The LIGO Project

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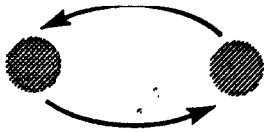
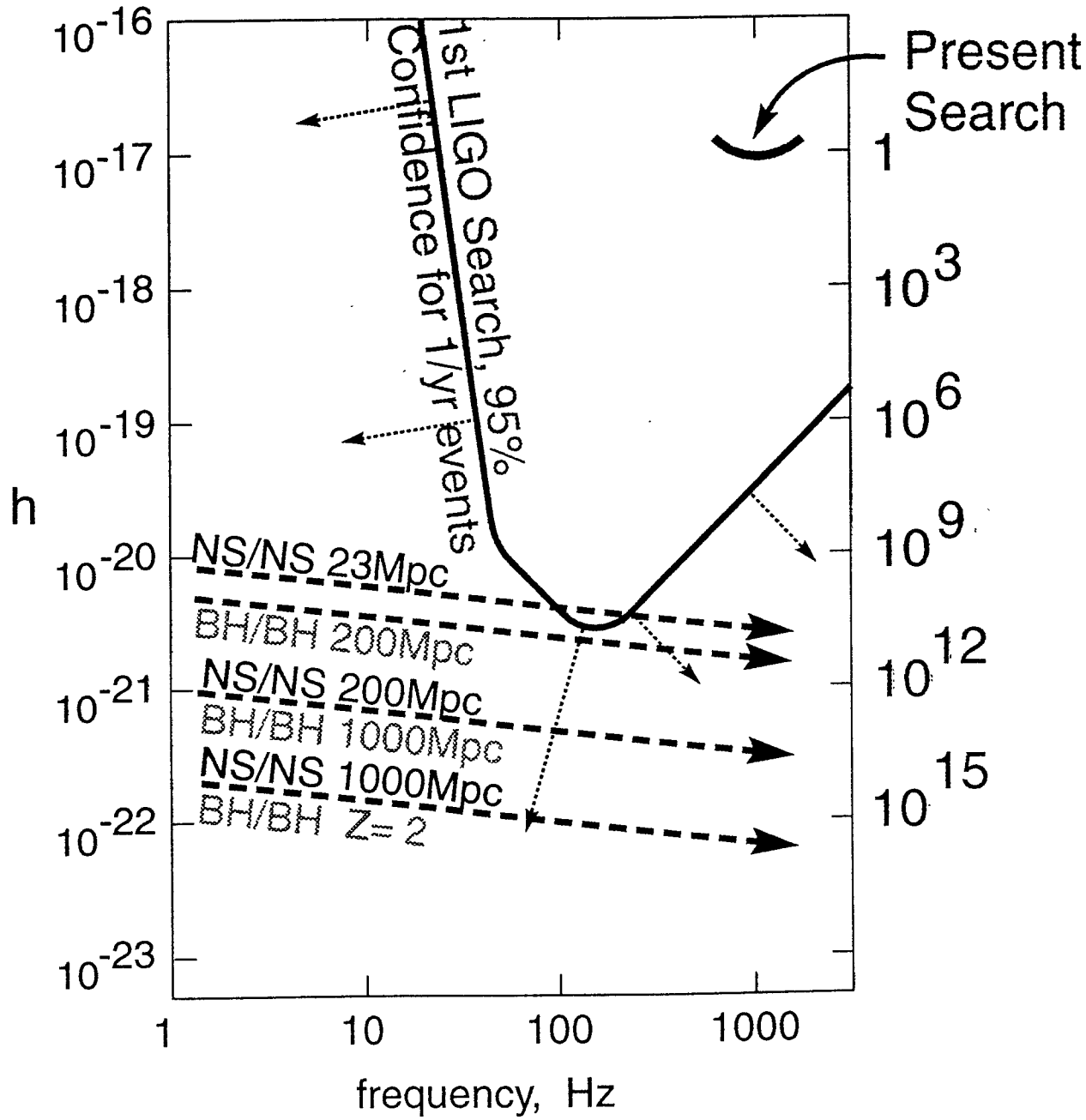
March 20, 1996

MIT NSF Review

NEUTRON STAR BINARIES



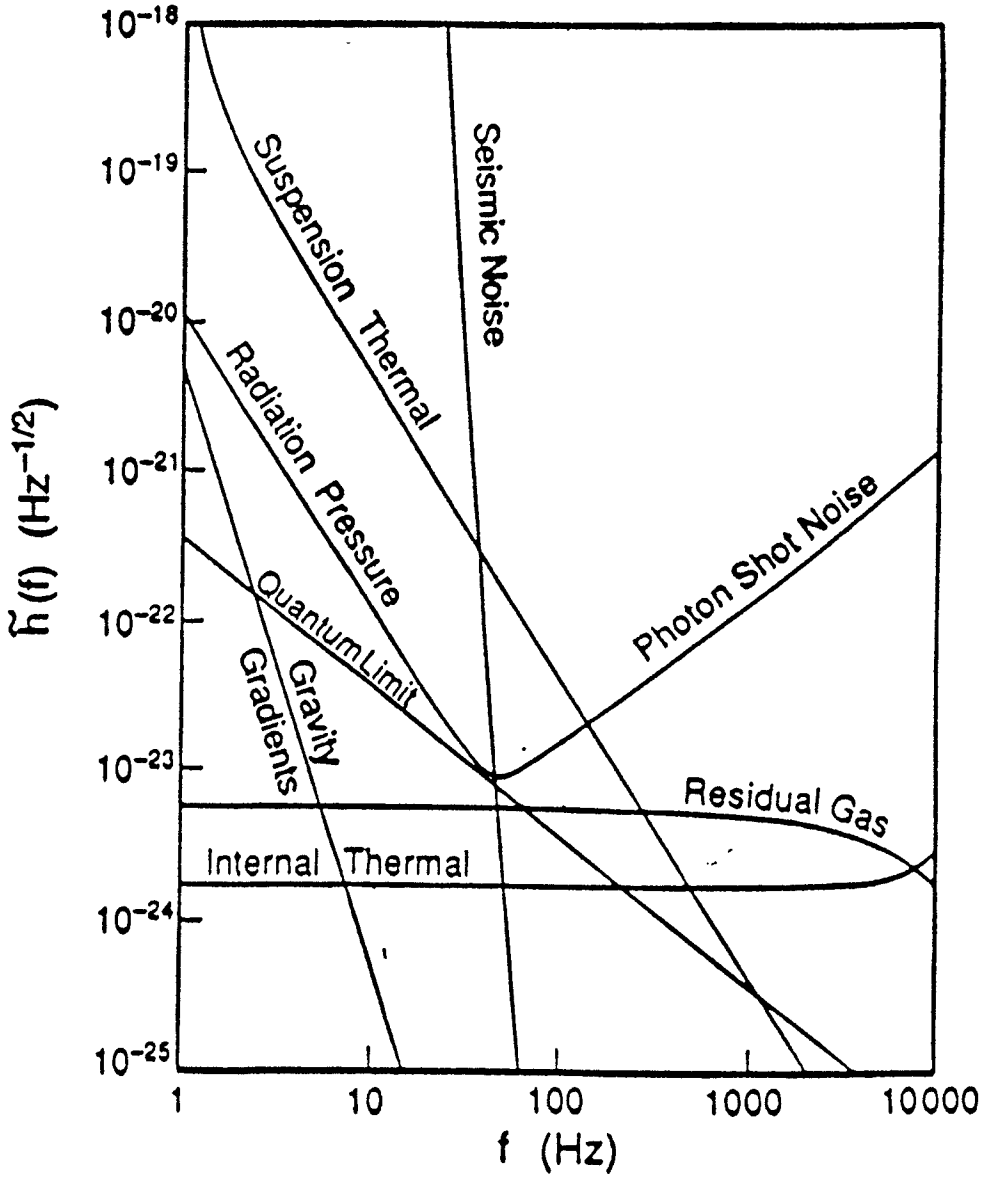
["Near-Guaranteed" source]



- *15 minutes &10,000 orbits in LIGO band*
- *Rich information in waveforms: masses, spins, distance, direction, nuclear equation of state*

Noise Budget For First LIGO Detectors

- 5 Watt Laser
- Mirror Losses 50 ppm
- Recycling Factor of 30
- 10 kg Test Masses
- Suspension $Q=10^7$



LIGO

LIGO Project
Technical

- Major Facilities
  - » Beam Tube
  - » Vacuum Systems
  - » Civil Construction
- Detector
  - » Detection Strategy
  - » Interferometers
- R&D
  - » Noise Sources and Sensitivity
  - » Demonstration Experiments
- Status and Plans

LIGO Facilities
Civil Construction

- Characteristics
  - » Structures, Foundation, Roads, etc...
    - – Large and Clean Laboratory Bldg.
    - – Beam Enclosures
    - – Office/Lab Space
  - » Requirements
    - – Seismic Stability, Noise Sources, etc...
    - – Cleanliness

- Status and Plans
  - » Both Sites Acquired
    - – Washington cleared; graded; pouring slab and constructing enclosure
    - – Louisiana cleared, grubbed; compacting, building berm underway; pipelines mitigated
  - » Facilities Design
    - – H.M. Parsons - slab, enclosures complete; FDR buildings April 26
    - – trade Studies; value engineering
  - » Construction Management
    - – LIGO/Parsons -- in place in Washington

LIGO Facilities

Beam Tube Enclosure

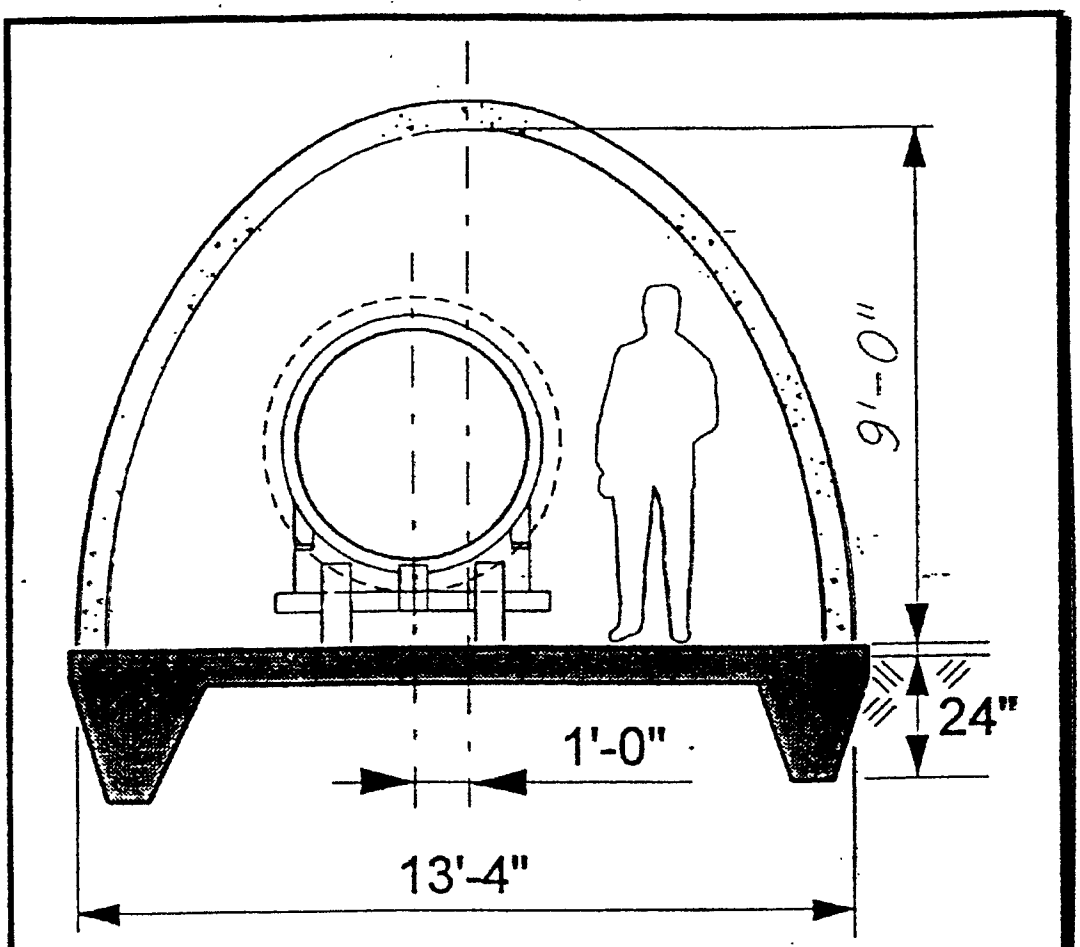
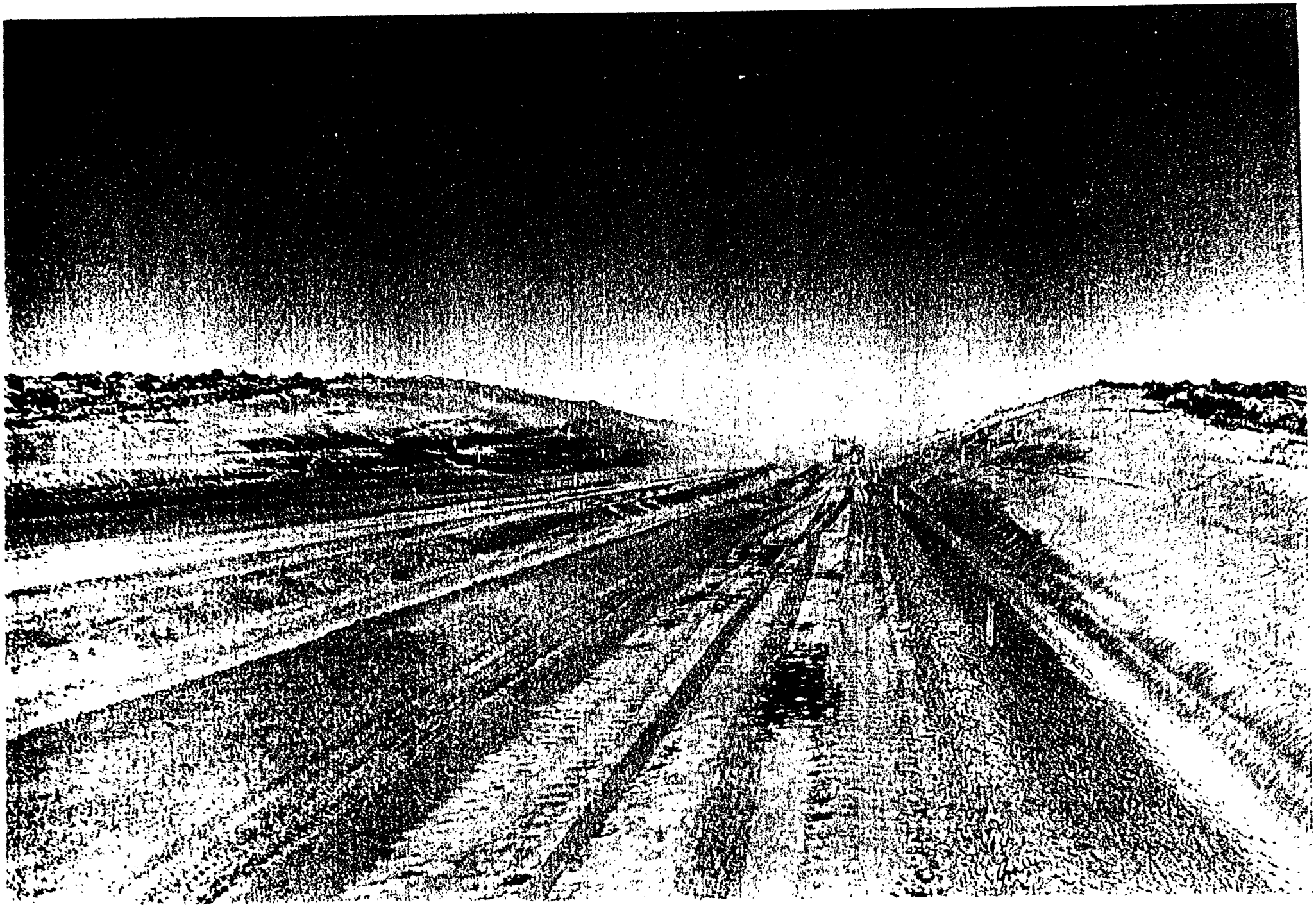
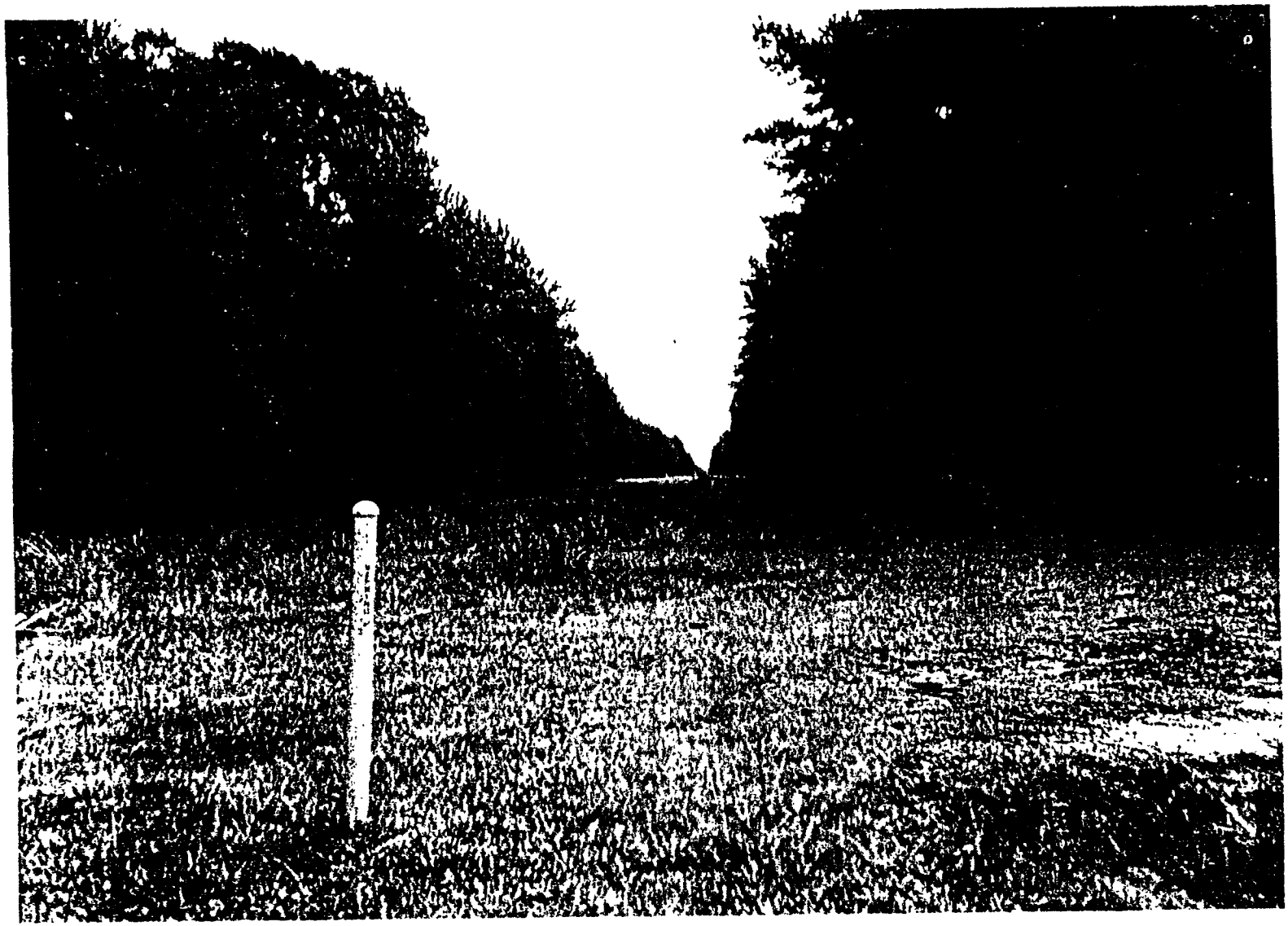
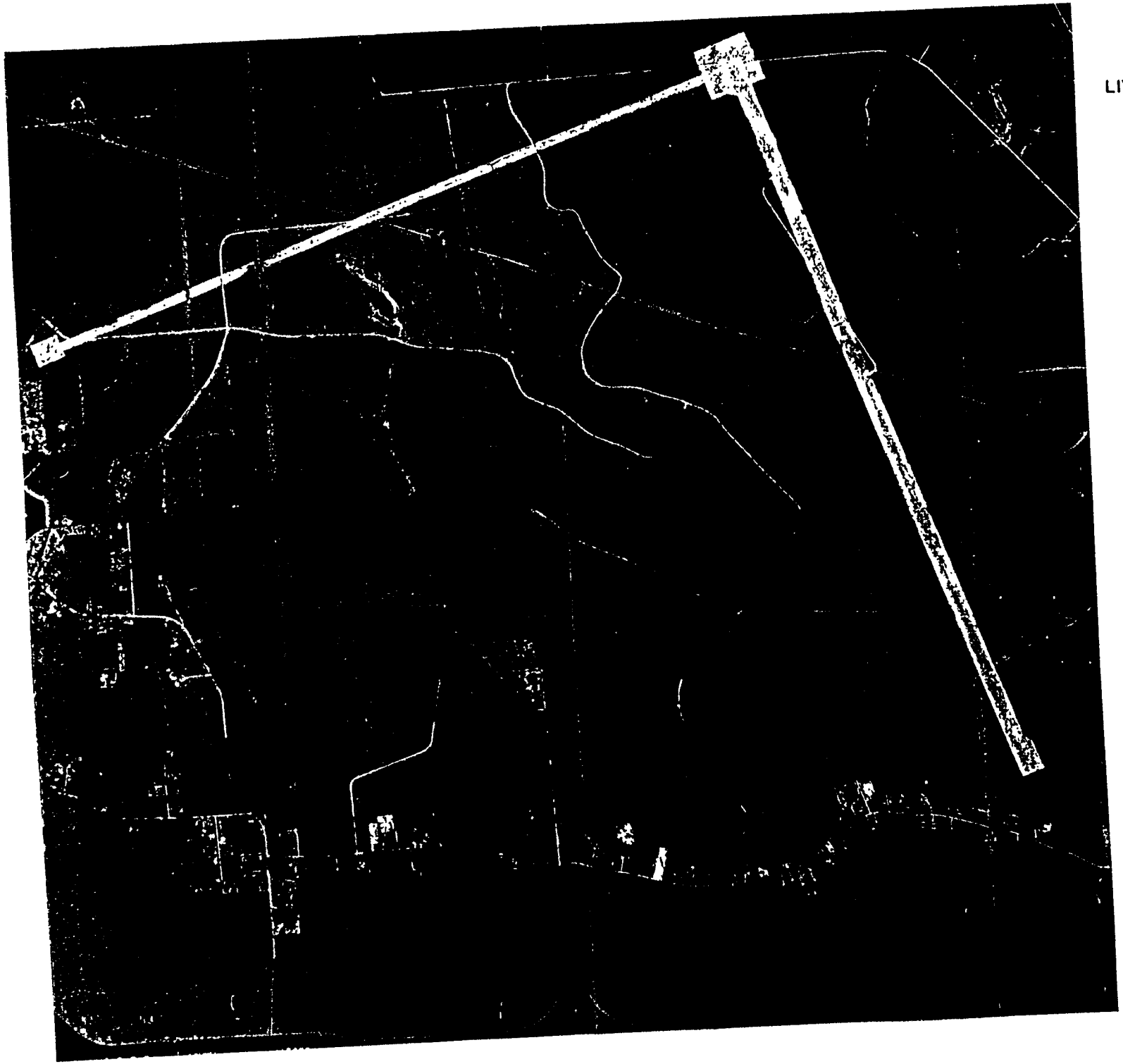


Figure 2.1-1 -- Cross Section of Design Baseline at Hanford







LIGO

LIVINGSTON PARISH

LOUISIANA

1A

AERIAL PHOTO BY:

GULF COAST AERIAL MAPPING

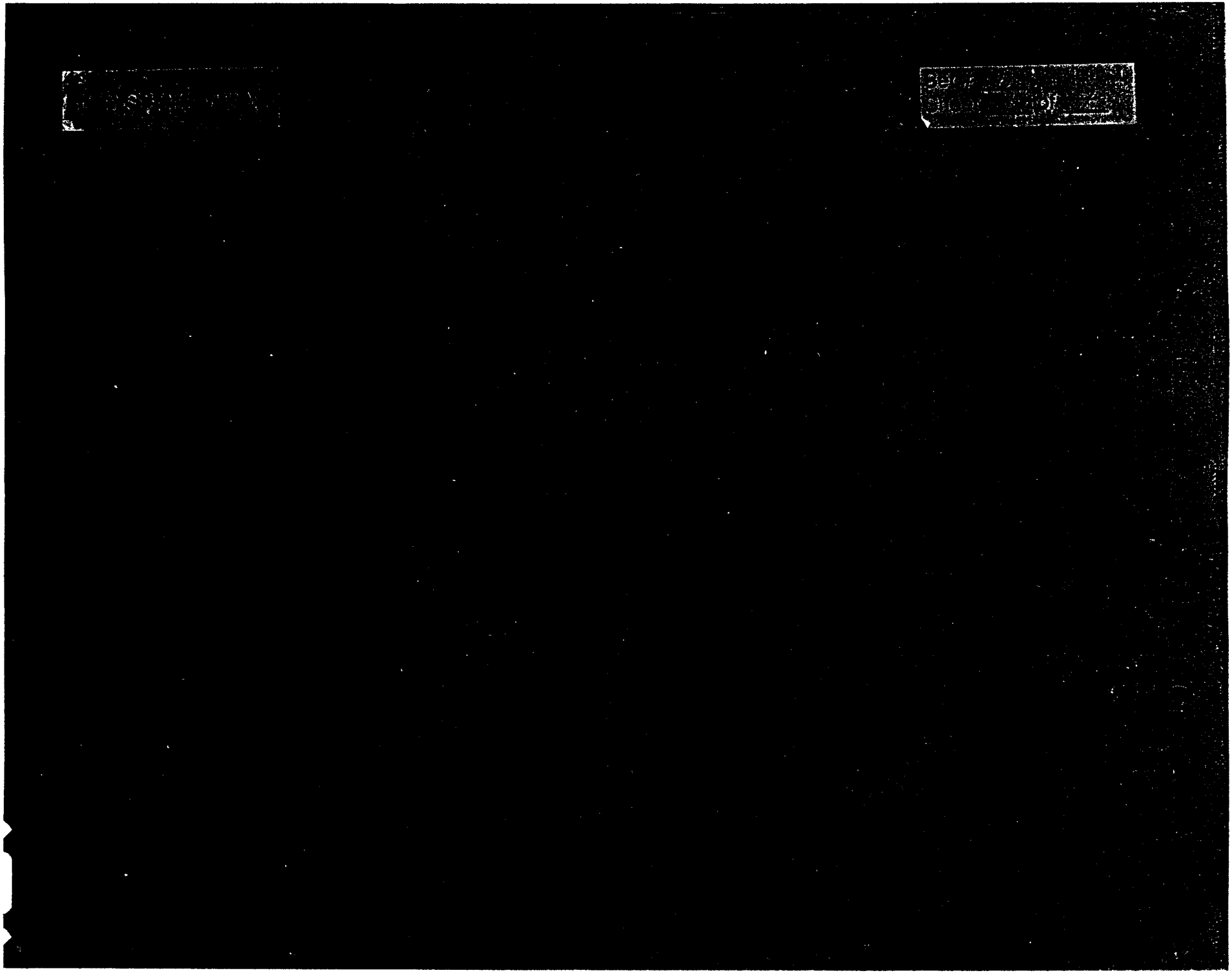
FLOWN: AUGUST 25, 1995

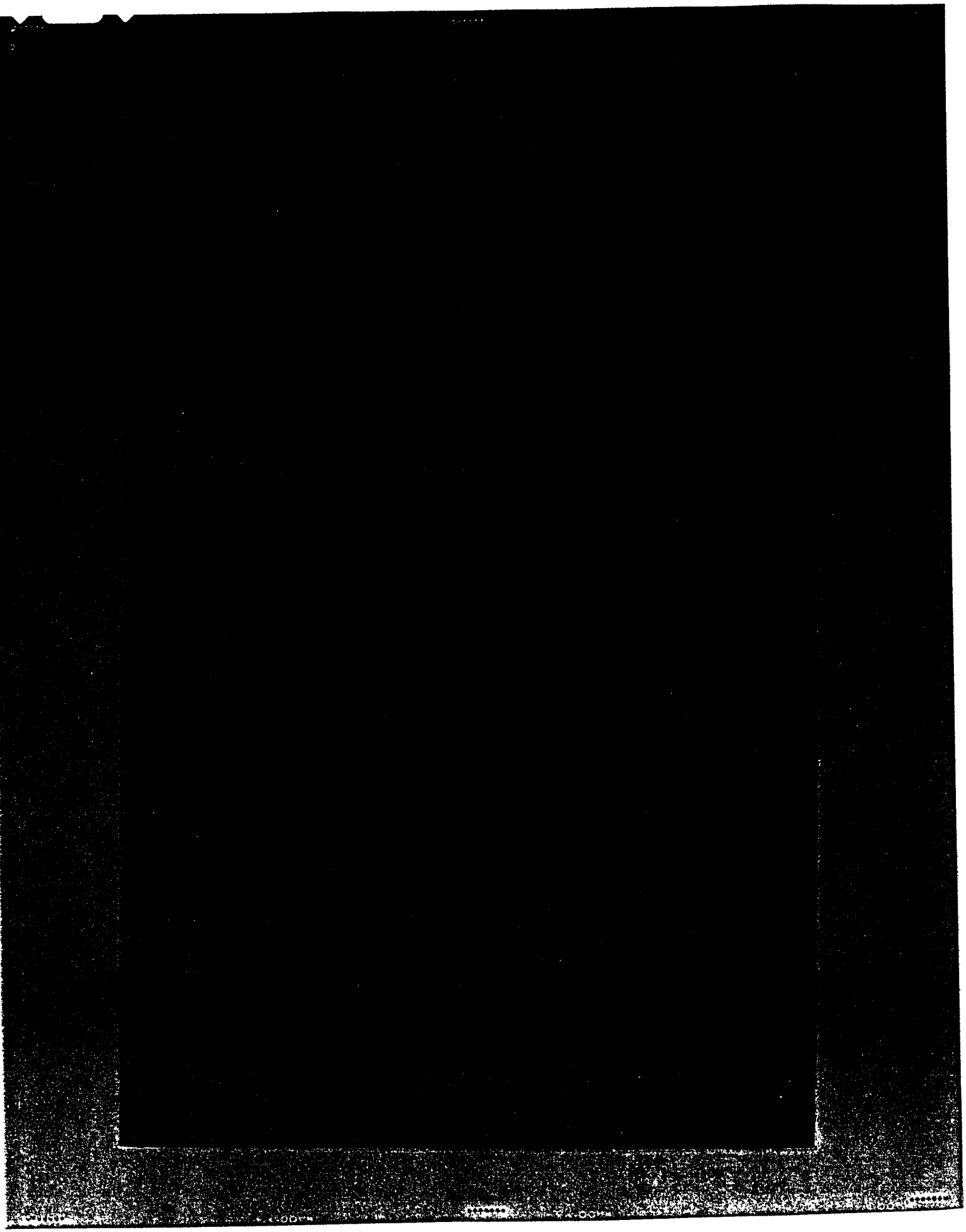
ALTITUDE: 12,000 FEET

LIGO Facilities
Vacuum Equipment

- Characteristics
  - » mostly standard vacuum equipment
    - – 1st stage roughing atm -> 0.1 torr
    - – 2nd stage roughing 0.1 torr -> 10^{-6} torr
    - – steady state - ion/getter pumps
  - » large gate valves (4 ft diam)
    - – access and flexibility
  - » controls and monitoring

- Status
  - » Science requirements and review 6/94
  - » RFP issued for design contract only
  - » Two competitive contracts awarded (CB&I, PSI)
  - » Final design and manufacturing
    - – down select (6/95) to PSI
    - – CDR approved 10/95
    - – FDR May 96; some prototype/acquisitions now





LIGO Facilities
Beam Tube

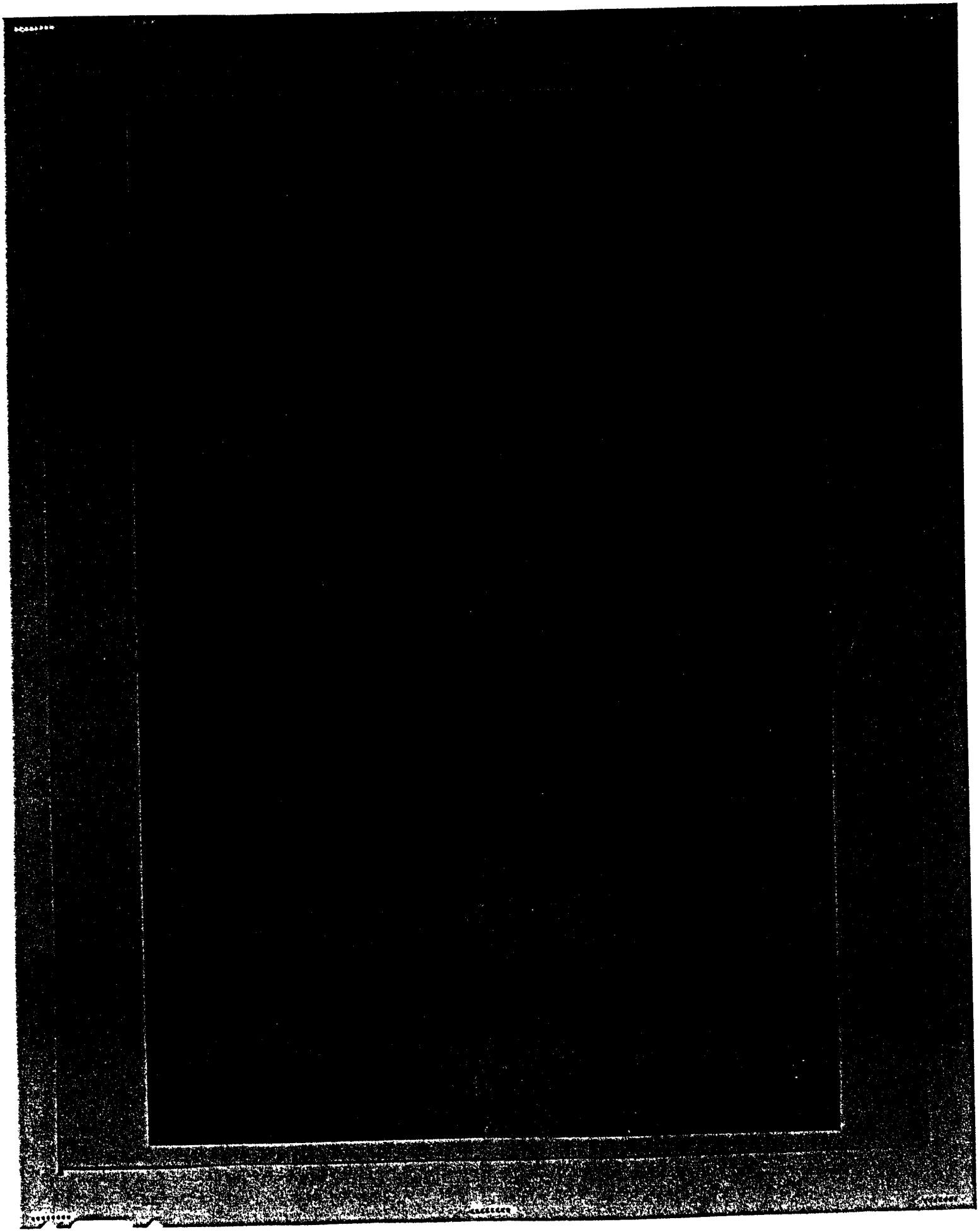
- Characteristics
  - » Arm Lengths - 4km
  - » Tube Diameter - 4 ft
  - » Initial Detector
    - – 10^{-6} torr Hydrogen; 10^{-7} torr Water
  - » Advanced Detectors
    - – 10^{-9} torr Hydrogen; 10^{-10} torr Water
  - » Quality Control
    - – (materials, welding, cleaning, etc..)

- Status and Plans
  - » Design Contract was with CBI
    - – Final Design Report Accepted (6/94)
  - » Qualification Test
    - – 130 ft Section - success (4/95)
  - » Contract Options

LIGO Facilities

Beam Tube

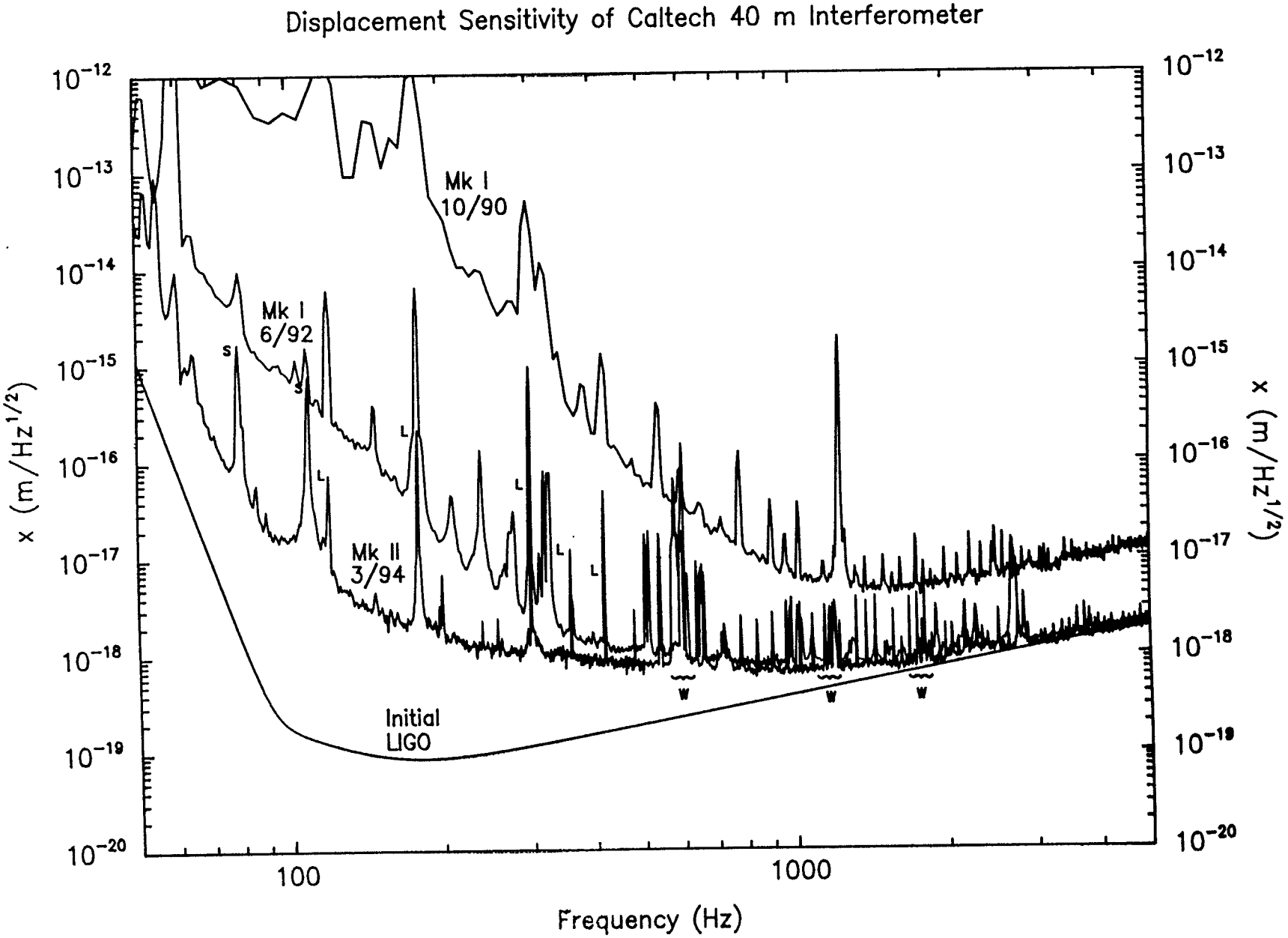
- Characteristics:
  - » length = 4 km (4 arms)
  - » diameter = 4 ft
  - » volume = 20, 000m^3
- Design Contract with CBI
  - » Design report accepted
    - – thin wall stainless spiral weld structure
    - – 65 foot sections with bellow
    - – quality control in material selection, welding, cleaning, etc..
  - » Qualification test -
    - – 130 ft section assembled, cleaned, baked and tested -- achieved design
- Construction contract
  - » negotiated option with CB&I (prepared to compete if necessary)
  - » contract placed December 95
  - » design review - March 27



LIGO Detectors

R&D Program

- Sensitivity
  - » main features of 40 m spectrum understood
  - » monolithic test masses improve sensitivity
- Demonstration Experiments
  - » optical recombination demonstrated on 40 m
  - » acquisition locking with LIGO controls
  - » MIT phase noise experiments
- Pre- [detector design freeze][<1998]
  - » Program testing directed at tasks that could effect design over the next two years
- Post- [detector design freeze][>1998]
  - » Program directed at improved sensitivity;
  - » understand performance of LIGO initial interferometer
  - » gain experience running an interferometer facility


Displacement Sensitivity of Caltech 40 m Interferometer
Mk I
10/90
Mk I
6/92
Mk II
3/94
Initial
LIGO
S
L
W
x (m/Hz^1/2)
Frequency (Hz)
100
1000
10^-12
10^-13
10^-14
10^-15
10^-16
10^-17
10^-18
10^-19
10^-20

LIGO Detectors

Detector Implementation

- Detector baseline established for Costing (9/94).
  - » This baseline is 'consistent' with sensitivity goals.
- Detector requirements established from sensitivity goals
- Switch to Nd:YAG lasers for LIGO
  - » decision in Sept '95
  - » YAG chosen for reliability and most direct path toward high power (improved sensitivity)
  - » Now integrating into LIGO baseline
  - » official change control action when plan is developed and cost/schedule impact understood

LIGO Detectors

Integration

- Science Goals for initial and improved detectors
- Establish Systems Requirements
  - » First draft document
- Modeling
  - » environment - AVS
  - » end to end model - underway
  - » lock acquisition, optics, etc.
  - » help final design and understand performance
- Interfaces
  - » facilities, detector

LIGO Management
Approach

Project Management Plan

- Sets out project organization, management, project controls, etc

NSF Budget Approval

- Construction + R&D Budget - $292.1M
  - » Construction Completed in 1999
- Commissioning/Operations - $68.7M
  - » Commissioning Commences in 1997
  - » 3-fold Sensitivity 10^{-20} by July 2000
  - » First Search for Gravitational Waves
  - » Sensitivity 10^{-21} by end of 2001
- Established as our Working Baselines

Project Organization

- Parallels WBS - Product Oriented
- Integrated Detector and R&D Efforts

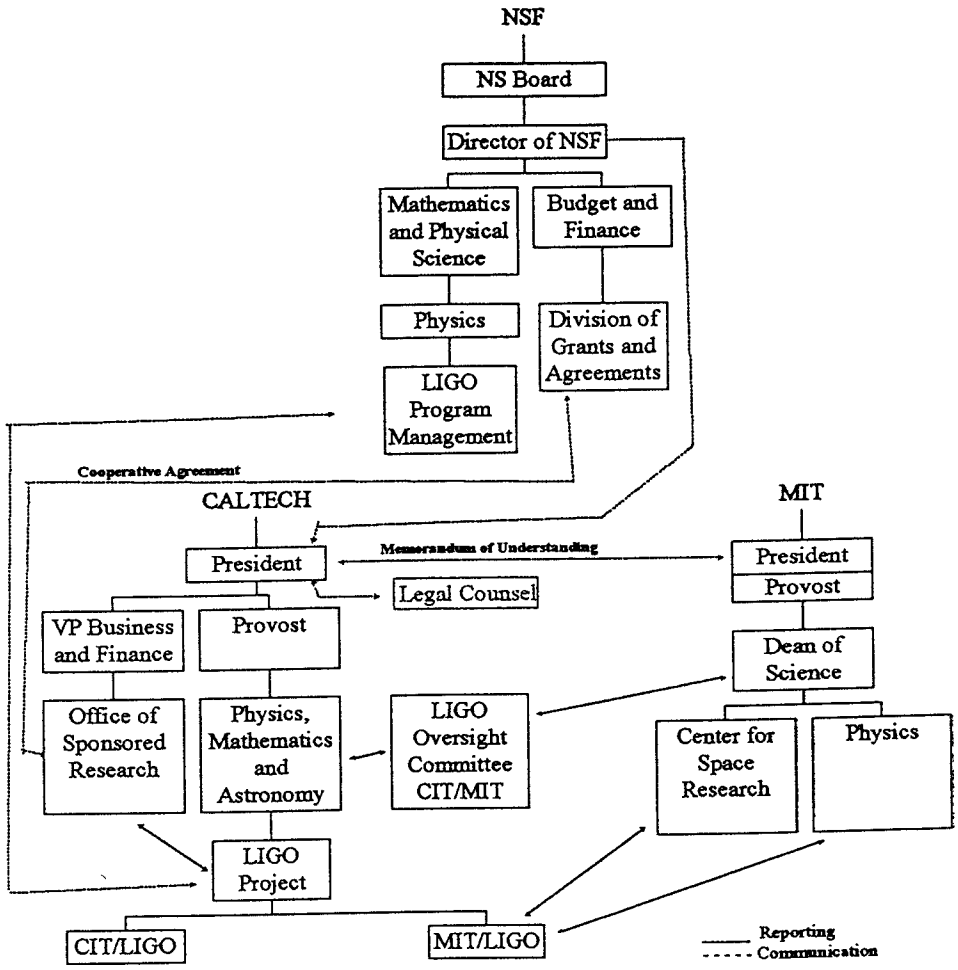
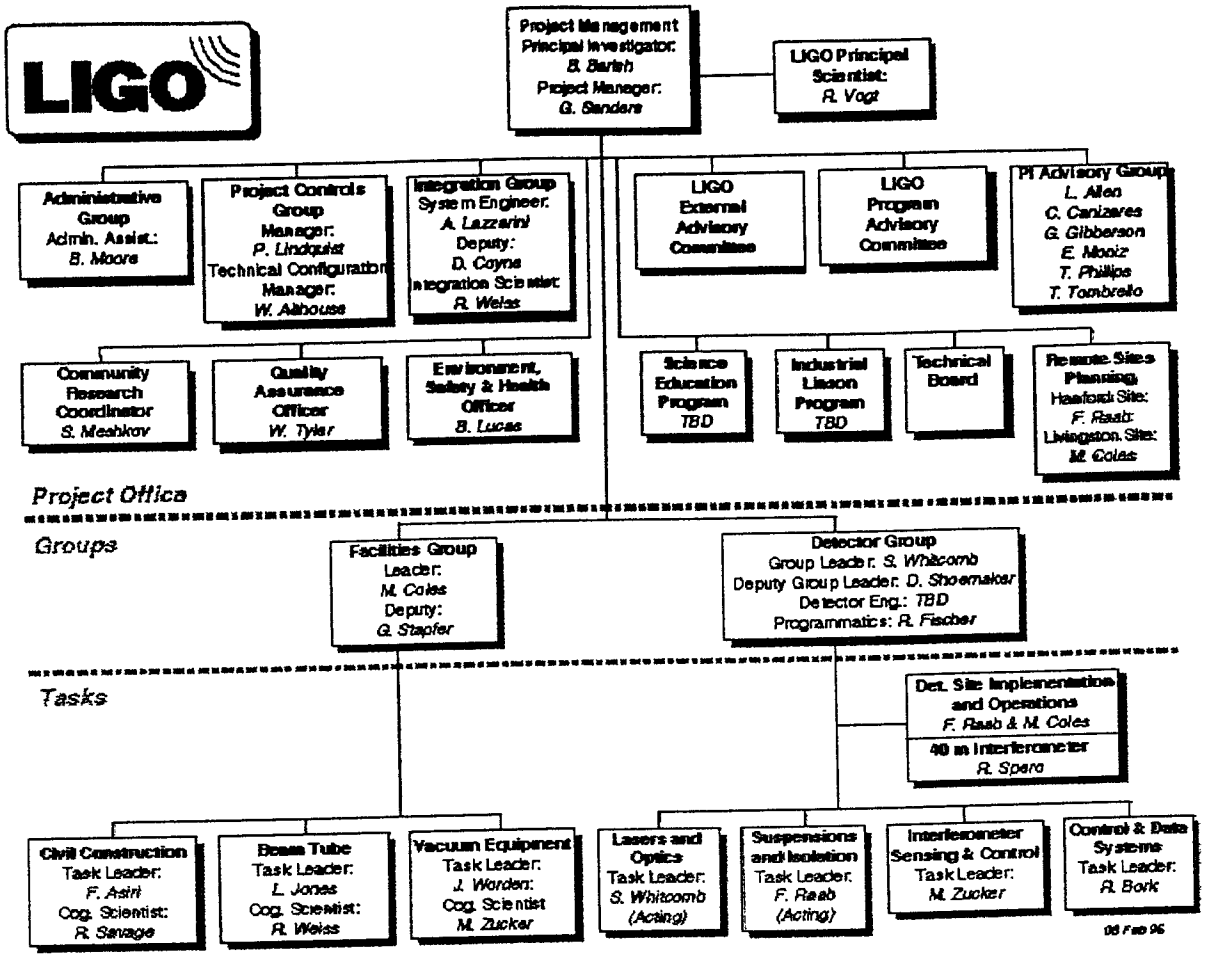


Figure 2-1. Organizational hierarchy.

LIGO

Approved Funding

Fiscal Year	Construction	R&D	Operations	Total
1992	$15.9M	$3.2M		$19.1M
1993	$20.0M	$4.0M		$24.0M
1994	0	$4.0M		$4.0M
1995	$85.0M	$4.0M		$89.0M
1996	$55.0M	$4.0M		$59.0M
1997	$55.0M	$0.8M	$0.3M	$56.1M
1998	$41.2M		$7.3M	$48.5M
1999			$20.9M	$20.9M
2000			$21.1M	$21.1M
2001			$19.1M	$19.1M
Total	**$272.1M**	**$20.0M**	**$68.7M**	**$360.8M**



Here is a link to the **LIGO** roster.

Here is a link to the LIGO meetings calendar for the next six months.

LIGO

Staffing as of June '95

Task	Caltech	MIT	Total
Proj Mgt	4	0	**4**
Admin	6	2	**8**
P Control	8	0	**8**
Syst Int	6	1	**7**
Facilities	7	0	**7**
Detector	17	2	**19**
R&D	10	7	**17**
Grad Stud	4	5	**9**
TOTAL	**62**	**17**	**79**

LIGO

Commissioning/Operations

- Management for Hanford:
  - » F. Raab (Head)
  - » O. Matherny (Facilities Manager)
  - » J. Worden (Vacuum Engineer)
- Management for Livingston
  - » M. Coles (Head)
  - » G. Stapfer (Facilities Manager)
  - » A. Sibley (Vacuum Engineer)
- MIT / Caltech
  - » support operations and running
  - » advanced detector development
  - » data analysis and physics

LIGO

The Community

- LIGO Users
  - » Aspen Workshops (Jan 95,96)
  - » Formed charter, membership of LRC (172 members)
  - » Elected Executive Board; Chairman (S.Finn)
  - » Meeting @ Spring APS
- Collaborations
  - » VIRGO : Workshop in April on Data Formats
    - – cooperate on technology, data analysis; MOU in process
  - » GEO 600:MOU - visitors program
  - » TAMA: MOU - visitors program
  - » MOUs :
    - – K. Thorne (Caltech), Bender (JILA), Cutler (Penn State), Saulson (Syracuse); Sandeman (Australian groups), etc.

LIGO Status and Plans

Conclusions

- The LIGO Project
  - » technical considerations for civil construction and vacuum systems in hand
  - » major contracts established and actual construction of facilities well underway
- R&D and Detector
  - » active and productive R&D program
  - » development of the detector design
  - » reconcile with requirements
- Detailed site planning underway
  - » staffing and organization
  - » plan for installation, commissioning and operations
  - » integration with the construction schedule
- Outside community being included, informed and organized