

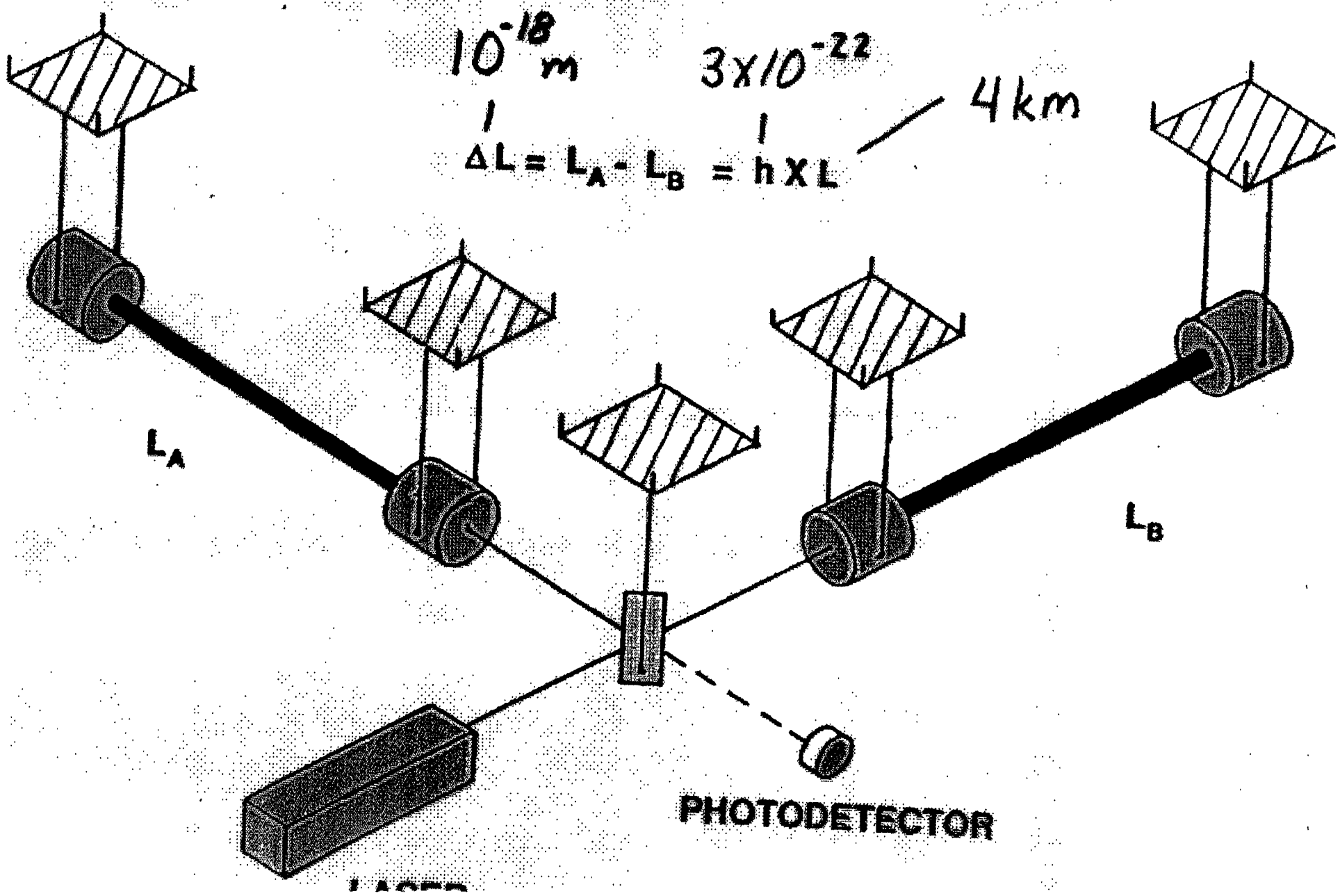
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# **LIGO Overview**

**Barry Barish**

**NSF Cost/Management Review  
September 20, 1994**

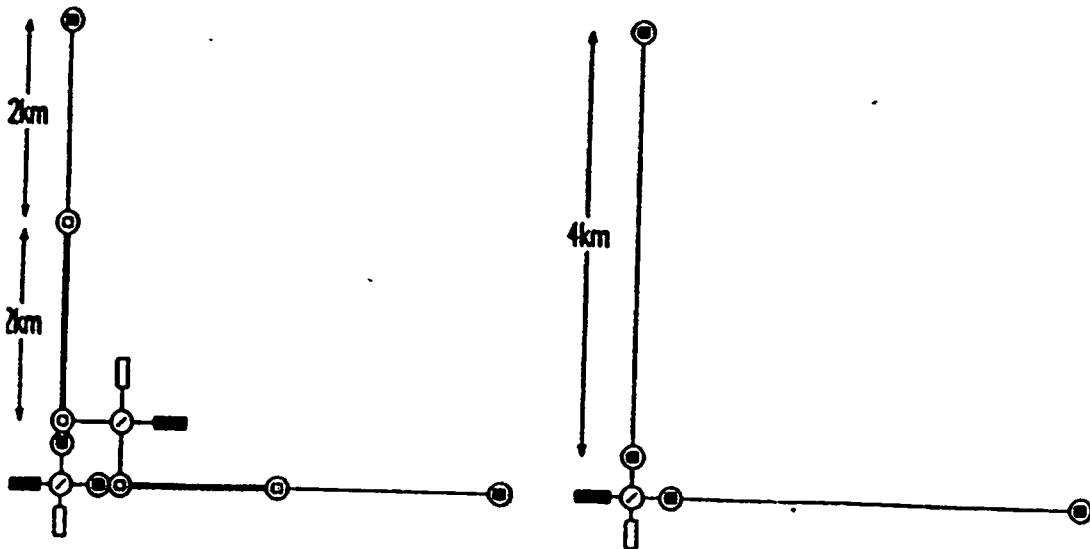
# SCHEMATIC INTERFEROMETRIC DETECTOR



# Description of LIGO

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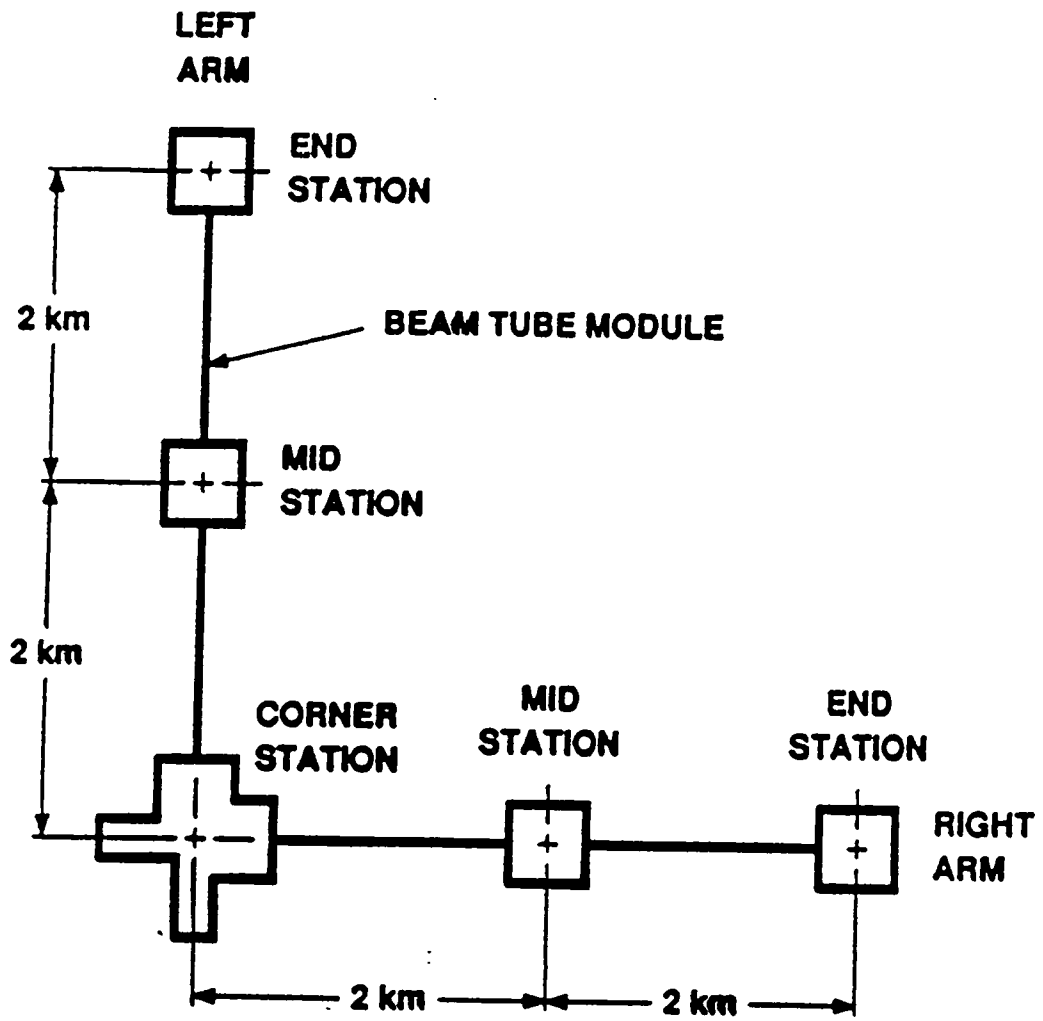
- Two Sites - Widely Separated
- Hanford, Washington
  - 4km and 2km Interferometers
- Livingston, Louisiana
  - 4 km Interferometer
- Expansion for Advanced Detectors



## LIGO Site Pair



- **Hanford, Washington**
  - Located on U.S. Dept. of Energy Reservation
  - Treeless, Semi-arid Desert
  - Approx. 25 km from Richland (Metropolitan Pop. 140,000)
  
- **Livingston, Louisiana**
  - Located in Forested Rural Area
  - Approx. 50 km from Baton Rouge (Pop. 450,000)



# Project Organization

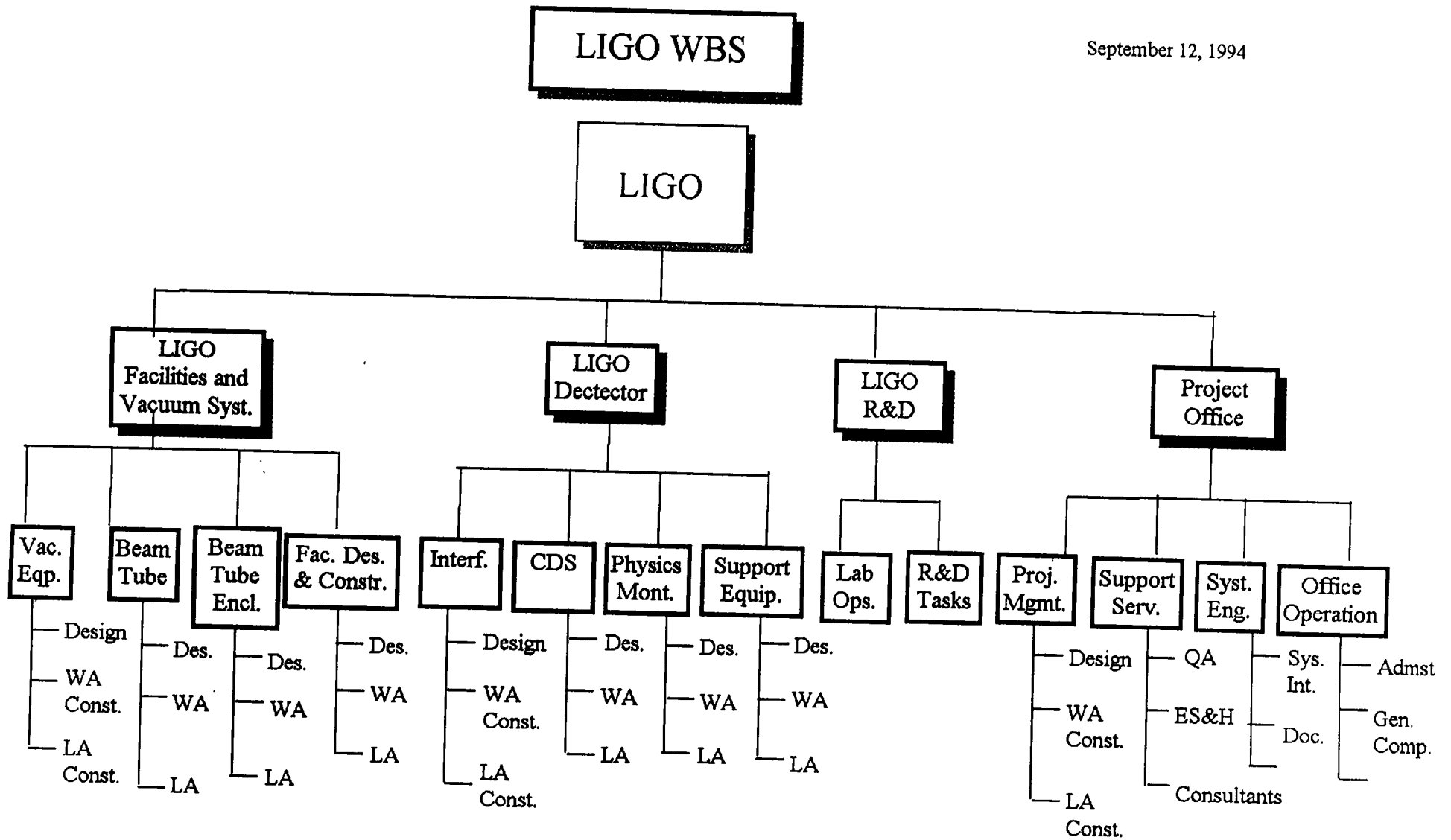
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- Strong Original Group + Key Additions
- Structure
  - » “Product” Oriented
  - » Parallels WBS
- Project Management (Level 1)
  - » Overall Integration, Project Controls, Configuration and Contingency Management
- Group and Task Leaders
  - » Responsible for deliverables, including cost and schedule

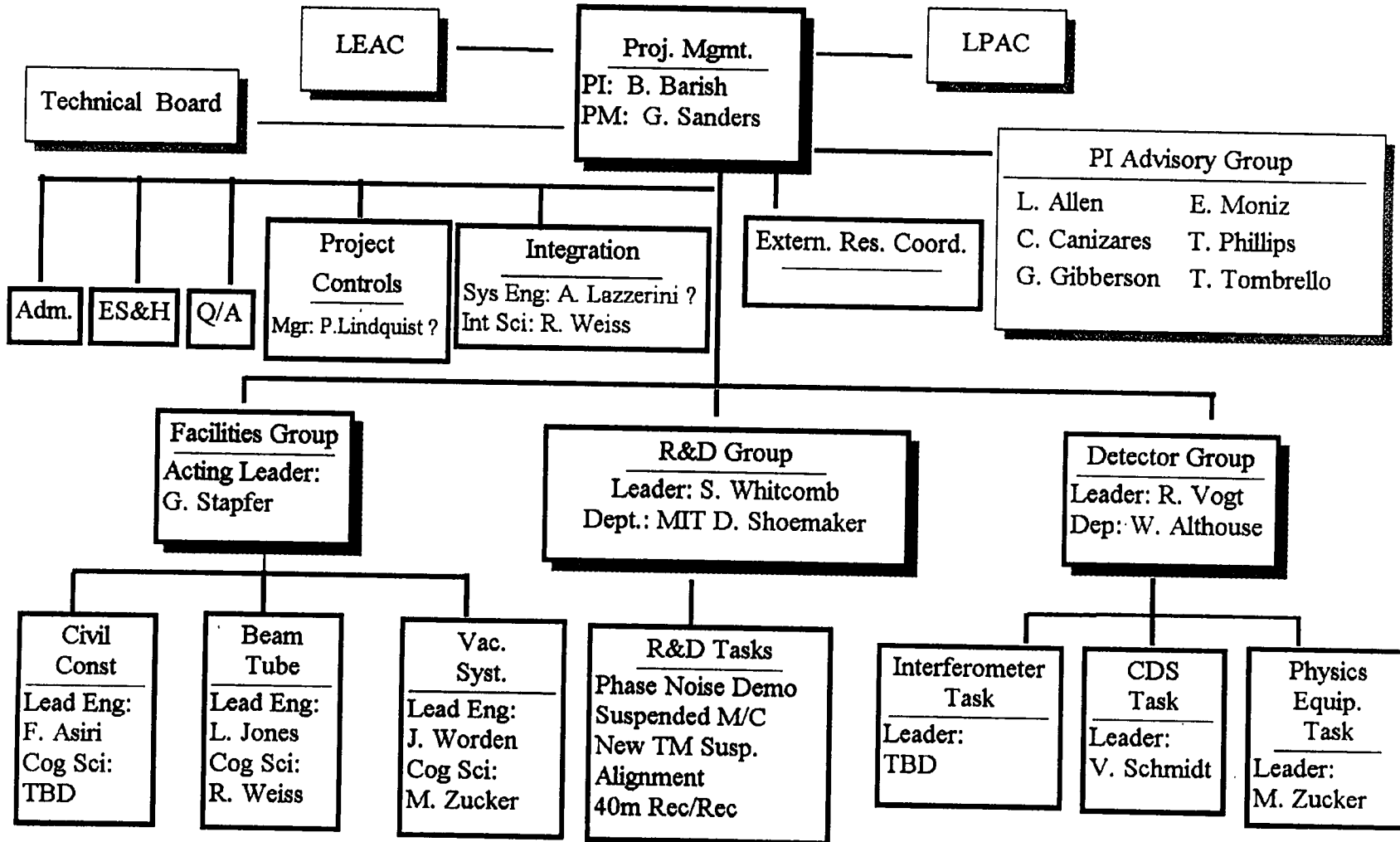
# LIGO WBS

September 12, 1994



# Proposed LIGO Organization

September 7, 1994  
DRAFT





# Key Personnel Additions

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- Key Management Personnel
  - » Project Manager: G. Sanders
  - » Project Controls: P. Lindquist
  - » Project Integration: A. Lazzerini
- Other Important Recent Additions
  - » J Worden - Vacuum Systems
  - » R Bork - CDS
  - » J Heifner - CDS
  
  - » M Gamble - Detector/R&D
  - » H Yamamoto - Detector Modeling

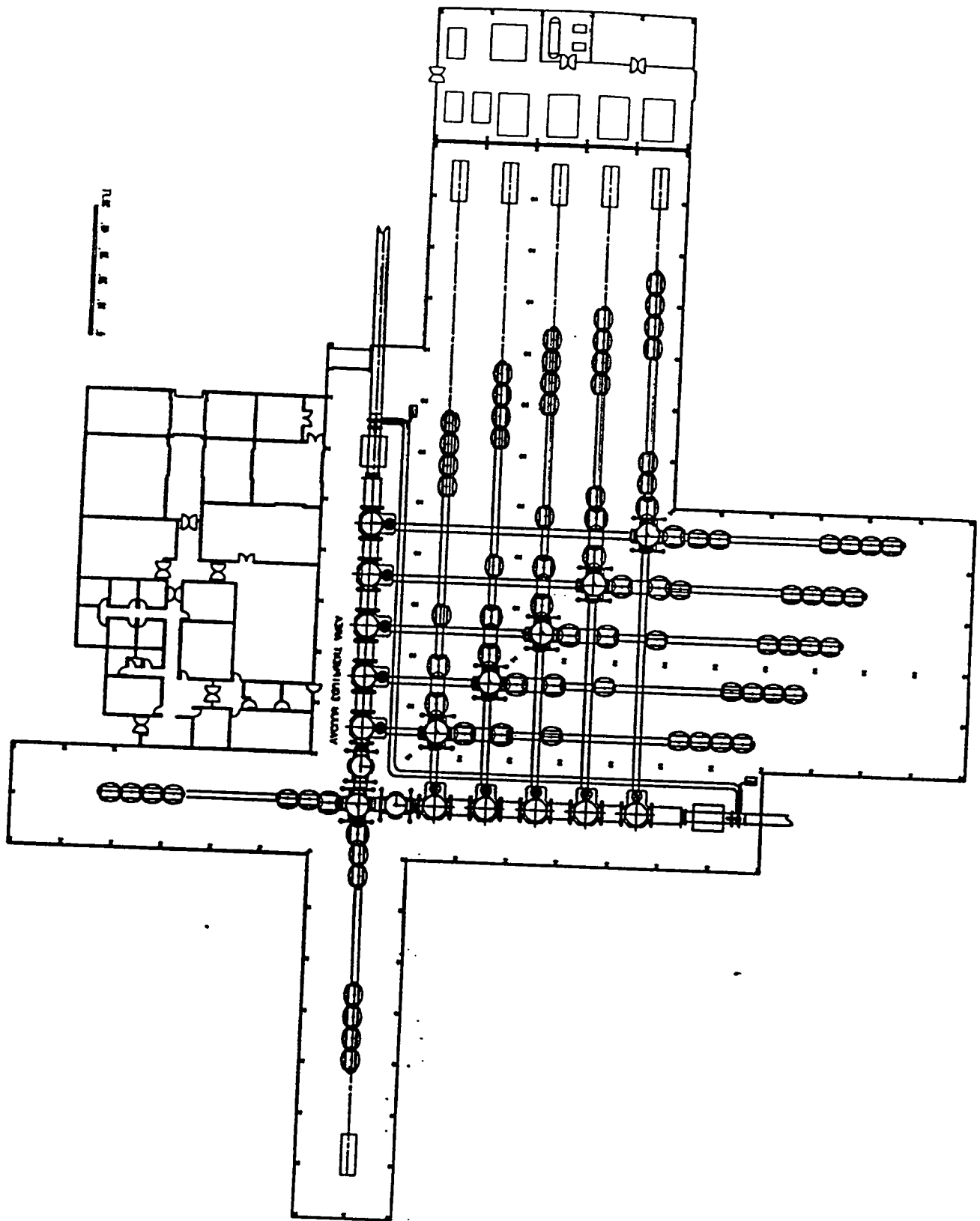
# Project Status Facilities

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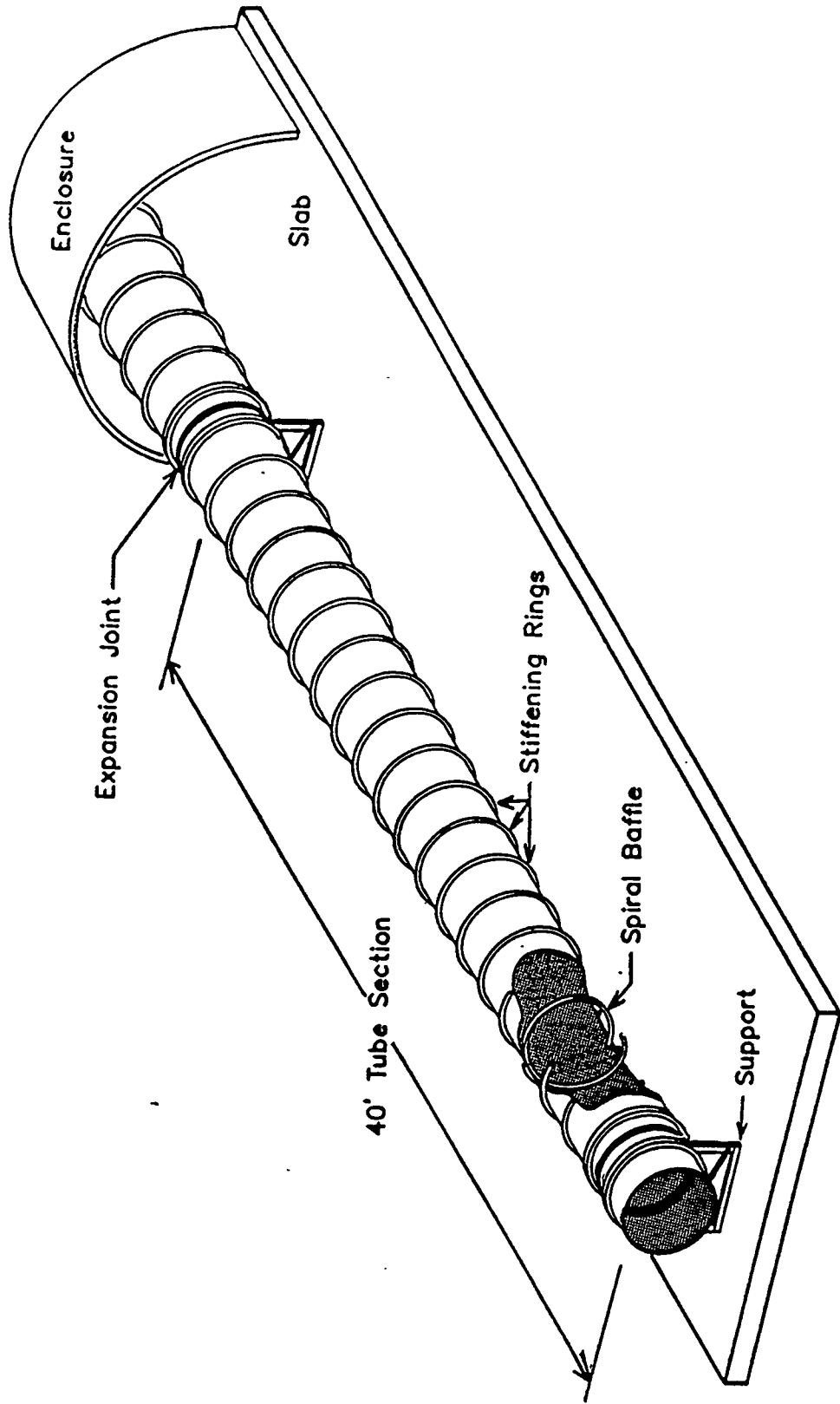
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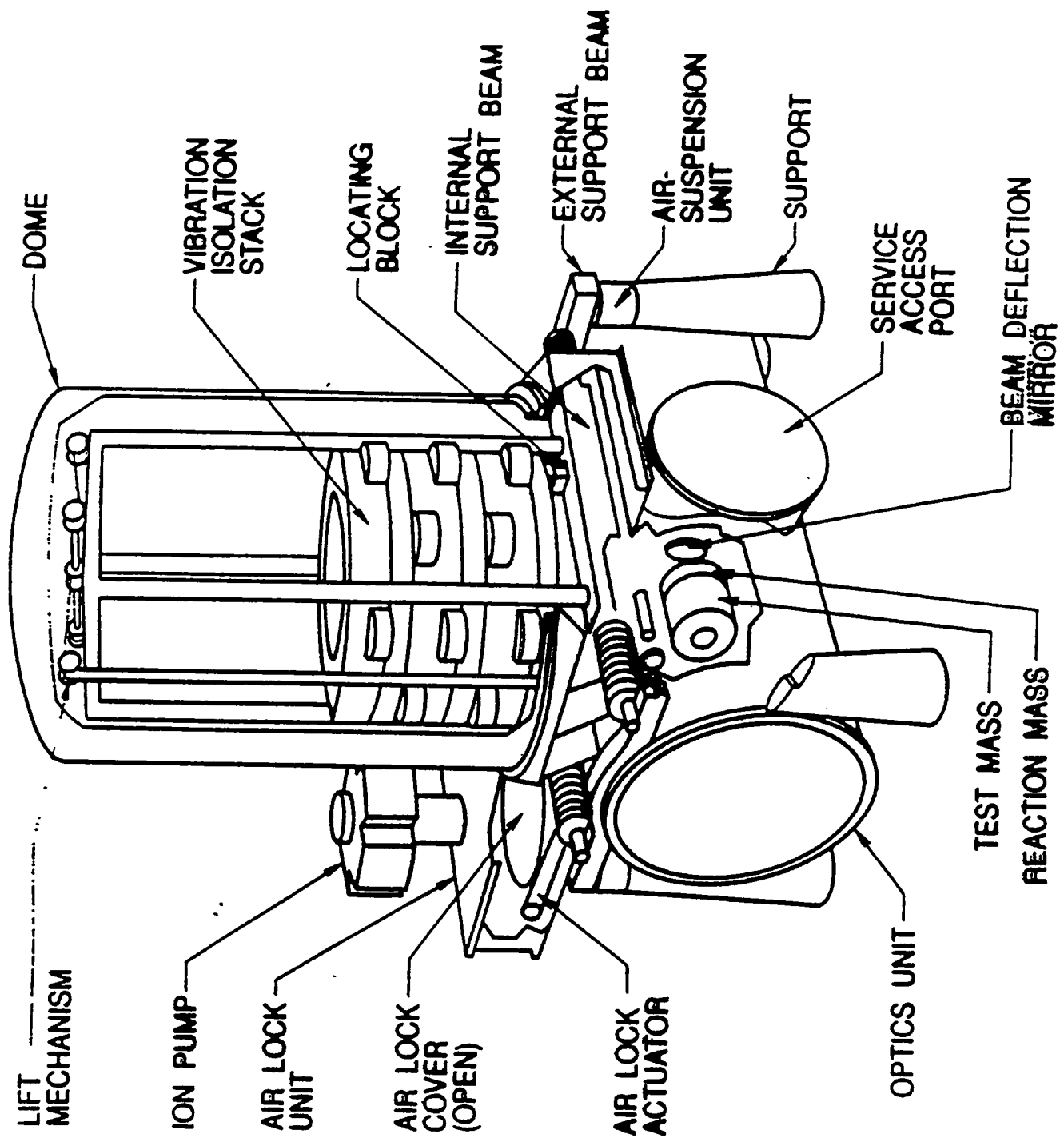
Acting Group Leader: G. Stapfer

- Civil Construction (Lead Eng: F. Asiri)
  - » Hanford Grating in Progress
  - » Louisiana Site acquisition - pending
  - » RFP for A&E (Proposals due Sept 23)
  - » Beam Enclosure Design (40%)
- Beam Tube (Lead Eng: L.Jones)
  - » CBI Final Design Report
  - » Qualification Test
  - » Option Phase or Competitive Bid
- Vacuum System (Lead Eng: J Worden)
  - » Vacuum System Equip. Specification
    - (Science Review)
  - » RFP Preparations



PLAN  
1/4" = 1'-0"





TMC-2, DIAGONAL CHAMBER

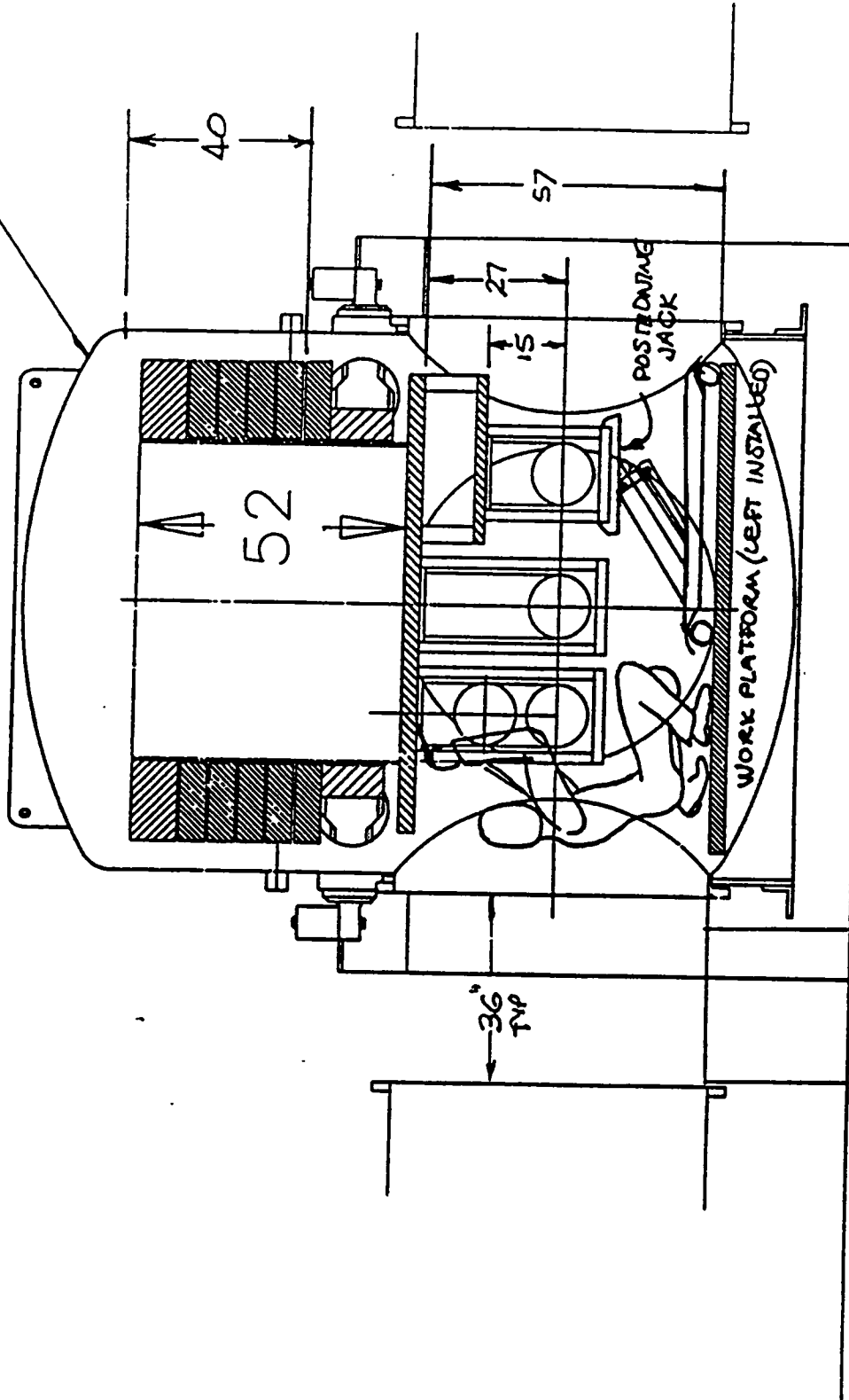


FIG. 3 INTERNAL ACCESS

SDms  
9-2-92

# Project Status

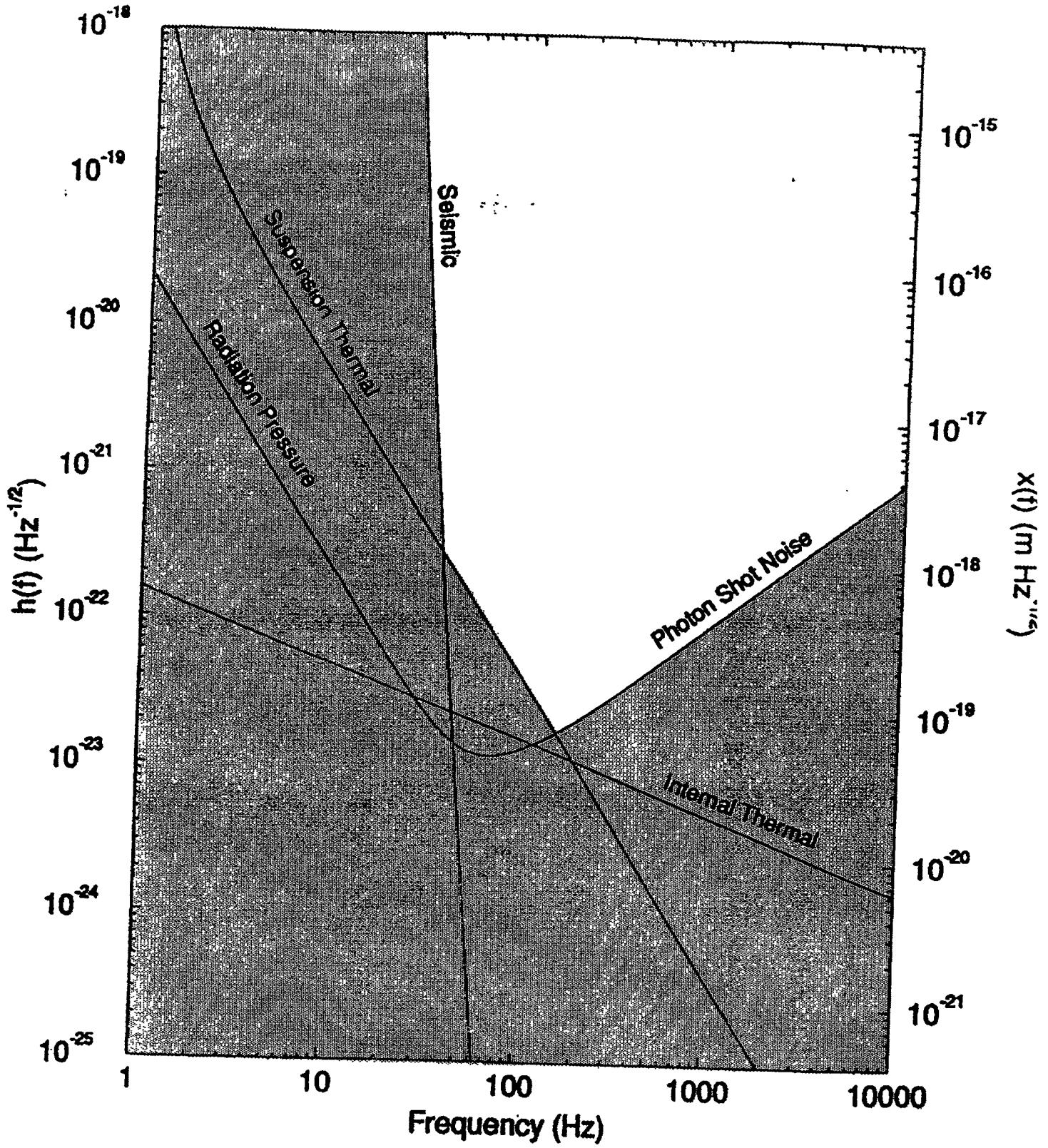
## R&D

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Group Leader: S. Whitcomb

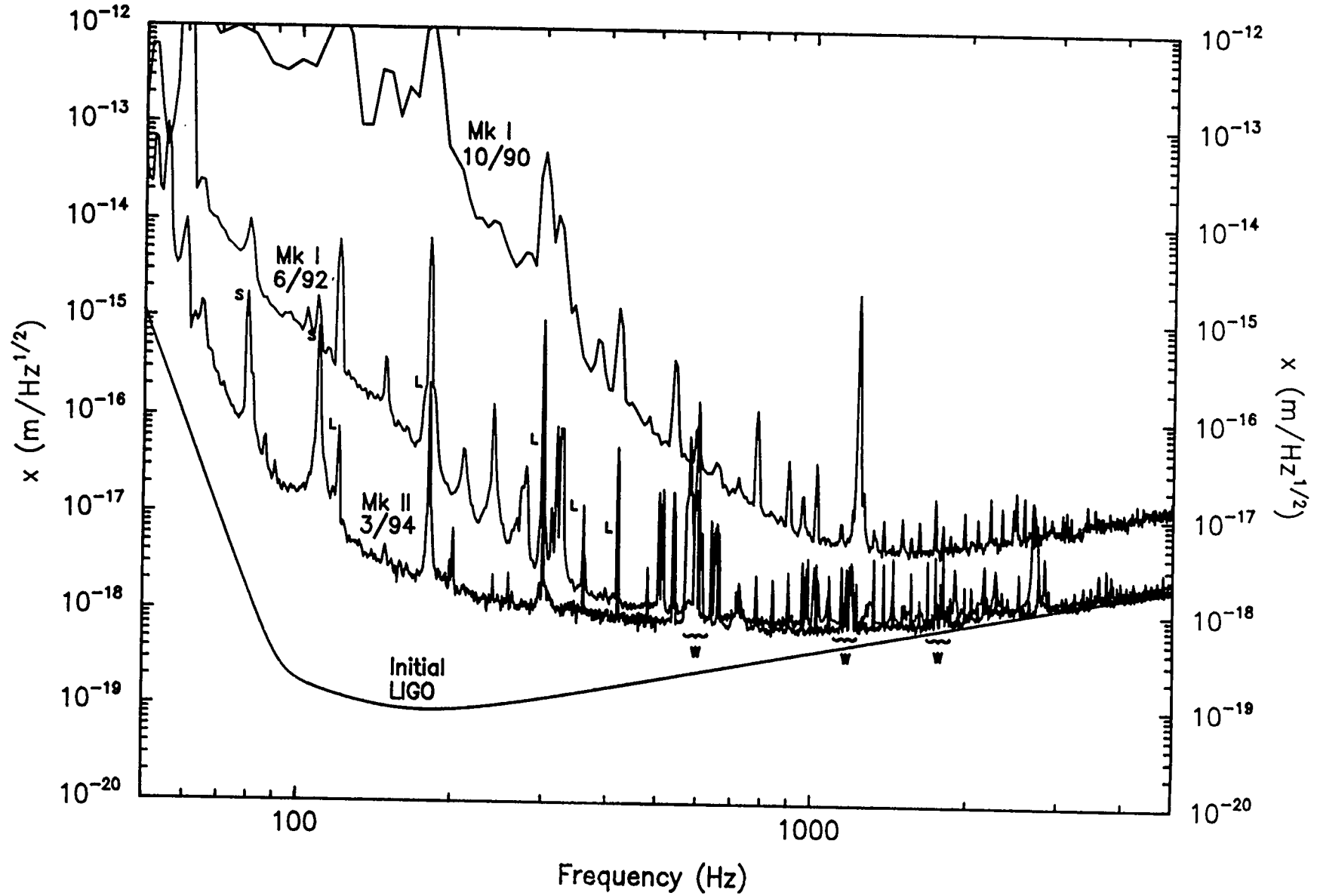
Assisst.: D. Shoemaker

- 40 meter Prototype
  - » Improved displacement noise
  - » Program toward design freeze
    - (R&D Program for FY95)
- 5 meter Phase Noise Studies (MIT)
- Optics Experiments, etc





# Displacement Sensitivity of Caltech 40 m Interferometer



# Reaching Design Sensitivity

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- Engineering Improvements
- Site Specific Factors
  - » length - 4 km
  - » seismic conditions
- R&D: Improvements & Lower Risk

**Baseline 1 Detector is compatible with design goals.**

- Improved Detectors(R&D)
  - » Enhance Initial Interferometer
  - » Advanced Interferometers

# Interferometer Threefold Coincidence DETECTOR

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- Non-local Interferometers
  - » Uncorrelated (Separation  $\sim 2500\text{km}$ )
- Local Correlations
  - » Local Monitors to Minimize
  - » Ratio of Signals a Constraint
- Double Coincidence (non-local)
  - » Coincidence Time  $\sim 20\text{msec}$
  - » Goal  $\sim 0.1$  bkgd event/year
    - Requires  $\sim 1.4/\text{hr}/\text{int.}$  singles rate
- Triple Coincidence
  - » Non-local Coincidence Time  $\sim 20\text{msec}$
  - » Local Coincidence Time  $\sim 1\text{msec}$ 
    - Uncorrelated Interferometers
      - Requires  $200/\text{hr}/\text{int.}$  singles rate
    - Correlated Interferometers (local)
      - Requires  $50/\text{hr}/\text{int.}$  singles rate for a correlated coincidences rate  $\sim 1/\text{day}$

# Project Status

## Detector Implementation

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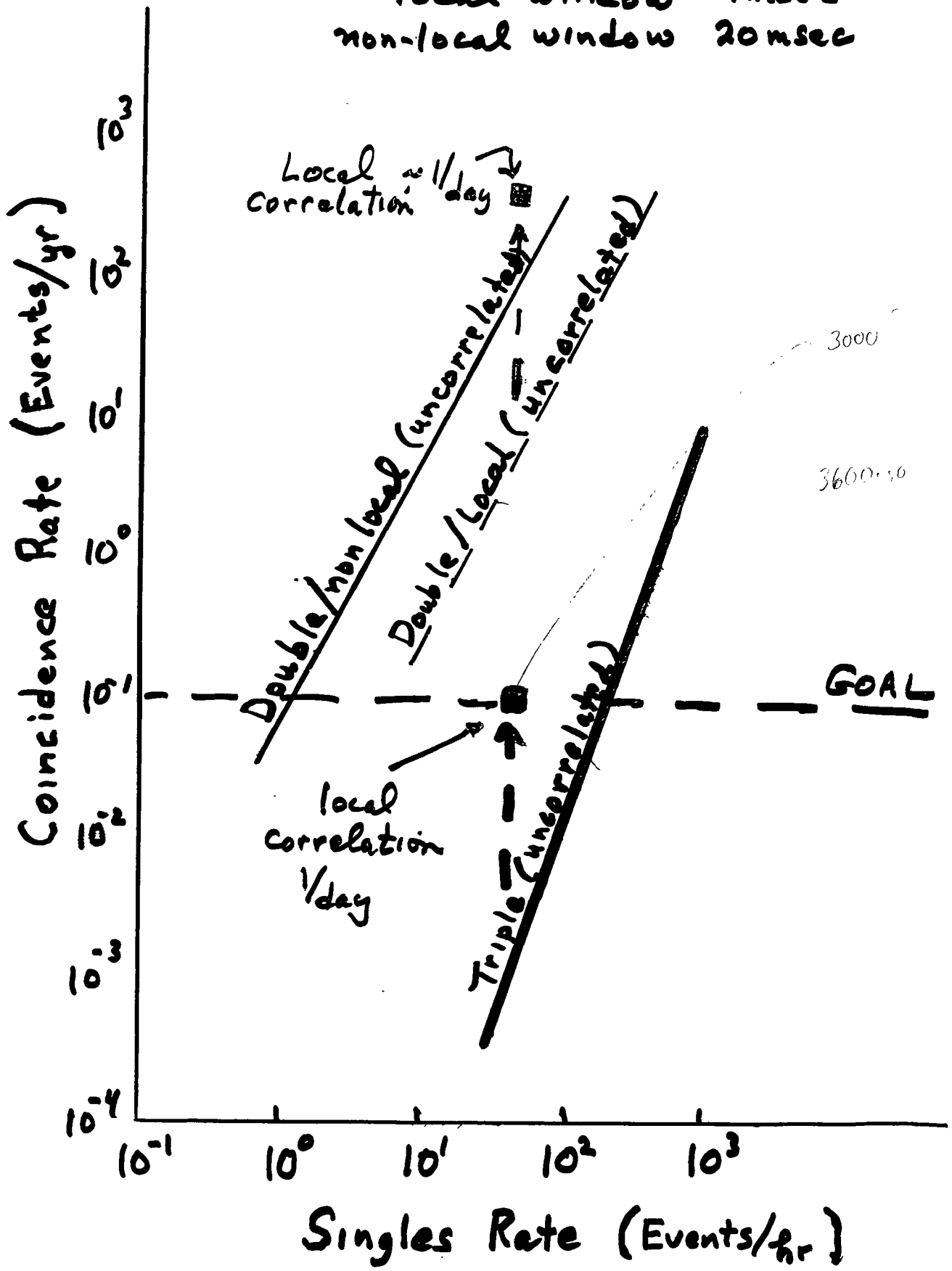
Leader: R.Vogt

Deputy: W.Althouse

- Interferometer (Mgr: TBD)
  - » Detector Implementation Plan
    - Engineering Design Freeze (1996)
    - Schedule / Manloading
    - Construction mostly in-house
  - » Initial Sensitivity Design Goals
  - » Direct Connection to R&D Program
- Control/Data System (Mgr. V.Schmidt)
  - » Control System - Feedback loops
  - » Data Acquisition
  - » Physics Monitoring
- Physics/Support Equip(Mgr: M.Zucker)
  - » Physics Monitors
  - » Support Equipment

# MULTIPLE COINCIDENCES

local window 1msec  
non-local window 20msec



# Budget Estimate

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- LIGO Costing Bases
  - » New WBS System-manpower loaded
  - » Contingency methodology
  - » Estimated in 94\$
- U.S. Cost - (C. Aguirre)
  - » Relational Data Base /SUCCESS
- LIGO (B.Barish, R.Bork, J. Heifner)
  - » Estimated by Task Leaders
  - » Independent Estimates by U.S. Cost
  - » LIGO Schedule (G. Stapfer)
- Documentation
  - » Cost Book
  - » Baseline 1
  - » Cost Summary Book
    - Cost Summaries and Breakdowns
    - Pre-ops and Operations
    - Cost Reduction Analysis

# LIGO PROJECT COST ESTIMATE SUMMARY

SEPTEMBER 1994

CURRENT YEAR COST (In millions of FY94 dollars)

Manpower/Expenses	41	
Materials	30	
Contracts	142	
Subtotal Direct Costs	<u>213</u>	
Contingency	40	(19%)
Subtotal	<u>254</u>	
R&D	23	(11%)
TOTAL LIGO PROJECT FY94 \$M	<u>276</u>	

\*% of Subtotal Direct Costs

## COST IMPACTS

	COST 93 \$M	TOTAL COST 93 \$M	TOTAL COST RUNCUT \$M
COOPERATIVE AGREEMENT	222.8	222.8	232.2
SALES TAX	8.1	230.9	241.0
5 YR → 6 YR STRETCHOUT	7.6	238.5	
UNIMPLEMENTED SCOPE REDUCTIONS	8.4	246.9	
SITE-RELATED CHANGES	2.4	249.3	
WBS 4 ADJUSTMENTS	0.7	250.0	
CONTINGENCY RE-ALLOCATION	-2.7	247.3	
<hr/>			
PROJECT MANAGEMENT PLAN	239.2		
+ SALES TAXES	8.1	247.3	266.6
<hr/>			
<b><u>REVISED PROJECT PLANS:</u></b>			
REMOTE SITE COSTS TO PRE-OPS	-2.1	245.2	
AUGMENTED STAFFING	14.2	259.4	
<b>SCHEDULE SLIPS FORCED BY FUNDING CAP:</b>			
• AUGUMENTED STAFFING	3.4		
• FY 94 FUNDING = \$39M	1.9	264.7	291.1
<b>POTENTIAL COST INCREASES:</b>			
• LA SITE DEVELOPMENT	2.6		
• SCHEDULE SLIP TO ACCOMMODATE FUNDING FOR COMMUNITY PROGRAM	2.9	270.2	296.9



**COST IMPACTS**

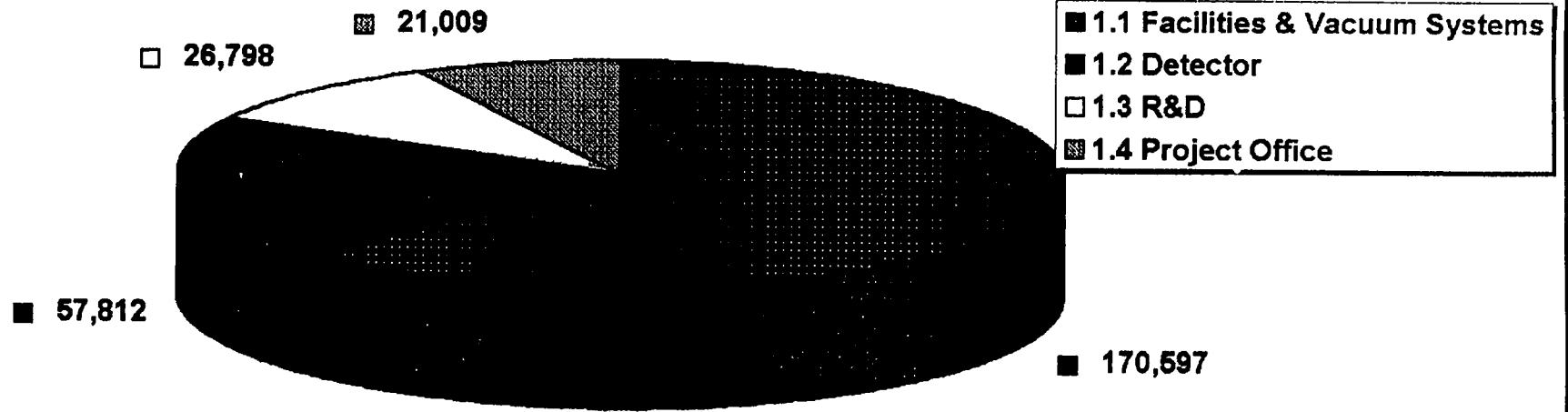
*from April 94 review*

	<b>COST</b>	<b>TOTAL COST</b>	<b>TOTAL COST RUNOUT</b>
	<b>93 \$M</b>	<b>93 \$M</b>	<b>\$M</b>
<b>COOPERATIVE AGREEMENT</b>	222.8	222.8	232.2
<b>SALES TAX</b>	8.1	230.9	241.0
<b>5 YR → 6 YR STRETCHOUT</b>	7.6	238.5	
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<hr/>			
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REVISED PROJECT PLANS:

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<b>POTENTIAL COST INCREASES:</b>			
• <b>LA SITE DEVELOPMENT</b>	2.6		
• <b>SCHEDULE SLIP TO ACCOMMODATE FUNDING FOR COMMUNITY PROGRAM</b>	2.9	270.2	296.9

**LIGO PROJECT**  
**LEVEL 2 COST DISTRIBUTION**  
**FY94 \$K**



# Significant Facility Milestones

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<b>MILESTONE NAME</b>	<b>WASHINGTON LATE DATE</b>	<b>LOUISIANA LATE DATE</b>
Initiate Site Development	03/14/94	08/07/95
Beam Tube Final Design Review	04/21/94	common
Select A/E Contractor	11/15/94	common
Complete Beam Tube Qualification Test	01/16/95	common
Select Vacuum Equipment Contractor	03/28/95	common
Initiate Beam Tube Fabrication	01/22/96	common
Complete Performance Measurement Baseline	04/28/95	common
Initiate Slab Construction	02/05/96	01/06/97
Initiate Building Construction	06/11/96	01/06/97
Accept Tube and Cover	03/16/98	09/28/98
Joint Occupancy	09/02/97	03/30/98
Beneficial Occupancy (Accept Buildings)	03/16/98	09/28/98
Accept Vacuum Equipment	03/16/98	09/28/98
Initiate Facility Shakedown	03/16/98	09/28/98

# Significant Detector Milestones

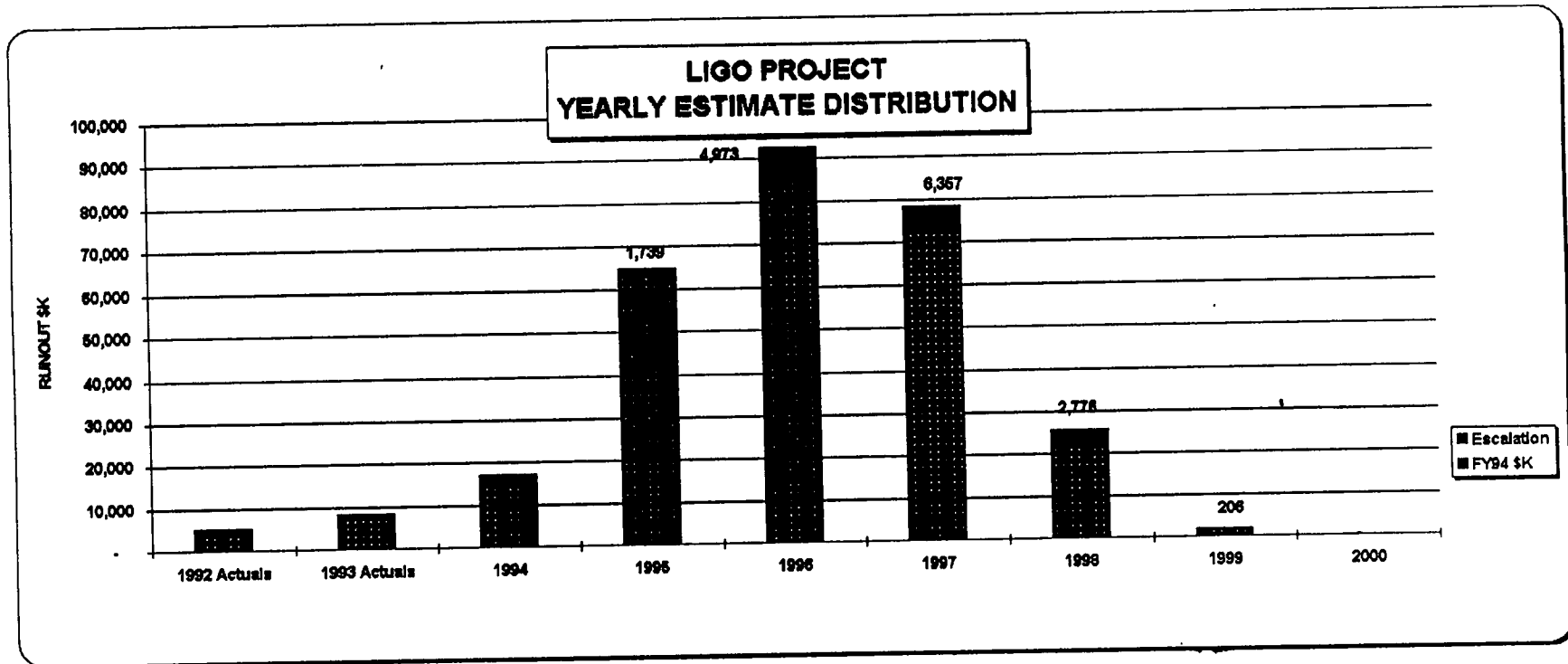
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<b>MILESTONE NAME</b>	<b>WASHINGTON LATE DATE</b>	<b>LOUISIANA LATE DATE</b>
<b>HAM Final Design Review</b>	09/03/97	common
<b>BSC/TMC Final Design Review</b>	09/22/97	common
<b>I/O Optics Final Design Review</b>	09/23/97	common
<b>Core Optics Support Final Design Review</b>	09/23/97	common
<b>Initiate Interferometer Installation</b>	07/06/98	01/29/99
<b>CDS DAQ Final Design Review</b>	10/01/98	common
<b>Begin Coincidence Tests</b>	07/04/00	common

# LIGO PROJECT RUNOUT COST SUMMARY

SEPTEMBER 1994

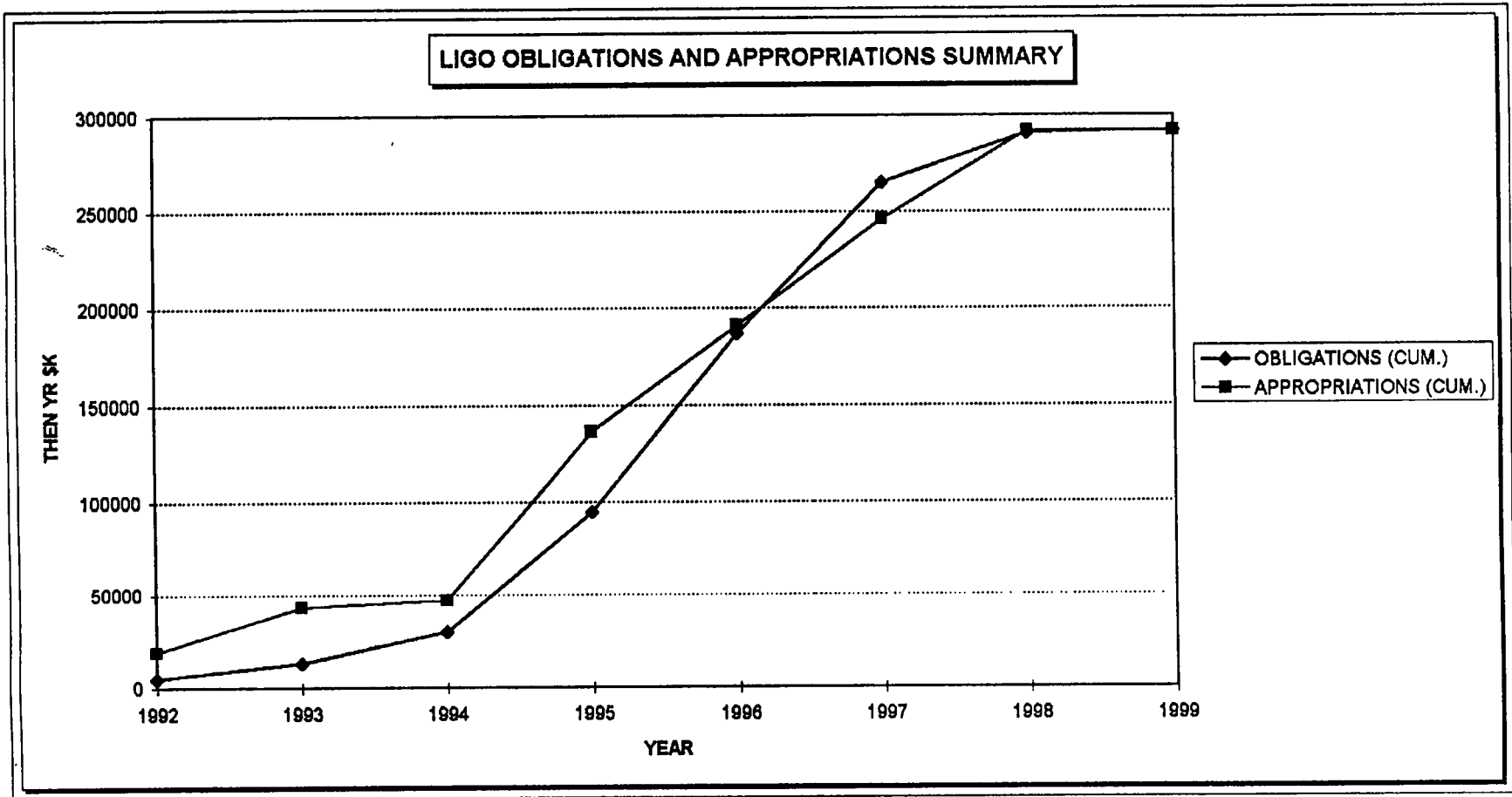
	1992	1993	1994	1995	1996	1997	1998	1999	2000	TOTAL
Actuals										
Estimate	4,860	8,034	16,987	64,652	92,817	76,212	25,594	1,502		270,217
Escalation										
FY94 \$K	4,860	8,034	16,987	64,652	92,817	76,212	25,594	1,502		292,268



# LIGO PROJECT APPROPRIATIONS AND OBLIGATIONS SUMMARY

## SEPTEMBER 1994

	THEN YEAR \$								
	1992	1993	1994	1995	1996	1997	1998	1999	TOTAL
OBLIGATIONS (YEARLY)	2860	8014	16987	64652	92417	78212	25594	1532	292268
APPROPRIATIONS (YEARLY)	19000	24000	4000	39000	55000	55000	46000	0	292000
	1992	1993	1994	1995	1996	1997	1998	1999	
OBLIGATIONS (CUM.)	2860	12874	29861	94513	186930	265142	290736	292268	
APPROPRIATIONS (CUM.)	19000	43000	47000	136000	191000	246000	292000	292000	



**LIGO PROJECT**

**ESTIMATE WBS SUMMARY**  
(1994 \$K)

WBS No.	WBS TITLE	SUBTOT EST.	CONTINGENCY ALLOCATION		TOTAL COST
			%	(\$K)	
1	-LIGO	235,729	17.18%	40,488	276,216
1.1	-Facilities and Vacuum Systems	147,977	15.29%	22,620	170,597
1.1.1	-Vacuum Equipment	43,084	17.01%	7,328	50,412
1.1.2	+Beam Tubes	40,780	13.60%	5,547	46,327
1.1.3	+Beam Tube Enclosures (BTE)	17,121	17.49%	2,994	20,115
1.1.4	+Facility Design and Construction	46,992	14.37%	6,751	53,743
1.2	-Detector	45,094	28.20%	12,718	57,812
1.2.1	+Interferometer Design/Fabrication	29,098	33.37%	9,710	38,808
1.2.2	+Control and Data System	11,456	24.28%	2,782	14,238
1.2.3	+Physics Monitoring	3,093	5.00%	155	3,248
1.2.4	+Support Equipment	1,446	5.00%	72	1,518
1.3	-Research and Development	22,688	18.12%	4,110	26,798
1.3.1	+Lab Operations	5,741	11.76%	675	6,416
1.3.2	+R & D Tasks	16,947	20.27%	3,435	20,383
1.4	-Project Office	19,970	5.20%	1,039	21,009
1.4.1	+Project Management	10,473	5.05%	529	11,001
1.4.2	+Support Services	808	4.95%	40	848



ESTIMATE WBS SUMMARY  
(1994 \$K)

WBS No.	WBS TITLE	SUBTOT EST.	CONTINGENCY ALLOCATION		TOTAL COST
			%	(\$K)	
1.4.3	+System Engineering	4,567	5.82%	266	4,833
1.4.4	+Office Operations	4,122	4.96%	204	4,326