

**VACUUM SYSTEM: OBJECTIVES, R&D,
PROCUREMENT PLAN, STATUS**

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PRESSURE REQUIREMENTS/GOALS

- Fluctuations in number of molecules in beam produces interferometer phase noise.
- 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
H ₂	10 ⁻⁶	10 ⁻⁹
H ₂ O	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

/

PUMPING STRATEGY

- **OBJECTIVES**

Low vibration

Rapid pumpdown (≈ 10 hr) for chambers

Capability to handle transient gas loads in chambers without contaminating beam tube

- **OBJECTIVES MET BY:**

Holding pumps: Ion pumps (baseline), Getter Pumps (under study)

Roughing pump sets: turbo backed by mechanical for pumpdown and bake

Isolation pumps: LN₂ pumps at module ends

- **HOLDING PUMPS**

One on each test mass chamber

Two on each diagonal/ham chamber set

Provision for seven pump assemblies along each 2km beam tube module

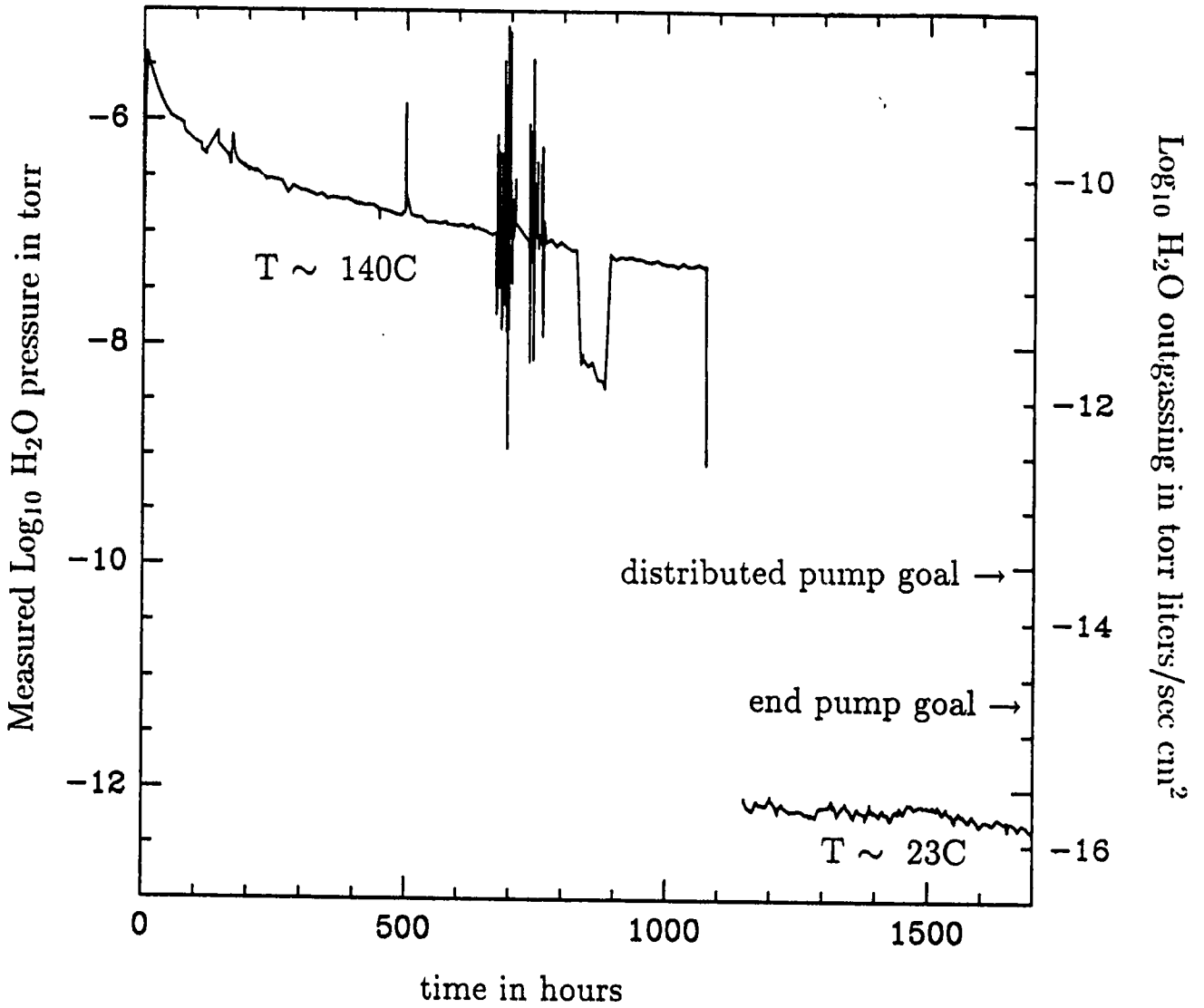
- **LN₂ ISOLATION PUMPS**

One at each end of beam tube module

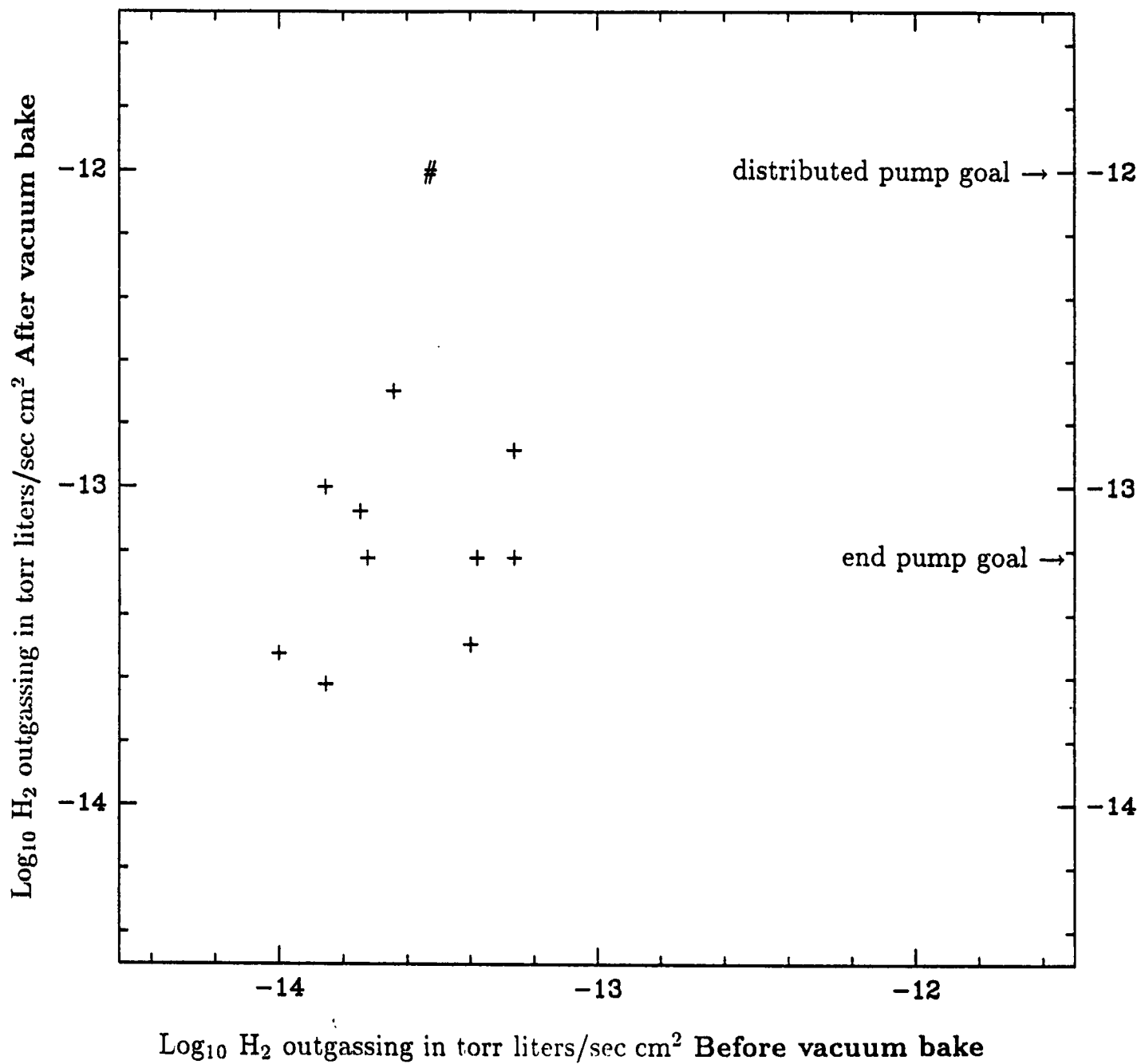
≈ 90 days between refill

≥ 1 year between servicing

SPIRAL WELDED TUBE BAKEOUT AND WATER OUTGASSING DEMONSTRATION



HYDROGEN OUTGASSING TESTS



Legend:

= Original Process

+ = Revised Process

OTHER RESULTS FROM VACUUM R AND D PROGRAM

- **SPIRAL TUBE BAKEOUT**

Outgassing rate of CO, CO₂, CH₄, hydrocarbons $\leq 5 \times 10^{-17}$
torr liters/sec cm²

Temperature dependence after bake, pressure doubles:

H₂O 8.7 C

H₂ ≈ 7 C

- **HEATING OF TUBE**

Joule heating with DC current using tube resistance

Economical insulation with radiation shield adequate for 140C

Extrapolation to LIGO: ~ 900 kW/beam tube module

- **SPIRAL WELD TESTS**

Hydrogen permeability of welds measured to be negligible

Fraction of ferritic grain growth within safe bounds for weld
reliability and low permeation

- **CLEANING**

Demonstration tube cleaned with "steam" and Oakite 33

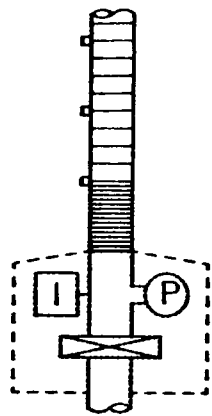
No strong correlations observed between cleaning techniques and
outgassing.

BEAM TUBE MODULE PROCUREMENT CONTRACTUAL REQUIREMENTS — OVERVIEW

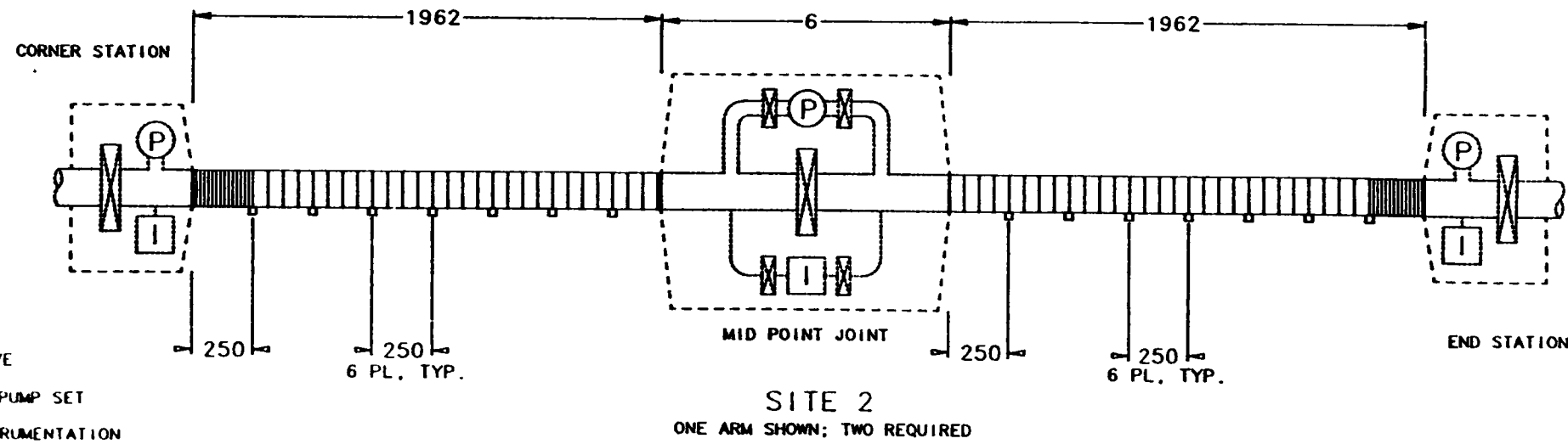
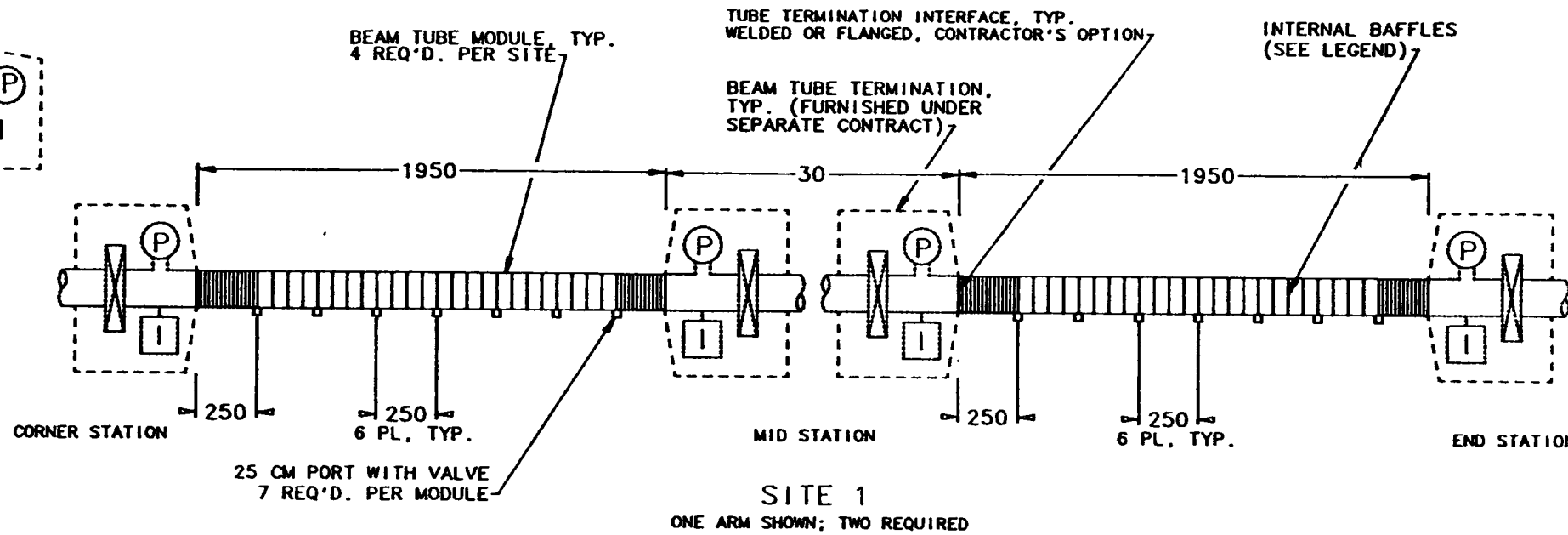
- **FIRM FIXED PRICE DELIVERY OF:**
 - **DETAILED DESIGN**
 - **QUALIFICATION TEST**

- **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**



NOTE: PORTS FACE OUTBOARD OF THE ANGLE BETWEEN THE ARMS



LEGEND:






-  VALVE
-  PUMP SET
-  INSTRUMENTATION
-  2 M BAFFLE SPACING
-  < 20 M BAFFLE SPACING

FIGURE 2 BEAM TUBE MODULE CONFIGURATION

NOT TO SCALE ALL LENGTHS ARE IN METERS

**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: PROPOSER'S CHOICE OF:**
 - **$J_{H_2} < 1 \times 10^{-13}$ torr·liter/s·cm²,**
 - **$J_{ALL OTHERS} < 1 \times 10^{-15}$ torr·liter/s·cm²,**

OR:

- **follow LIGO Process Specification 1100007**

**BEAM TUBE MODULE PROCUREMENT
TECHNICAL REQUIREMENTS (con'd)
PROCESS SPECIFICATION FOR LOW H₂, TYPE 304L S/S PRODUCTS
LIGO SPECIFICATION 1100007
DRAFT VERSION**

- **INTENDED TO PROVIDE THESE OUTGASSING RATES:**
 - $J_{H_2} < 1 \times 10^{-13}$ torr·liter/s·cm²
 - $J_{H_2O} < 1 \times 10^{-15}$ torr·liter/s·cm²

- **TECHNICAL REQUIREMENTS:**
 - **initial material: 304L s/s, wall thickness ≤ .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**

BEAM TUBE MODULE PROCUREMENT SOURCE EVALUATION AND SELECTION

- **PROCESS**
 - **EVALUATION OF PROPOSALS**
 - **ESTABLISHMENT OF COMPETITIVE RANGE**
 - **OPTIONAL DISCUSSIONS**
 - **SELECTION FOR NEGOTIATIONS**

- **EVALUATION CRITERIA CATEGORIES**
 - **TECHNICAL**
 - UNDERSTANDING OF REQUIREMENTS**
 - TECHNICAL APPROACH**
 - **MANAGEMENT**
 - ORGANIZATION AND RESOURCES**
 - MANAGEMENT APPROACH**
 - **PRICE**
 - PRICE FOR BASIC EFFORT (DESIGN AND QUALIFICATION TEST)**
 - BUDGETARY ESTIMATE FOR OPTION (FABRICATION, INSTALLATION AND ACCEPTANCE TEST)**
 - **OTHER FACTORS**

BEAM TUBE MODULE PROCUREMENT ADVISORY QUALIFICATION CRITERIA

- **FOR PROPOSERS OR PROPOSER TEAMS:**
 - **≥ \$50M ANNUAL SALES (PRIME CONTRACTOR)**
 - **EXPERIENCE BELOW 10^{-9} TORR**
 - **EXPERIENCE WITH LARGE, COMPLEX, REMOTELY INSTALLED MECHANICAL SYSTEMS**

EVENTS/TASKS	CY 1992				CY 1993				CY 1994				CY 1995				CY 1996															
	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D
PROPOSALS REQUESTED	X																															
CONFERENCE	X																															
PROPOSALS DUE		X																														
EVALUATION, NEGOTIATION																																
AWARD																																
DESIGN																																
QUALIFICATION TEST																																
OPTION AWARD																																
FABRICATION																																
FIELD INSTALL, SITE 1																																
LEAK TEST, SITE 1																																
FIELD INSTALL, SITE 2																																
LEAK TEST, SITE 2																																
COMPLETION REVIEW																																

DATE: 6-16-92
 PREPARED BY: L. JONES
 APPROVED BY: _____
 DATE: _____

LIGO BEAM TUBE EFFORT

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BEAM TUBE MODULE PROCUREMENT PROCUREMENT STATUS

- **RFP RELEASED (6/19/92)**
- **REPRESENTATIVES FROM 45 COMPANIES ATTENDED PROPOSER'S CONFERENCE (7/16/92)**
- **FOUR PROPOSALS RECEIVED (9/1/92)**
- **EVALUATION IN PROCESS; DISCUSSIONS PLANNED FOR EARLY DECEMBER**
- **FIRST CONSTRUCTION BUDGET COMPARISON DATA:**
 - **EVALUATED OPTION PHASE ESTIMATES (PRELIMINARY):**
 - \$31.3M**
 - \$31.8M**
 - \$32.1M**
 - \$37.0M**
 - **COMPARE WITH CONSTRUCTION PROPOSAL BUDGET:**
 - \$27.6M**
 - **ESTIMATED LOCAL TAXES:**
 - \$1.2M**
 - \$0.5M**