LIGO-I Installation and Commissioning

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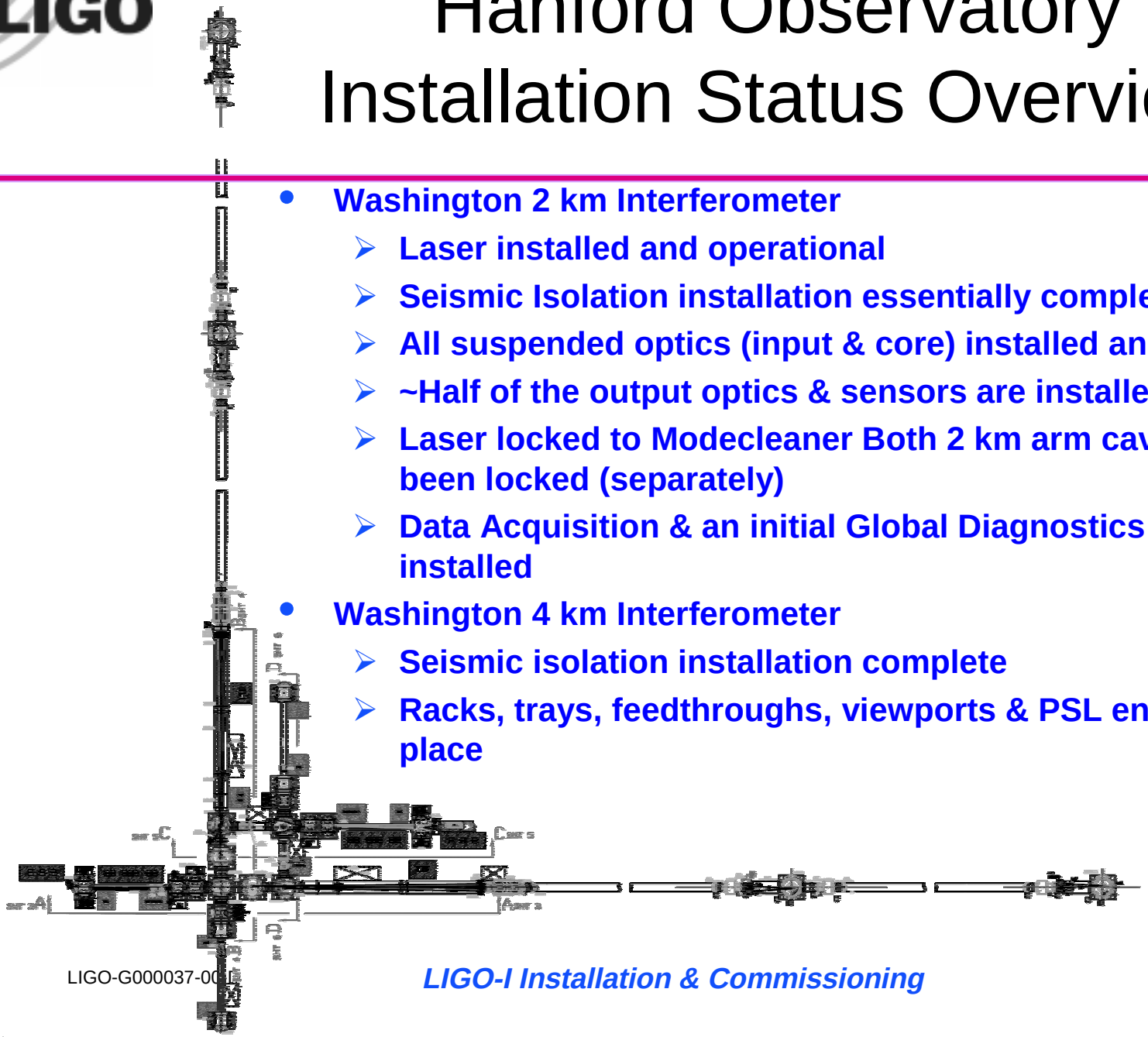
LIGO Oversight Committee Meeting

April 21, 2000

Detector

- Installation
- Commissioning
- Schedule Status

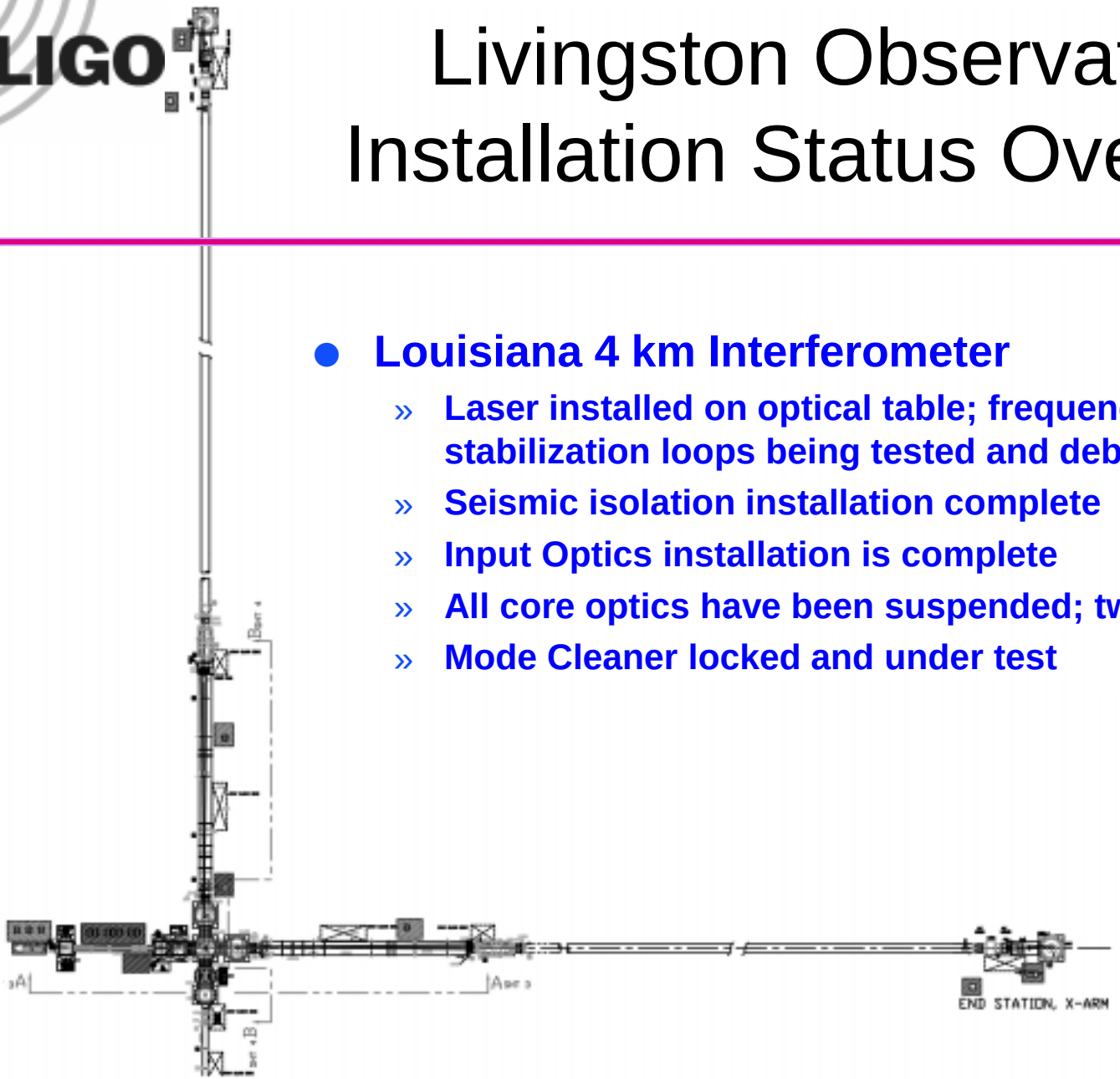
Hanford Observatory Installation Status Overview



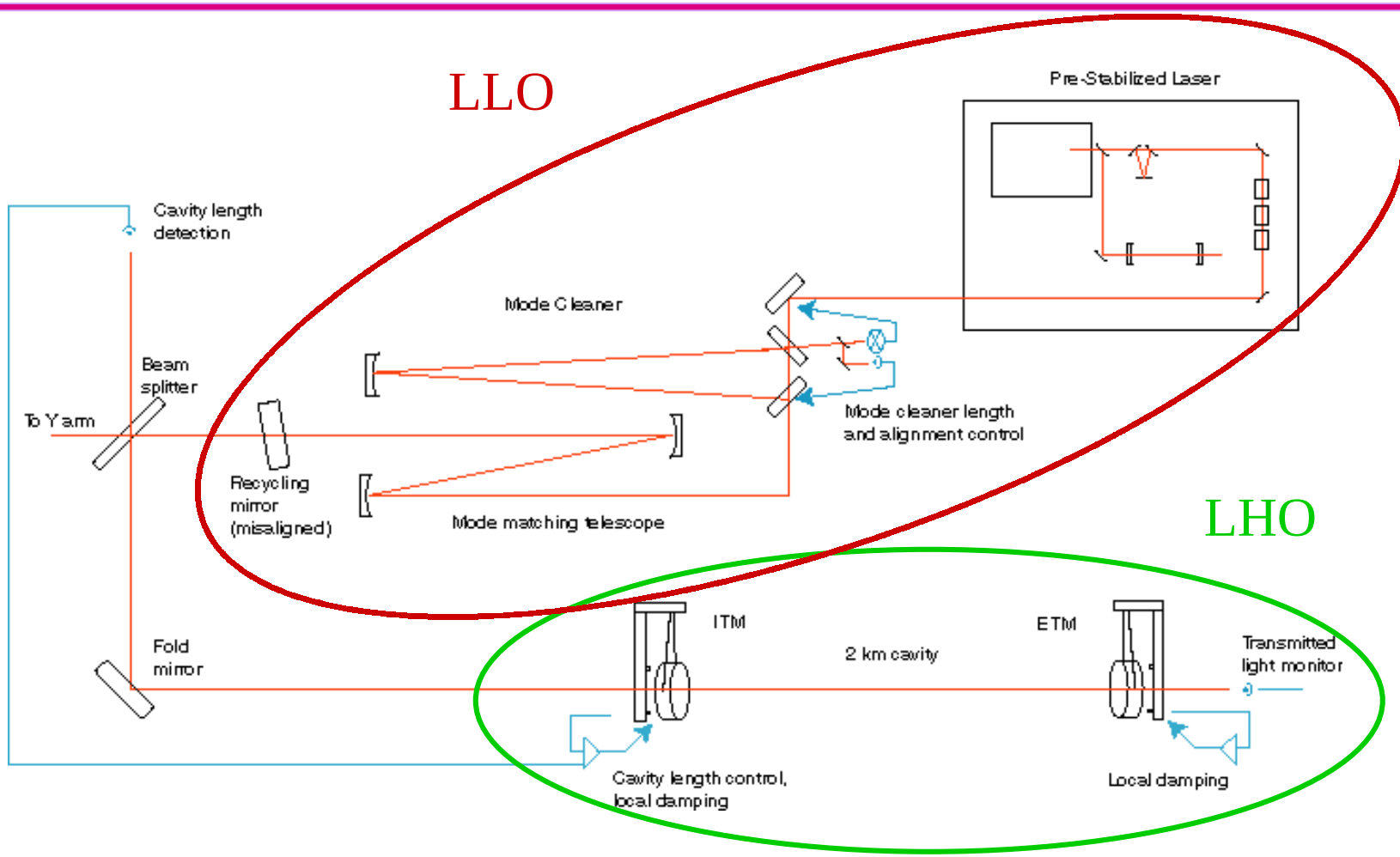
- **Washington 2 km Interferometer**
  - **Laser installed and operational**
  - **Seismic Isolation installation essentially complete**
  - **All suspended optics (input & core) installed and aligned;**
  - **~Half of the output optics & sensors are installed**
  - **Laser locked to Modecleaner Both 2 km arm cavities have been locked (separately)**
  - **Data Acquisition & an initial Global Diagnostics System installed**
- **Washington 4 km Interferometer**
  - **Seismic isolation installation complete**
  - **Racks, trays, feedthroughs, viewports & PSL enclosure in place**

Livingston Observatory Installation Status Overview

- **Louisiana 4 km Interferometer**
  - » **Laser installed on optical table; frequency and intensity stabilization loops being tested and debugged**
  - » **Seismic isolation installation complete**
  - » **Input Optics installation is complete**
  - » **All core optics have been suspended; two are installed**
  - » **Mode Cleaner locked and under test**



Commissioning Configurations

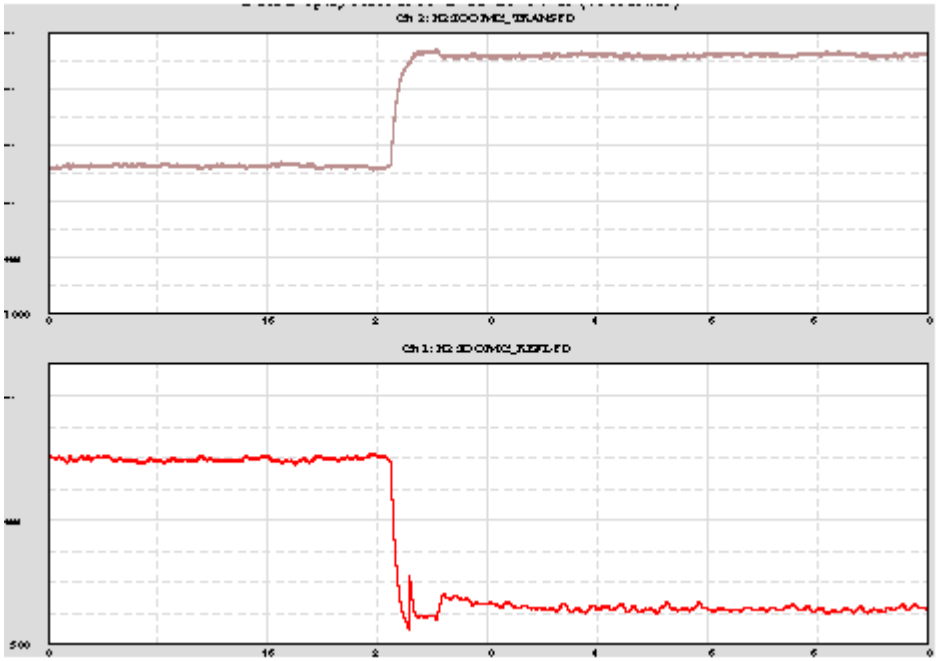


Pre-Stabilized Laser/ Mode Cleaner

- 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
- Environmental Inputs (seismic noise, etc)

Wavefront sensing on Mode Cleaner cavity

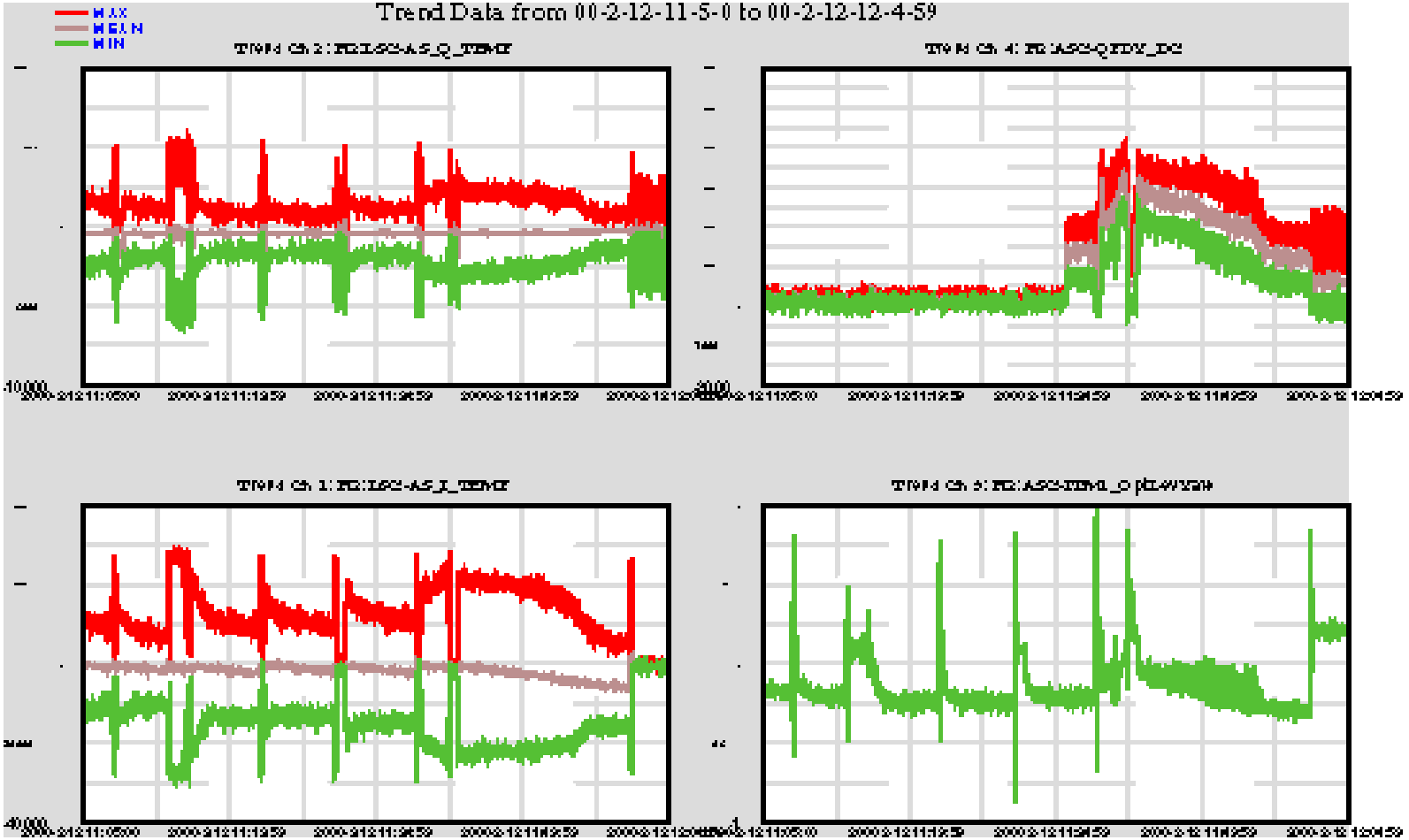
- Alignment system function verified



2km Fabry-Perot cavity

- Includes all interferometer subsystems
  - » most in final form form;
- Confirmation of initial alignment
  - » ~100 microrad errors; beams easily found in both arms
- Ability to lock cavity improves with understanding
  - ➢ 0 sec 12/1 flashes of light
  - ➢ 0.2 sec 12/9
  - ➢ 2 mins 1/14
  - ➢ 60 sec 1/19
  - ➢ 5 mins 1/21 (and on a different arm)
  - ➢ 18 mins 2/12
  - ➢ 10 hours! 3/26

2km Fabry-Perot cavity: 15 minute locked stretch



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
- Diagnostic analysis tools
  - » fourier transforms, coherence, etc.
- Change of paradigm: 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

Progress Against Schedule?

- Installation and commissioning of the interferometers have been progressing and preliminary results are encouraging
- However there have been delays and problems:
  - » production start problems in seismic isolation and a slow early production pace
  - » process control problems for the magnet/standoff assembly adhesion to the optics
  - » handling and fixture problems associated with the transport and alignment of completed suspension assemblies
  - » re-manufacture of much of our flourel component stock as a result of losses from a tornado which destroyed the manufacturing facility
  - » re-baking of the flourel spring seats (and associated seismic stack rebuild) to mitigate water load on the vacuum system
  - » a number of secondary delays (not pushing the critical path, but “just in time”) indicating that the project has been stressed to meet the demanding installation schedule

Original Installation and Commissioning Plan

- The original installation and commissioning plan suffers from two main weaknesses:
  - By installing all three interferometers before beginning commissioning, any design deficiencies are replicated three times
  - Having a period of installation followed by a period of commissioning does not use the range of skills of the LIGO staff as effectively as possible
- and one unnecessary constraint:
  - That coincidence testing begin only after all three interferometers are operational, unduly drives the installation of the third interferometer

Reformulated Installation and Commissioning Plan

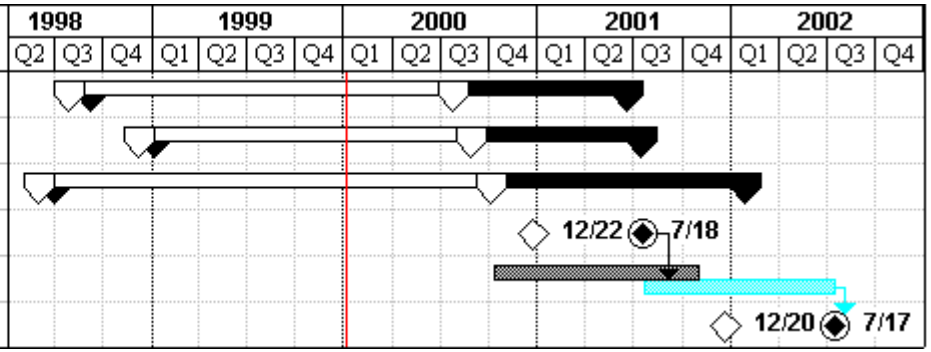
- Delay completion of the third interferometer (the Hanford 4km interferometer) :
  - » Enable lessons learned from the first two interferometers to be realized in redesign before installation (minimizes re-work/ re-installation)
  - » Reduce simultaneous installation and commissioning workload on the LIGO lab staff
- Use the Hanford 2 km interferometer as a “pathfinder” to identify problems early
- Use the Livingston 4 km interferometer for problem resolution & detailed characterization
- Initiate Coincidence testing when the first two interferometers are at an operational strain sensitivity

Reformulated Installation and Commissioning Plan (continued)

- Define clear decision points in the schedule for the third interferometer installation elements:
  - » Perform all in-vacuum work and infrastructure as early as possible
  - » Delay installation of the servo-control electronics until we've gained enough experience to incorporate anticipated re-design.
- LIGO I Science Run
  - » Begins with reliable and calibrated coincidence data on three interferometers and stable configuration
  - » Improvements to reach final design goals in sensitivity and reliability will be alternated with data running
  - » Goal is to obtain at least one year of integrated sensitivity at $h \sim 10^{-21}$ before initiating LIGO II

Top Level Schedule

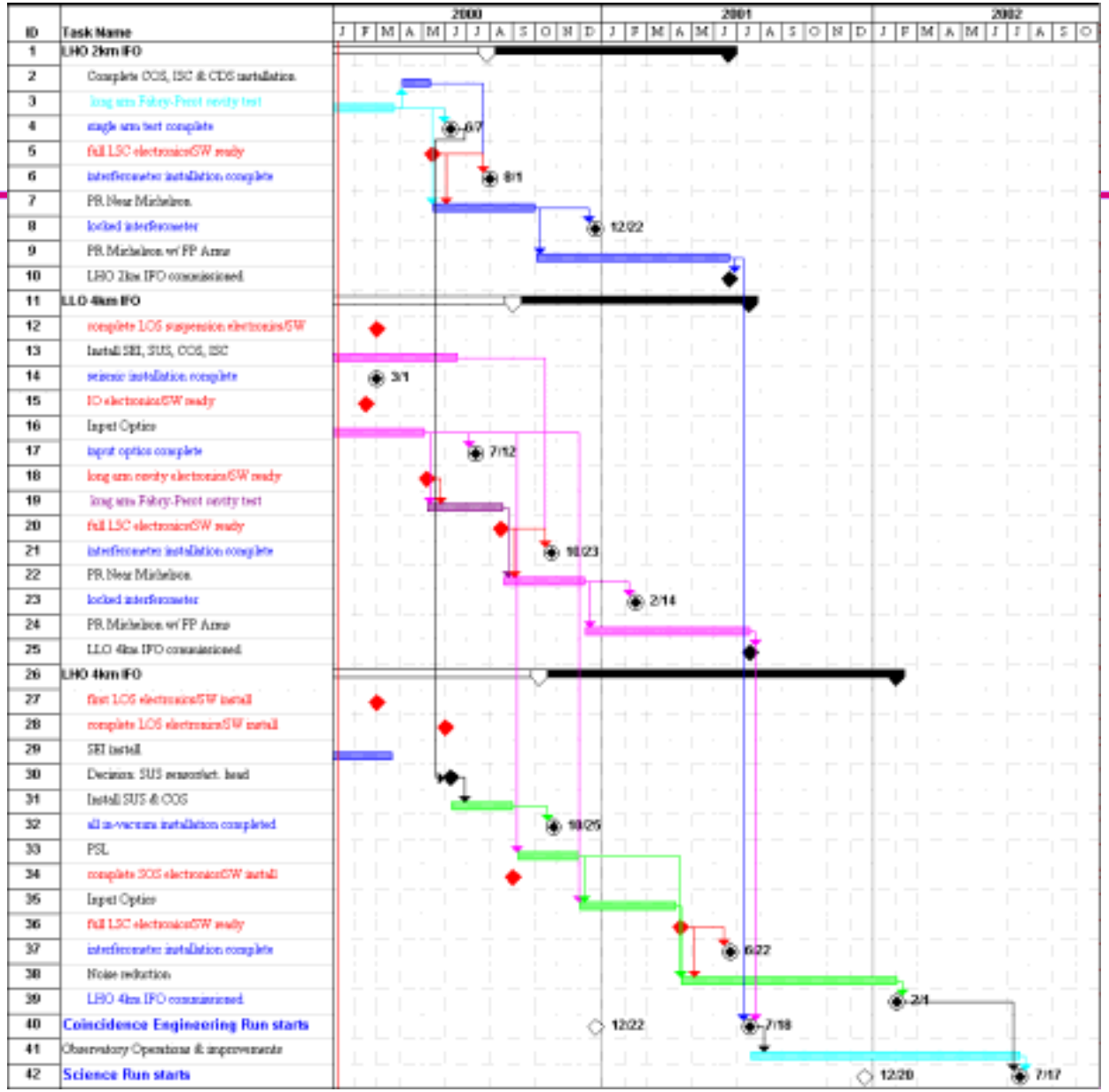
ID	Task Name
1	LHO 2km IFO
14	LLO 4km IFO
30	LHO 4km IFO
44	Coincidence Engineering Run starts
45	Observatory Operations & improvements
46	Science Run starts



Projected Significant Events

Hanford 2km interferometer	Seismic isolation installed Input Optics completed Single arm test complete Interferometer installed Interferometer locked	done done done 8/00 12/00
Livingston 4km interferometer	Seismic isolation installed Input Optics completed Interferometer installed Interferometer locked	done 7/00 10/00 2/01
Coincidence Engineering Run (Hanford 2km & Livingston 4km)	Initiate Complete	7/01 7/02
Hanford 4km interferometer	Seismic isolation installed All in-vacuum components installed interferometer installed interferometer locked	done 10/00 6/01 8/01
LIGO I Science Run (3 interferometers)	Initiate Complete (obtain 1 yr @ h ~ 10^{-21})	7/02 1/05

Schedule


ID
Task Name
2000
2001
2002
1 LHO 2km IFO
2 Complete COS, ISC & CDS installation
3 long arm Fabry-Perot cavity test
4 single arm test complete
5 full LSC electronics/SW ready
6 interferometer installation complete
7 PR Near Michelson
8 locked interferometer
9 PR Michelson w/ FP Arms
10 LHO 2km IFO commissioned
11 LLO 4km IFO
12 complete LOS suspension electronics/SW
13 Install SEI, SUS, COS, ISC
14 seismic installation complete
15 IO electronics/SW ready
16 Input Optics
17 input optics complete
18 long arm cavity electronics/SW ready
19 long arm Fabry-Perot cavity test
20 full LSC electronics/SW ready
21 interferometer installation complete
22 PR Near Michelson
23 locked interferometer
24 PR Michelson w/ FP Arms
25 LLO 4km IFO commissioned
26 LHO 4km IFO
27 first LOS electronics/SW install
28 complete LOS electronics/SW install
29 SEI install
30 Decision: SUS removal/ext. head
31 Install SUS & COS
32 all in-vacuum installation completed
33 PSL
34 complete SOS electronics/SW install
35 Input Optics
36 full LSC electronics/SW ready
37 interferometer installation complete
38 Noise reduction
39 LHO 4km IFO commissioned
40 Coincidence Engineering Run starts
41 Observatory Operations & improvements
42 Science Run starts
6/7
8/1
12/22
3/1
7/12
10/23
2/14
10/25
6/22
2/4
12/22
7/18
12/20
7/17

Installation & Commissioning Summary

- Installation & Commissioning successes!
  - » The 2 km interferometer Mode Cleaner is aligned and locked
  - » The 2 km Interferometer recycling cavity and both arms are aligned
  - » The 2km long arm cavity test completed this month (Lock durations up to 10 hours!)
  - » The Livingston Mode Cleaner is aligned and locked
- Delays have caused us to re-evaluate our Installation & Commissioning plan & schedule :
  - » Delays due principally to installation problems on the critical path
  - » Anticipated problems/delays in the servo-control electronics
  - » We project a 7 month slip in the start of coincidence testing, redefined as a single interferometer at each site operating reliably and at a low strain sensitivity