

LIGO PROJECT

**(Briefing for Preliminary Design Review Board,
LIGO Beam Tube Modules)**

**W. E. Althouse
November 30, 1993**

Gravitational Waves:

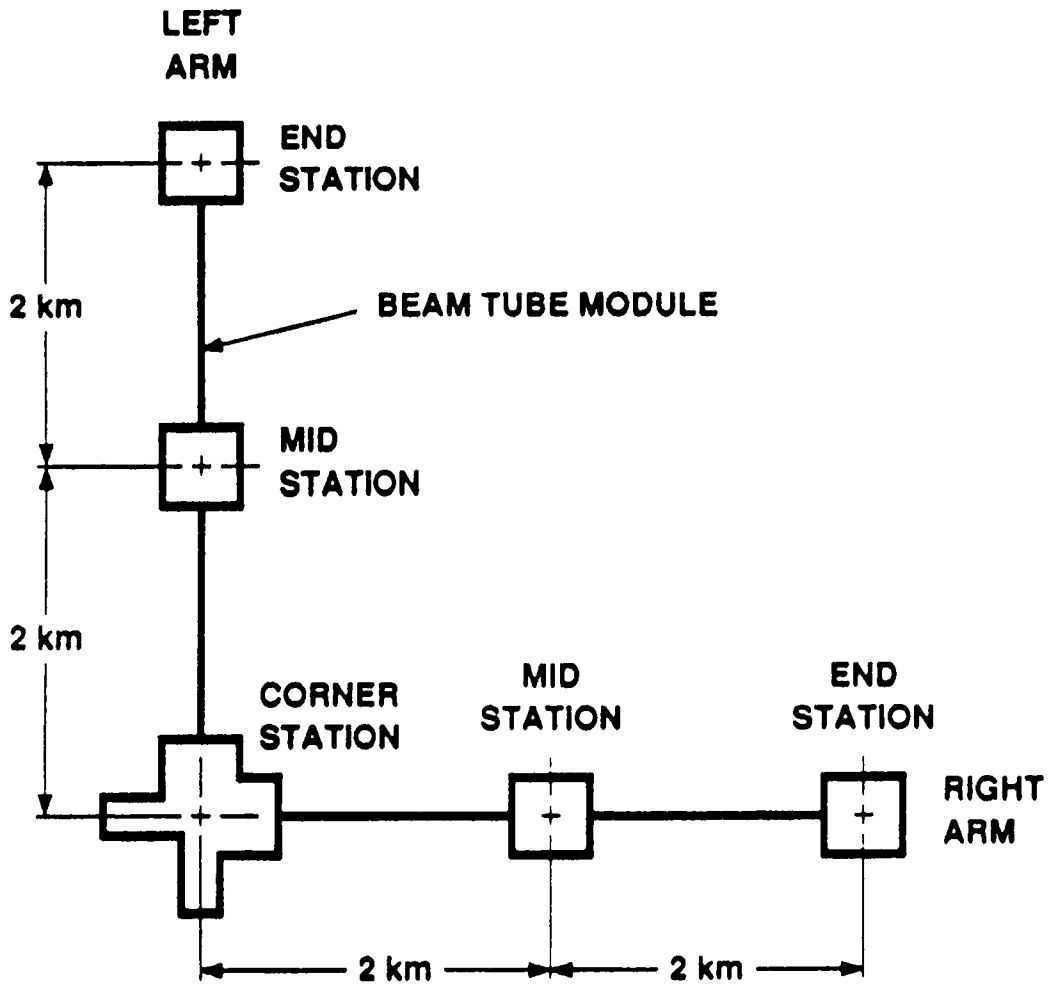
- **Existence of gravitational waves predicted by General Theory of Relativity (Einstein, 1916).**
- **Distortion of space, causes change in separation of free masses.**
- **Predicted sources: black holes, neutron stars, supernovae, big bang, etc.**

LIGO Facilities:

- **Two observatory facilities: Livingston, LA and Hanford, WA.**
- **L-shaped vacuum system with arms of 4 km housing laser interferometer detectors.**
- **Correlation of data from two sites allows identification of gravitational waves and permits extraction of astrophysical information.**
- **LIGO facilities to operate around the clock. Full-up configuration open to participation by broad scientific community.**
- **LIGO to become part of a planned worldwide network.**

LIGO Detectors:

- **Compare separations of test masses at corner and ends of "L."**
- **Test masses suspended on wires from vibration-isolated platform within vacuum, free to move horizontally.**
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VACUUM SYSTEM

KEY OBJECTIVES

- **L-SHAPED VACUUM SYSTEM: 2 BEAM TUBES CONNECTING CHAMBERS**
- **4 km TUBES WITH 1 m CLEAR APERTURE**
- **6 FABRY-PEROT BEAMS (BACKUP: 1 DELAY LINE)**
- **NON-INTERFERING ACCESS**
- **LOW VIBRATION ENVIRONMENT**
- **CONTROL OF SCATTERED LIGHT PROPAGATION**
- **BEAM TUBE VACUUM: SINGLE PUMPDOWN**
- **CLEAN ENVIRONMENT FOR OPTICAL COMPONENTS**
- **MODULAR DESIGN: FLEXIBLE VACUUM ENVELOPE**

PRESSURE REQUIREMENTS / GOALS

- **Fluctuations in number of molecules in beam limits interferometer performance**
- **Initial requirements satisfy needs of initial interferometers**
- **Goals meet needs of advanced interferometers**
- **Average partial pressures of main gas species (torr at 300K)**

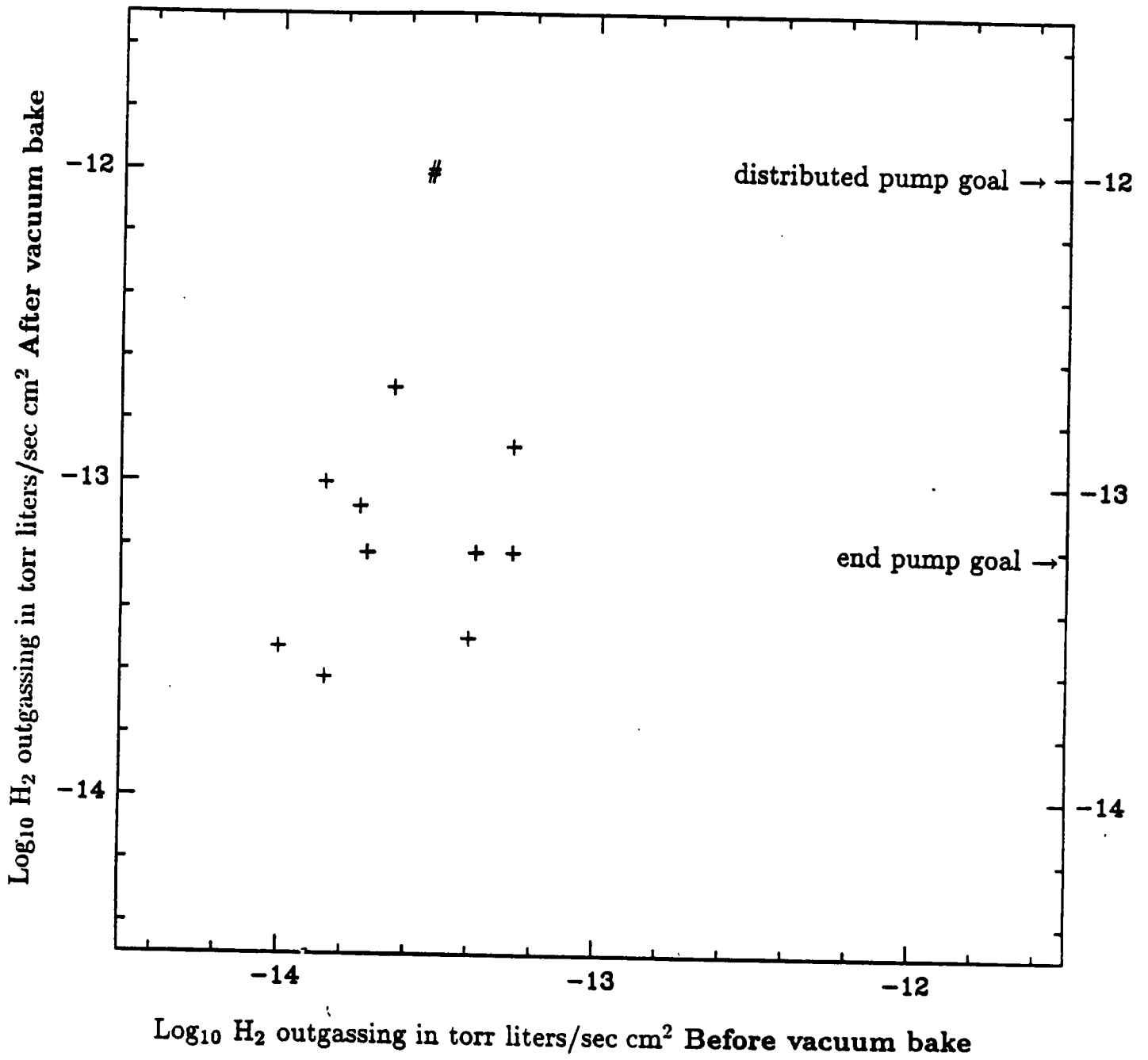
	Initial Requirement	Goal
H₂	10⁻⁶	10⁻⁹
H₂O	10⁻⁷	10⁻¹⁰

- **Strategy is to lower outgassing rather than increase pumping**
- **Beam tube a “passive” system with decreasing gas load**
- **Initial requirements met by:**
 - Pumping only in stations**
 - H₂ by low outgassing steel**
 - H₂O by low temperature bake**
- **Goal assured by:**
 - 7 pump ports / tube module**
- **Welded construction for leak free long term reliability**
- **Total pressure in test mass chambers $\leq 10^{-6}$ to avoid thermal noise from gas damping**

VACUUM R&D PROGRAM OBJECTIVES

- **DEVELOP ECONOMICAL MEANS TO ACHIEVE GOAL PRESSURES**
 - **DEVELOP STEEL PROCESS FOR LOW HYDROGEN OUTGASSING**
 - **DEVELOP WATER DEGASSING METHOD**
- **DEMONSTRATE PRODUCTION PROCESSES FOR BEAM TUBE ON LIGO SCALE**
 - **0.6 m DIAM × 40 m LONG DEMONSTRATION OF BEAM TUBE FABRICATION, CLEANING AND BAKEOUT TECHNIQUES**
 - **IN-PROCESS (TUBE SECTION) LEAK TESTS**
 - **APPARATUS FOR PRODUCTION STEEL SAMPLE SCREENING TESTS**
 - **TEST CHAMBERS FOR HYDROGEN PERMEATION MEASUREMENTS**
- **DEVELOP MATERIAL / COMPONENT PROCESSING QUALIFICATION AND SCREENING TESTS TO CONTROL OUTGASSING OF INSTALLED EQUIPMENT**
 - **RGA SPECTRUM QUALIFICATION / CHARACTERIZATION TESTS**
 - **RGA SPECTRUM BULK SCREENING TESTS**
 - **MIRROR EXPOSURE TESTS WITH AND WITHOUT HIGH OPTICAL POWER**

HYDROGEN OUTGASSING TESTS

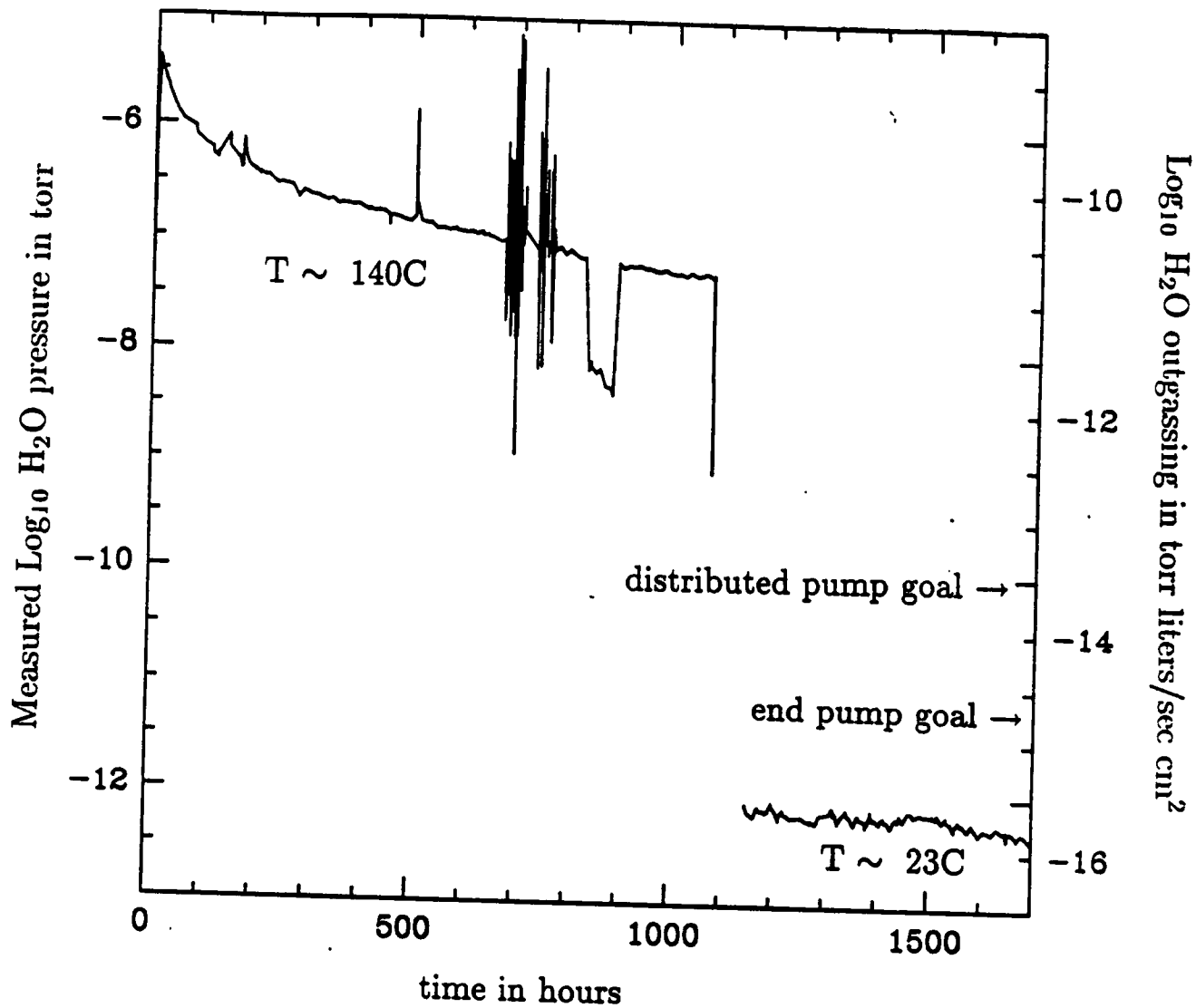


Legend:

= Original Process

+ = Revised Process

SPIRAL WELDED TUBE BAKEOUT AND WATER OUTGASSING DEMONSTRATION



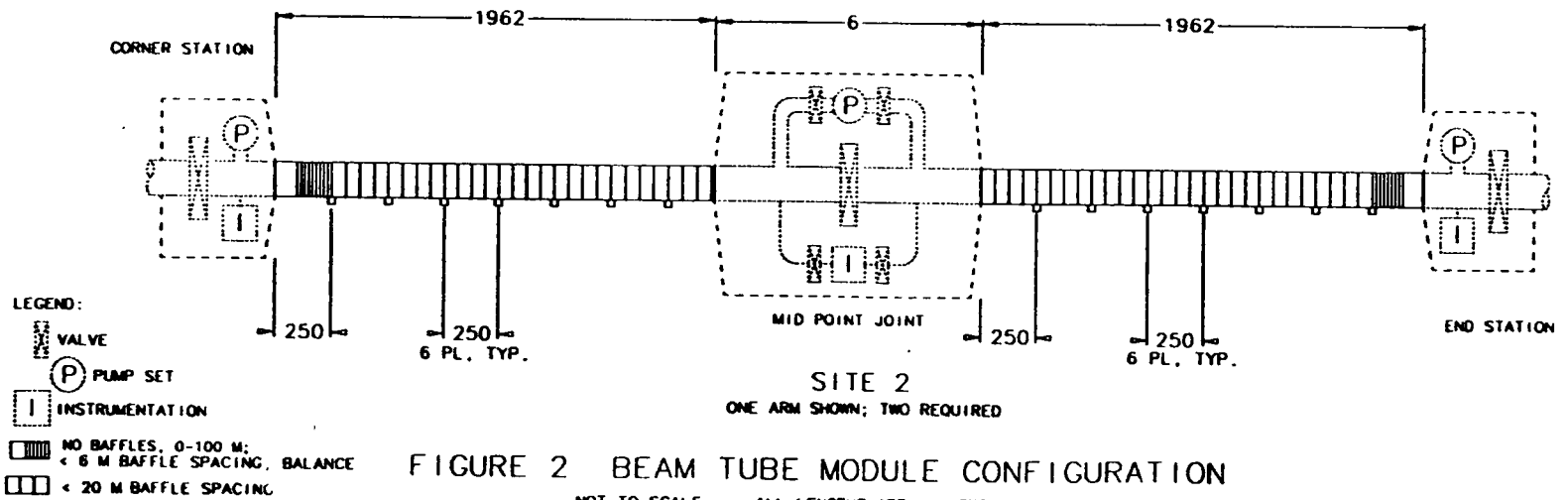
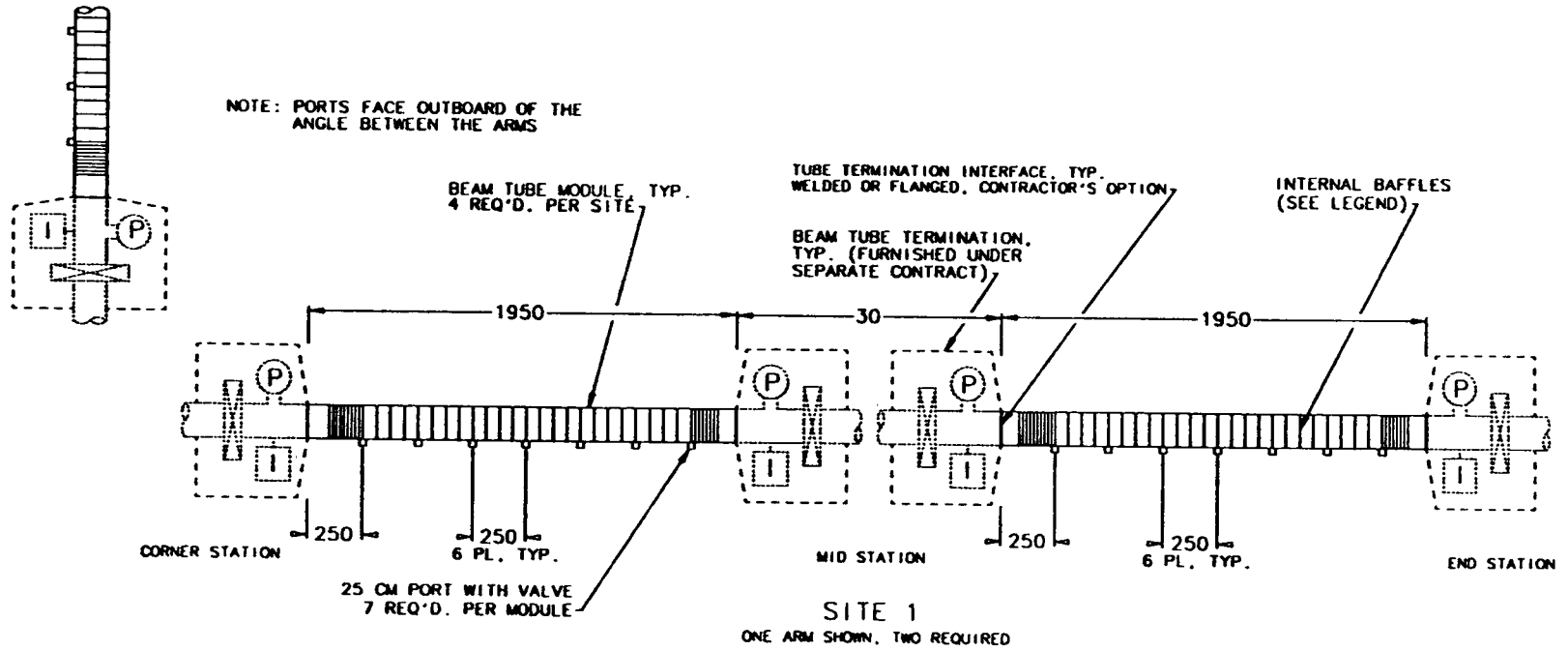


FIGURE 2 BEAM TUBE MODULE CONFIGURATION

NOT TO SCALE ALL LENGTHS ARE IN METERS

BEAM TUBE MODULE PROCUREMENT CONTRACTUAL REQUIREMENTS — OVERVIEW

- FIRM FIXED PRICE DELIVERY OF:
 - DETAILED DESIGN
 - QUALIFICATION TEST
- UNPRICED OPTION FOR FABRICATION, INSTALLATION AND ACCEPTANCE TEST
- OPTION EXPECTED TO BE EXERCISED UPON:
 - SUCCESSFUL COMPLETION OF DESIGN AND QUALIFICATION TEST EFFORT
 - SATISFACTORY NEGOTIATION OF OPTION PRICE
 - CONTINUED SUPPORT BY NSF

CONTRACTUAL REQUIREMENTS DELIVERABLES (partial list)

1. DETAILED DESIGN

a. DRAWINGS / SPECIFICATIONS

- as needed to fully describe the final installed product

b. FABRICATION AND INSTALLATION PROCEDURES

- as needed to adequately control processes

c. PLANS AND PROCEDURES FOR SCREENING AND ACCEPTANCE TESTS

d. FIELD INSTALLATION / CONSTRUCTION PLAN

- as needed for programmatic control and Caltech coordination of LIGO construction activities

e. OPERATIONAL ALIGNMENT TEST PROCEDURE

- for Caltech use during LIGO operation to detect and correct alignment drifts

f. RELIABILITY AND QUALITY ASSURANCE PLAN

2. DESIGN QUALIFICATION TEST

- full-scale model configured to demonstrate:

- control of fabrication, field installation and acceptance test techniques

- compliance with requirements

- affords contractor opportunity to prototype fabrication, field installation and test processes

TECHNICAL REQUIREMENTS DESCRIPTION

- **2 KM LONG BEAM TUBE MODULES**
- **TERMINATED EACH END BY VALVE & PUMP SET***
- **7 DISTRIBUTED PUMP PORTS WITH VALVES***
- **INTERNAL BAFFLES**
- **MODULE INSTALLED ON CONCRETE SLAB***
- **EXPANSION JOINTS & TUBE SUPPORTS AS REQUIRED**
- **CONCRETE ENCLOSURE* INSTALLED AFTER TUBE INSTALLED**
- **OUTGASSING, CONTAMINATION, ALIGNMENT, & LEAKAGE CRITICAL**
- **WELDED JOINTS**
- **OPERATIONAL VACUUM LEVEL 10^{-9} — 10^{-10} TORR**

***CALTECH RESPONSIBILITY**

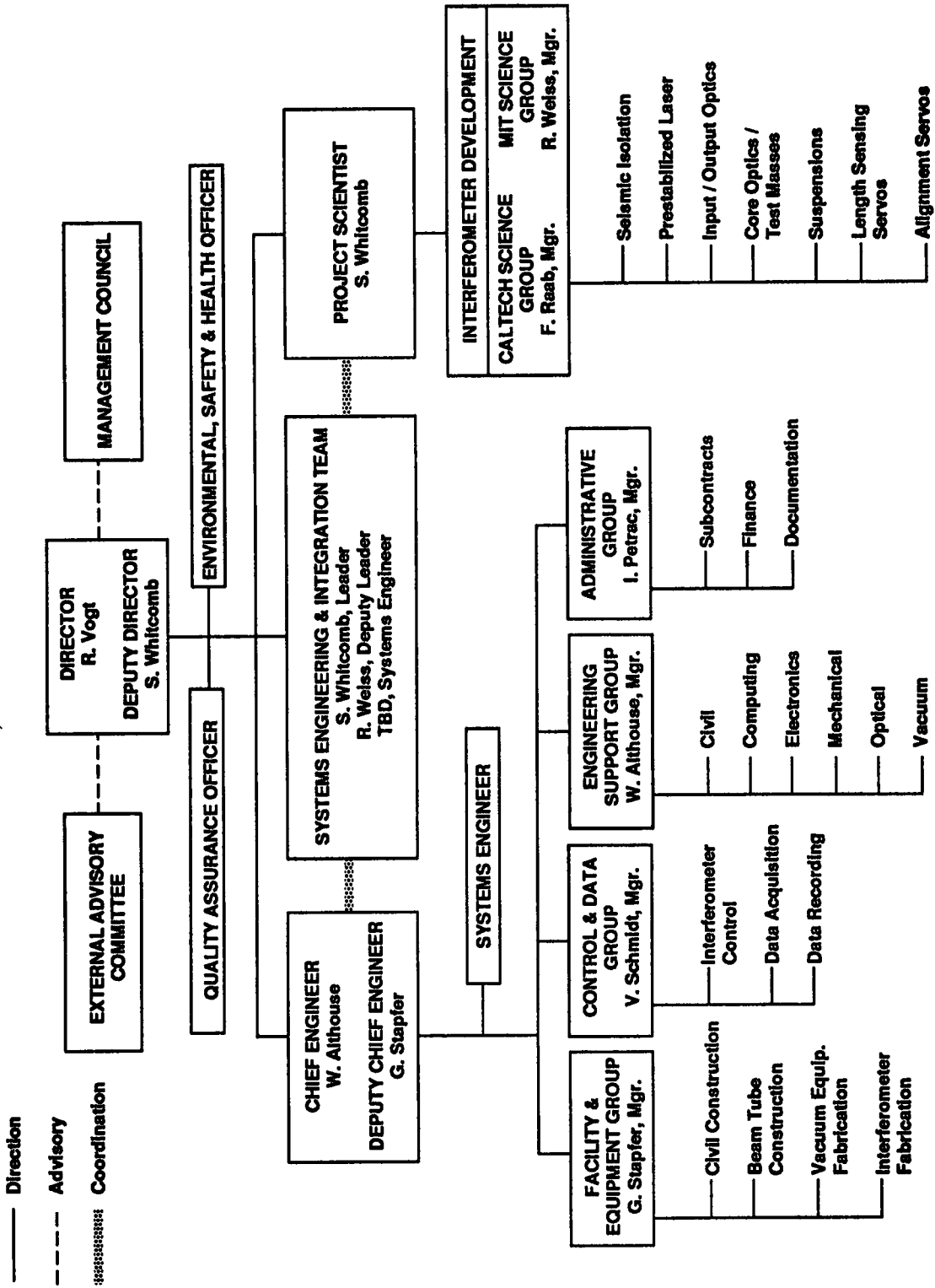
**BEAM TUBE MODULE PROCUREMENT
TECHNICAL REQUIREMENTS — PERFORMANCE**

- **HELIUM LEAK RATE:** $\leq 1 \times 10^{-10}$ atm cc/s
- **CLEAR APERTURE:** ≥ 1.07 M DIA.
- **OUTGASSING RATE:** follow LIGO process specification 1100007:
 - **INTENDED TO PROVIDE THESE OUTGASSING RATES:**
 $J_{H_2} < 1 \times 10^{-13}$ torr·liter/s·cm²,
 $J_{ALL OTHERS} < 1 \times 10^{-15}$ torr·liter/s·cm²
 - **TECHNICAL REQUIREMENTS:**
Initial material: 304L S.S., wall thickness $\leq .13$ inch, sheet or coil
raw material air bake: 440°C, 36 hours
welding:
vacuum welds: TIG, no filler wire
all welds: inert purge on vacuum side
cleaning: “steam” clean, with Oakite 33
vacuum bake: 140°C, 30 days (Caltech responsibility)
 - **RELIABILITY AND QUALITY ASSURANCE:** MATERIAL SAMPLES FROM EACH AIR BAKE TO BE TESTED FOR H₂ OUTGASSING PRIOR TO MATERIAL USE FOR FABRICATION

**BEAM TUBE MODULE PROCUREMENT
RELIABILITY AND QUALITY ASSURANCE REQUIREMENTS**

- **PLANS: TESTING, CONTAMINATION CONTROL: CALTECH APPROVAL REQUIRED**
- **QUALIFICATION TESTS: 3 SECTION LENGTH: LEAK RATE, ALIGNMENT, OUTGASSING RATE DEMONSTRATION**
- **SCREENING TESTS:**
 - **tube wall material sample test**
 - **tube section leak test**
 - **tube section dimensional test**
- **ACCEPTANCE TESTS**
 - **module leak test**
 - **clear aperture verification**

LIGO ORGANIZATION



REVIEW PROCEDURES

Review Board Charter:

- **Advisory to LIGO Director.**
- **Assess compliance with requirements.**
- **Evaluate risk areas.**

Considerations:

- **Have key issues been addressed?**
- **Are all available data considered in trade off decisions?**
- **Are design approaches sufficient to proceed with detailed design?**
- **Is proposed test program adequate?**

Participation:

- **Executive sessions for discussion.**
- **Question presenters to:**
 - **Clarify understanding of presentation.**
 - **Amplify details as necessary.**
- **Use RFAs to:**
 - **Identify potential problems / concerns.**
 - **Suggest options / alternatives to be considered.**
 - **Make recommendations.**
- **RFA's will form basis for formal report to LIGO Director.**
- **Splinter sessions may be suggested to explore specific technical issues in depth.**

Recommendation For Action (RFA)

CALIFORNIA INSTITUTE OF TECHNOLOGY
MASSACHUSETTS INSTITUTE OF TECHNOLOGY

LIGO PROJECT

Review: _____

Reviewer: _____

Date: _____

STATEMENT OF CONCERN:

RECOMENDED ACTION:

For Project Use Only

DISPOSITION: (Check boxes below)

ACCEPTED

REJECTED

ADVISORY

NO ACTION
 REQUIRED

ASSIGNED TO: _____

AI DUE DATE: _____

ACTION ITEM NO.: _____

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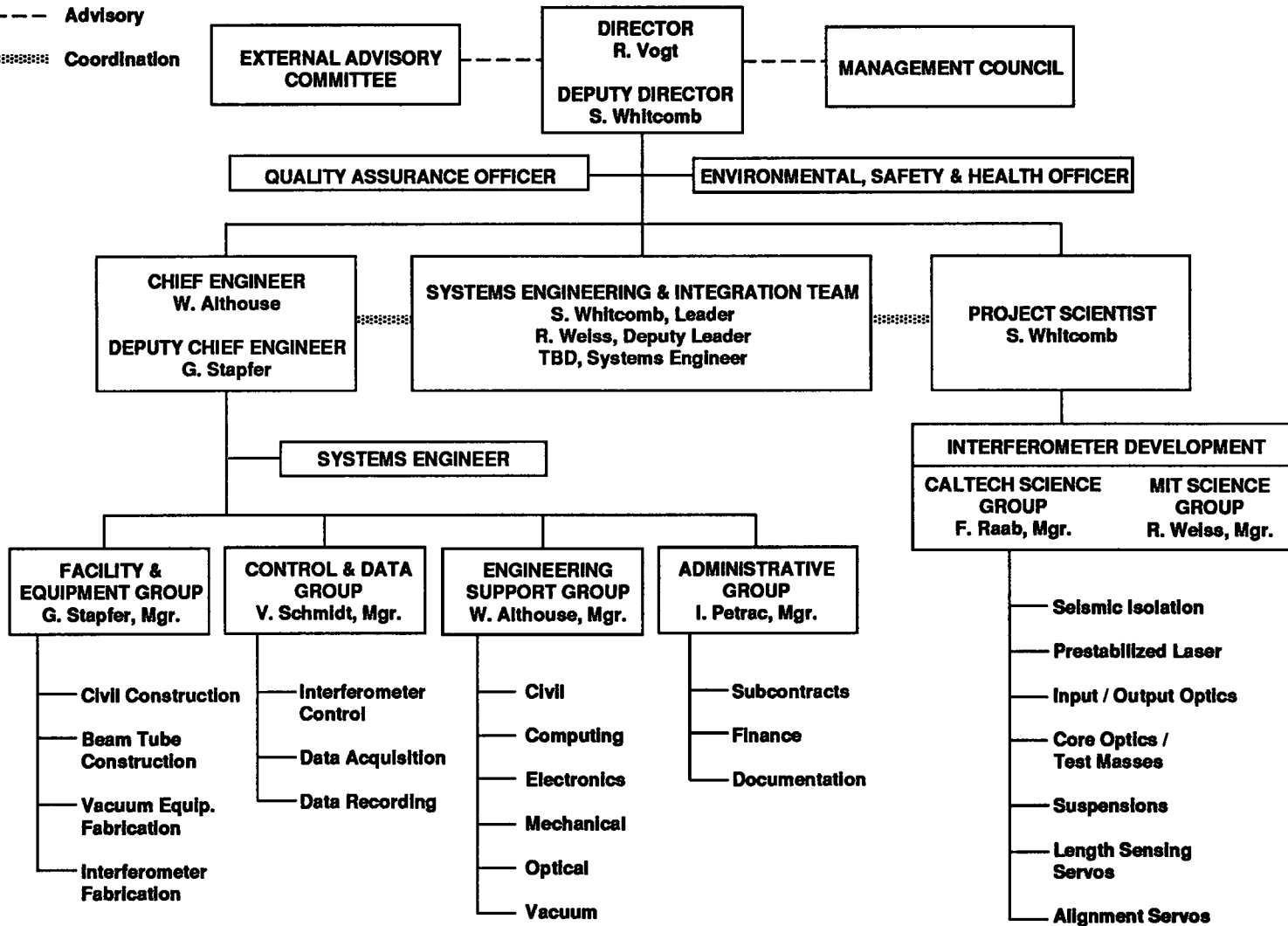
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———— Direction

----- Advisory

⋯⋯⋯ Coordination



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