LIGO NSF Review

April 21-23, 1999

Overview

Barry Barish

LIGO Plans

main activity

1996 **Construction Underway**

-mostly civil

1997 **Facility Construction**

-vacuum system

1998 **Interferometer Construction**

-complete facilities

1999 **Construction Complete**

-interferometers in vacuum

2000 **Commission Detectors**

-first light; testing

2001 **Engineering Tests**

-sensitivity; engineering run

LIGO Science

physics schedule

- First Physics Run (~2002-2004)
  - » begins after h ~ 10^{-21} attained
  - » two year run allows first neutron binary search (live time ~ 1 yr)
  - » LIGO I Collaboration
- Implement LIGO II (~2004-07)
  - » Advanced R&D underway to reach h ~ 10^{-22}
  - » LSC White Paper (detector and data analysis) to set out plan
  - » implemented from ~2004 over several years
  - » physics runs interleaved
- Advanced Detectors (> 2007-)
  - » new optical configurations, new vacuum systems, floor space, etc

Hanford

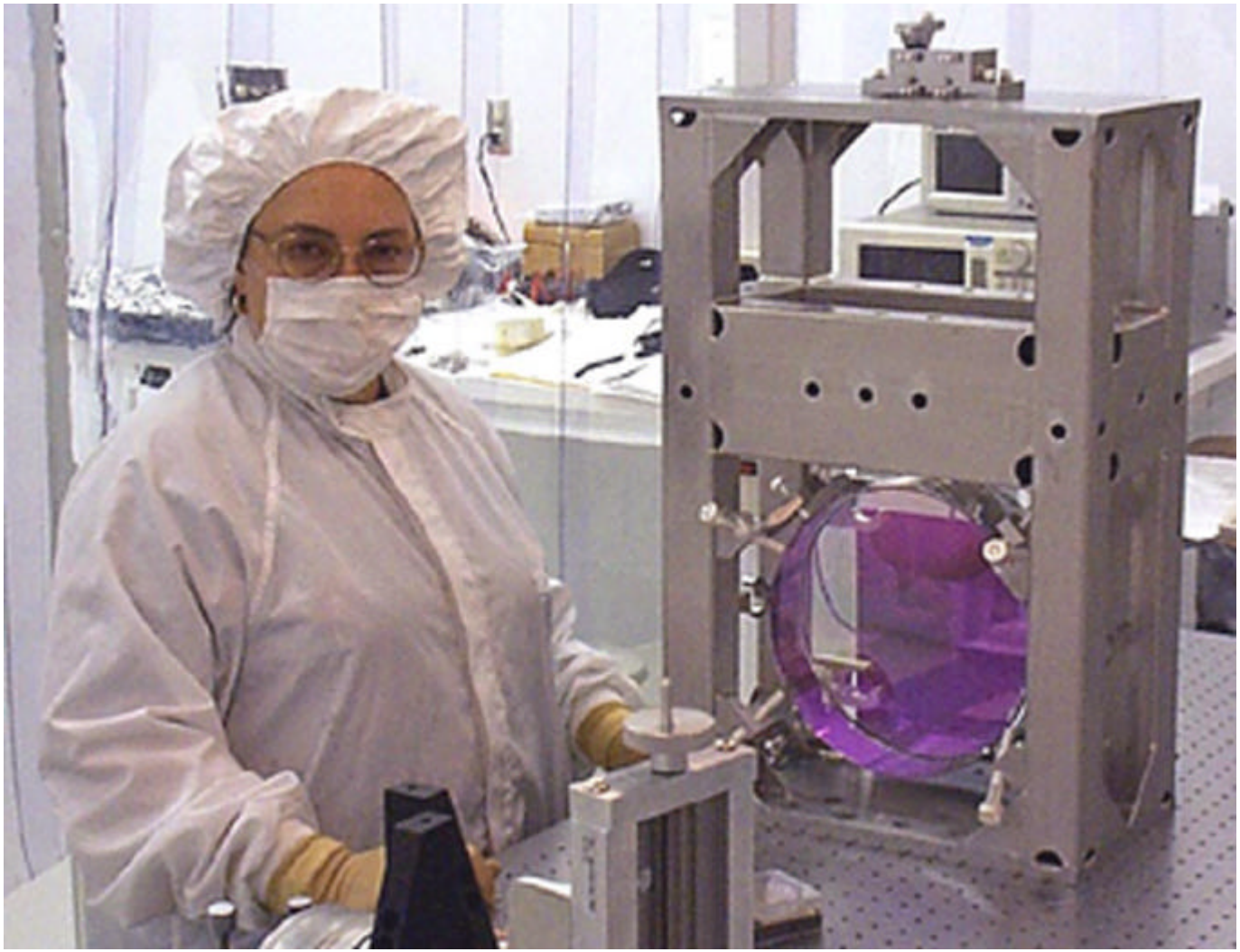
Hanford

activities

- Staffing continues to grow on schedule
- Bakeout will be complete in May
  - » begin transfer of equipment to Livingston
- Optics and Vacuum preparations fully operational and now a central activity
- Laser and prestabilization installed in 2K and performance studied
- HAM Seismic Isolation tables installed
- BSC Seismic Isolation tables underway
- Control room becoming a ‘control room’
- Outreach (REU, High School teachers, etc)

Hanford

optics preparation/installation



Livingston

vacuum systems

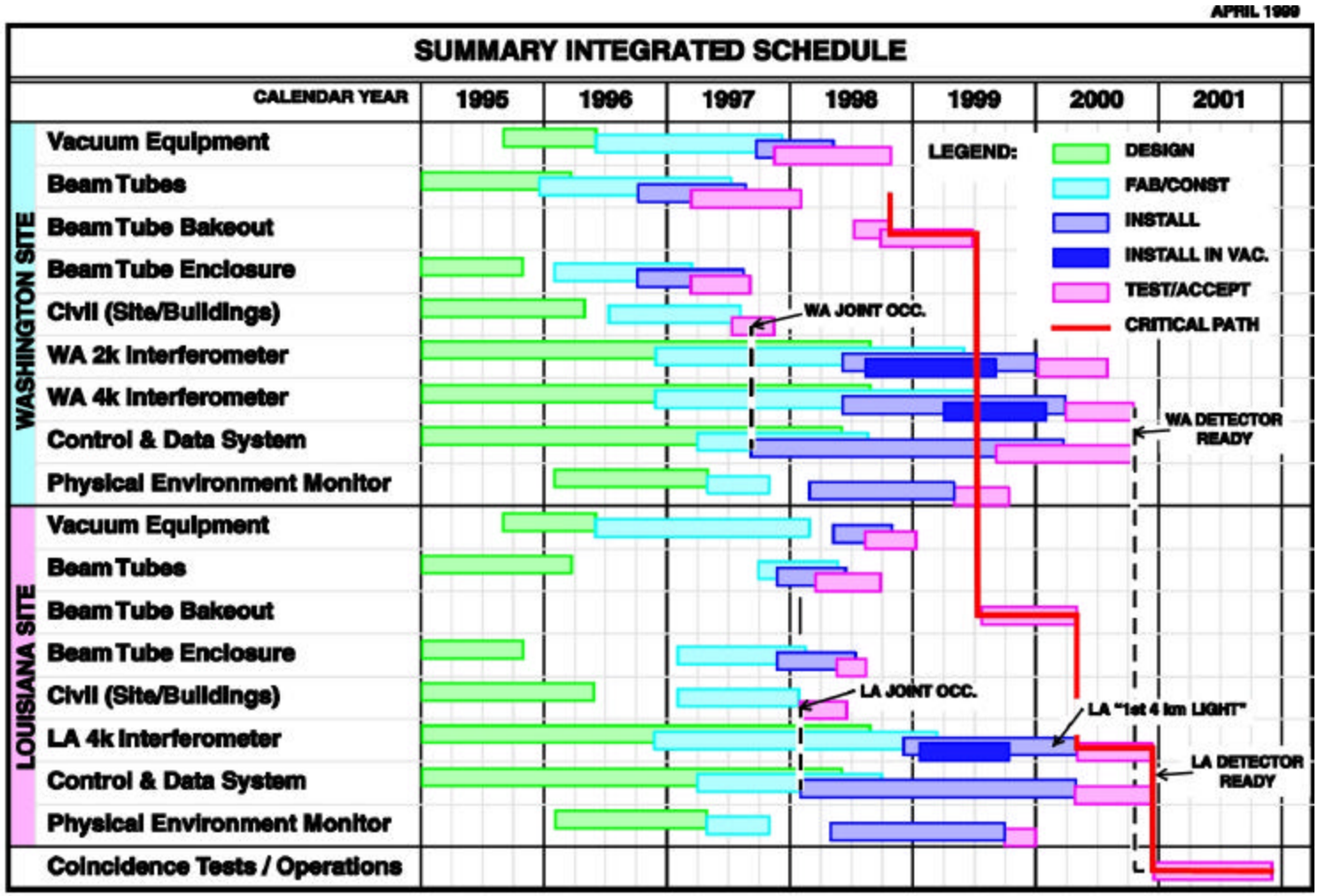
Livingston

activities

- Developing site infrastructure
- Beginning installation
- Preparing for bakeout
- O-ring problem and refit
- Environmental measurements satisfy design
- Seismic measurements - levels, transients, etc being studied
- Road construction underway
- Mitigation for shooting incidents

Summary

integrated schedule



LIGO

facilities milestones

Milestone Description	PMP	Projection/ Actual	PMP	Projection/ Actual
	Hanford		Livingston	
Initiate Site Development	Mar-94	Mar-94	Aug-95	Jun-95
Beam Tube Final Design Review	Apr-94	Apr-94	Apr-94	Apr-94
Select A&E Contractor	Nov-94	Nov-94	Nov-94	Nov-94
Complete Beam Tube Qualification Test	Feb-95	Apr-95	Feb-95	Apr-95
Select Vacuum Equipment Contractor	Mar-95	Jul-95	Mar-95	Jul-95
Complete Performance Measurement Baseline	Apr-95	Apr-95	Apr-95	Apr-95
Initiate Beam Tube Fabrication	Oct-95	Dec-95	Oct-95	Dec-95
Initiate Slab Construction	Oct-95	Feb-96	Jan-97	Jan-97
Initiate Building Construction	Jun-96	Jul-96	Jan-97	Jan-97
Joint Occupancy	Sep-97	Oct-97	Mar-98	Feb-98
Accept Tubes and Covers	Mar-98	Mar-98	Mar-99	Oct-98
Beneficial Occupancy	Mar-98	Mar-98	Sep-98	Dec-98
Accept Vacuum Equipment	Mar-98	Nov-98	Sep-98	Jan-99
Initiate Facility Shakedown	Mar-98	Nov-98	Mar-99	Jan-99

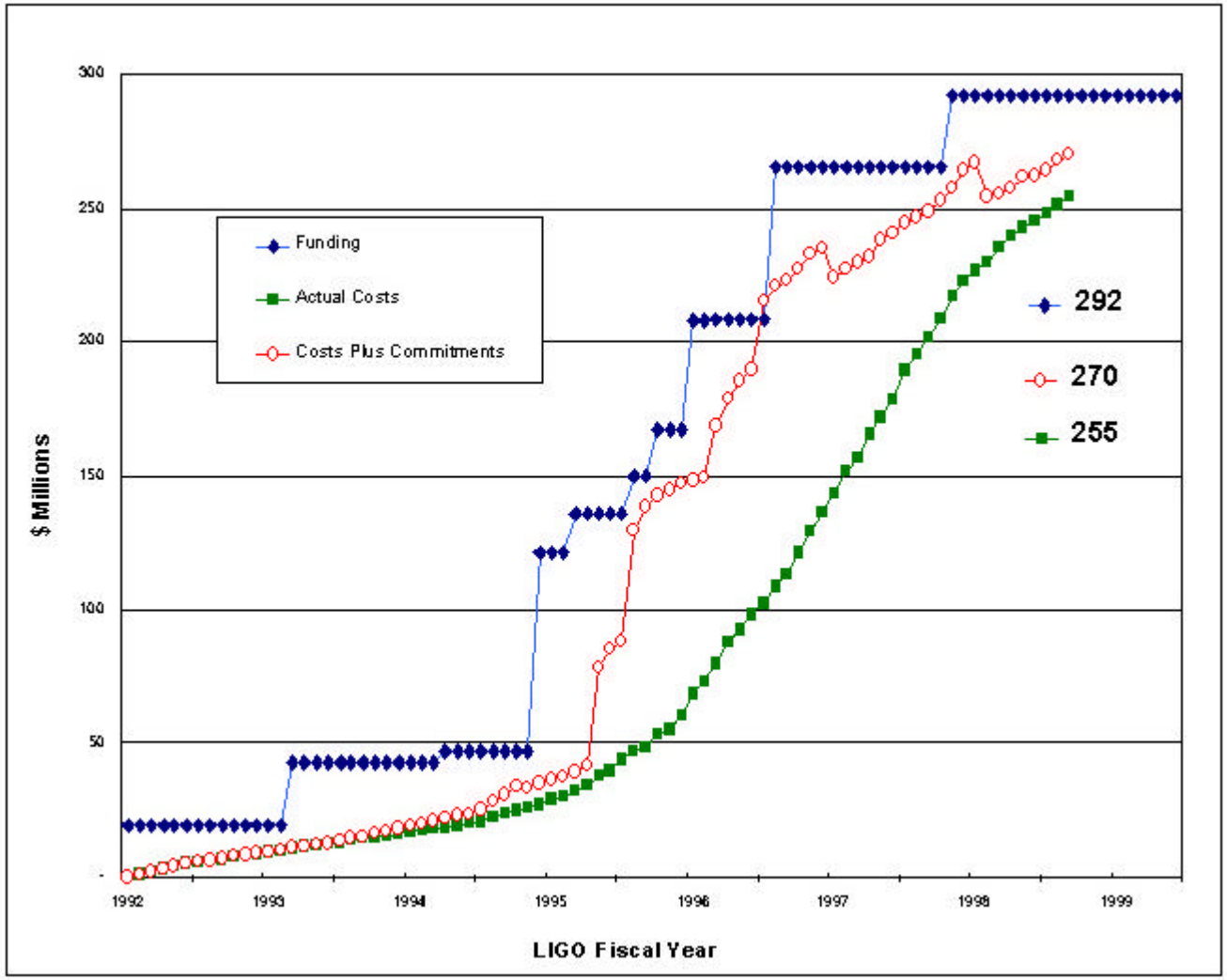
LIGO

detector milestones

Milestone Description	PMP	Projection/ Actual
Beam Splitter Chamber Stack Final Design Review	Apr-98	Aug-98
Core Optics Support Final Design Review	Feb-98	Nov-98
Horizontal Access Module Final Design Review	Apr-98	Jun-98
Core Optics Components Final Design Review	Dec-97	May-98
Input/Output Optics Final Design Review	Apr-98	Mar-98
Pre-Stabilized Laser Final Design Review	Aug-98	Mar-99
Alignment Sensing Final Design Review	Apr-98	Jul-98
Length Sensing Final Design Review	May-98	Jul-98
Washington Controls Area Net Ready to Install	Apr-98	Mar-98
Control and Data System (CDS) Data Acquisition Fi	Apr-98	May-98
Physics Environment Monitoring Final Design Revie	Jun-98	Oct-97
Detector System Preliminary Design Review	Dec-97	Oct-98
Begin Washington Interferometer Installation	Jul-98	Jul-98
Begin Louisiana Interferometer Installation	Jan-99	Jan-99
Begin Coincidence Tests	Dec-00	Dec-00

LIGO

costs & commitments



LIGO

construction costs and commitments

WBS		Costs Thru Nov 1997	LIGO Fiscal Year 1998	Dec-98	Jan-99	Feb-99	Cumulative Costs	Open Encumbrances	Total Cost Plus Commitments
1.1.1	Vacuum Equipment	30,517	11,406	20	392	1,425	43,760	1,566	45,326
1.1.2	Beam Tube	32,978	13,273	632	138	-	47,021	159	47,180
1.1.3	Beam Tube Enclosure	13,274	6,145	1	3	(6)	19,415	52	19,467
1.1.4	Civil Construction	44,681	6,563	52	141	202	51,639	1,259	52,898
1.1.5	Beam Tube Bake	75	3,078	161	111	158	3,584	507	4,092
1.2	Detector	14,340	20,537	1,311	1,870	1,362	39,421	9,805	49,226
1.3	Research & Development	19,681	1,661	53	139	19	21,552	558	22,111
1.4	Project Management	22,649	4,914	189	265	148	28,166	1,461	29,627
7LIGO	Unassigned	1	18	8	-	-	27	13	40
TOTAL		178,196	67,595	2,427	3,061	3,308	254,586	15,381	269,967
Cumulative Actual Costs		178,196	245,791	248,218	251,278	254,586			
Open Commitments		62,510	16,422	16,470	16,904	15,381			
Total Costs plus Commitments		240,706	262,213	264,688	268,182	269,967			
NSF Funding - Construction		$ 265,089	$ 291,900	$ 291,900	$ 291,900	$ 291,900			

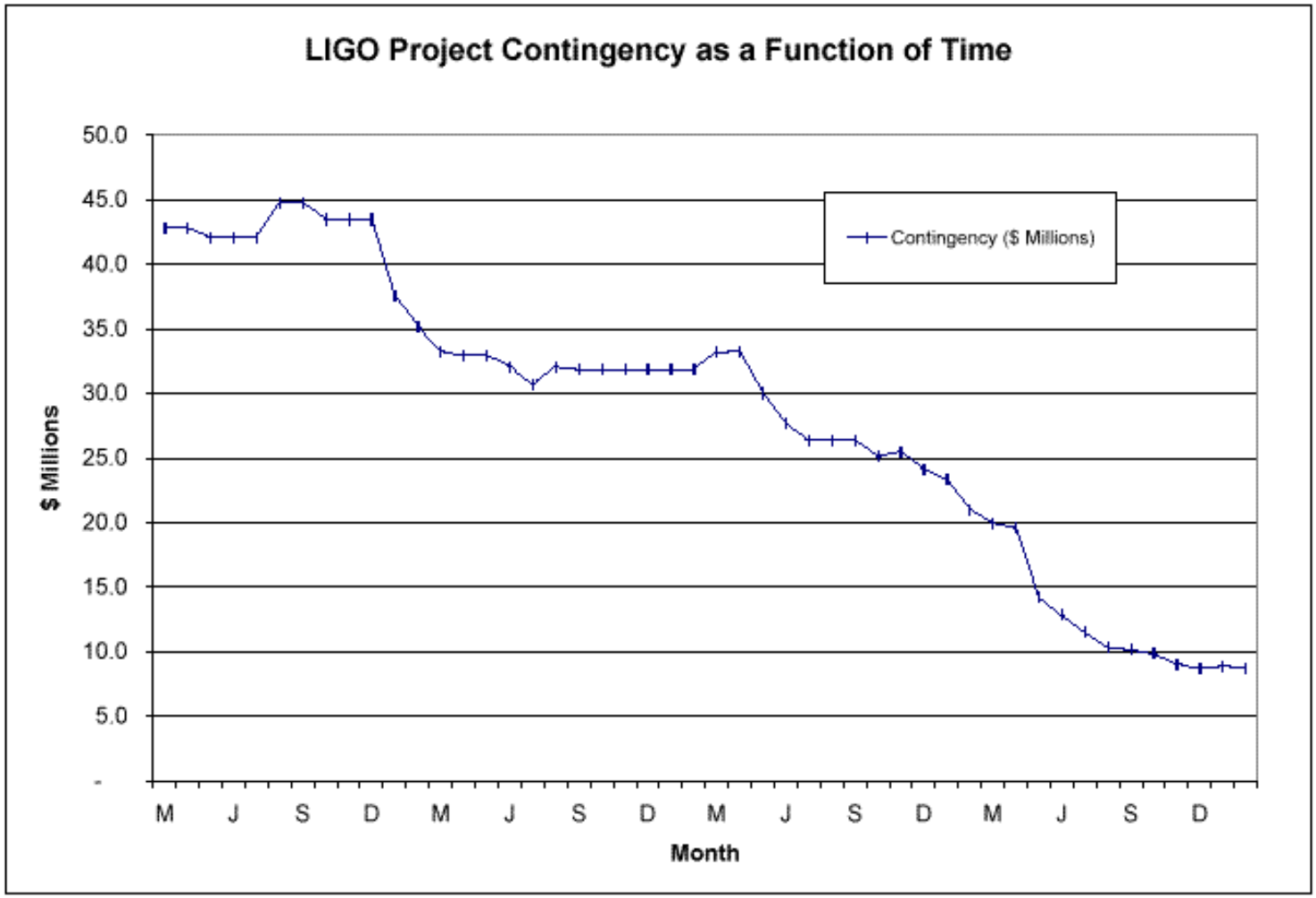
LIGO

contingency allocation

Description	WBS	Direct	Benefits	Overhead	Total	Resp.
Vacuum Equipment	1.1.1	361,916	-	28,725	390,641	**worden**
Beam Tube	1.1.2	(236,000)	-	-	(236,000)	**jones**
Beam Tube Enclosure	1.1.3	(500,000)	-	-	(500,000)	**asiri**
Civil Construction	1.1.4	704,000	-	57,000	761,000	**asiri**
Beam Tube Bake	1.1.5	730,000	-	-	730,000	**wea**
Detector	1.2.1	2,603,500	30,000	384,916	3,018,416	**sew**
CDS	1.2.2	1,032,000	32,500	179,531	1,244,031	**bork**
Physics Environment Monitoring	1.2.3	100,000	-	-	100,000	**bork**
Support Equipment	1.2.4					
Construction Related R&D	1.3	(1,500,000)	-	-	(1,500,000)	
Project Office	1.4	1,040,000	-	-	1,040,000	**sanders**
Contingency Reserved		**3,719,912**			**3,719,912**	
Total		**8,055,328**	**62,500**	**650,172**	**8,768,000**	

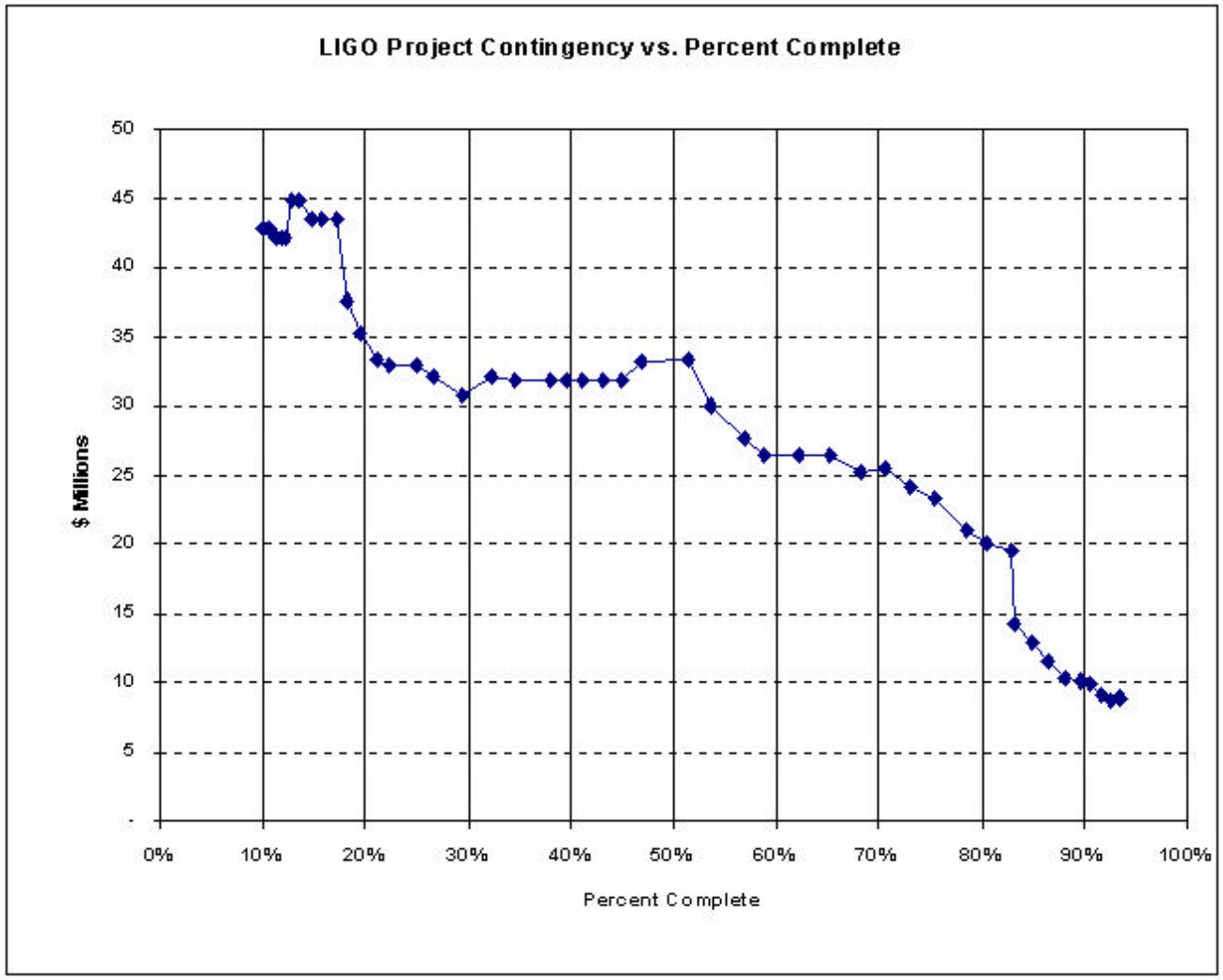
LIGO

contingency vs time



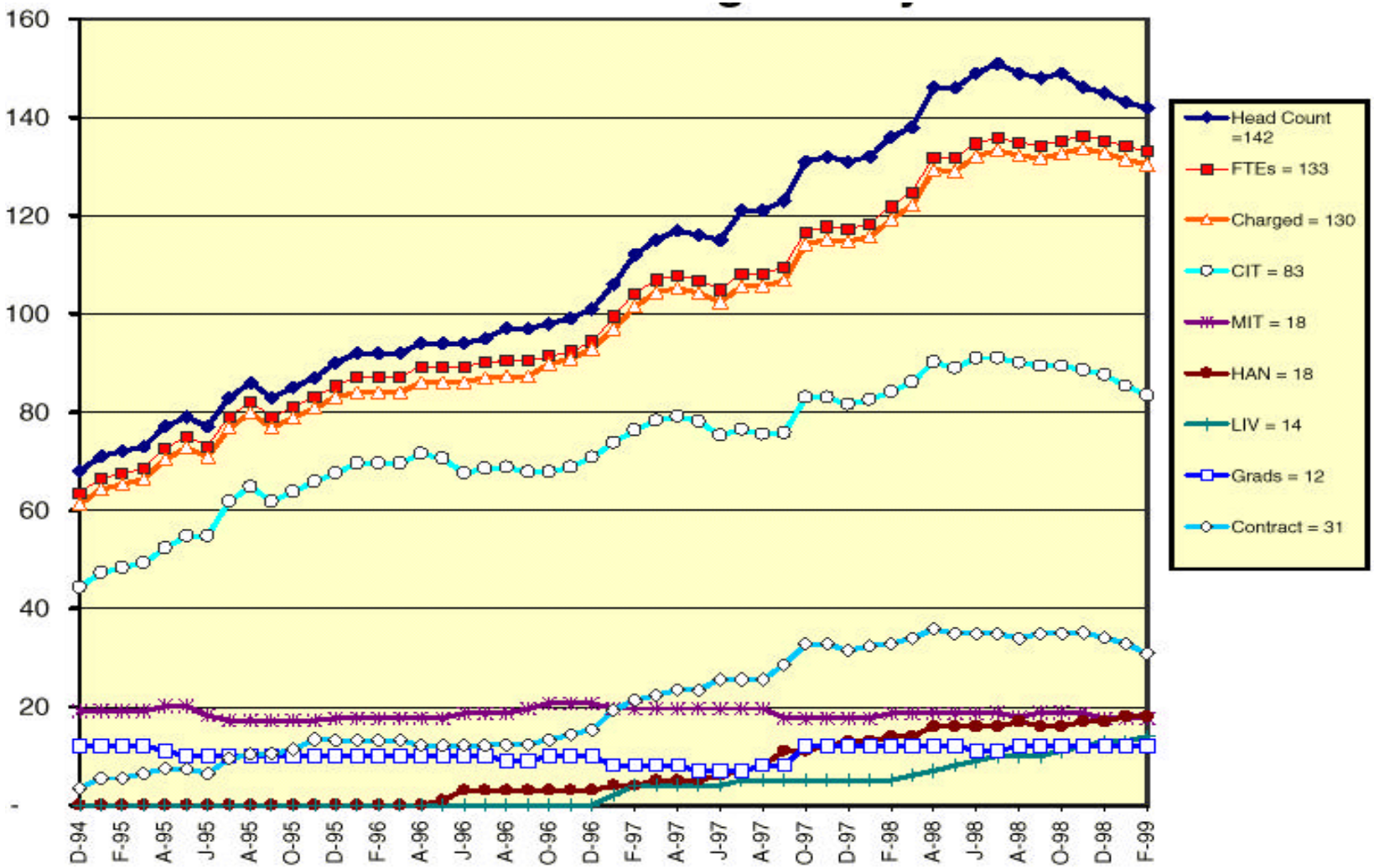
LIGO

contingency vs percent complete



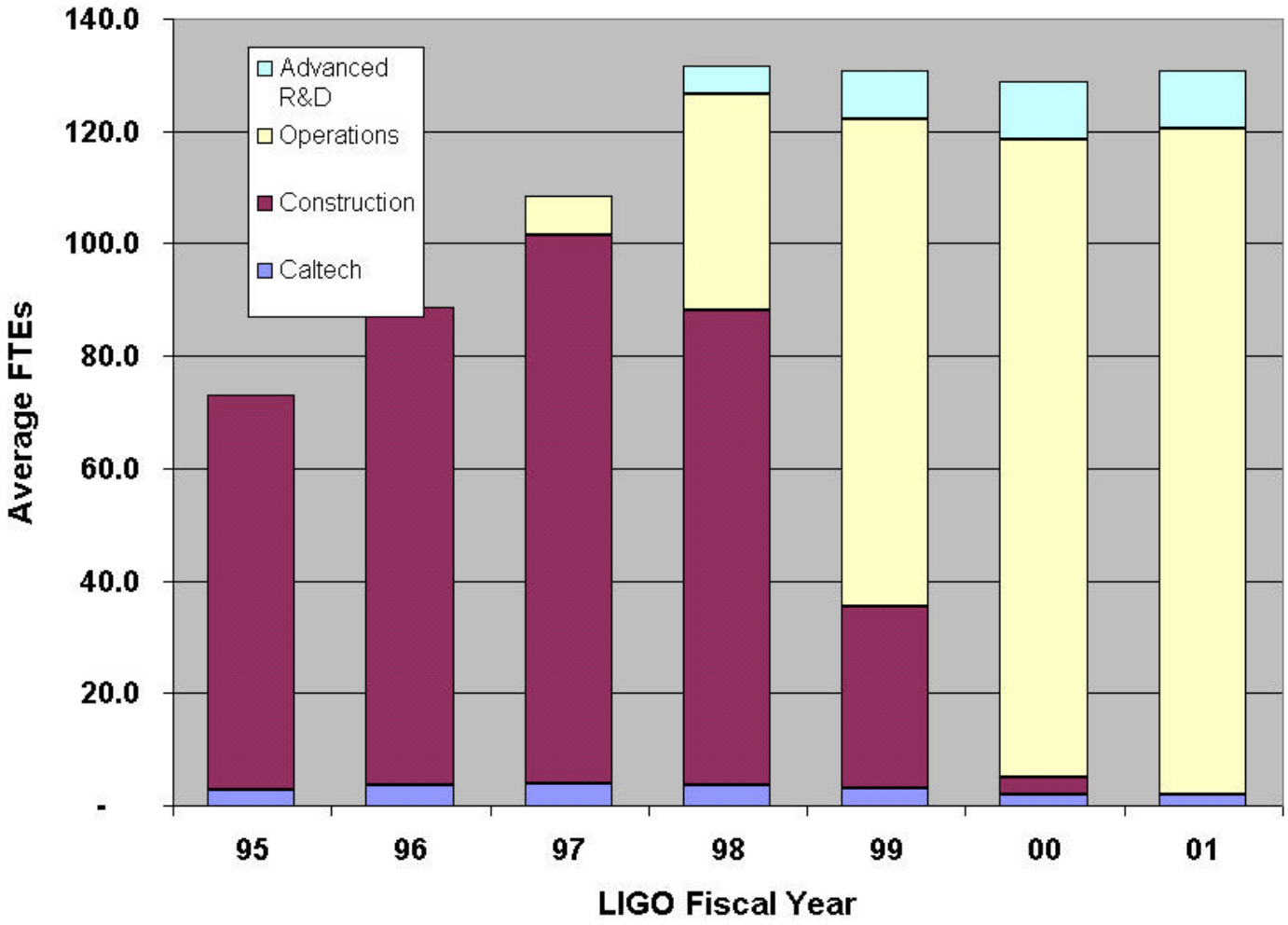
Staffing

history



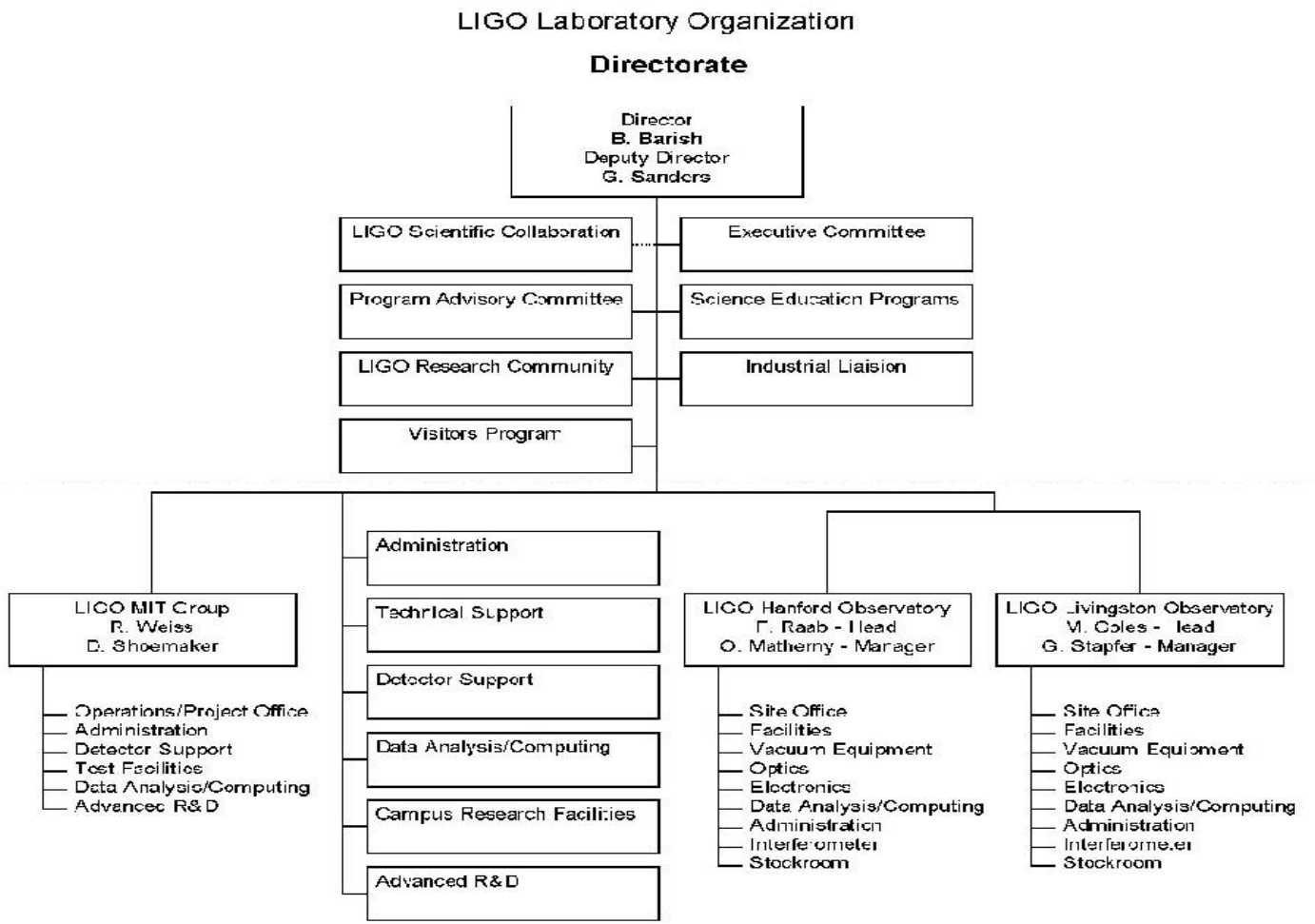
Staffing

labor distribution projections



LIGO Laboratory

organization



Detector

construction and installation

- Production Status:
  - » Seismic Isolation well along
  - » Large Optics Suspensions under production
  - » Small Optics - most are fabricated
  - » Sensor/Actuator - sufficient quantity fabricated
  - » Core Optics Components - most polished and coated
  - » Lasers - 5 received
  - » Pre-stabilized laser - installed in 2K at Hanford
  - » Input optics - all polished and coated; installation in progress for Hanford 2K
  - » Core optics support - production underway
  - » Interferometer sensing and control (ISC) installation underway
  - » CDS - installation proceeding
- Overall about 2-3 months behind schedule

Early Installation

process/technique issues

- **Seismic and Suspension Fixturing and Tooling**
  - » First Article and Hanford 2K Installation suggested Tooling/Fixture improvements
  - » Improvements have been used in successive installations with success

- **Viton as Source of Contamination**
  - » Two transient contamination events observed in Caltech tests suggesting fluorine release
  - » Other tests fail to show any deleterious effects
  - » Based upon disk drive industry experience, LIGO Vacuum Review Board has approved added cleaning step in viton O-ring and spring seat preparation
  - » Investigation continues to clarify Caltech observations

Early Installation

process/technique issues

- **Magnet/Optic Bonding Failure Rate Is Higher Than Expected**
  - » Bonding success rate has required repeat bonding steps for small and large optics
  - » Possible causes include unknown contamination, bond interaction with cleaning process, inappropriate bake temperature, fixturing problems ...
  - » "Tiger team" is currently studying causes with goal to requalify process as we proceed with installation

Interferometers

commissioning plan

- Management organized
- Subsystem testing and commissioning
  - » functionality demonstrated and independent performance
- 2 km IFO commissioning
  - » Integration of PSL and modecleaner
  - » Single arm cavity (2 km)
  - » Power-recycled (short) Michelson
  - » Power-recycled Fabry-Perot Michelson
- Brings together all our expertise - subsystems, interferometers, modeling, diagnostics and data analysis

Data Analysis

- LIGO Laboratory building underlying systems
  - » On site and off site data analysis hardware
  - » Data analysis architecture and non science software development
  - » Subsystem and end to end simulation systems
- LSC organizes the data analysis
  - » White paper describing the goals, organization, responsibilities and schedule being written
- LSC Working groups
  - » Detection Confidence and Statistical Analysis
  - » Detector Characterization
  - » Astrophysical Source Identification and Signature

Outreach

REU/SURF 99

- **LIGO Livingston Observatory**:
  - » Project: *"Environmental Characterization of the LIGO Livingston Site"* Mentor: Mark Coles Student: Matt Ashman, Caltech
  - » Project: *"Measurement of Residual Gases in the LIGO Beam Tubes"* Mentor: Mark Coles Student: Qunicy Robertson, Southeastern Louisiana Univ.
- **LIGO Hanford Observatory**:
  - » Project: *"Developing an Earth-Tides Model for LIGO Interferometers"* Mentor: Fred Raab Student: Eric Morganson, Caltech
  - » Project: *"Investigation of the bonding techniques for the test masses of LIGO Interferometers"* Mentor: Haisheng Rong Student: Richard Karnesky, Caltech
  - » Project: *"Characterization of the optics used in LIGOs Input Optics system"* Mentor: Haisheng Rong Student: Richard Helms, Vanderbilt

Outreach

REU/SURF 99

- **CALTECH**
  - » Project: *"Measuring Displacement Noise with the Thermal Noise Interferometer"* Mentor: Eric Black Student: Sam Makonnen, Caltech
  - » Project: *"Investigation of Magnetic Levitation of LIGO Test Masses (Expt)"* Mentor: Eric Black Student: Sinead Quinn, Univ of Leicester
  - » Project: *"Investigation of Magnetic Levitation of LIGO Test Masses (Theory)"* Mentor: Eric Black Student: Kim Page, University of Leicester
  - » Project: *"Fabrication and Analysis of Fused Silica Suspension Fibers"* Mentor: Phil Willems Student: David Berns, Tufts
  - » Project: *"Investigations of Hydroxide-Catalysis Bonding Mentor"* Phil Willems Student: John Johnson, Univ. of Missouri-Rolla
  - » Project: *"Fast simulation of a signal-recycled LIGO interferometer"* Mentor: Biplab Bhawal and Hiro Yamamoto Student: Sam Mandegaran, Caltech

Outreach

REU/SURF 99

- **CALTECH (continued)**
  - » Project: *"What happens when the mirrors in a "mode-cleaner" move?"* Mentor: Biplab Bhawal and Hiro Yamamoto Student: Michelle Kingham, LSU
  - » Project: *"Detection of Non-Gaussian Noise Processes in Noisy Signals"* Mentor: Albert Lazzarini and Tom Prince Student: Denis Petrovic, Univ. of Belgrade, Yugoslavia
  - » Project: *"Low-Noise Active Damping and Mirror Control for the LIGO Thermal Noise Interferometer"* Mentor: Jay Heefner Student: David Robison, MIT
  - » Project: *"Modeling the LIGO Advanced Seismic Attenuation System"* Mentor: Riccardo DeSalvo Student: Nicolas Viboud, INSA de Lyon, France
  - » Project: *"Construction of a creep measurement facility"* Mentor: Riccardo DeSalvo Student: David Akhavan, UC Berkeley

Responses

Oct 98 Report

- **NSF Review Committee Final Report (Oct. '98 Meeting) : the following recommendations should be addressed at the April '99 meeting:**
  - » 1. LSC & LIGO should organize a series of beginning-to-end infrastructure and data analysis software validation tests.
  - » 2. LIGO Director and LSC Spokesman must find a way to provide validated physics analysis software for the collaboration and exercise it through the system described in (1) above.
  - » 3. LSC Spokesman should assure that the constraints inherent in the computing model adopted by the LIGO Laboratory are well understood by the LSC.
  - » 4. The operations plan for the central LIGO computing facility, and a description of CACR's plans for the support of the facility should be presented at the next review.

[LAZZARINI + LSC LSC GROUP LEADER TALKS]

Responses

Oct 98 Review

» 5. Degradation of mirror reflectivity due to contamination observed in the 40 m interferometer, and in other tests, should be reinvestigated with better instrumentation to identify the nature of the contamination.

[COYNE + PARALLEL SESSION (CAMP, WEISS]

- **Major emphasis should be on computer facilities for data analysis, including plans for LSC involvement**

[LAZZARINI et al PARALLEL SESSION]

Responses

Oct 98 Report

- **Other items (Vic Cook):"I expect will be of interest to the committee are":**
  - » Progress on interferometer installation at Hanford and Livingston.

[RAAB/COLES (SITES) + COYNE (INSTALLATION) + WHITCOMB (COMMISSIONING]

  - » Update on security issues and access road status at the Livingston site.

[SANDERS AND STAPFER PARALLEL SESSION]

  - » Progress on Advanced R&D

[40 METER UPGRADE - MAVALVALA - PARALLEL SESSION].