Detector Installation and Commissioning Status

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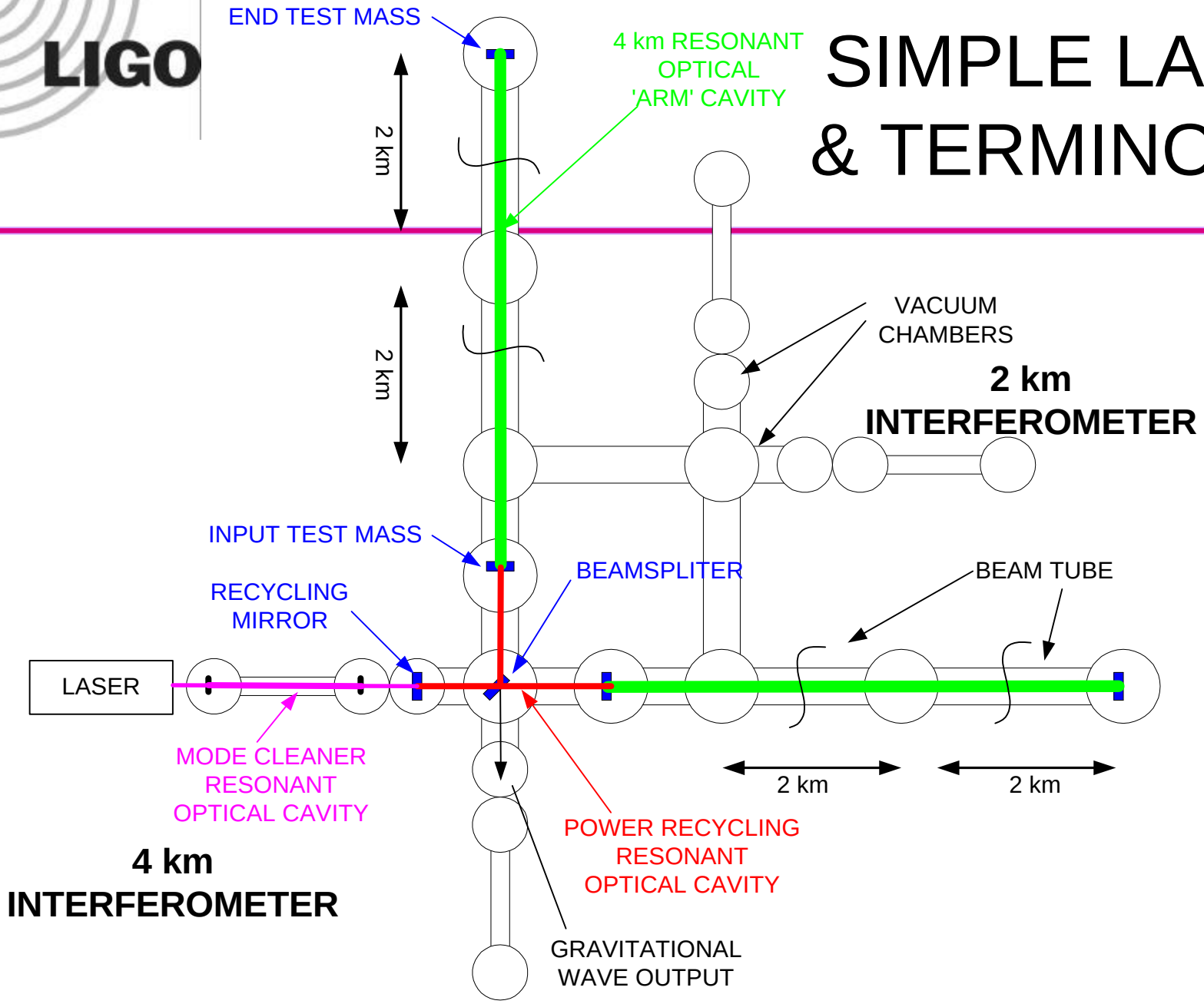
NSF Review

May 9, 2000

Detector

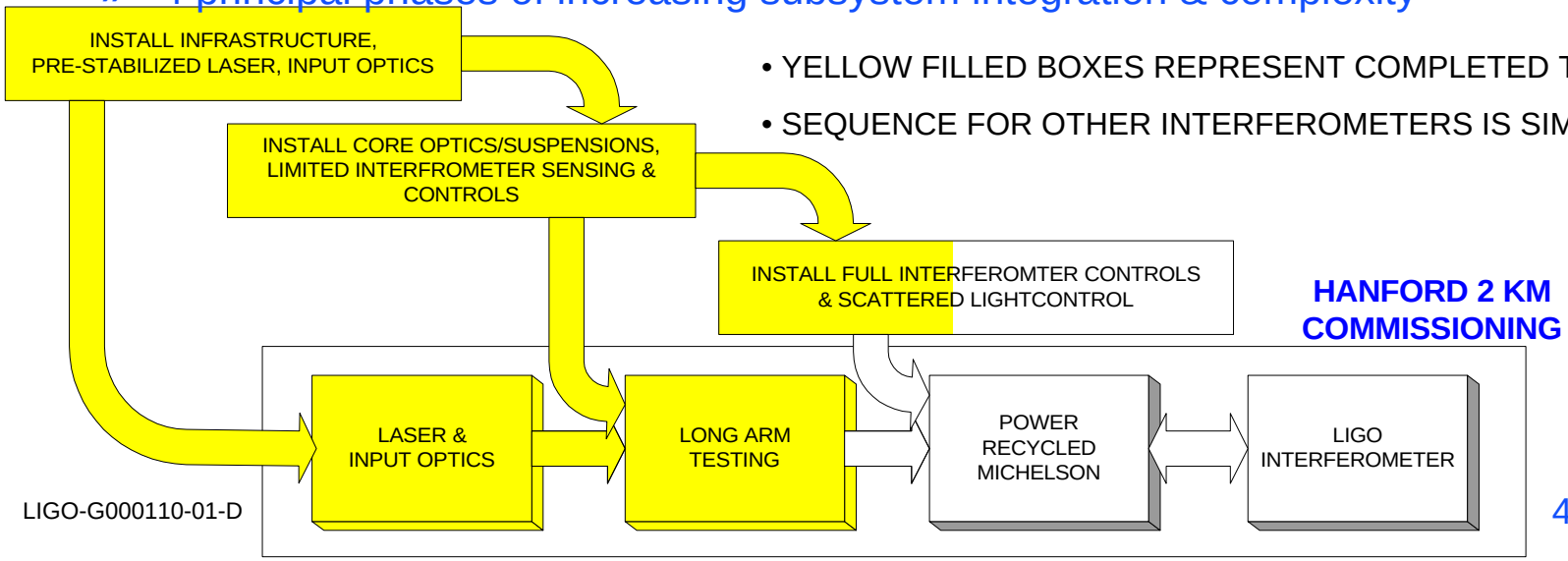
- Installation
- Commissioning
- Schedule Status covered in Replan

SIMPLE LAYOUT & TERMINOLOGY



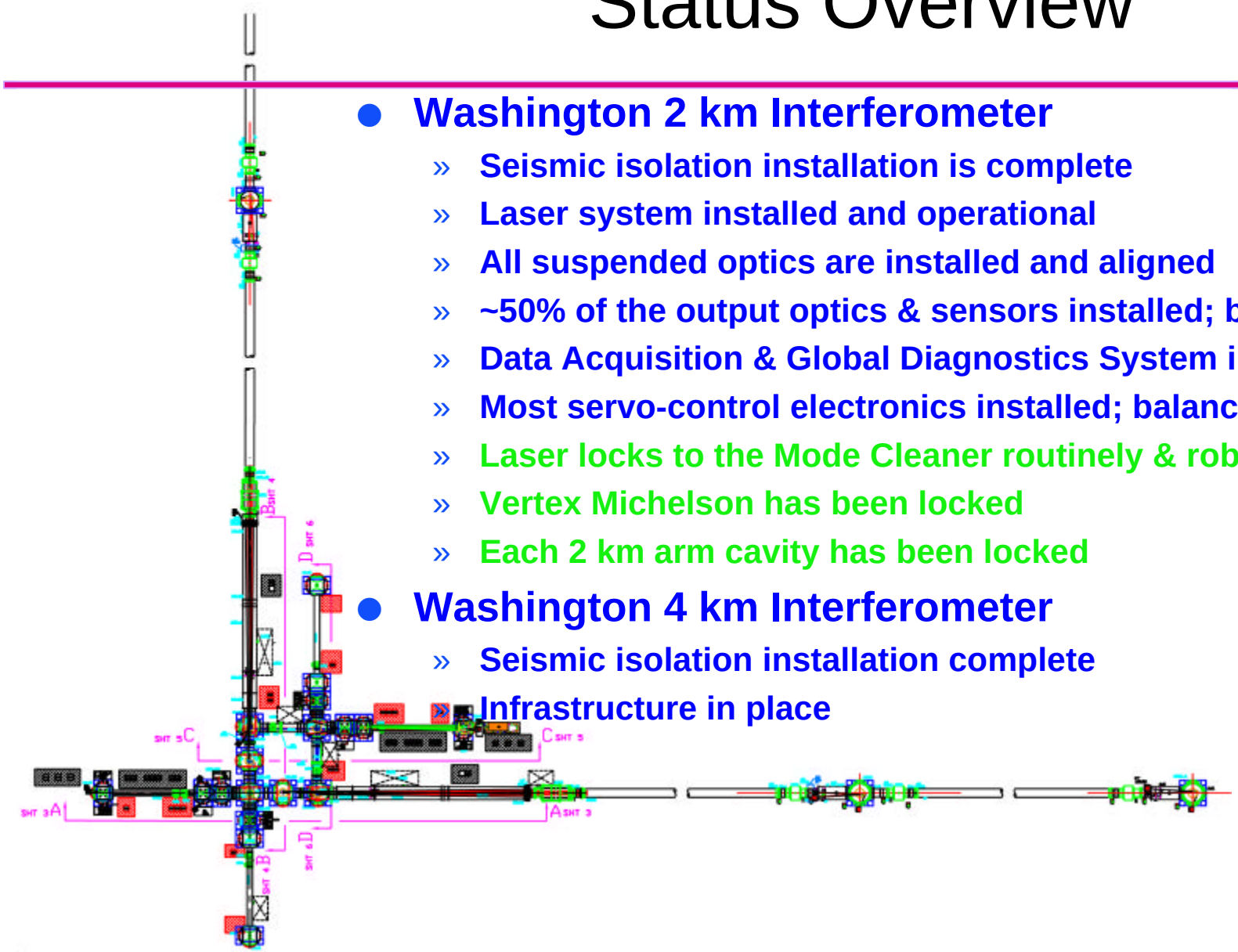
INSTALLATION & COMMISSIONING SEQUENCE

- Installation and Commissioning are parallel activities
  - » emphasis on early discovery of problems at integrated systems level
  - » emphasis on installation of in-vacuum components as soon as possible
- Installation
  - » 3 principal phases (continuous and parallel)
  - » Includes subsystem commissioning (testing & characterization)
- Interferometer Commissioning
  - » 4 principal phases of increasing subsystem integration & complexity



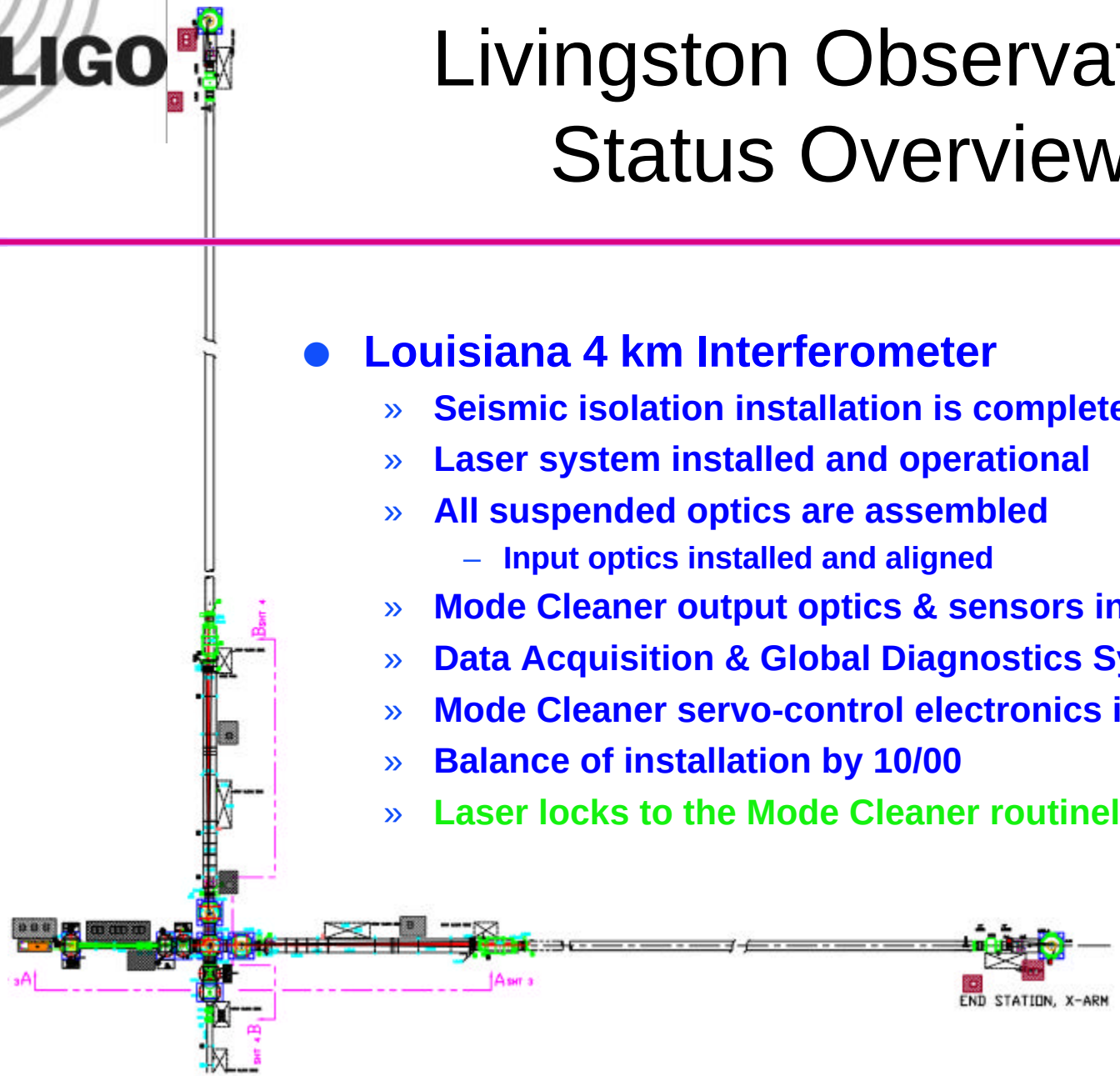
Hanford Observatory Status Overview

- **Washington 2 km Interferometer**
  - » Seismic isolation installation is complete
  - » Laser system installed and operational
  - » All suspended optics are installed and aligned
  - » ~50% of the output optics & sensors installed; balance by 6/00
  - » Data Acquisition & Global Diagnostics System installed
  - » Most servo-control electronics installed; balance by 7/00
  - » Laser locks to the Mode Cleaner routinely & robustly
  - » Vertex Michelson has been locked
  - » Each 2 km arm cavity has been locked
- **Washington 4 km Interferometer**
  - » Seismic isolation installation complete
  - » Infrastructure in place



Livingston Observatory Status Overview

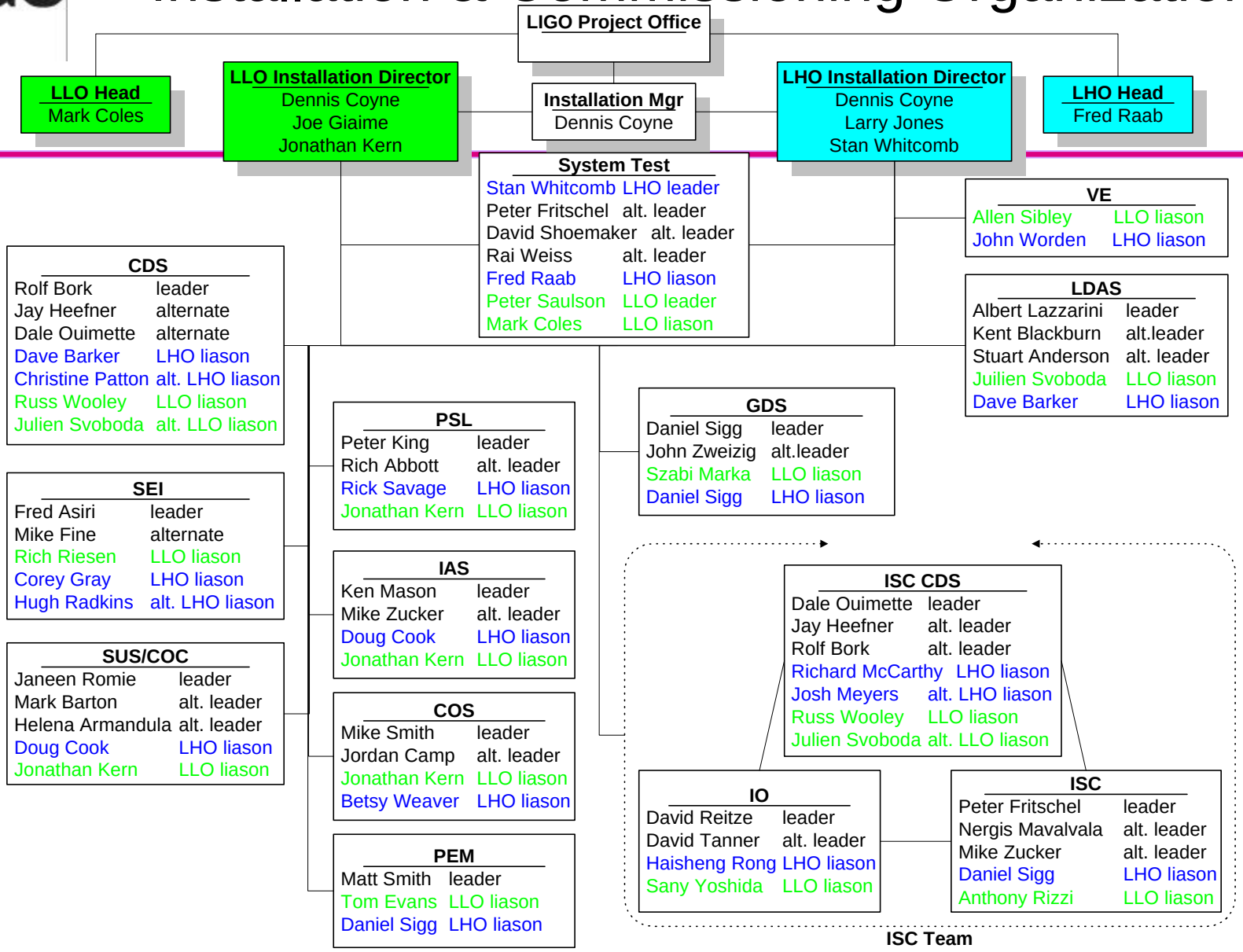
- **Louisiana 4 km Interferometer**
  - » **Seismic isolation installation is complete**
  - » **Laser system installed and operational**
  - » **All suspended optics are assembled**
    - – **Input optics installed and aligned**
  - » **Mode Cleaner output optics & sensors installed**
  - » **Data Acquisition & Global Diagnostics System installed**
  - » **Mode Cleaner servo-control electronics installed**
  - » **Balance of installation by 10/00**
  - » **Laser locks to the Mode Cleaner routinely**



Installation Plan

- Basic Strategy:
  - » Simultaneous installation at both observatories (optimum staff utilization)
  - » Time phased installation of subsystems (leveling load on experts)
  - » Significant participation & support from observatory staff (training)
  - » Early as possible installation of all in-vacuum components (fab/assy/install. risk reduction)
  - » Early as possible system integration & commissioning (early warning)
  - » Hanford 2km Mission: Problem finding/solving ('pathfinder')
  - » Livingston 4km Mission: Robust implementation & characterization
- Organization:
  - » Centralized, flat organization
  - » staff from LIGO Lab (CIT, MIT, UFL, LHO, LLO)
  - » Focused on subsystems for installation:
    - – subsystem leaders from the universities
    - – Observatory liaisons
  - » Separate installation & commissioning leadership

Installation & Commissioning Organization



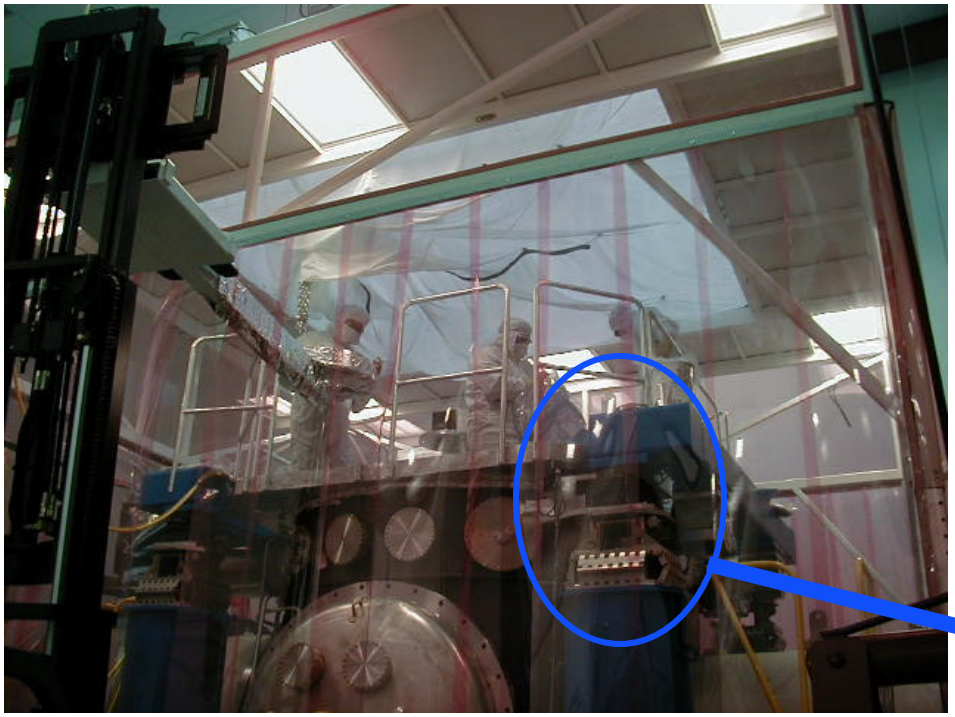
Seismic Isolation Systems

- Outstanding progress:
  - » Production and delivery of components meeting or exceeding installation schedule needs (and now complete)
  - » The coarse actuation system for the BSC seismic isolation systems has been installed and tested successfully in the LVEA at both Observatories
  - » BSC seismic systems at Livingston went as quickly as any installation at Hanford indicating that the transfer of experience was successful.
- All Seismic Isolation System Installation has been completed, with the exception of the tidal compensation (fine actuation) system

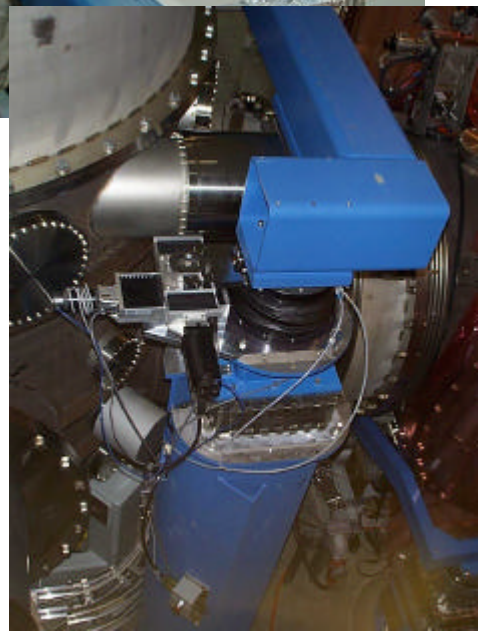
HAM Door Removal
(Hanford 4km)

Seismic Isolation Systems

Support Tube Installation
(Hanford WBSC7)



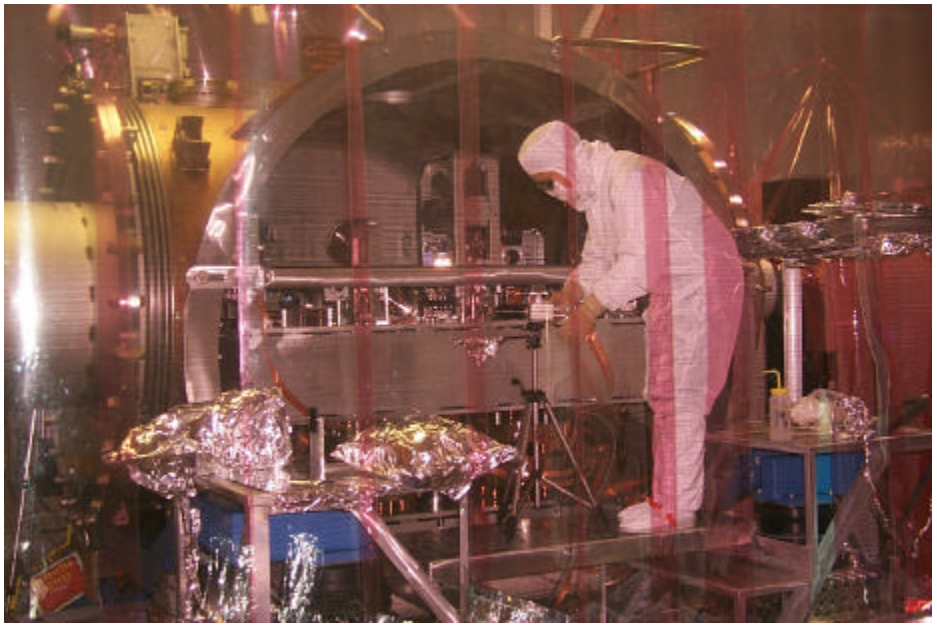
Stack Installation
(Hanford X-Mid)



Coarse Actuation
System

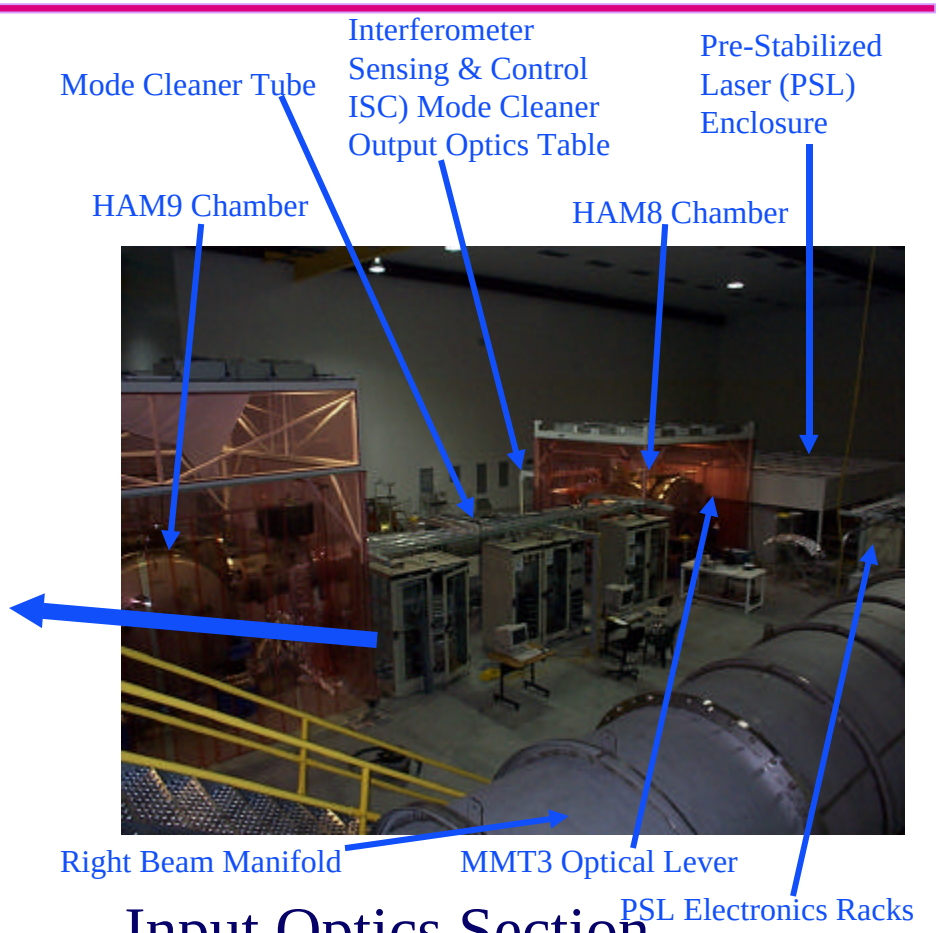
Input Optics (IO)

- Hanford 2 km & Livingston 4 km Input Optics (IO) Installations are complete
  - » Univ. of Florida led this subsystem installation effort
  - » The Mode Cleaner routinely holds length servo-control lock for days
  - » Mode cleaner parameters are close to design specs, including the length, cavity linewidth and visibility
  - » Further characterization is underway (optics suspension diagonalization & PSL freq. noise measurement)



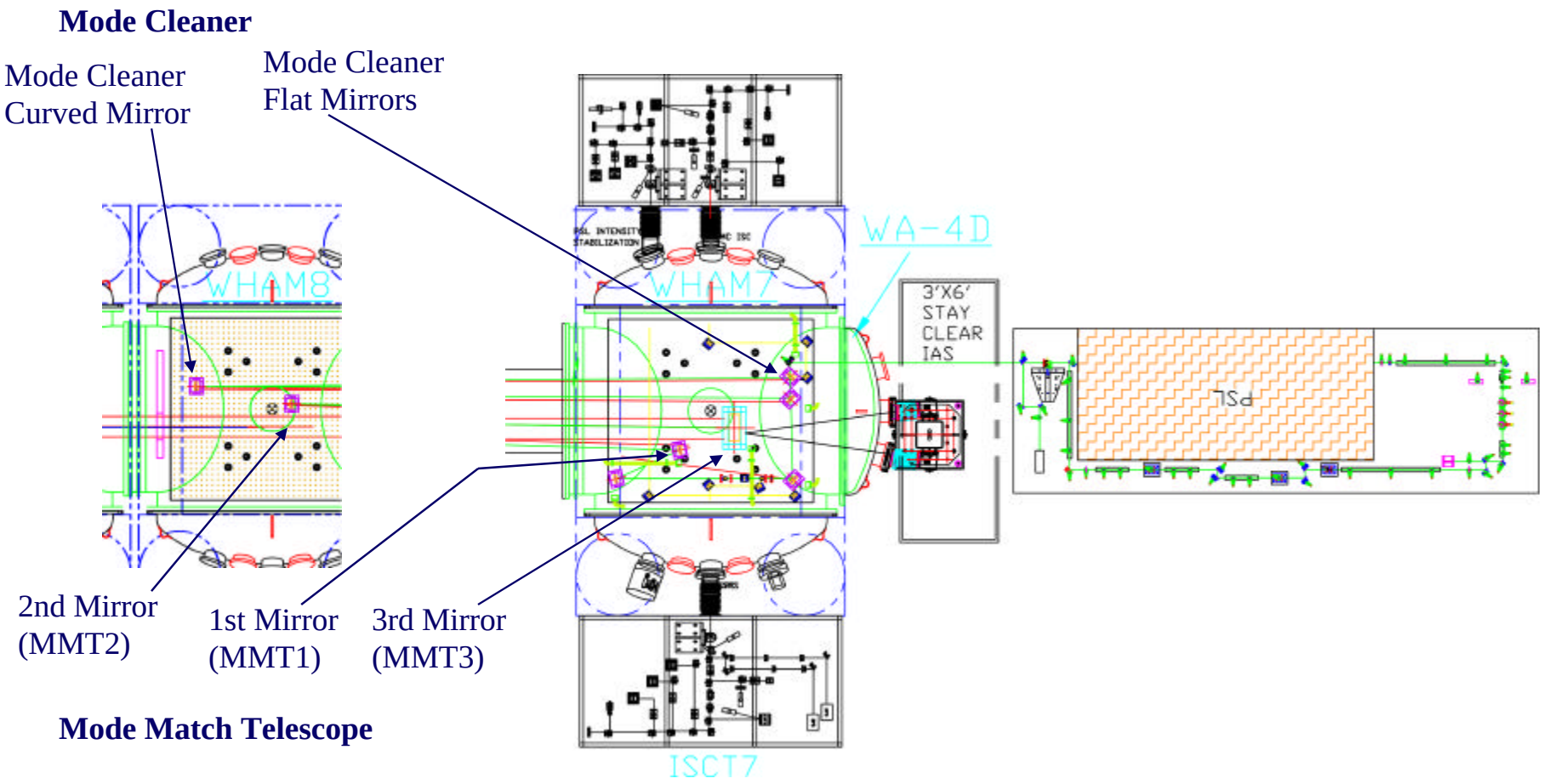
Input Optics (IO)

Control System Racks
(2km Interferometer)



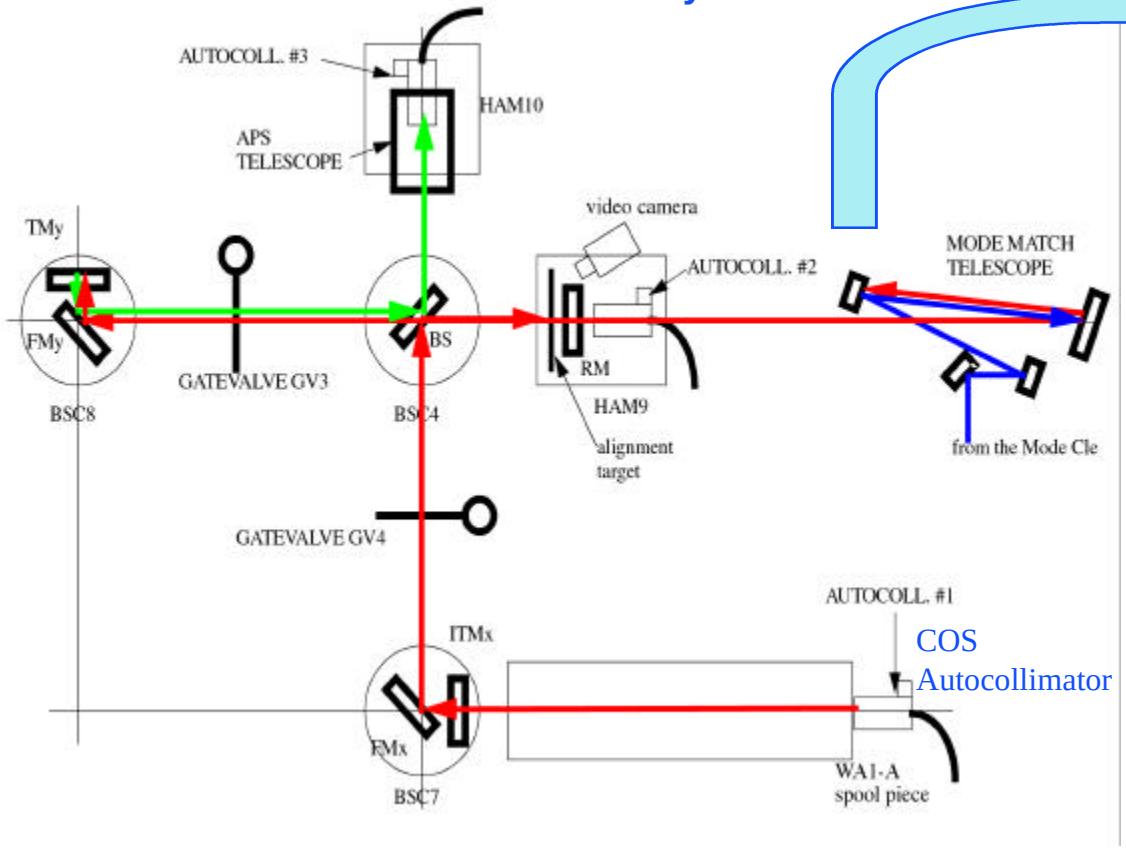
Input Optics Section
(2km Interferometer)

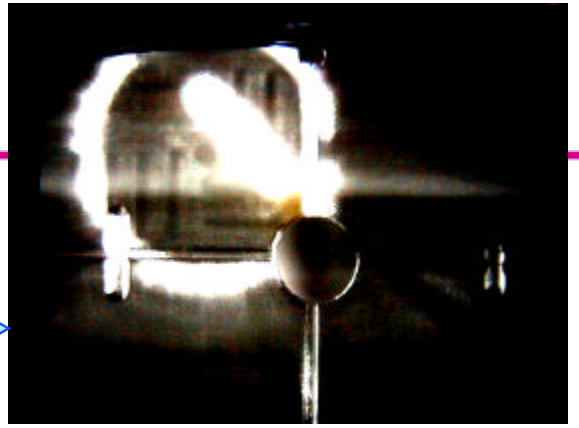
Input Optics (IO) Layout



Recycling Cavity Alignment

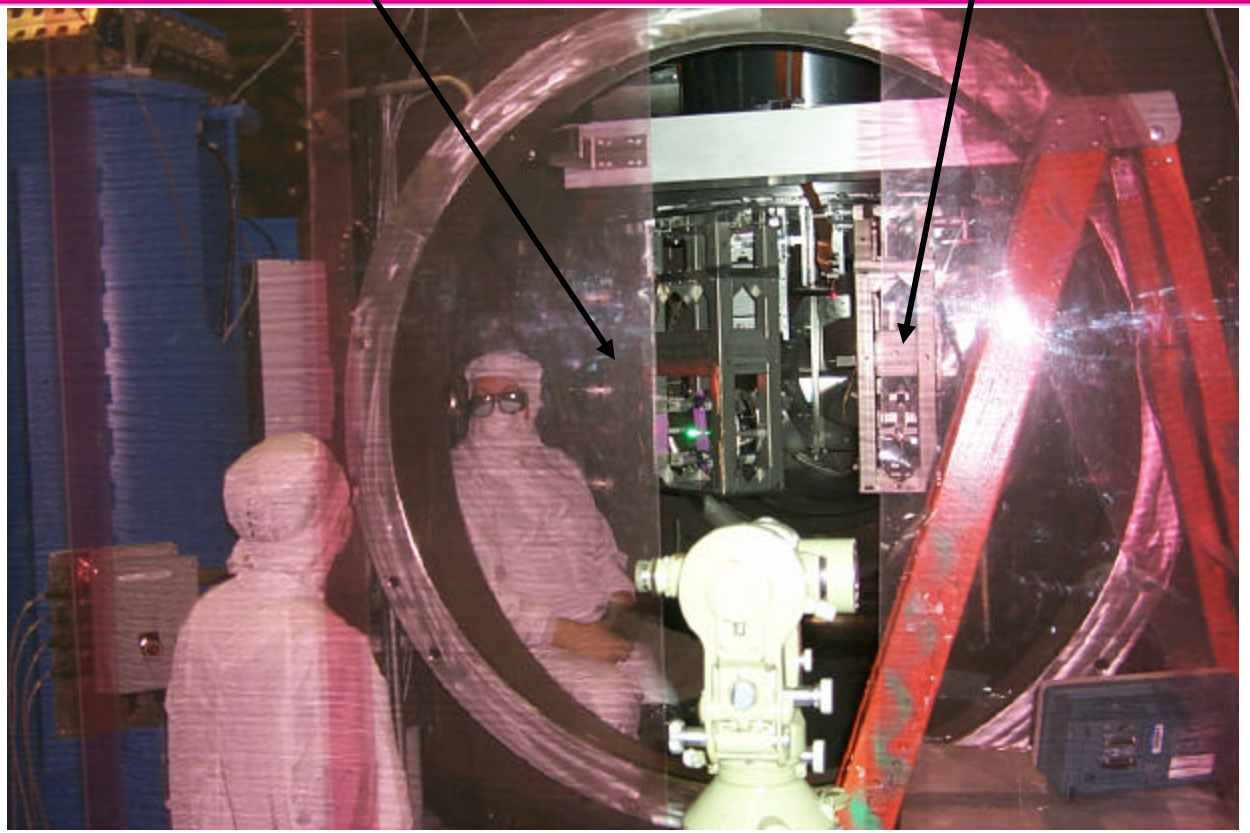
- **Initial alignment procedures proved successful!**
  - » **~100 microradian accuracy**





Projected reticule pattern & PSL beam on target in front of MMT2

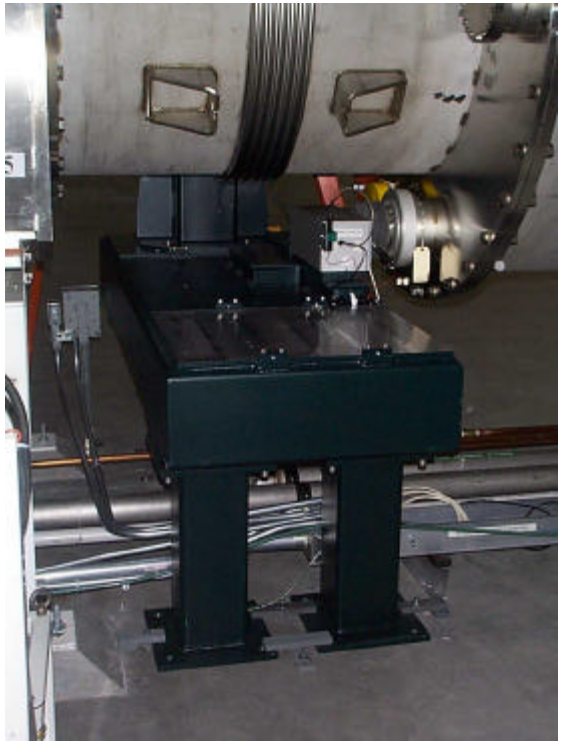
Recycling Cavity Alignment



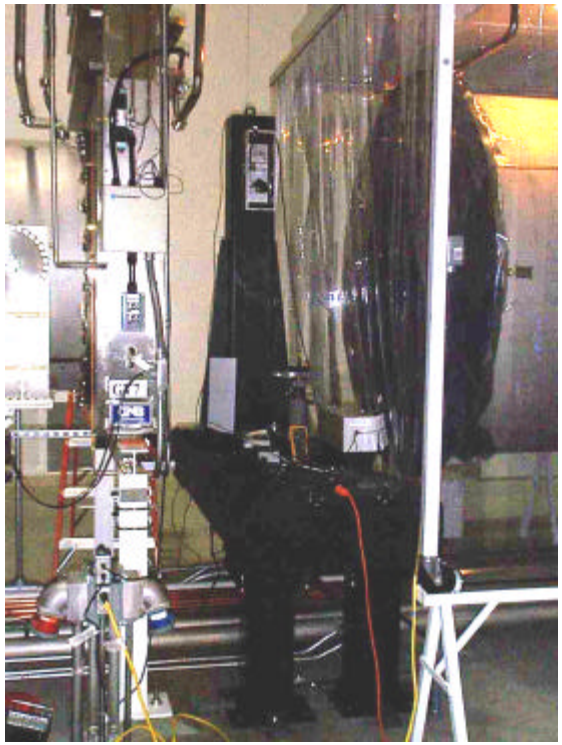
Adjusting the Fold Mirror (FMx) Alignment

Initial Alignment System: Optical Levers

- Optical levers have been installed, aligned & are operational for all core optics in the 2km interferometer

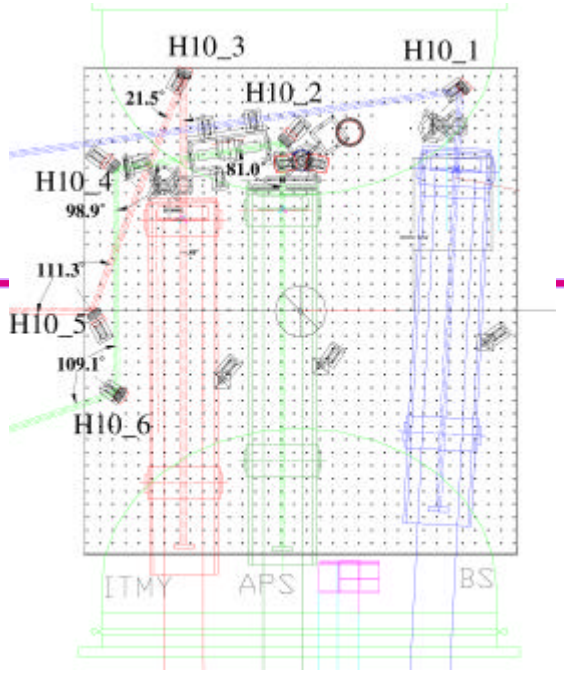


Input Test Mass (ITMx) Optical Lever

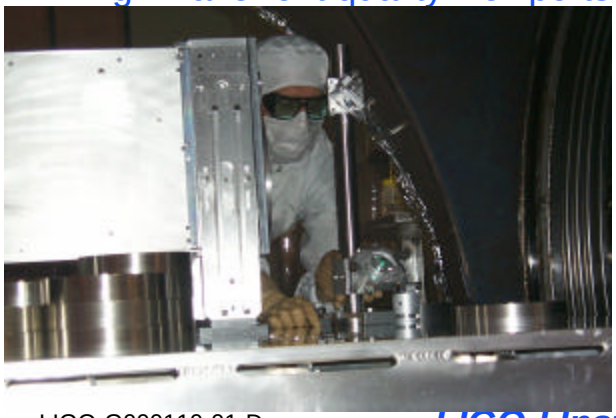


Transmit & Receive modules visible with spool piece removed for ITMx alignment

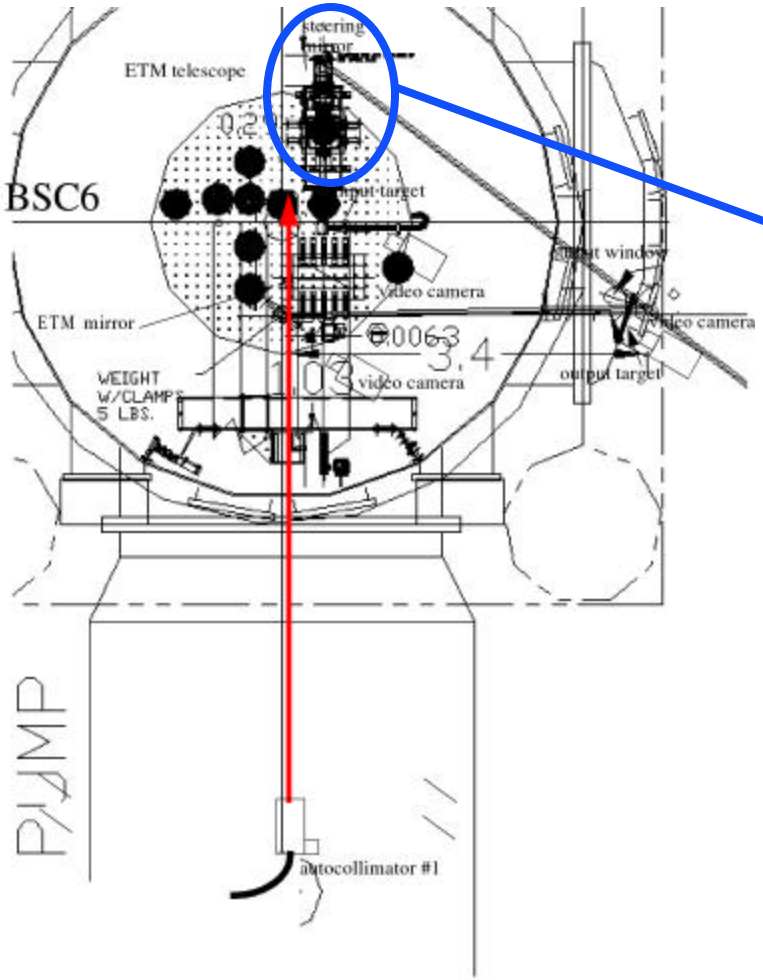
Core Optics Support



- Fabrication has been completed
- Installed for the 2km:
  - » Beam Dumps (most)
  - » Recycling cavity baffles, IO baffle & cryopump baffle
  - » Pick-Off Mirrors
  - » Antisymmetric Port Pick-Off Telescope
  - » Both End Test Mass Transmission Telescopes
- Current installation for the 2km:
  - » arm cavity baffles
  - » 3 pick-off telescopes
  - » high wavefront quality viewports

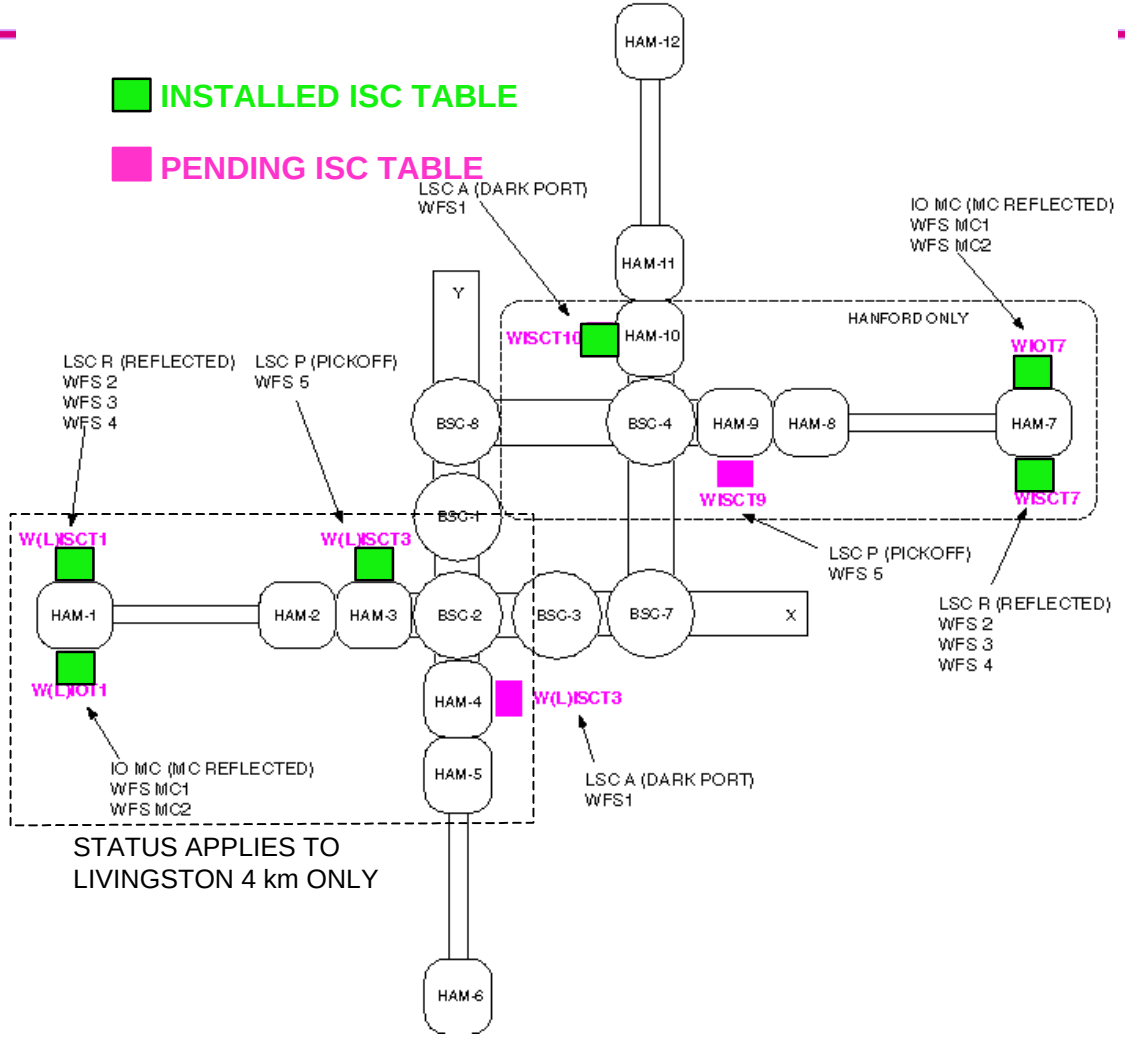


Core Optics Support:
End Test Mass Transmission Telescope



Interferometer Sensing & Control (ISC): Readout Optics and Electronics

- All 2 km Interferometer read-out sensors and electronics will be installed by 7/00
- All 2 km Interferometer alignment control electronics are installed; nearing completion at Livingston
- Common mode length control electronics have been tested (one arm)
- Differential mode whitening/de-whitening, anti-aliasing boards & software controls to be installed on the 2 km interferometer by 7/00

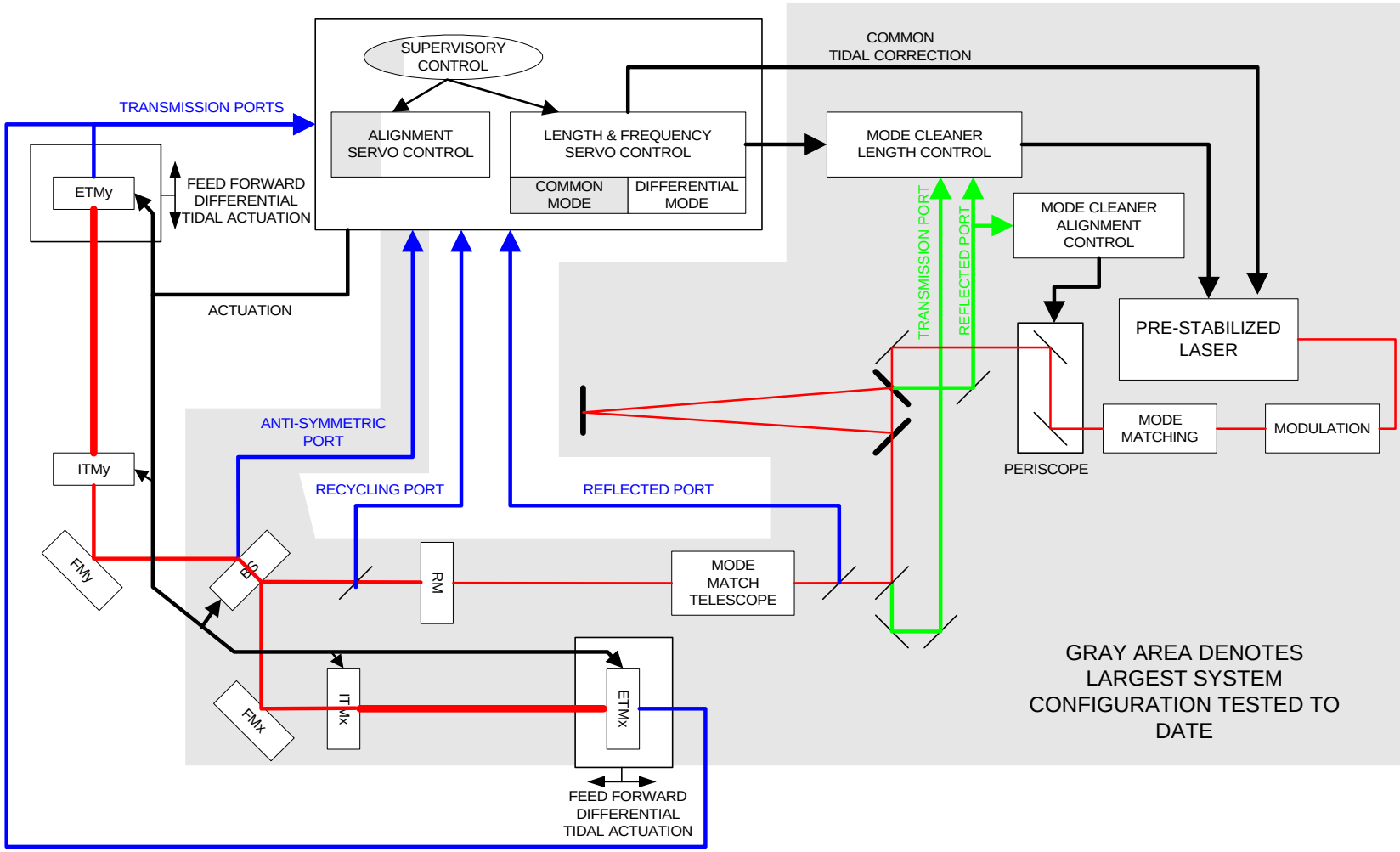


Commissioning Configurations

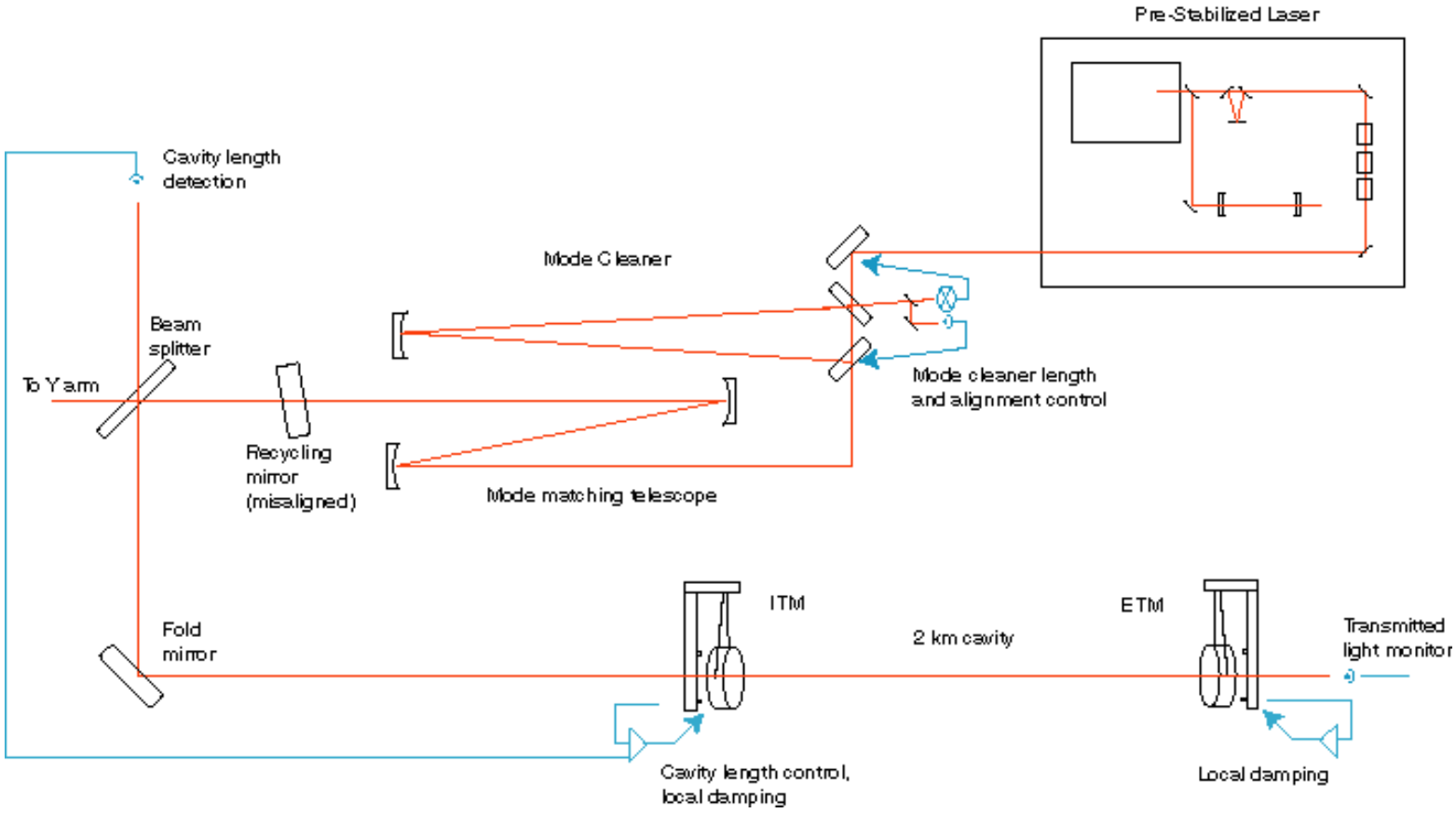
- Mode cleaner and Pre-Stabilized Laser
- Michelson interferometer
- 2km one-arm cavity

Activities at both Observatories

LIGO BLOCK DIAGRAM



Schematic of Configuration used to date in Commissioning

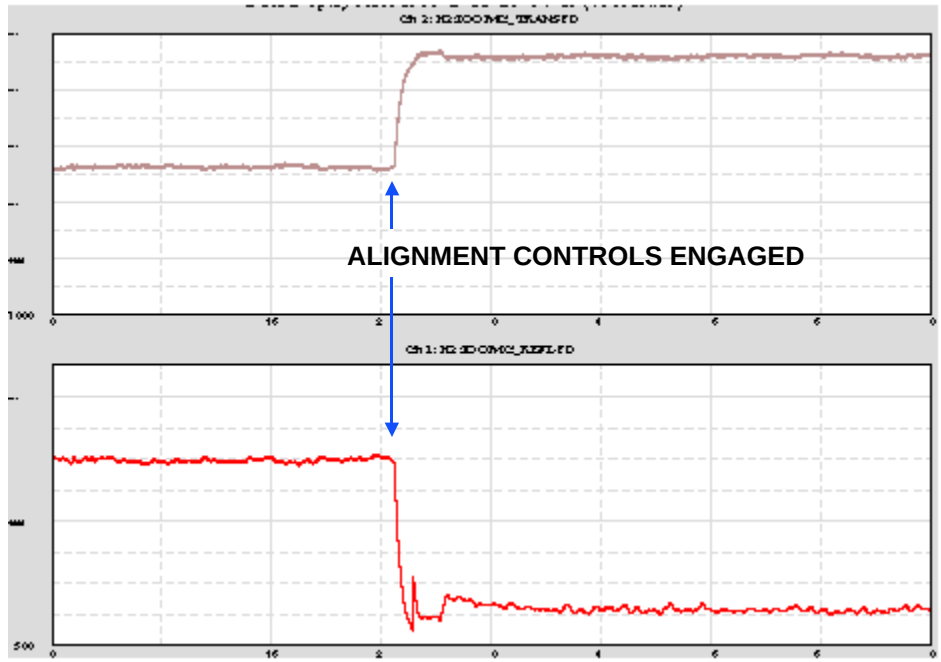


Pre-Stabilized Laser-Mode Cleaner

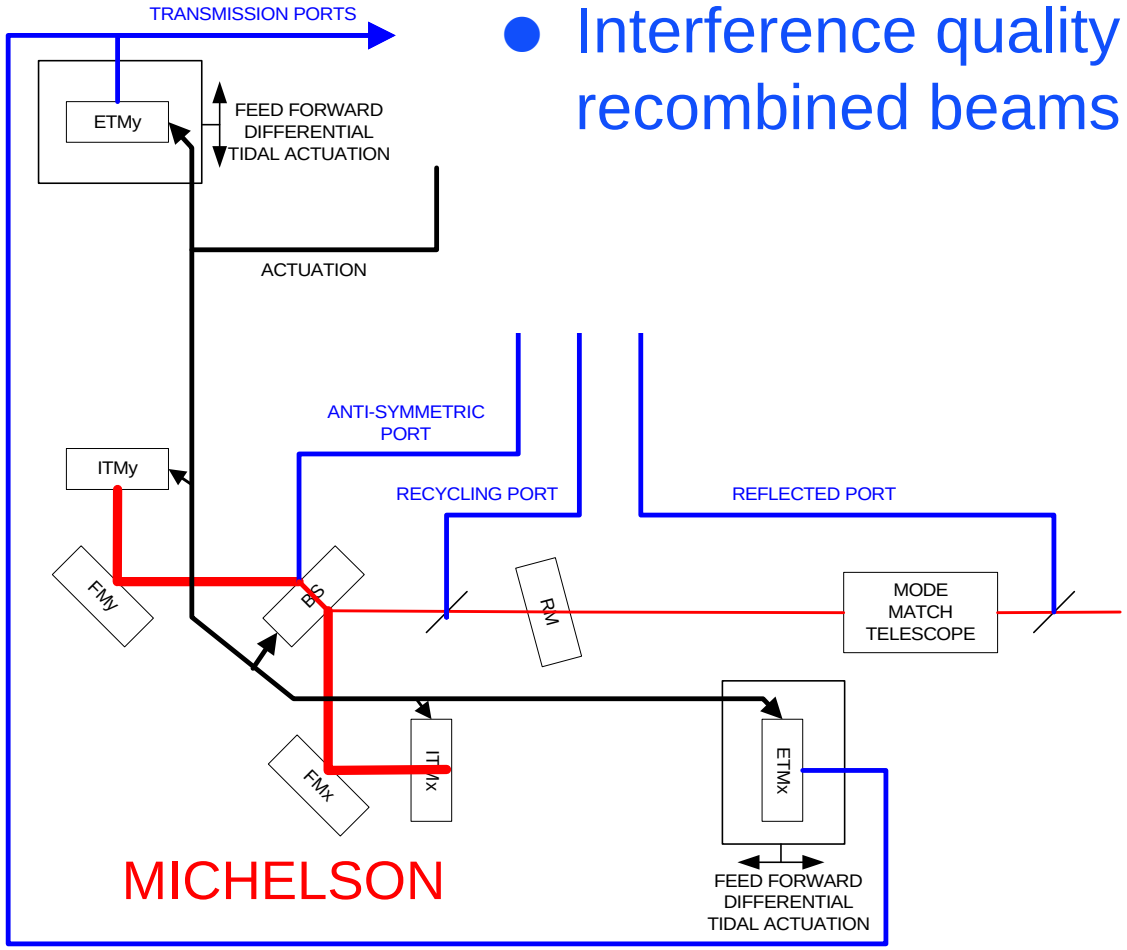
- Suspension characterization
  - » actuation/diagonalization
  - » sensitivity of local controls to stray Nd:YAG light
  - » Qs of elements measured, 3e5-1e6
- Laser - Mode Cleaner control system shakedown
- Laser frequency noise measurement

Wavefront sensing on Mode Cleaner cavity

- Alignment system function verified

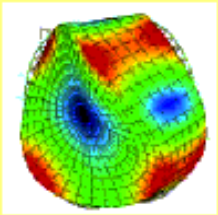
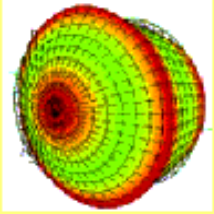
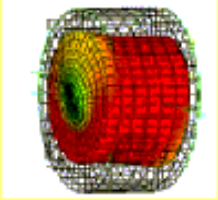


Michelson Interferometer



- Interference quality of the recombined beams > 0.99

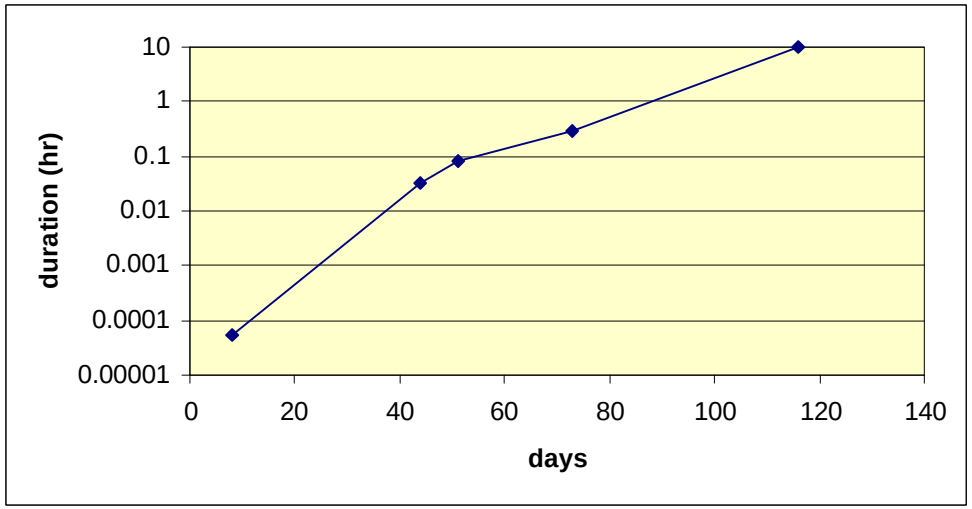
Core Optic Mechanical Resonance Quality Factors

Mode		Optic	Frequency (kHz)	Q factor
	Butterfly	ITMx	6.748	1.4×10^6
		ETMx	6.639	2.8×10^6
		BS	3.7337	1.85×10^6
	Drumhead	ITMx	9.395	6×10^5
		ETMx	9.254	7.8×10^4
		BS	5.478	2.5×10^4
	Breathing	ITMx	14.374	1.2×10^7
		ETMx	14.372	5.1×10^6
		BS	11.1387	3.6×10^5

- Measured the quality factors (Q) for internal resonances of the core optics
- Q factors are high and meet requirements

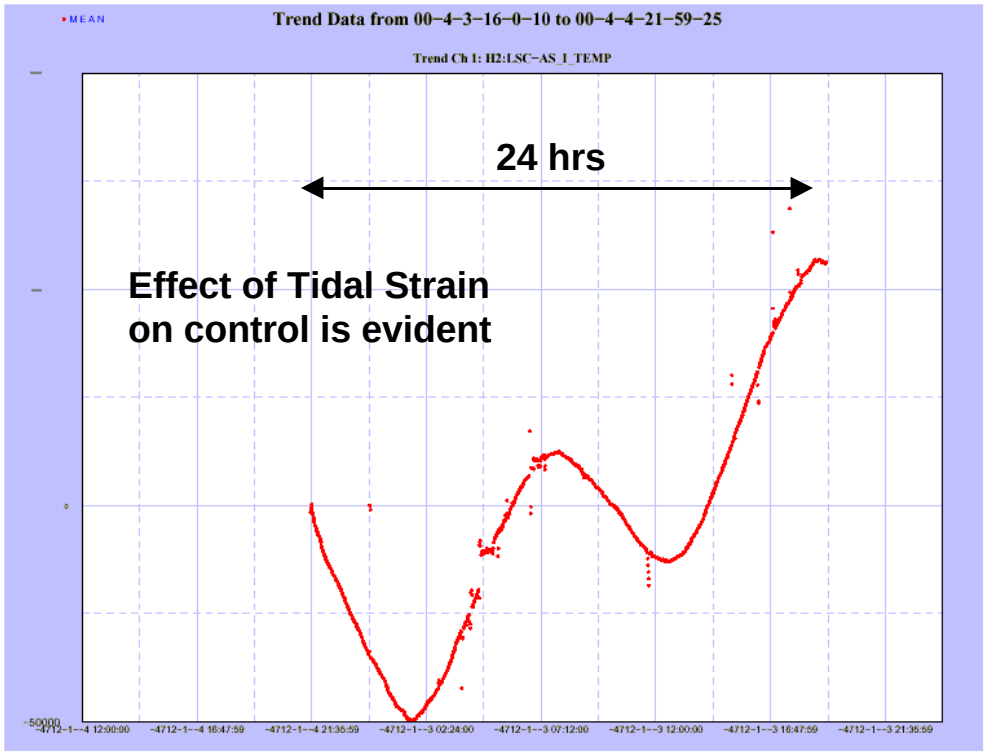
2 km Fabry-Perot Cavity

- Includes all interferometer subsystems
  - » many in definitive form; analog servo on cavity length for test configuration
- Ability to lock cavity improves with understanding



2km Fabry-Perot cavity

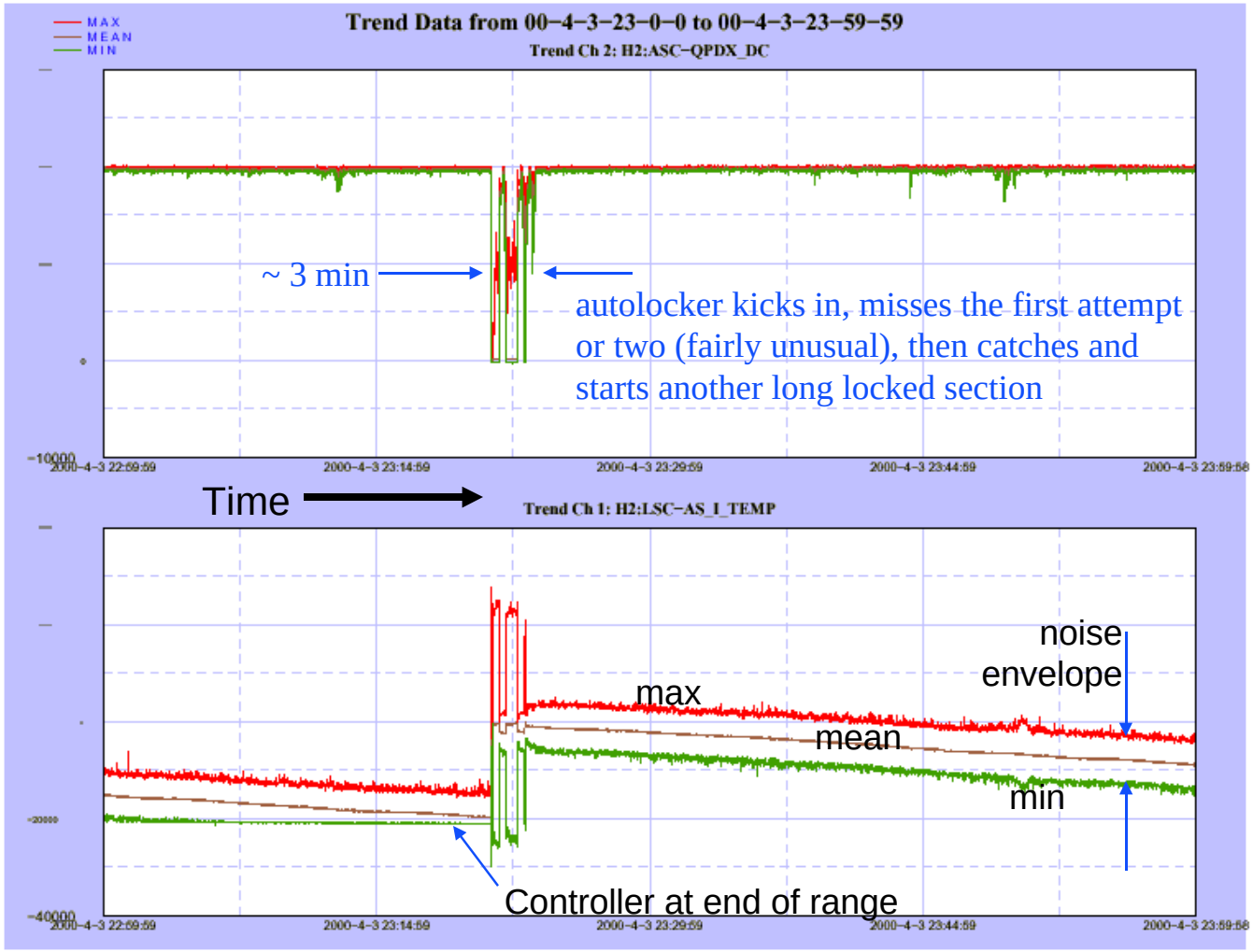
- models of environment
  - » temperature changes on laser frequency
  - » tidal strains changing baselines
  - » seismometer/tilt correlations with microseismic peak
- mirror characterization
  - » losses: 1-2% dip in reflected signal intensity
  - » scatter: appears to be better than requirements



2km Fabry-Perot cavity: 1 hr stretch with Unlock-Lock Transient

Cavity Transmitted Signal

Input Test Mass Control Signal



24 hr Engineering Run

- A 24-hour engineering data run was conducted 4/3-4 using the 2 km x-arm
- Quite useful for detector characterization studies
  - » understanding the single arm's behavior
  - » exercising algorithms
  - » excellent opportunity for LSC members to learn more about the interferometer
- Invited any interested LSC physicist
  - » 8 non-detector scientists participated
- Data is archived on hpss at CACR: http://www.srl.caltech.edu/personnel/sba/hpss/index.html

Data Analysis: 24 hr Engineering Run

- Analysis of the data is underway by many groups, e.g.
  - » University of Michigan: test and refine algorithms for
    - – detection of servo instabilities
    - – detection of modulating or drifting line sources
    - – detecting large instrumental transients
    - – quantifying linear and bi-linear correlations
  - » University of Oregon:
    - – develop and test routines for on-line data reduction
    - – search for correlations between environmental monitors and the laser control signals
  - » University of Florida: test and refine algorithms for
    - – wavelet analysis of transients
    - – data compression
    - – line feature variability

Software tools for Diagnostics

- Data acquisition system
  - » site-wide, synchronized, flexible
  - » reduced data sets for later study
- time series viewing tools
  - » multiple time series, trends
  - » on-line
- diagnostic analysis tools
  - » fourier transforms, coherence, etc.
  - » on-line
- Change of paradigm for this field: research performed in the control room

Commissioning

- Relatively ‘young’ undertaking
  - » unlike (much better than) previous prototype environments
- tools, researchers quickly maturing
- learning rules for structuring the work
  - » temporary hardware setups
  - » useful software tools
  - » coordination with installation
  - » multiple shifts
- second derivative is non-zero and positive

Installation & Commissioning Summary

- Mode Cleaners (MC) at both Hanford and Livingston have both been aligned and locked
  - » Detailed characterization of the Livingston Mode Cleaner (MC) is underway
- The 2 km Interferometer near Michelson has been locked
- Each arm of the 2 km Interferometer has been locked
- The 2 km long arm cavity test has been completed
  - » Lock durations of ~10 hrs
  - » a 24 hr Engineering Data Run has been completed