BEAM TUBE BAKEOUT

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BAKEOUT PLAN DISCUSSION

- Objectives
- Scope of bakeout tasks
- Preliminary requirements
- Configuration
- Bakeout plan
- Responsibilities, subcontracts and staffing
- Time line
- Technical/cost issues
- Schedule
- Cost summary

BAKEOUT OBJECTIVES

- Reduce H_2O, CH_4, CO, CO_2, etc. outgassing to achieve partial pressure less than LIGO goal level (10^{-10} torr for H_2O)

  ›› allows setting an upper limit on leaks at the LIGO specification level ($<10^{-9}$ torr-L/s) using air signature method (cost of traditional He tracer method on unbaked beam tube would exceed cost of bakeout)

- Reduce outgassing of contaminating hydrocarbons to minimize risk to interferometer optics

SCOPE OF BAKEOUT TASKS

- Design requirements, design definition and trade studies
  - Design Requirements Document
  - Special attention to boundaries and interfaces
- Specifications and subcontract SOWs
- Thermal insulation
- Heating power and control
- Pumping and instrumentation
- Data acquisition and logging
- Setup, bake, moving to next module
- Data analysis
- Safety

PRELIMINARY REQUIREMENTS

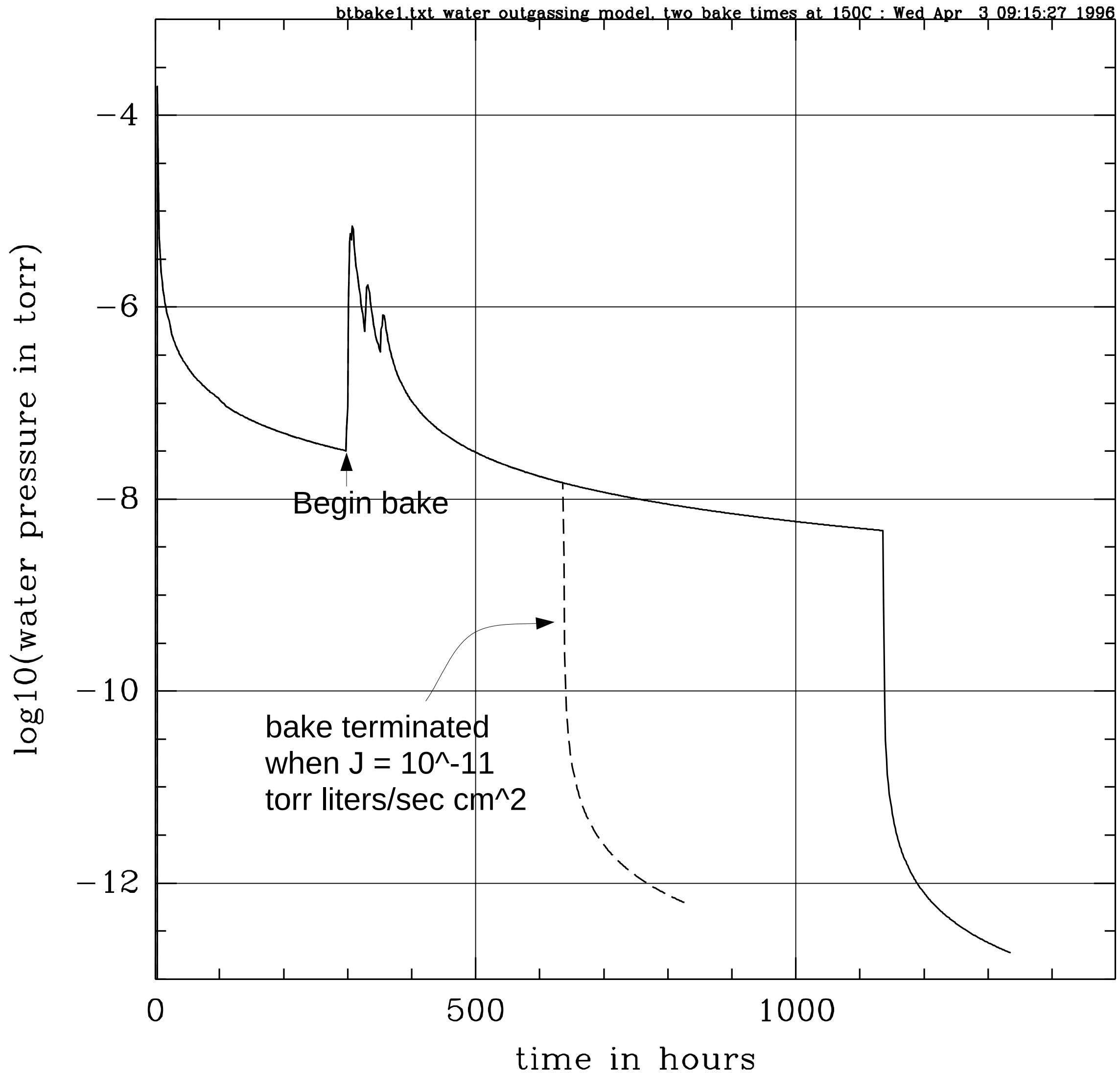
- T_{min} (cold spot) = 130°C, T_{max} (hot spot) = 170°C (except at bellows)
- $T_{average}$ = 150°C ± 5°C
- T > 145°C for 30 days or H_2O outgassing @ 150°C < 10^{-11} torr L s^{-1} cm^{-2}
- Pumping speed for H_2O > 1,500 L/s × 9 until cooled down to ambient temp. [P(H_2O) < 10^{-12} torr after cool down]
- Pumping speed for H_2 > 500 L/s (1 point) [P(H_2) < 10^{-5} torr @ 150°C]
- Monitoring during bake:
  - RGA (low sensitivity), 1 point
  - Temperature monitors:
    - 16 × 2 ends to probe special points around module ends = 32 channels
    - 4 × 9 ports to probe tube wall, special points at pump ports = 36 channels
    - 28 channels TBD for total of 96 channels

QT TEMPERATURES

Typical temperatures on the beam tube and support in the middle of the bake

02-26-1995 00:00:21,

TE 31 N end center line	141.5,	
TE 32 N support NE stiffener	138.9,	
TE 33 N support N Plate	143.0,	
TE 34 N support SW Kicker	65.3,	* not near tube
TE 35 N support S Plate	136.1,	MINIMUM
TE 36 N support SE Kicker	68.5,	* not near tube
TE 37 22b tube top center	152.0,	
TE 38 22b top stiffener	150.5,	
TE 39 Flex support stiffener	143.2,	
TE 40 Bellows ins conv top	171.2,	MAXIMUM
TE 41 Bellows outs conv top	164.8,	
TE 42 22a bottom center	146.9,	
TE 43 22a bottom stiffener	148.3,	
TE 44 S support NW stiffener	145.8,	
TE 45 S support NW plate	147.8,	
TE 46 S support NW kicker	82.9,	
TE 47 S support SE plate	141.6,	
TE 48 S support SE kicker	52.1,	* not near tube
TE 49 S support W Beam	137.8,	
TE 50 S end head center	146.3,	



waterbake.f model for beamtube bake at 150C. Liquid Nitrogen traps at the 10 inch ports every 250 meters., F = 2500 liters/sec/port
Model parameters: T0 = 9000K, R = 0.7, σ = 45 monolayers at t = 0

BAKEOUT CONFIGURATION

- Inherit beam tube modules already rough-pumped after acceptance testing from CBI
- Tube insulation:
  - Commercial fiberglass duct insulation
  - Nominal 6” (2 $\times$ 3” layers; single, upper layer over bellows)
- Insulate end regions, 48” gate valves, 10” pump ports, pumps and RGA with pre-engineered portable heater blankets like (identical to?) those furnished by PSI for Vacuum Equipment bake
- Heating mode:
  - Resistive heating with DC current (1750 A nominal) through tube walls
  - Use CBI plan? (3 sets of parallel DC welding power supplies, 35 VDC max)
- Control:
  - Manual ramp-up, 10°C steps
  - Single-point control temperature sensors (independent of monitor system) for each heater section

CONFIGURATION (con'd)

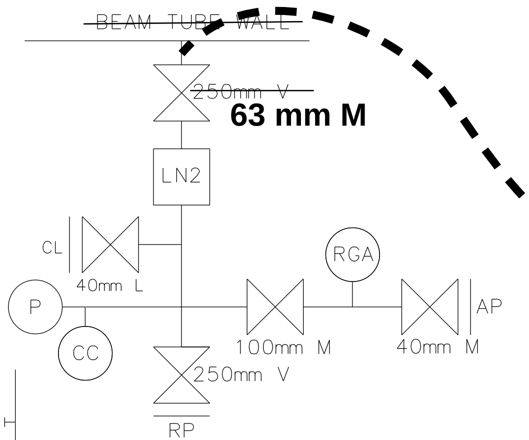
- Temperature monitoring: stand-alone 100-point temperature data acquisition with data logging, display, alarms and single control output (switch closure)
- Bake pumping and vacuum monitoring:
  - 1 ea. 500 L/s turbo
  - 9 ea. 10" cryo (refrigerator) pumps
  - One low-sensitivity RGA with data logging and display
  - Dedicated during setup, bakeout and cool down
- Post-bake pumping and vacuum monitoring:
  - Independent, cleaned and pre-baked 500 L/s turbo
  - Cleaned and pre-baked high sensitivity RGA with LN_2 trap
  - 8 more RGAs standing by for leak localization, if necessary; centralized data logging and display
  - 3 ea. 50 L/s turbo portable pump sets and separate portable heater blankets with controllers for setup

CONFIGURATION (CON'D)

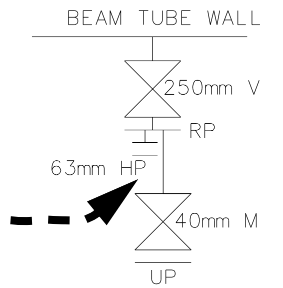
- Power source:
  - ››Temporary transformers connected to existing 13 kV line
  - ››Average DC power during bake = 535 kW (including return lead losses), demand ≅ 900 kVA
  - ››2 sets of auxiliary transformers required to power pumps during cool down and then post-bake equipment while simultaneously setting up next module

PUMP PORT HARDWARE

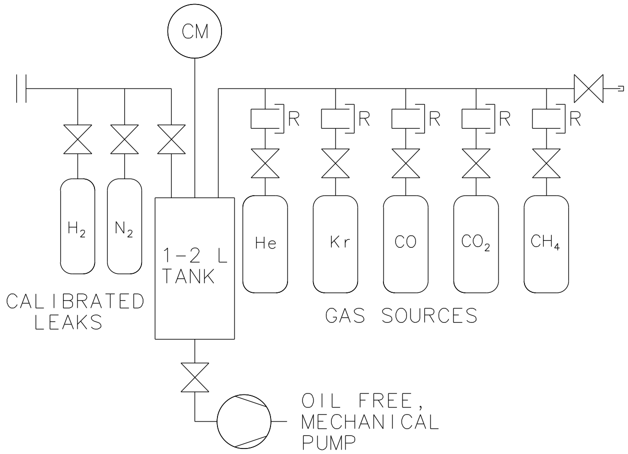
TYPE B: FOR PORTS DURING
BAKE & LEAK CHECK
10 UNITS REQUIRED, INCLUDING
1 SPARE



TYPE H: FOR PORTS DURING HOLD
(AFTER ACCEPTANCE,
BEFORE OPERATION)
75 UNITS REQUIRED: 36 PER SITE,
PLUS 3 SPARES



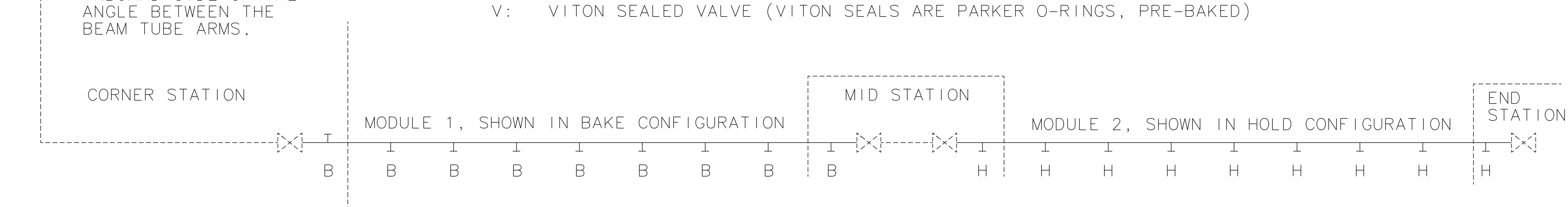
PORTABLE CALIBRATION MODULE



LEGEND FOR PUMP PORT HARDWARE:

AP: BLANKED PORT FOR AUXILIARY TURBO PUMP
CC: COLD CATHODE GAUGE
CL: BLANKED PORT FOR CALIBRATED LEAKS
CM: CAPACITANCE MANOMETER GAUGE (ABSOLUTE)
G: BOURDON GAUGE
HP: BLANKED PORT FOR RGA HEAD INSTALLATION
LN2: LIQUID NITROGEN TRAP, 1 M^2 COLD SURFACE
L: VARIABLE LEAK VALVE
M: METAL SEALED VALVE
P: PIRANI GAUGE
R: REGULATOR WITH DUAL GAGES
RGA: THE FOLLOWING SYSTEM OR ITS EQUIVALENT: BALZERS QMG 421-1 (MASS RANGE 1-100, CONSISTING OF QMS 421-1, QUADSTAR 421, QMA 125 WITH GRID ION SOURCE 110V AND SEM 90 DEG OFF AXIS/FARADAY) PLUS IC 421 ION COUNTER, CP 400 ION COUNTER PREAMPLIFIER, AND QAM ANALYSIS MATRIX SOFTWARE
RP: BLANKED PORT FOR ROOTS AND TURBO PUMPS
TP: BLANKED PORT FOR TURBO PUMP
UP: BLANKED PORT FOR UTILITY PURPOSES
V: VITON SEALED VALVE (VITON SEALS ARE PARKER O-RINGS, PRE-BAKED)

NOTE THAT PUMP PORTS AT MODULE ENDS AT THE CORNER STATION ARE POSITIONED ON THE INBOARD SIDE OF THE ANGLE BETWEEN THE BEAM TUBE ARMS.



PLAN VIEW OF ARM AT HANFORD SITE, SHOWING TYPES OF HARDWARE AT EACH PUMP PORT

CALIFORNIA INSTITUTE OF TECHNOLOGY
MASSACHUSETTS INSTITUTE OF TECHNOLOGY
LIGO PROJECT

DRWN L. JONES
CHKD
ENGR
APPD
APPD
SCALE: NTS

BEAM TUBE PUMP PORT HARDWARE

TYPE | DRAWING NUMBER D950027 | SHEET 1 of 1 | REV B

EDITION: 11/3/95

BAKEOUT PLAN

- Acquire additional equipment so that bakeout can be conducted without interference with CBI and PSI installation activities
- Schedule bakeouts so that on-site LIGO staff can handle setup and execution
- Conduct first module bakeout to:
  - Validate insulation, heating and pumping designs
  - Evaluate beam tube mechanical behavior during bake
  - Shakedown the setup, bakeout and post-bake procedures (and maybe the post-bake leak localization and repair procedures)
- Iterate procedures and designs as needed
- Bake 3 remaining modules, ship equipment to other site, and bake 4 modules

RESPONSIBILITIES, SUBCONTRACTS

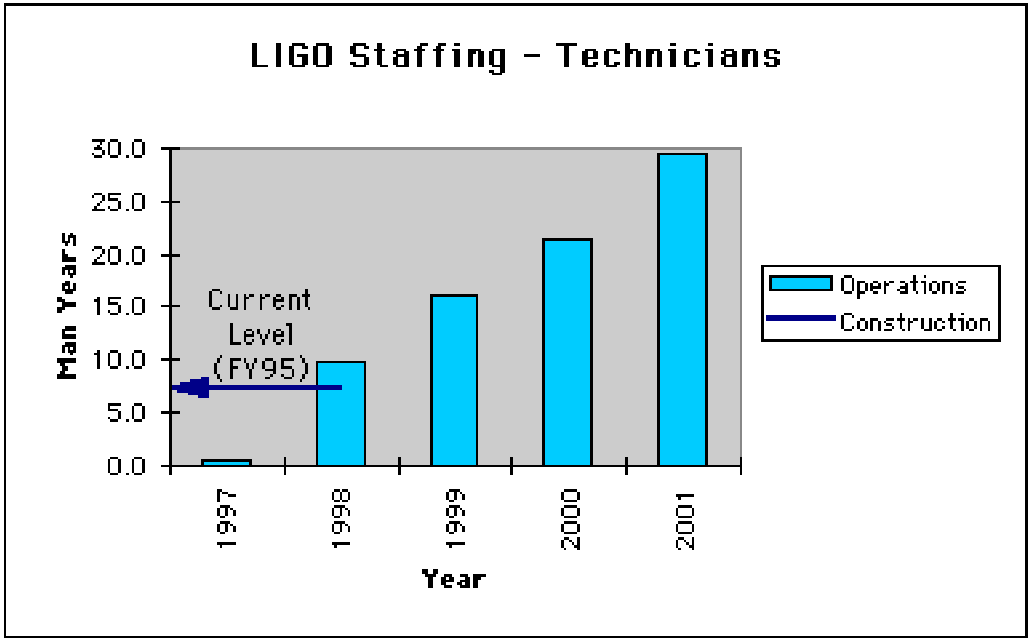
- LIGO Systems Engineering:
  - Perform system design and trade studies; prepare Design Requirements Document
  - Prepare conceptual, preliminary and final (detailed) designs, and present reviews
  - Prepare specifications and procedures
  - Procure pumps, RGAs (with data acquisition); design, procure and assemble vacuum hardware
  - Place and oversee subcontracts for insulation, heater blankets, temperature monitoring system, DC power, AC power
  - Pre-installation checkout and acceptance of purchased and subcontracted equipment
- Subcontracts:
  - Design, fabrication and assembly of temperature monitor data acquisition system
  - Fabrication of portable heater blankets and controls (use PSI specs/drwgs; use same supplier?)
  - Design, fabrication and off-site assembly of DC power source, cabling, connections and controls
- Local insulation contractor: purchase, prepare and install beam tube insulation
- Local power company: furnish, install and connect temporary transformers for primary AC power

RESPONSIBILITIES (con'd)

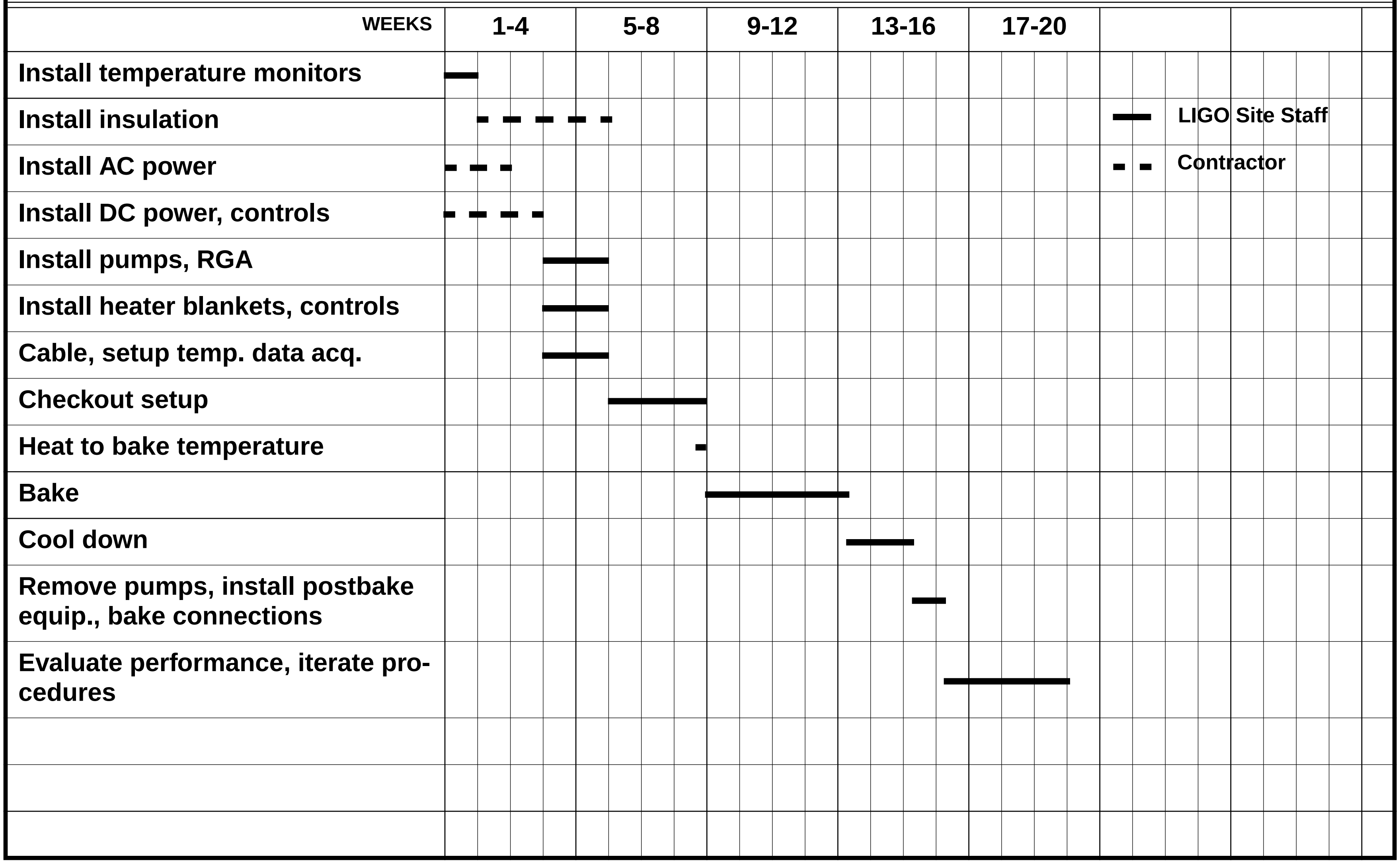
- Local electrical contractor: install and connect DC power source and auxiliary AC power for pumps, instrumentation and controls
- LIGO WA and LA on-site staff:
  - Install temperature monitors and setup temperature monitoring system
  - Supervise contractor installation of insulation, AC power and DC power
  - Install pumps and bake-monitor RGA
  - Checkout bakeout setup
  - Conduct bake and cool down
  - Remove bakeout pumps/RGA and install post-bake pump/RGA
  - Evaluate post-bake condition
  - Locate and arrange repair of leaks if needed
- On-site staffing requirements:
  - ~ 2 technician FTEs for equipment installation, checkout and removal
  - ~ 4 technicians, 1.5 m-yr. per site for 1-person-24 hr. bake monitoring

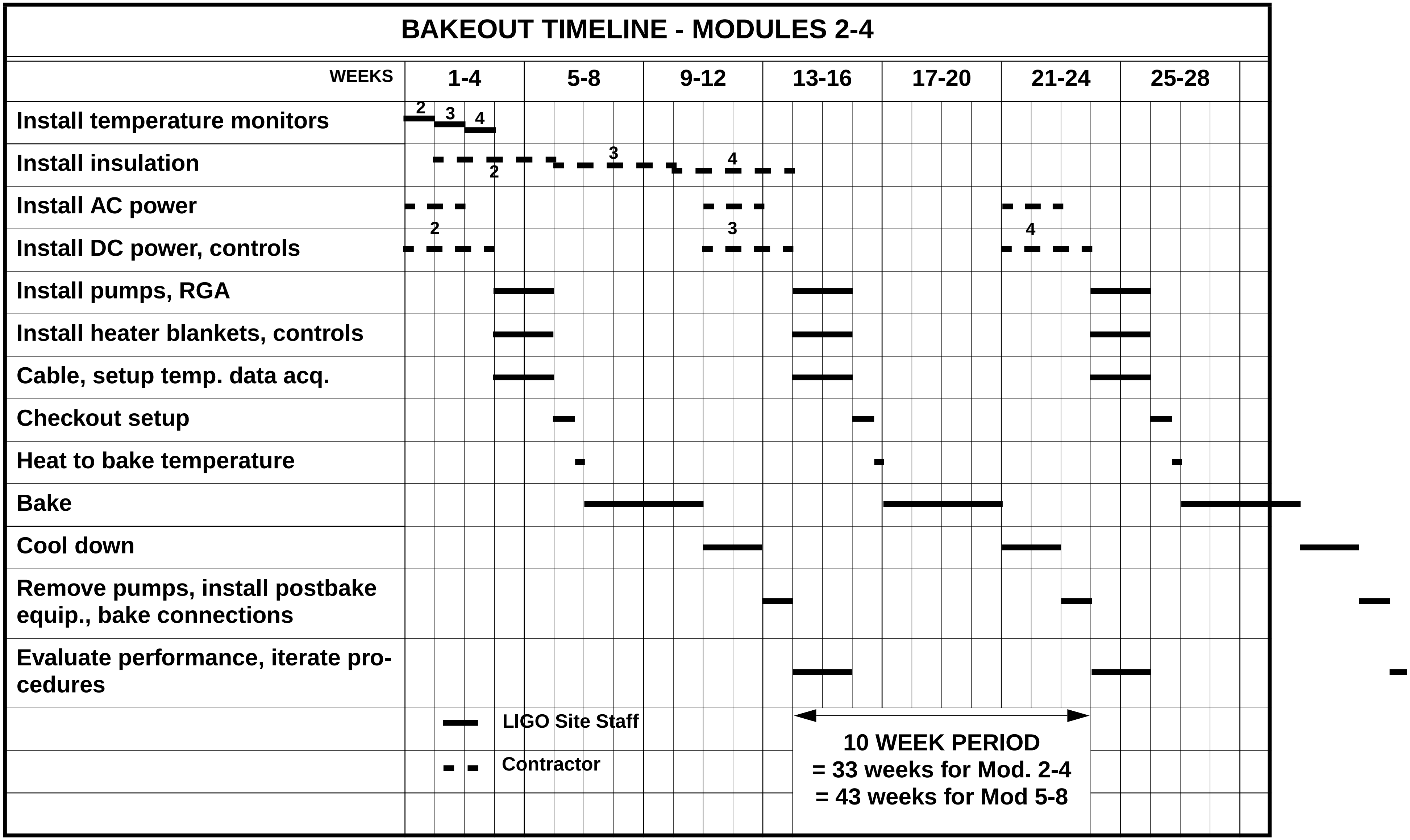
LIGO SITE TECHNICIAN STAFFING

From Ops. Plan, LIGO-M950020-01-M



BAKEOUT TIMELINE - FIRST MODULE




BAKEOUT TIMELINE - MODULES 2-4
WEEKS
1-4
5-8
9-12
13-16
17-20
21-24
25-28
Install temperature monitors
Install insulation
Install AC power
Install DC power, controls
Install pumps, RGA
Install heater blankets, controls
Cable, setup temp. data acq.
Checkout setup
Heat to bake temperature
Bake
Cool down
Remove pumps, install postbake equip., bake connections
Evaluate performance, iterate procedures
LIGO Site Staff
Contractor
10 WEEK PERIOD
= 33 weeks for Mod. 2-4
= 43 weeks for Mod 5-8

SCHEDULE

DESIGN ACTIVITIES

- Design requirements and conceptual design:

  ›› Document design and performance requirements, review BTD and QT experience, develop complete conceptual design, recommend trade studies.

  – Design Requirements Review/Conceptual Design Review **11/96**

- Preliminary design:

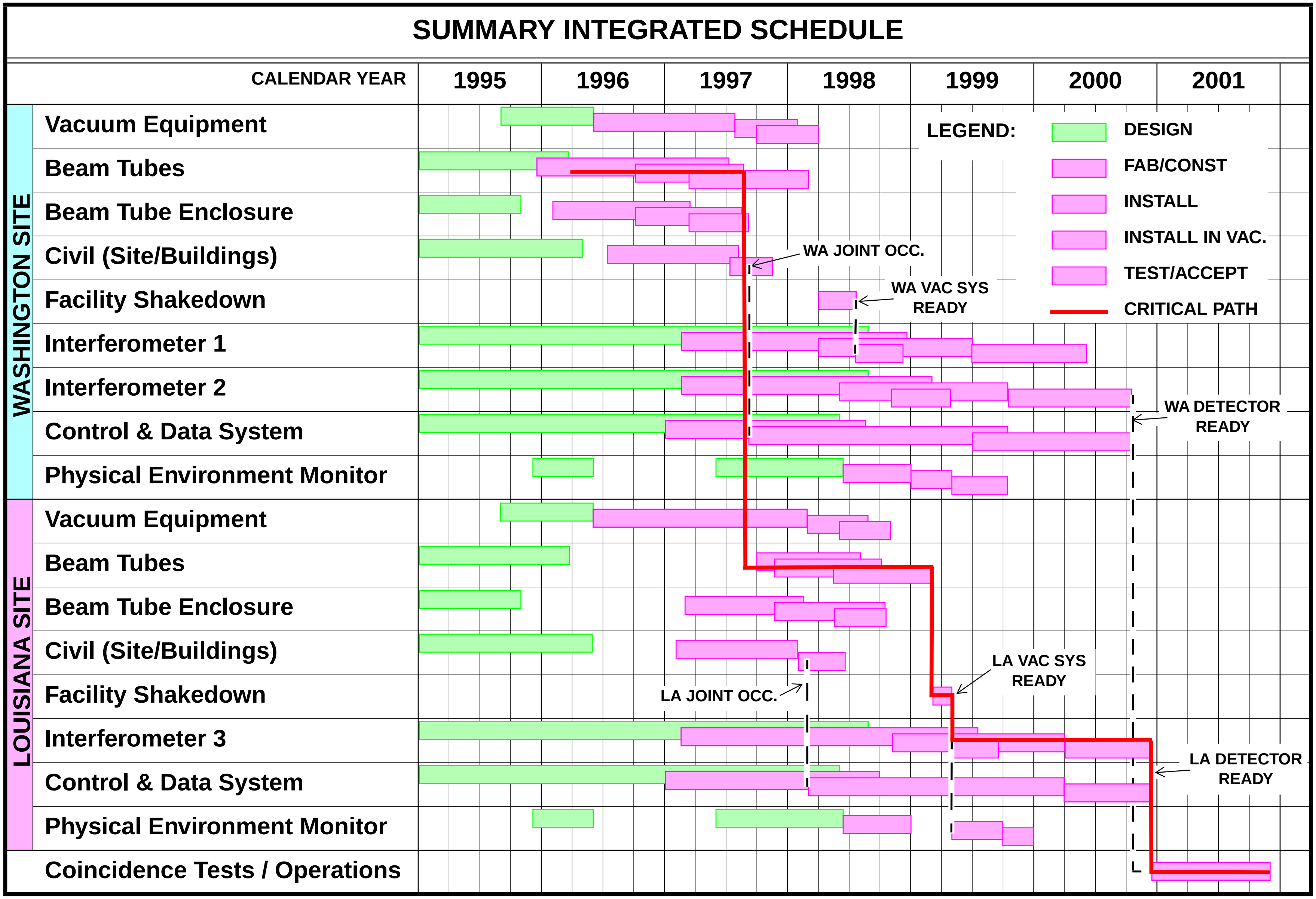
  ›› Perform trade studies, optimize design, develop subcontracting plans, resolve all technical issues.

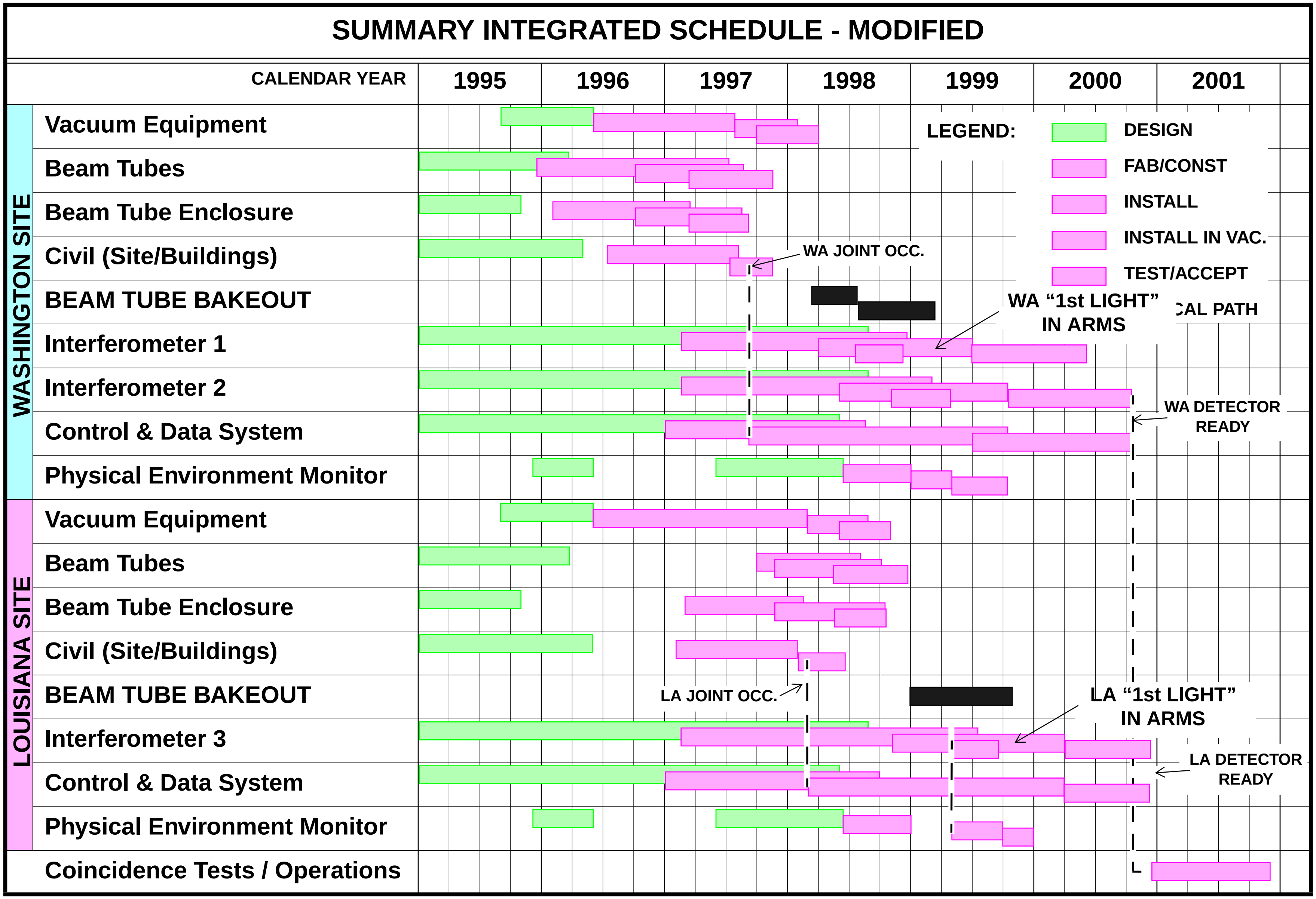
  – Preliminary Design Review **2/97**

- Detailed design:

  ›› Document design details, procedures and test criteria, solicit subcontract proposals/bids.

  – Final Design Review **6/97**


SUMMARY INTEGRATED SCHEDULE
CALENDAR YEAR
1995
1996
1997
1998
1999
2000
2001
WASHINGTON SITE
Vacuum Equipment
Beam Tubes
Beam Tube Enclosure
Civil (Site/Buildings)
Facility Shakedown
Interferometer 1
Interferometer 2
Control & Data System
Physical Environment Monitor
LOUISIANA SITE
Vacuum Equipment
Beam Tubes
Beam Tube Enclosure
Civil (Site/Buildings)
Facility Shakedown
Interferometer 3
Control & Data System
Physical Environment Monitor
Coincidence Tests / Operations
LEGEND:
DESIGN
FAB/CONST
INSTALL
INSTALL IN VAC.
TEST/ACCEPT
CRITICAL PATH
WA JOINT OCC.
WA VAC SYS READY
WA DETECTOR READY
LA JOINT OCC.
LA VAC SYS READY
LA DETECTOR READY



SUMMARY INTEGRATED SCHEDULE - MODIFIED
CALENDAR YEAR
1995
1996
1997
1998
1999
2000
2001
WASHINGTON SITE
Vacuum Equipment
Beam Tubes
Beam Tube Enclosure
Civil (Site/Buildings)
BEAM TUBE BAKEOUT
Interferometer 1
Interferometer 2
Control & Data System
Physical Environment Monitor
LOUISIANA SITE
Vacuum Equipment
Beam Tubes
Beam Tube Enclosure
Civil (Site/Buildings)
BEAM TUBE BAKEOUT
Interferometer 3
Control & Data System
Physical Environment Monitor
Coincidence Tests / Operations
LEGEND:
DESIGN
FAB/CONST
INSTALL
INSTALL IN VAC.
TEST/ACCEPT
WA JOINT OCC.
WA "1st LIGHT" IN ARMS
WA DETECTOR READY
LA JOINT OCC.
LA "1st LIGHT" IN ARMS
LA DETECTOR READY

COST SUMMARY

Cost Item	CBI Prop. Direct+O/H (no G&A/P) $K	Current estimate $K	Comments
System design/trade studies			
Prepare specs, subKs; write procedures	63		
Insulation:			
tube (subK)	1248	1248	Early LIGO est.= 514K (4”)
ends & ports - cap. cost		100	
ends & ports - install & remove			On-site labor cost not incl.
Electrical power/controls/temperature instrumentation:			
Transformers - cap. cost		135	CBI numbers; local
Transformers - install & remove		260	Power Co. cheaper?
DC supplies - cap. cost	288	288	Can subK beat it?
Instrumentation - cap. cost	160	160	“
DC & Instrumentation - install & remove	502	502	1800 m-hr / module!
Other Direct Costs	166	100	freight, travel, tools, etc.
Pumping / Vacuum instrumentation:			
2 ea. 500 L/s turbo/backing pump packages		50	
10 ea. 10” cryo pumps		250	
3 ea. 50 L/s turbo/backing pump packages		30	
1 ea. low-sensitivity RGA		20	
9 PEM RGAs			Return to DET installed
Metal valves & plumbing @ $15K/port		150	
Calibration module		20	

Cost Item	CBI Prop. Direct+O/H (no G&A/P) $K	Current estimate $K	Comments
Bake labor: **CBI = 8 m-yr. per site** **24-hr. monitor (1 person) = 1.5 m-yr. per site**	**2073**	**150**	**This is where the real $ difference comes from...**
CBI G&A/etc. **CBI profit @ 10%**	**732** **523**		
SUBTOTAL	**5755**	**3463**	
Bakeout power: **@ $.04/kW-hr., WA** **@ $.08/kW-hr., LA**	**67** **135**	**67** **135**	
TOTAL	**5957**	**3665**	**3240 = Cost Book/ COBRA**