BEAM TUBE CONTRACT

PRESENTATION TO
NATIONAL SCIENCE FOUNDATION
NOVEMBER 30, 1995

OVERVIEW

- OVERALL SCOPE OF BEAM TUBE TASK
  - » DESIGN AND QUALIFICATION (DESIGN PHASE)
    - – BEAM TUBE REQUIREMENTS
    - – BEAM TUBE DESIGN
    - – QUALIFICATION TEST
  - » FABRICATION, INSTALLATION AND ACCEPTANCE (OPTION PHASE)
    - – CONTRACT SCOPE AND TECHNICAL APPROACH
- CONTRACTING HISTORY AND STRATEGY
- REVIEWS
- RECOMMENDATION

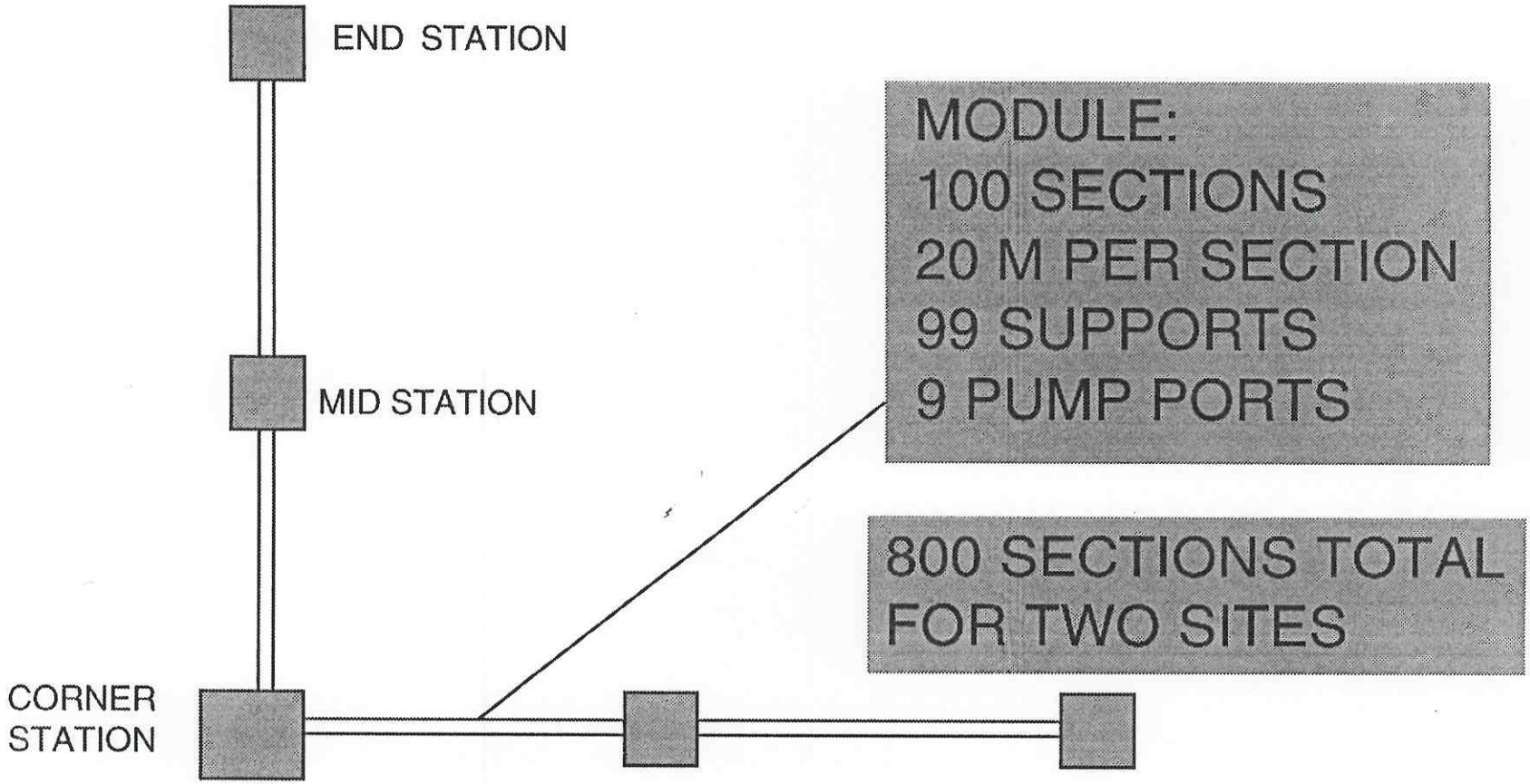
SCOPE OF BEAM TUBE WBS

- THE LIGO VACUUM SYSTEM IS DIVIDED INTO TWO DISTINCT WBS ELEMENTS
  - » VACUUM EQUIPMENT (WBS 1.1.1)
    - – VACUUM CHAMBERS
    - – PUMPS
    - – MANIFOLDS AND VALVES
  - » BEAM TUBE (WBS 1.1.2)
    - – BEAM TUBE SECTIONS AND MODULES
    - – TUBE SUPPORTS
    - – TUBE ALIGNMENT
    - – OPTICAL BAFFLES

BEAM TUBE TASK

- PHASED TASKS
  - DESIGN-QUALIFICATION PHASE
  - FABRICATION, INSTALLATION AND ACCEPTANCE PHASE
- THE DESIGN-QUALIFICATION TEST PHASE HAS BEEN SUCCESSFULLY COMPLETED
  - REQUIREMENTS
  - DESIGN SUMMARY
  - QUALIFICATION TEST RESULTS
- **THE FABRICATION, INSTALLATION AND ACCEPTANCE PHASE IS THE ESSENCE OF THIS PROCUREMENT ACTION**

BEAM TUBE MODULES



DESIGN-QUALIFICATION PHASE SUMMARY

- CONTRACT WAS AWARDED IN AUGUST 1993
- REVIEWS
  - REQUIREMENTS REVIEW, SEPTEMBER 1993
  - PRELIMINARY DESIGN REVIEW, DECEMBER 1993
  - FINAL DESIGN REVIEW, APRIL 1994
- QUALIFICATION TEST WAS CONDUCTED IN FEBRUARY-MARCH 1995
  - ALL TEST OBJECTIVES WERE SUCCESSFULLY MET
  - QUALIFICATION TEST REVIEW COMPLETED IN APRIL 1995

BEAM TUBE REQUIREMENTS

- MECHANICAL/OPTICAL
  - 16 KM OF BEAM TUBE (8 MODULES @ 2KM EACH)
  - UNOBSTRUCTED APERTURE OF 1 METER
- VACUUM
  - CLEAN, LESS THAN 1 MONOLAYER OF HYDROCARBON/MONTH
  - LEAK FREE
    - 1X10 EXP-9 TORR LITERS/SEC (AT MODULE LEVEL)
- OPERATIONAL
  - CAPABILITY TO ISOLATE BEAM TUBES FROM CHAMBERS
  - MINIMAL TUBE WALL MOTION (NO SLIP-STICK SUPPORTS)
  - ADJUSTABLE SUPPORTS TO ALLOW FOR REALIGNMENT
  - 20 YEAR LIFE TIME

BEAM TUBE DESIGN

- TUBE SECTIONS (800 EA)
  - SPIRAL WELDED; 3 mm THICK, 304L STAINLESS STEEL
  - 1.24 M DIAMETER, 20 M LONG
  - WELDED STIFFENING RINGS, 0.76 M SPACING
  - MACHINED/WELDED SUPPORT RINGS AT EACH END
- EXPANSION JOINTS (400 EA)
  - 6 CONVOLUTIONS
  - 2.7 mm THICK MATERIAL FOR ADDED ROBUSTNESS
- SUPPORTS
  - ALTERNATE FIXED AND GUIDED SUPPORTS
  - ADJUSTABLE, VERTICALLY AND HORIZONTALLY (+/- 7.5 CM)

QUALIFICATION TEST

- CONDUCTED IN FEBRUARY-MARCH 1995
  - FABRICATED AND ASSEMBLED 40 M OF TUBE SECTIONS
  - TEST ASSEMBLY INCLUDED PUMP PORT, EXPANSION JOINT, FIXED AND GUIDED SUPPORTS
  - OPERATED UNDER VACUUM FOR 45 DAYS
  - CONDUCTED A 28 DAY BAKE-OUT TEST (150 C)
- SUCCESSFULLY DEMONSTRATED
  - DESIGN FABRICATION AND ASSEMBLY OF TUBE SECTIONS
  - ACCEPTABLE LEAKAGE ≤1X10 EXP-10 T*L/S
  - LOW HYDROGEN OUTGASSING <1X10 EXP-13 T*L/S*CM2
  - LOW WATER OUTGASSING <1X10EXP-16 T*L/S*CM2

LESSONS LEARNED

- DESIGN PHASE WAS MORE OF AN R&D TASK
  - MANY USEFUL TECHNICAL ISSUES WERE RESOLVED
  - CBI WAS EXTREMELY COOPERATIVE AND TECHNICALLY COMPETENT
- SPIRAL WELD TECHNOLOGY
  - CBI's SUBCONTRACTOR WAS ABLE TO PRODUCE HIGH QUALITY THIN WALLED TUBING
- CLEANING AND LEAK TESTING
  - CLEANING PROCEDURES WERE STRENGTHENED
  - DEVELOPED NON-CONVENTIONAL LEAK HUNTING METHODOLOGY

OPTION PHASE CONTRACT REQUIREMENTS

- THIS PHASE COMBINES PROCESS AND PERFORMANCE
  - » **PROCESS**
    - CONTRACTOR IS REQUIRED TO FOLLOW DETAILED WRITTEN PROCEDURES DEVELOPED BY CBI AND APPROVED BY LIGO
      - STAINLESS STEEL BAKE
      - TUBE CLEANING
      - HYDROCARBON RESIDUES
  - » **PERFORMANCE**
    - CONTRACTOR IS RESPONSIBLE FOR
      - CLEAR APERTURE
      - LOCALIZE AND SEAL LEAKS LARGER THAN TWO TIMES THE SMALLEST LEAK MEASURABLE (1X10EXP-5 T*L/SEC MAX.)

CONTRACT SCOPE

- COMPLETE REMAINING DESIGN TASKS
  - TERMINATION DESIGN
  - DESIGN UPDATES
- FABRICATE AND ASSEMBLE TUBE SECTIONS
  - SPIRAL WELD TUBES
  - STIFFENERS AND SUPPORT RINGS
  - EXPANSION JOINTS AND PUMP PORTS
  - CLEAN AND LEAK TEST ALL TUBE SECTIONS
- INSTALL AND ALIGN EIGHT MODULES
  - EACH MODULE IS TWO KILOMETERS LONG
  - FOUR MODULES PER SITE
- LEAK TEST
  - ACCEPTANCE TESTING OF EACH MODULE

FABRICATION

- QUALIFY EQUIPMENT PRIOR TO FABRICATION
- PROCURE SPIRAL MILL
  - TUBETEC WAS UNABLE TO MEET SCHEDULE AND QA REQUIREMENTS
  - PACIFIC ROLLER DIE INC.. PROVIDES AUTOMATED PROCESS CONTROL AND QUALIFICATION TRAINING
- SET UP MILL IN WASHINGTON; AFTER COMPLETION, MOVE TO LOUISIANA
- FABRICATE ALL TUBE SECTIONS IN LEASED FACILITIES NEAR THE TWO SITES
- TRANSPORT COMPLETED SECTIONS TO SITE

FABRICATION QUALIFICATION

- LEAK TESTING
  - EXPANSION BELLOWS ARE TESTED AT THE SUBCONTRACTOR'S FACILITY PRIOR TO ACCEPTANCE
    - » CRITERION: 1X10EXP-10 T*L/S
  - COMPLETELY ASSEMBLED TUBE SECTION, INCLUDING EXPANSION BELLOWS AND PUMP PORT AT THE FABRICATION FACILITY
    - » CRITERION: 1X10EXP-10 T*L/S
- CLEANING
  - DELAYED UNTIL NEEDED FOR INSTALLATION
  - MODIFIED QUAL TEST PROCESS
  - FTIR SAMPLING FOR TREND ANALYSIS
  - SEALED BEFORE TRANSPORT

INSTALLATION

- STARTING AT MID STATION, PROCEED TO CORNER AND END STATION
  - TWO TUBES SECTIONS PER DAY
  - MAINTAIN CLEAN AIR FLOW THROUGH TUBES AT ALL TIME
- SELF CONTAINED WELD/LEAK TEST STATIONS
  - BUTT WELD SECTIONS, PURGE GAS MANAGEMENT
  - **LEAK CHECK CIRCUMFERENTIAL WELD**
- PORTABLE CLEAN ROOMS
  - ONE FOR EACH MODULE
  - PROTECTS TUBE INTERIOR
  - PROVIDES ENTRY INTO TUBE
  - CONTAINS GAS CYLINDERS FOR WELDING AND LEAK CHECK

ACCEPTANCE TEST

- OUTGASSING AND CLEANLINESS
  - ACCEPTABLE HYDROGEN OUTGASSING IS ASSURED BY FOLLOWING THE LIGO DEVELOPED STEEL BAKE PROCESS AND IS VERIFIED BY COUPON TESTS
  - CLEANLINESS IS CONTROLLED BY PROCEDURES WHICH WERE VALIDATED DURING THE DESIGN PHASE
- LEAK TESTING
  - LIGO IS RESPONSIBLE TO PROVIDE THE SOFTWARE WHICH LOCALIZES LEAKS TO A DESIGNATED AREA OF +\- 100 FT
  - CONTRACTOR IS RESPONSIBLE FOR LOCATING AND SEALING LEAKS WITHIN THE DESIGNATED AREA
    - ALL LEAKS LARGER THAN 2 TIMES THE LOWEST MEASURABLE SIZE (1X10EXP-5 T*L/S MAX. ALLOWED)

CONTRACTING HISTORY

- THE ORIGINAL 1992 RFP WAS COMPETITIVE
  - DESIGN PHASE
  - FABRICATION/INSTALLATION PHASE AS AN UNPRICED OPTION
- THE CONTRACTOR SELECTION WAS BASED ON
  - PROPOSERS TECHNICAL APPROACH
  - COST FOR BOTH PHASES OF THE PROPOSALS
  - AWARDEE HAD TO BE QUALIFIED FOR BOTH CONTRACT PHASES
- DESIGN PHASE WAS AWARDED TO CBI (1993)
  - DESIGN PHASE IS COMPLETE
- THE PRESENT PROCUREMENT ACTION IS FOR THE OPTION PHASE

1993 DESIGN PHASE AWARD

- FOUR PROPOSALS WERE RECEIVED
  - THREE PROPOSALS WERE QUALIFIED
  - EVALUATION CRITERIA WERE UNDERSTANDING OF TECHNICAL CHALLENGE AND COST OF OPTION PHASE
- CBI's SELECTION WAS BASED ON
  - TECHNICAL UNDERSTANDING AND SUPERIOR WELD TECHNOLOGY
  - THE LOWEST OPTION PHASE COST ESTIMATE
- CONTRACT STRATEGY
  - WORK WITH CBI TO GUIDE THE DESIGN PHASE TO AN AFFORDABLE OPTION COST
  - UP-DATE OPTION COST ESTIMATE AT PDR, FDR AND QTR
  - REDUCE RISK BY EXERCISING THE OPTION AFTER QTR

STATUS AT QTR

- DESIGN STATUS
  - COMPLETED AN ACCEPTABLE DESIGN
- TECHNOLOGY STATUS
  - CBI GAINED CONSIDERABLE TECHNOLOGY "KNOW HOW" DURING THE DESIGN AND QUALIFICATION PHASE
  - SPECIALIZED PROCESSES FOR CLEANING, COUPON TESTING LEAK ASSESSMENT HAVE BEEN WORKED OUT DURING THE DESIGN PHASE AND CBI HAS VALIDATED THESE PROCESSES DURING THE QUAL TEST PHASE
- COST ESTIMATE
  - THE ESTIMATED OPTION COST INCREASED BY 10%

CONTRACTING OPTIONS

- EXERCISE THE OPTION AND NEGOTIATE BEST PRICE WITH CBI
  - LOWEST TECHNICAL RISK, DESIGN AND PROCESSES HAVE BEEN VALIDATED
  - NO SCHEDULE INCREASE DUE TO PROCUREMENT DELAYS
  - MINIMAL COMPETITION WITH THE POSSIBILITY OF UNFAVORABLE PRICE
- RE-COMPETE THE OPTION PHASE
  - HIGHER TECHNICAL RISK, DESIGN REQUIRES VERIFICATION
  - SERIOUS ADDITIONAL SCHEDULE DELAYS DUE TO LONGER PROCUREMENT PROCESS AND DESIGN VERIFICATION
  - UNCERTAINTY OF RESPONSES DUE TO THE SMALL NUMBER OF QUALIFIED CONTRACTORS
  - POTENTIAL OF LOWER (HIGHER) COST THROUGH COMPETITION

CONTRACTING APPROACH

- APRIL 1995, LIGO DECIDED TO EXERCISE THE OPTION WITH CBI
  - PROVIDED NOTICE OF INTENT TO CBI (NON BINDING)
  - ISSUED RFP IN JUNE 1995
  - RECEIVED CBI PROPOSAL IN AUGUST 1995
- DECISION WHETHER TO NEGOTIATE OR TO RE-COMPETE BASED ON
  - PROPOSAL COST
  - POTENTIAL FOR COST NEGOTIATION
  - MAINTAINING RE-COMPETE OPTION DURING NEGOTIATION
- LIGO DECIDED TO NEGOTIATE WITH CBI IN AUGUST 1995

DECISION BASIS

- NEGOTIATED PRICE FOR CBI OPTION
  - NEGOTIATED PRICE $ 39.545 M
- LIGO IN-HOUSE COST ESTIMATE
  - BUDGETED COST $ 35.288 M
- COST DIFFERENTIAL
  - HIGHER THAN BUDGETED COST $ 4.257 M
- COST INDEPENDENT OF VENDOR
  - SPIRAL TUBE MILL $ 1.300 M
  - HANFORD SITE AGREEMENT $ 1.000 M

COST ANALYSIS

- CBI COST SUMMARY
  - » CBI COSTS SUBSTANTIATED BY LIGO
    - – MATERIALS $ 13.7 M
    - – EQUIPMENT $ 9.7 M
  - » CBI COST ABOVE LIGO ESTIMATE
    - – LABOR $ 16.1 M
  - » TOTAL COST $ 39.5 M
- COST EXPOSURE FOR RE-COMPETING THE OPTION
  - – DESIGN VALIDATION $ .8 M TO $ 1.2 M
  - – SCHEDULE ESCALATION (3% OF $ 40 M) $ 1.2 M
  - – OTHER UNKNOWN COST AND RISKS

DECISION ARGUMENTS

- RE-COMPETING THE OPTION INCREASES BOTH TECHNICAL AND SCHEDULE RISK
- MARKET SURVEY INDICATED LIMITED INTEREST
  - LOCKHEED, DISBANDED THEIR CAPABILITY
  - PSI, DID NOT BID ON DESIGN PHASE
  - GRUMMAN, SAID NO
  - PDM, EXPRESSED MARKETING INTEREST
- TO WARRANT THE CONSIDERABLE INCREASE OF SCHEDULE AND TECHNICAL RISK INCURRED BY RE-COMPETING, REQUIRES
  - A $ 2 M TO $ 3 M COST SAVINGS TO BE COMPETITIVE WITH CBI
  - AN EQUALLY WELL QUALIFIED CONTRACTOR

DECISION ARGUMENTS

- THE PROSPECT OF RECEIVING A QUALIFIED PROPOSAL AT THIS REDUCED PRICE IS JUDGED TO BE LOW
  - COST OF MATERIALS AND EQUIPMENT IS PRIMARILY BASED ON VENDOR QUOTES
  - THE POTENTIAL FOR COST SAVING WOULD BE IN LABOR
- A "NO BID" MUST BE CONSIDERED AS A POSSIBLE OUTCOME

LIGO DECIDED TO EXERCISE THE OPTION WITH CBI

LIGO REVIEW

- BEAM TUBE PROCUREMENT REVIEW BOARD

LEW ALLEN (CHAIR)	FORMER DIRECTOR, JPL
GENE GIBERSON	RET. JPL ASST. LAB DIRECTOR
JOSE LOPEZ-TIANA	GOV'T SUBCONTRACTS, CIT
YASMIN MERALI	ASST. PURCHASING MGR. CIT
CHARLES PECK	DIVISION CHAIR, PMA
BILL TYLER	QA MGR. JPL

- **THE BOARD MET ON OCTOBER 26, 1995 TO REVIEW THE TECHNICAL AND CONTRACTUAL APPROACH AND CONCURRED WITH THE LIGO DECISION TO CONTRACT WITH CBI FOR THE BEAM TUBE TASK**

CALTECH REVIEW

- SOURCE SELECTION BOARD

JOHN CURRY	SOURCE SELECTION OFFICIAL
WILLIAM ALTHOUSE	DEPUTY DETECTOR GROUP LEADER
BARRY BARISH	PRINCIPAL INVESTIGATOR
PAUL JENNINGS	PROFESSOR CIT
CHARLES PECK	DIVISION CHAIR, PMA
ROBERT POOL	LEGAL COUNCIL CIT

- **THE BOARD MET ON NOVEMBER 17, 1995, AND UNANIMOUSLY ENDORSED THE LIGO RECOMMENDATION, TO EXERCISE THE OPTION FOR THE BEAM TUBE MODULES WITH CHICAGO BRIDGE & IRON**

NSF PROGRAM REVIEW

- FEEDBACK FROM THE OCTOBER 9-11, 1995 TECHNICAL REVIEW, CLOSE OUT SESSION
  - THE COMMITTEE COMPLIMENTED LIGO ON THEIR SUCCESS IN DEALING WITH THE TECHNICAL ISSUES AND HIGHLIGHTED CBI's WILLINGNESS TO PROCURE THE NEEDED SPIRAL TUBE MILL

RECOMMENDATION

- **UNDER THESE CIRCUMSTANCES, IT IS DEEMED IN THE BEST INTEREST OF LIGO, CALTECH AND THE NSF, TO EXERCISE THE OPTION, PLACING THE BEAM TUBE FABRICATION AND INSTALLATION CONTRACT WITH CBI**