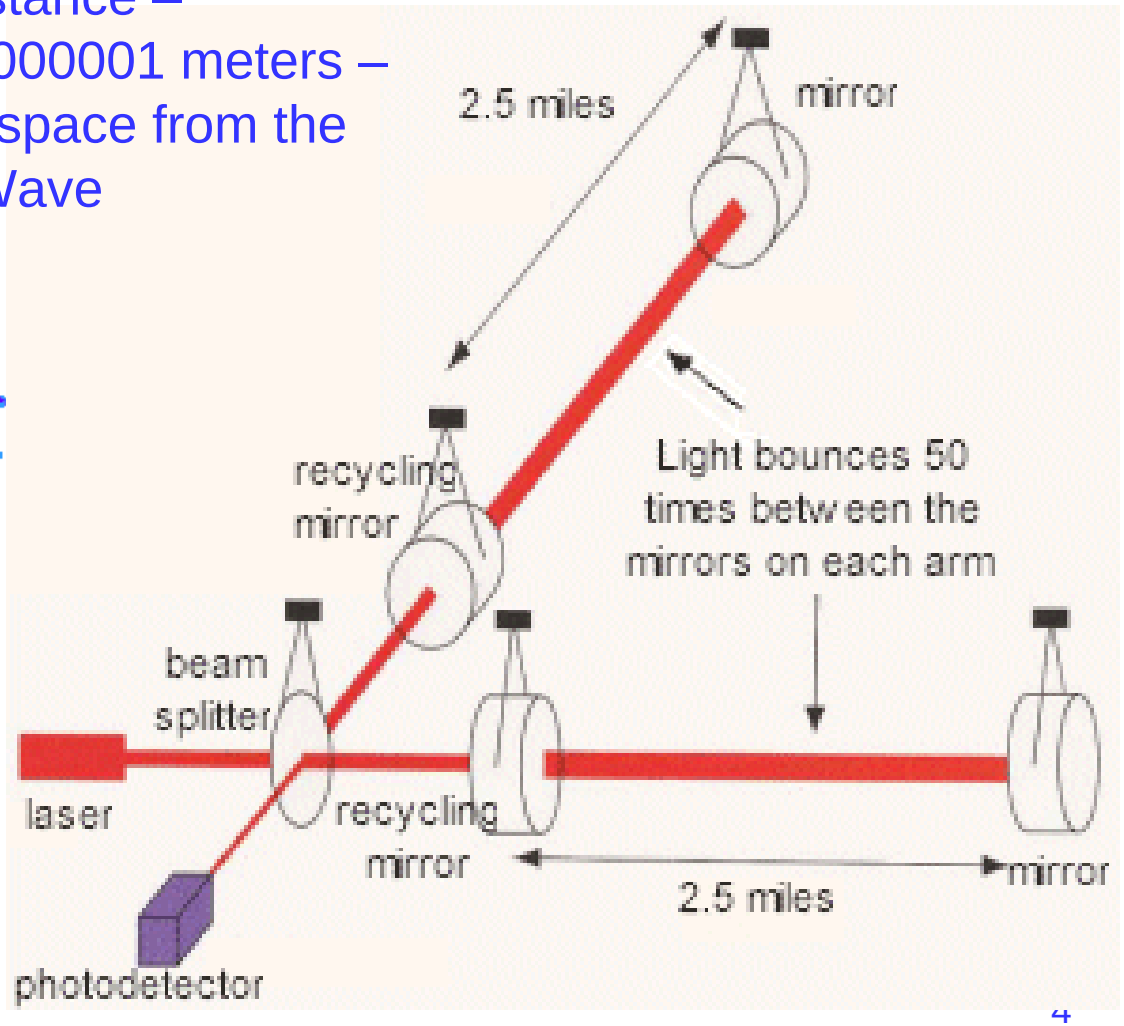
- Ripples of space time, propagating through space at the speed of light
- Generated in astrophysical catastrophes – supernovae, pairs of stars spirling into eachother, leftover from the Big Bang
- Predicted by Einstein's gravitational theory, not yet directly detected
- Similar to radio waves in some ways, but much harder to generate or observe



How do we detect Gravitational Waves?

Measure the change in distance –
0.00000000000000000001 meters –
due to the distortion of space from the passing Gravitational Wave





Why detect gravitational waves?

Further confirmation of Einstein's theory – which gives us explanations of exotica like slowing clocks, distortions of objects; but also practical applications like precision spacecraft orbits, and the Global Positioning System (GPS)

Magnificent physics of extraordinarily extreme events

Visible

Radio Telescope

GW

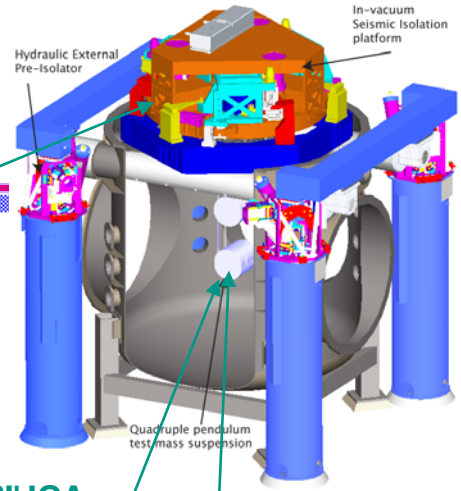
A completely new window on the universe, allowing us to see farther, much closer to the beginning of time

LIGO Status

- Buildings, infrastructure, instruments built – on schedule, on budget
- Initial LIGO sensitivity achieved, and exceeded
- Initial LIGO data runs complete, data analysis underway
  - No signals identified to date – still may be some lurking in the data
- Modest improvements underway using Initial LIGO equipment

- …time for Advanced LIGO, which should guarantee frequent observations
- **Advanced LIGO replaces all of the initial LIGO detector equipment**
  - Re-uses the infrastructure – buildings, vacuum system, etc.

Advanced LIGO Design Features



ACTIVE SEISMIC ISOLATION

FUSED SILICA, MULTIPLE PENDULUM SUSPENSION

40 KG FUSED SILICA TEST MASSES

INPUT MODE CLEANER

180 W LASER, MODULATION SYSTEM

ACTIVE THERMAL CORRECTION

T=0.5%

LASER

MOD.

125W

830KW

BS

PRM T~6%

ITM

ETM

SRM T=5%

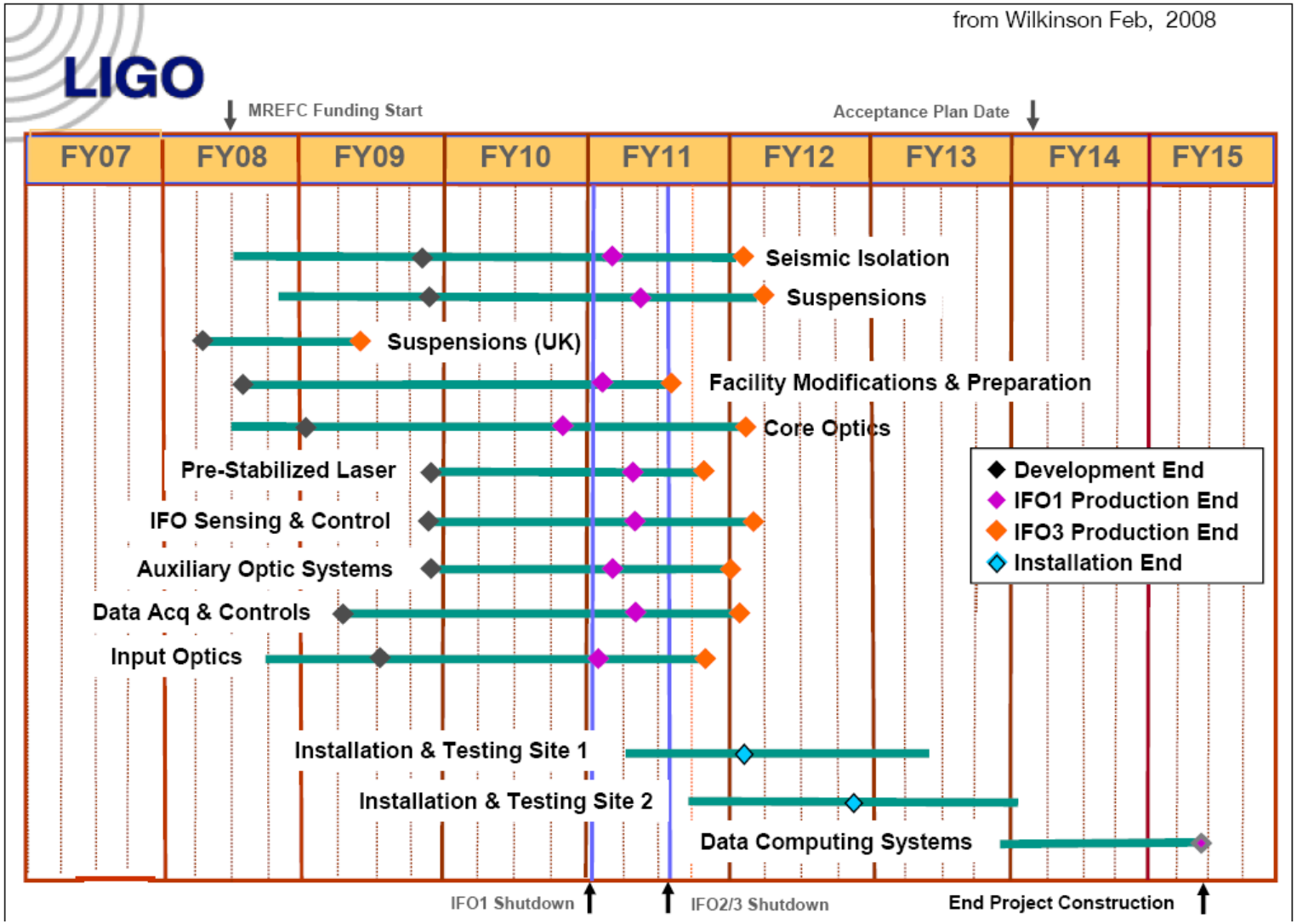
OUTPUT MODE CLEANER

PD

GW READOUT

PRM Power Recycling Mirror
BS Beam Splitter
ITM Input Test Mass
ETM End Test Mass
SRM Signal Recycling Mirror
PD Photodiode

Advanced LIGO Schedule



Procurements

The following slides are intended to give a notion of the near-term large procurements (those listed in the recently submitted Acquisition Plan)

Taken from prototypes, or initial LIGO equivalents, of items – not always identical to the Advanced LIGO item, but similar enough to be useful

We won't go over these in much detail now, but these slides can be a reference for later or to help if you have a question later and want to point to something we can all be looking at.

CO-102
Metrology inst. Lab large aperture interferometer with custom LIGO modifications

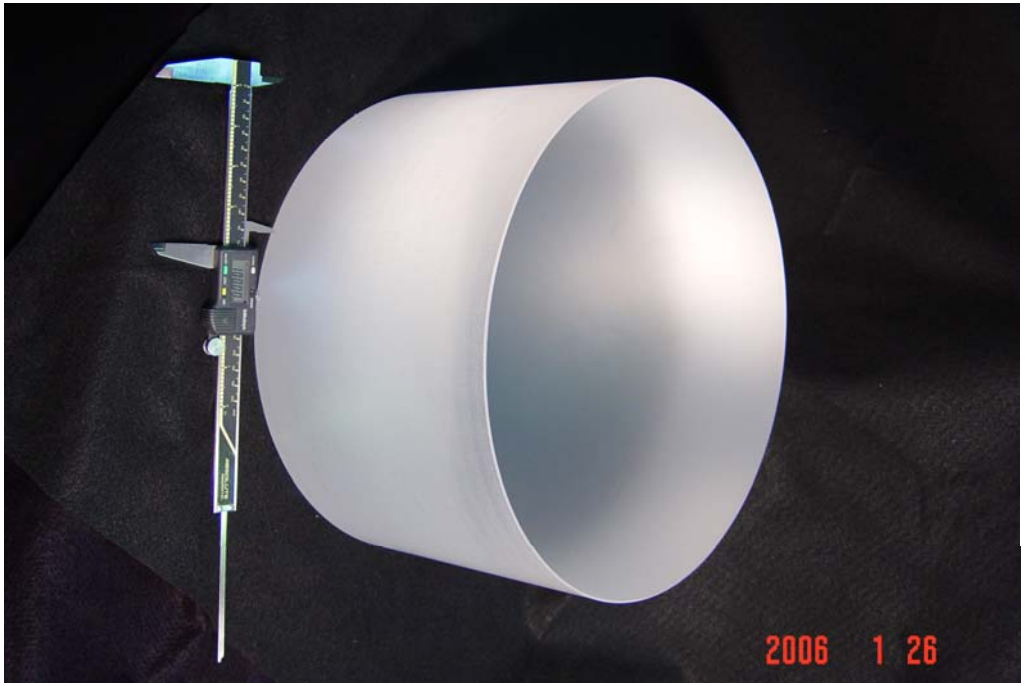
Example of a commercial system (courtesy Zygo, Inc.) – instrument to measure mirror surfaces with very high precision.

Mirror Blanks

CO-105 Mirror blanks BS, CP, ITM

CO-106 Mirror blanks R3, ETM, FM

These are very pure glass cylinders, weighing ~100 Lbs, to be polished and coated to become mirrors (or ‘test masses’)



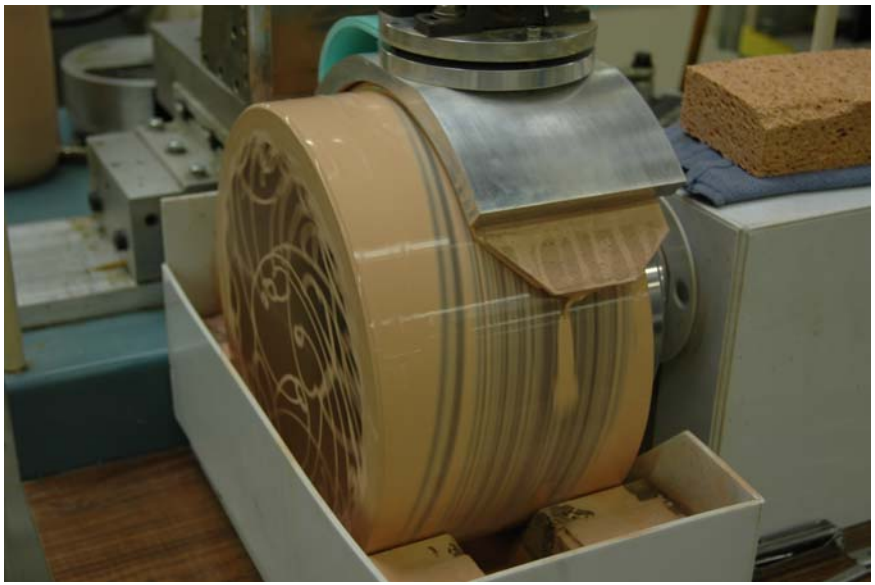
Optic Polishing

CO-110 Polishing ETM, ITM

CO-112 Polishing BS, CP,PRM, SMR

CO-114 Polishing ETM, ITM, ETM

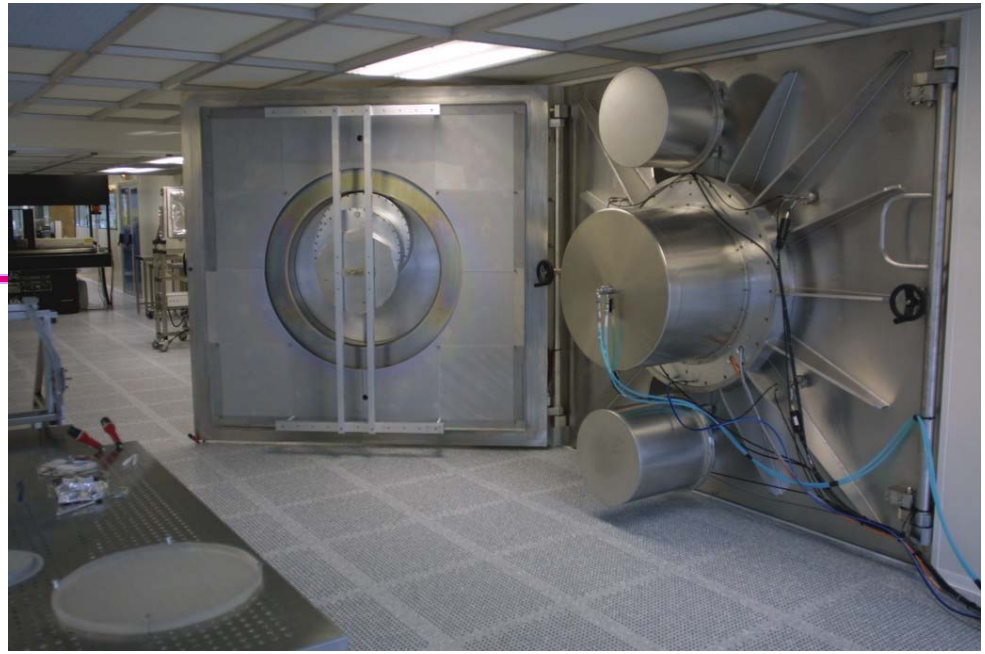
This uses an abrasive mixture of water and finer and finer hard sand-like material to wear the surface down to the intended form and to polish the surface

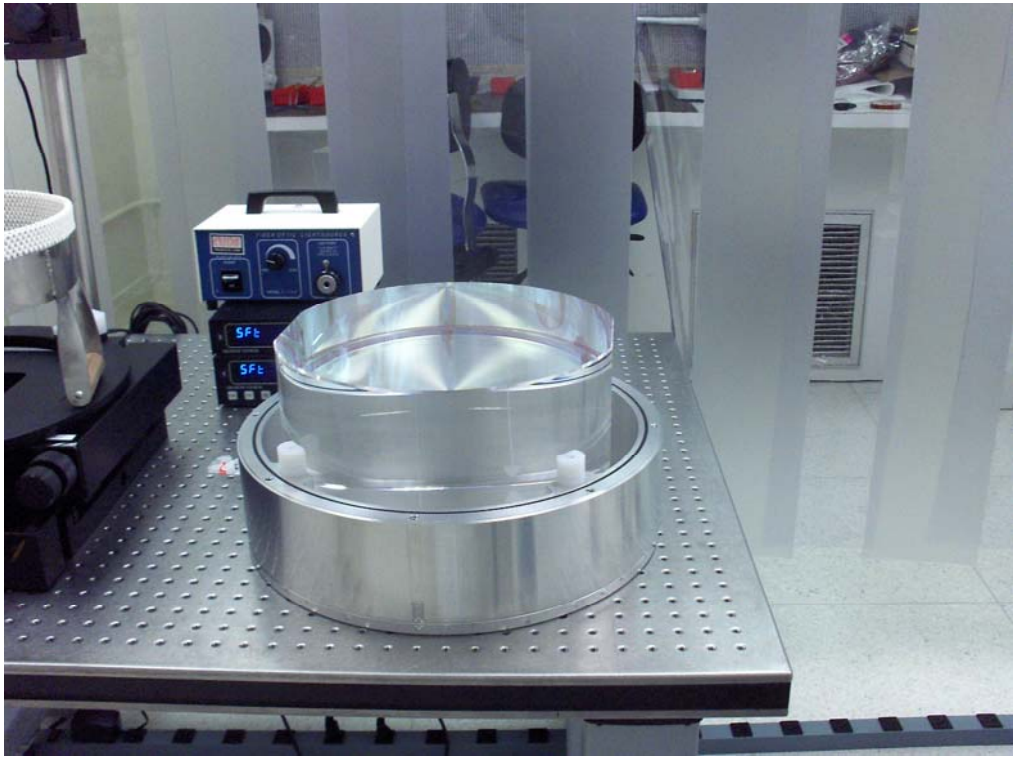


Reflective coating

CO-118 Coating of core optic components

This is an image of a huge coating machine (LMA Lyon) at a potential vendor; highly specialized equipment





This shows a prototype polished mirror blank, after the reflective coating was applied

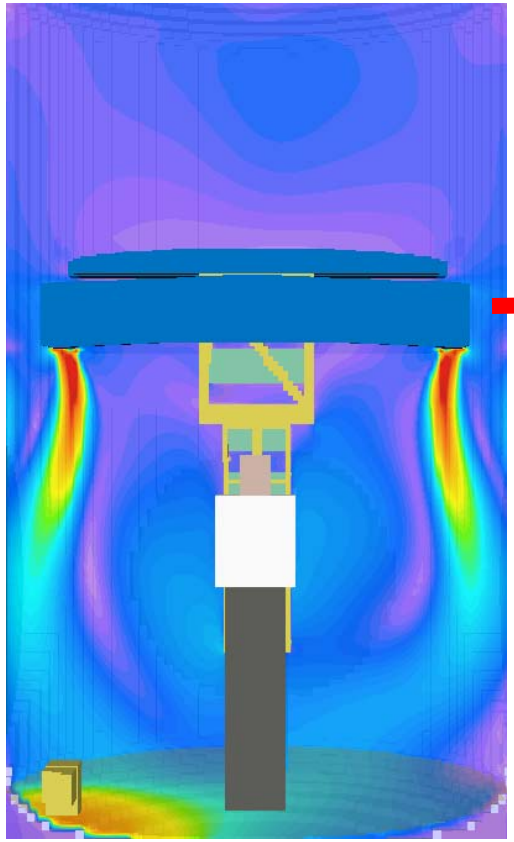
Procure, refurbish clean rooms for Install and assembly

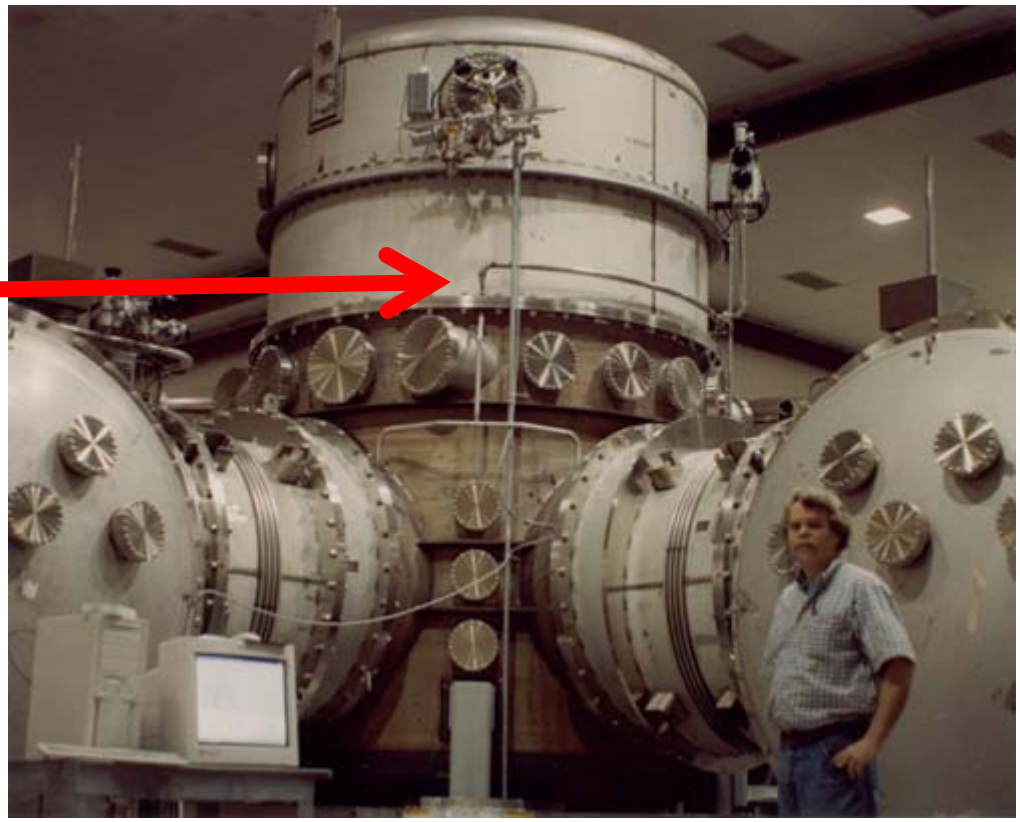
- FM-144, FM-115, FM-119, FM-123
- Provides a very-low-dust environment for clean assembly and installation
- Clean-air blowers and lights in the ceiling
- Custom manufactured to fit our spaces and vacuum equipment

FM-117 Procure Air Shower for BSC (Test Mass Chamber) Clean Room

- Source of dust-free air inside the vacuum chamber
- Custom manufactured for us

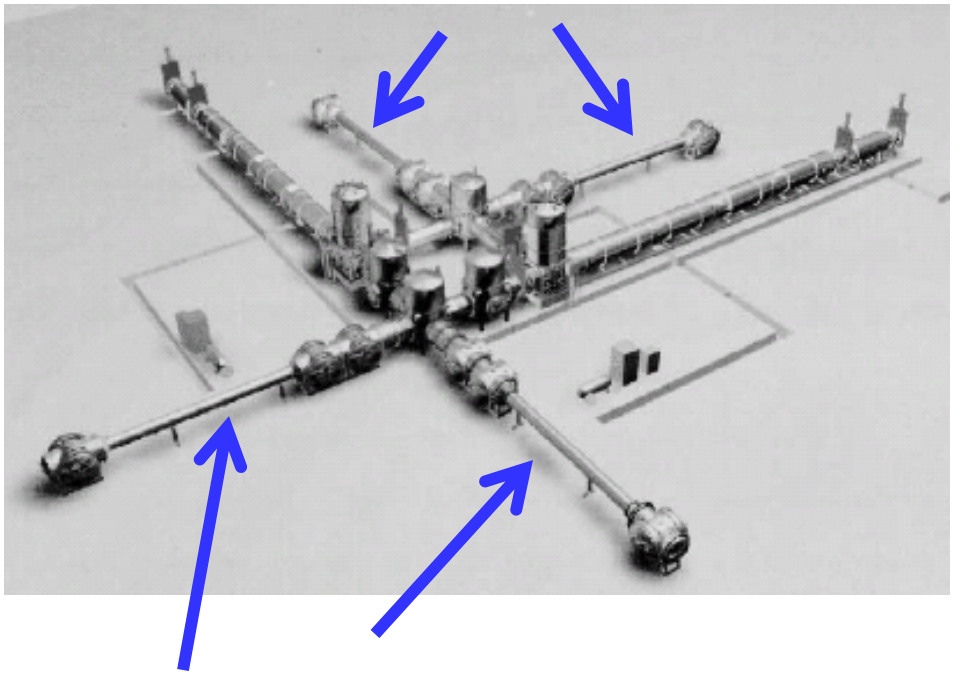
Airflow model





FM-107 Fabricate IO tubes

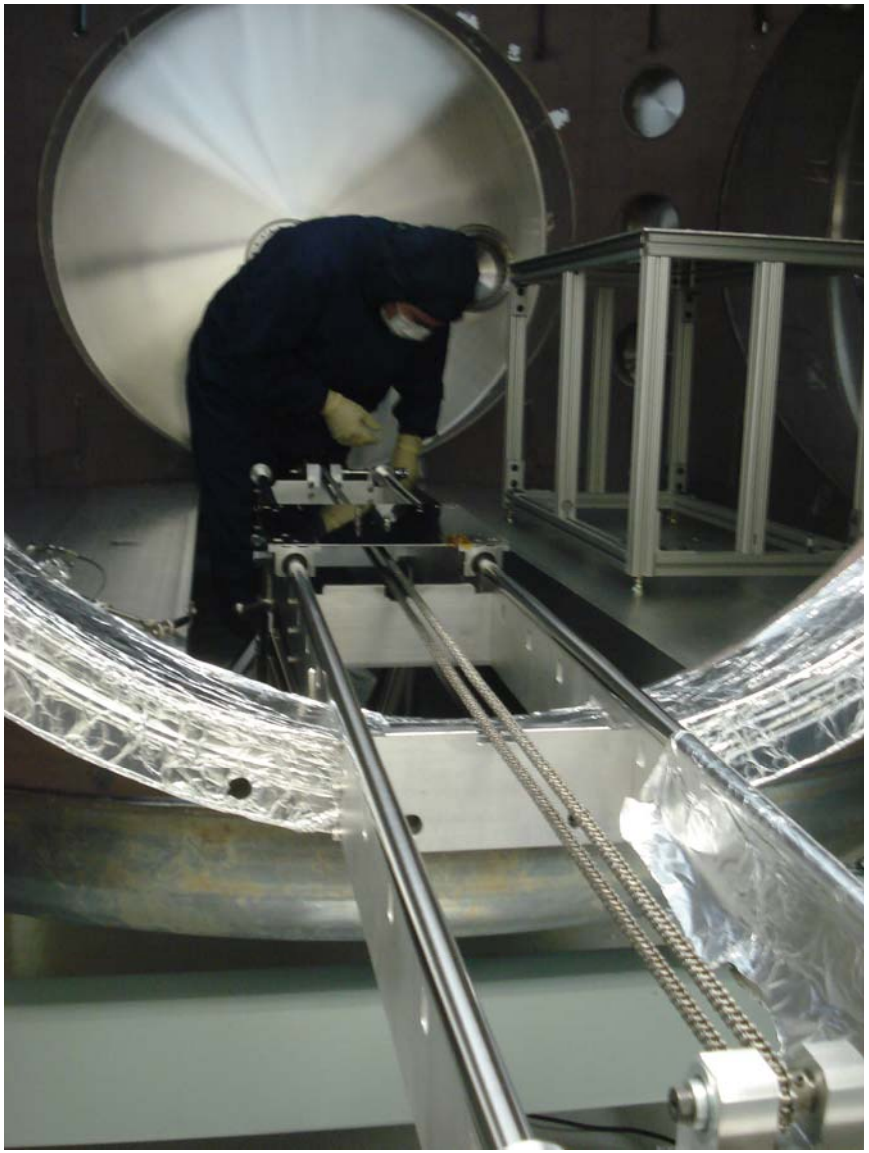
- Larger diameter tubes between vacuum chambers to accommodate the new Advanced LIGO laser beams in the Input Optics



View of the interior of the current tube

FM-128 SUSpensions Install Fixtures

- Conveyors, elevators, manipulators, and positioners custom designed and fabricated to carry the optic suspension systems into the vacuum chamber and attach them to the seismic isolation system

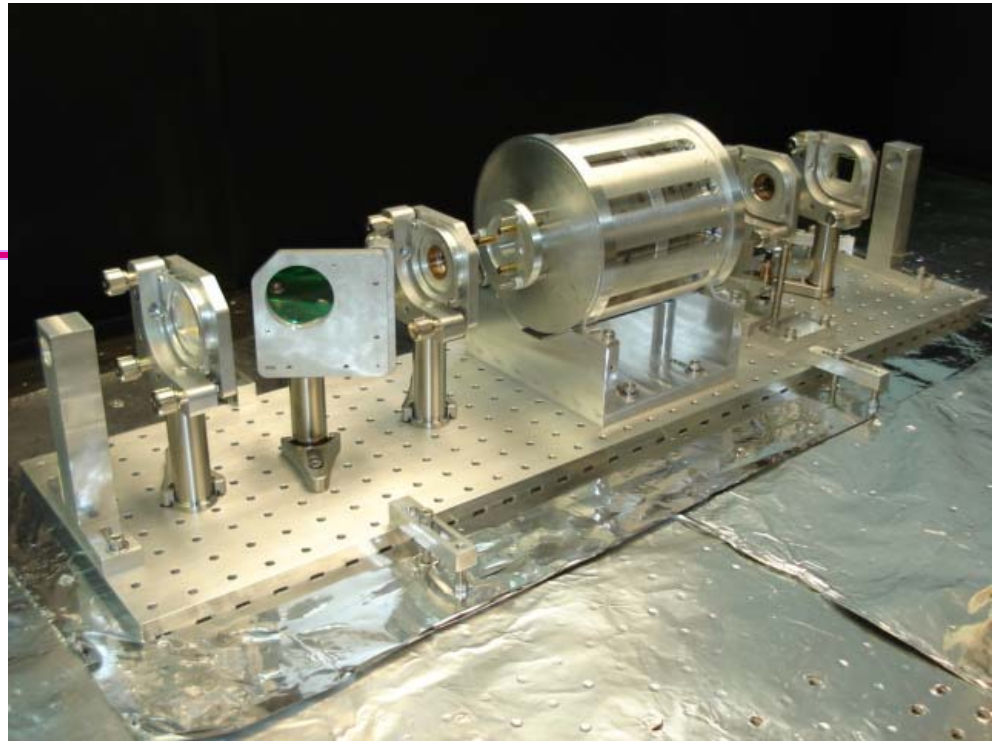


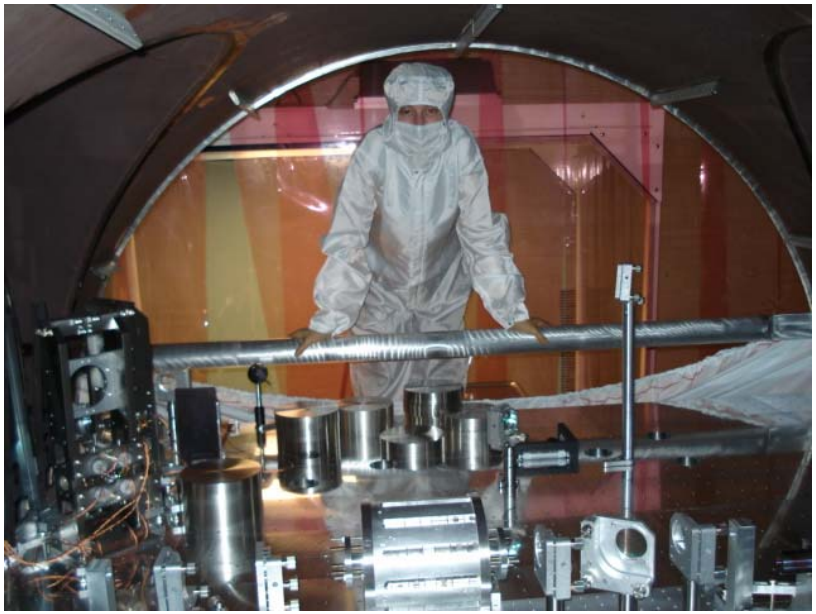
IO-F01 UFL Input Optics

University of Florida group which takes responsibility for one of the subsystems, the Input Optics

Same group took responsibility for initial LIGO – unique expertise, and faculty support from the University endowment

On subcontract for fixed scope





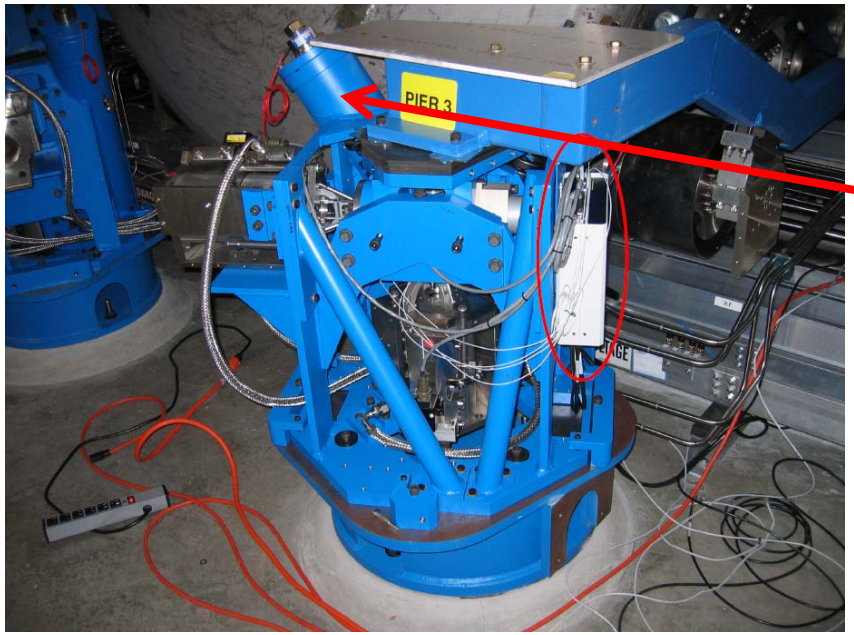
PM-102
Contractor project controls staff

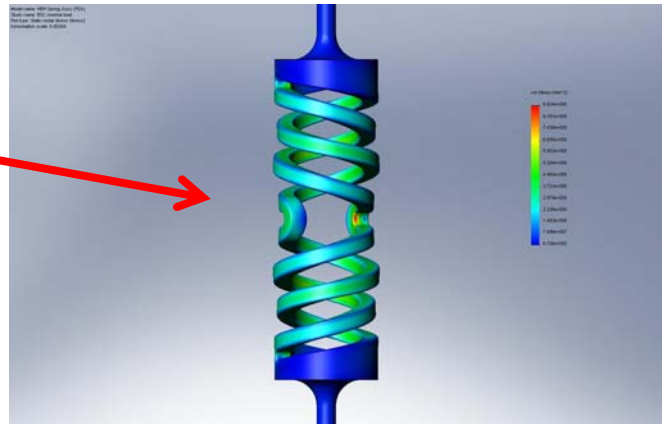
- Carol's Project Controls team, made up of contract experts
- Some long-term, some on as-needed basis
- Proximity to Project Manager crucial; nearby Hanford DOE and Batelle Labs provide a 'reservoir' from which to draw flexibly

(sorry, no photo!)

Seismic Isolation HEPI
Hydraulic External Pre-Isolator

- SI-106 EPI housing
- SI-109 HEPI hydraulic actuator machined parts, HEPE actuator welding/assembly, and HEPI hydraulic actuator bellow
- SI-113 HEPI Machined double helical, maraging steel springs





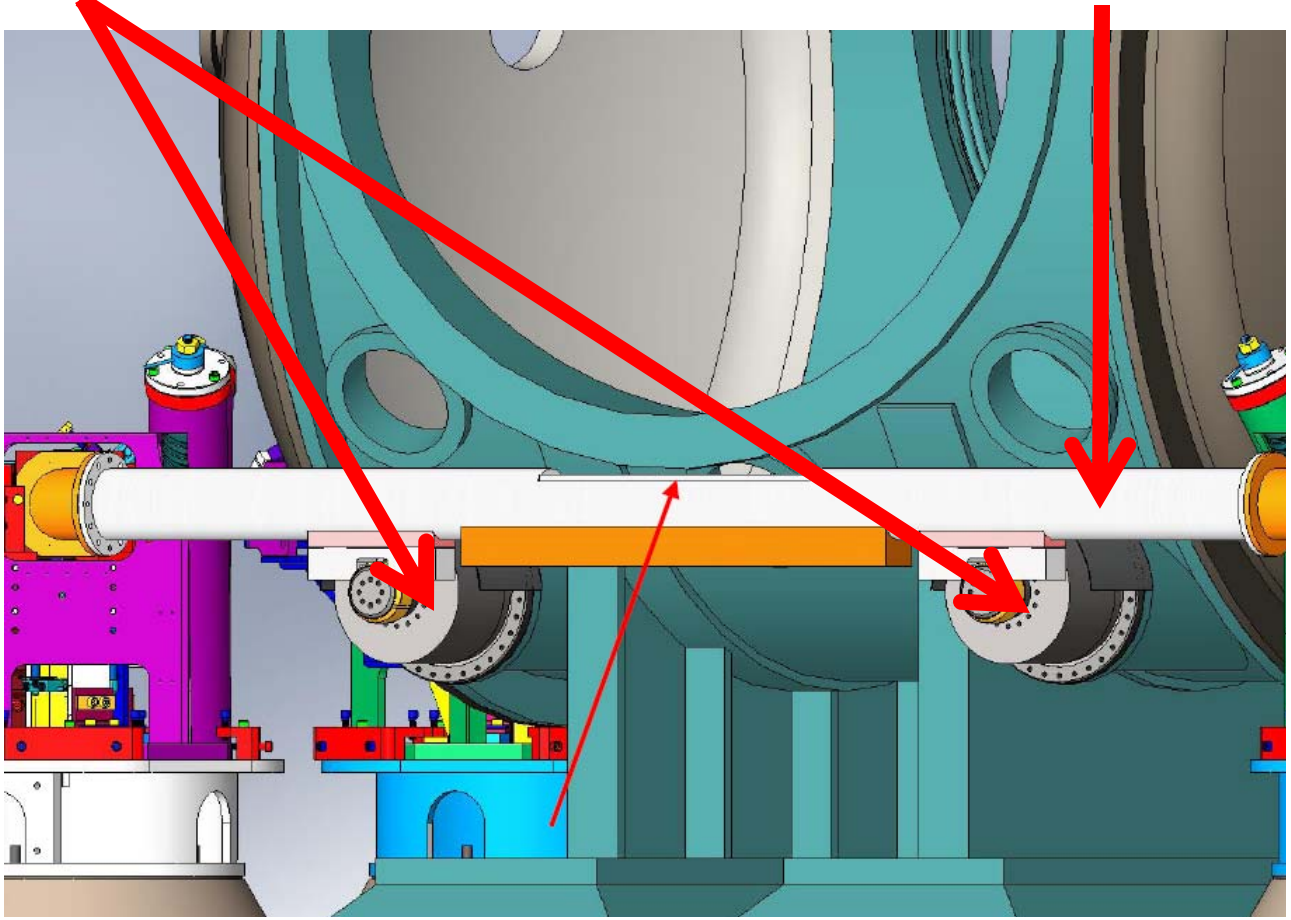
Seismic Isolation HEPI sensors

- SI-101 HEPI inductive position sensors
- SI-105 HEPI geophones

Seismic Isolation external hardware

SI-150 Mechanical components, tubes, bellows, bearings, tube mounting bases & caps & piers

SI-151 Replace HAM Crossbeams with stiffer & Stronger Design



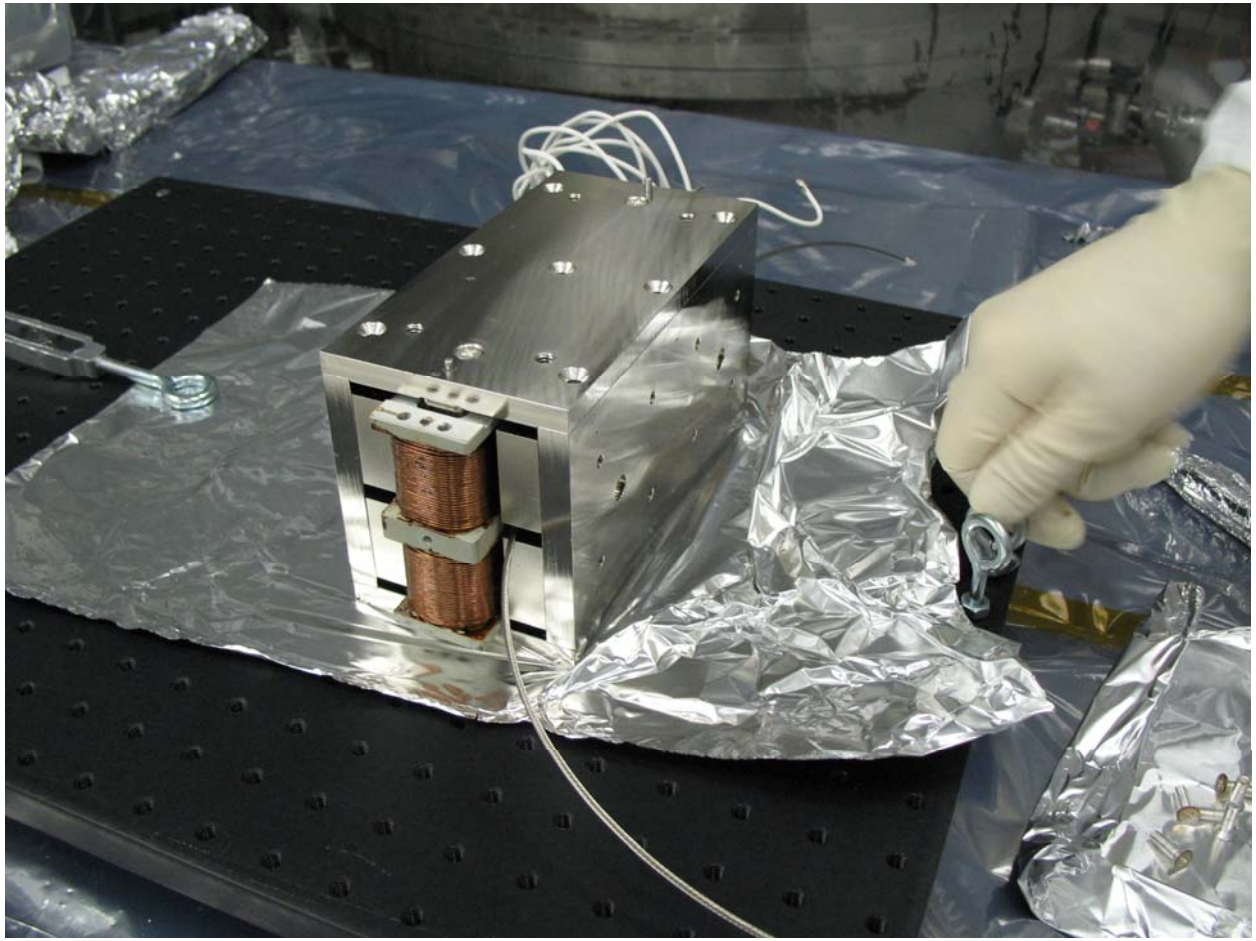
Seismic Isolation Instrumentation

- SI-107 BSC/HAM ISI instruments - broadband seismometers for in chamber use
- SI-132, SI-162 Capacitive displacement sensors, ADE, MODEL #4800
- SI-134 HAM and SI-164 BSC ISI cable & clamp hardware - custom
- SI-136, SI-165 GS-13 seismometers

GS-13

Seismic Isolation Instrumentation

- SI-140, SI-170 Large (stage 0-1) electromagnetic actuators



Test Mass (BSC) Seismic Isolation main structure

- SI-146 Fab/assemble In-chamber (in-vacuum) mechanical components after 1st article (BSC); SI-193 BSC first article & in-chamber (in-vacuum) mechanical components without UHV cleaning + finer optics table hole spacing.
- SI-152 shipping for UHV cleaning

SU-108 Installation tooling/parts

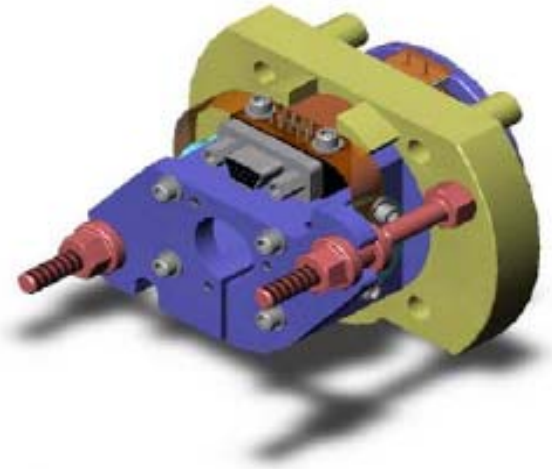
- The fabrication of the specialized equipment needed for the installation and initial positioning of the Suspension (SU) systems into the vacuum chambers.
- Here a weighted plywood box stands in for a suspension system, sitting on a prototype articulated arm of custom design

SU-201 BSC ADCs IFO1,2,3

- Catalog off-the-shelf electronics, including Analog-to-Digital Converters (ADC), for the Test Mass (BSC) suspension elements.
- SU-260 BSC DAC/SPARE IFO3

Suspension sensor/motors ('BOSEM')

- SU-300 Various sensors & actuators for MC's, RM's,PRM SM1/2 and SRM fab. Custom position sensors and linear motors for a variety of suspension types: Mode Cleaner (MC), Power Recycling Mirror (PRM), and Signal Recycling Mirror (SRM)



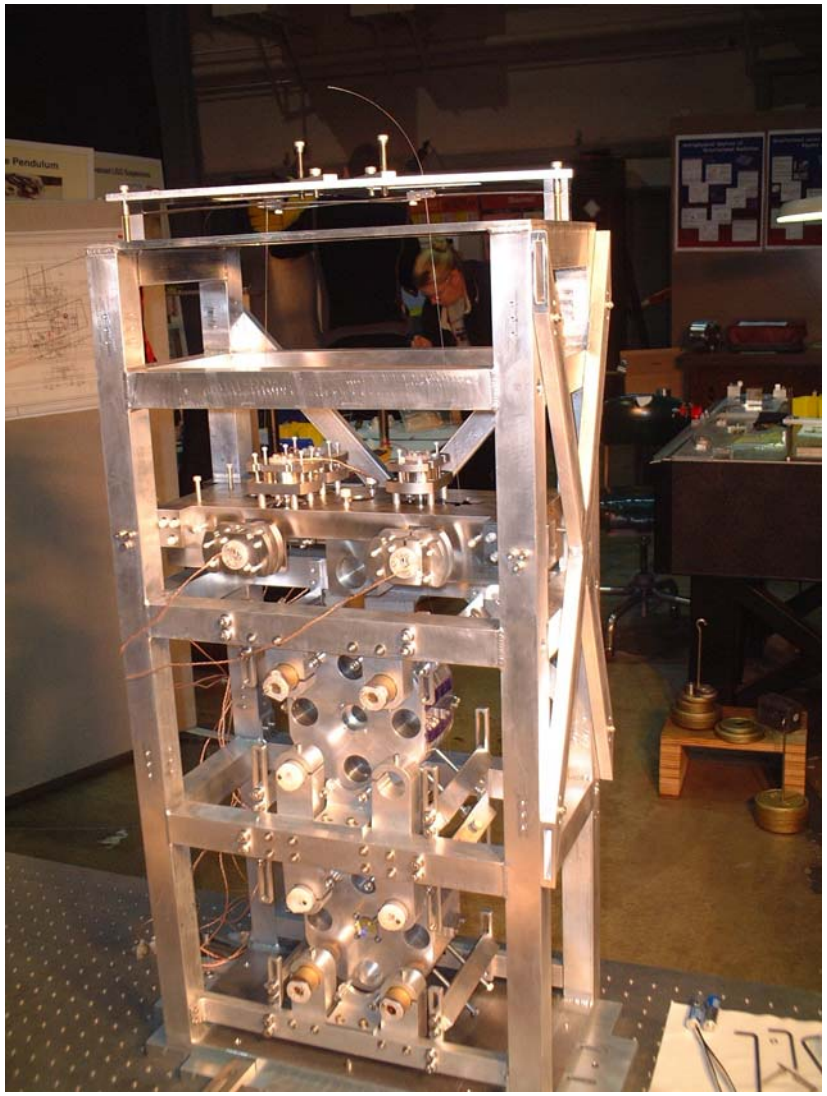
Advanced LIGO

Noise Prototype (B-OSEM)

Assembled BOSEMS at testing station

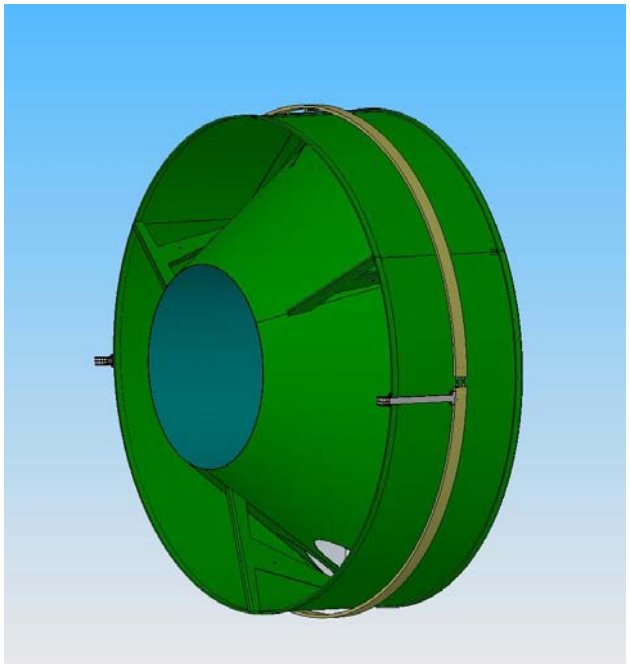
Optic Suspension mechanical components

- SU-301 MC1,2 & 3 blade spring (with spares) Leaf (blade) springs custom fabricated to be used in the Mode Cleaner (MC) suspensions
- SU-302 Misc. machined parts, nuts, bolts for MC1, MC2, MC3, RM, PRM, SRM, OMMT2/IMMT3 and spares
- SU-304 Structural parts/weldments for MC1,MC2,PRM, SRM,OMMT2/IMMT3



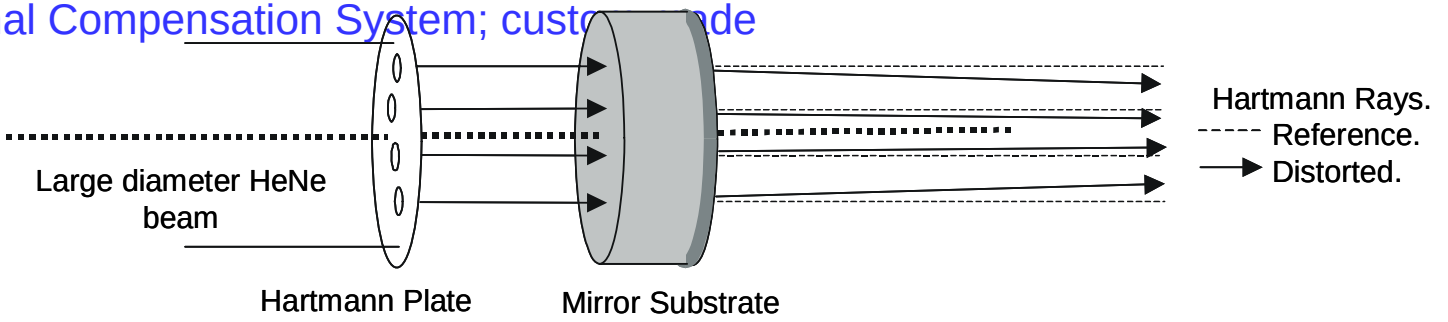
Auxiliary Optics components – Beam Dump, dampers, sensor

- AO-105 Cavity Beam Dump, Eddy current damper
  - For the Auxiliary Optics (AO) subsystem, the fabrication of a magnetic system using Eddy currents to reduce or 'damp' the motion of a laser beam absorber (dump)



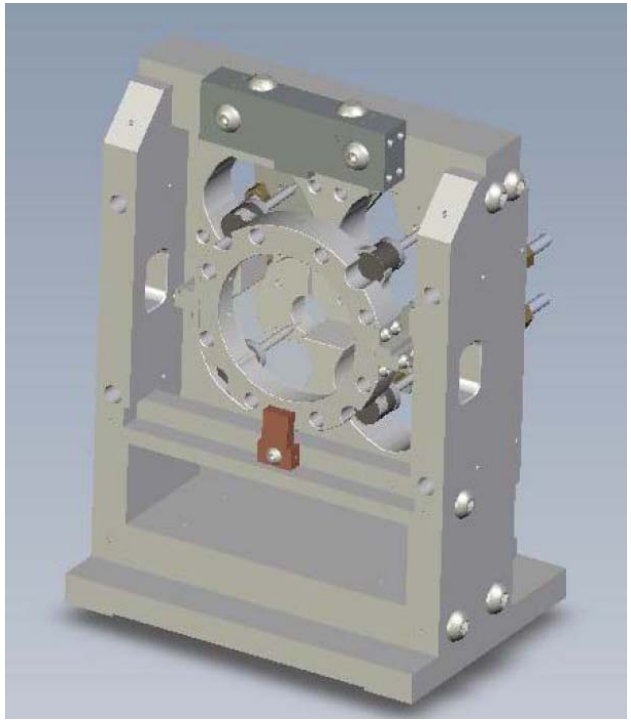
- AO-147 Optical Lever viewport 7.8 ISI 4.9722012

- AO-229 TCS controls, Hartmann sensor – Part of the Thermal Compensation System; custo[illegible]ade



Interferometer sensing and control hardware

- IS-234 ADC's AND DAC's
- IS-236 Procure vac detection infrastructure ISC tables
- IS-253 Piezo mirror tilting system, Spares included



Installation Labor

- IN-103 Craft labor for installation at Livingston
- IN-105 University of Florida support for installation
- IN-104 Craft labor for installation at Hanford

- Technical staff to carry out procedures, including ‘clean’ installations

Data and Computing Equipment

- DC-101 Cluster Node, all sites
- DC-102, DC-105, DC-106, DC-107 Data servers, conditioning servers, grid analysis servers – LHO, LLO, MIT, CIT
- DC-110 Disk archive (3yr/3.6PB)- all sites
- DC-130 Networks/Ethernet – Main switch for servers / LAN interconnection
- DC-140 Misc Hardware, Racks, UPSs, PDUs, Cabling,fibers, Small Switches, etc.
- DC-160 Sales tax @ 8.25% on Equipment