LIGO-T890034-00-R

#61

List of 4/06/89

LIGO SUPPORT FACILITIES

AA, MB, FJR, MZ

3/13/89

[typed copy ~ 03/20/89]

TABLE OF CONTENTS

* LOOK HERE FOR LISTS OF EQUIPMENT

Campus and Ancillary Facilities

We have identified the tasks to be carried out by the campus facilities. These are listed in Sections (1), and in Section (2) we give a list of requirements by task. Section (3) tallies equipment needs by category (this list is more general and includes items tallied in Section (2)). Section (5) gives scenarios by which certain tasks are accomplished. These were helpful in identifying requirements. Section (6) estimates the scientific manpower requirements to support LIGO through campus operations. The time required for scientific personnel at the remote sites is not included. Section (7) gives scientific requirements for ancillary facilities at the remote sites.

We have attempted to outline how things could be "done right" while exercising reasonable economy. Further savings could be gotten, for instance, by combining Tasks (1) and (2) and having only one prototype. Task (1) would then require at most the addition of several HAM's. However this would require Tasks (1) and (2) to proceed sequentially, rather than in parallel. Absorbing the FTE's from (1) would provide little benefit in helping prototype efforts but could speed up Tasks (3)--(7). Since these compromises involve major decisions, we sought to provide the raw data rather than choose policy.

Surprisingly the additional space required for prototyping LIGO modules is more than currently available at the 50--100% level rather than the order of magnitude level. Thus it may be possible to meet space requirements by moving walls.

1. Tasks of Campus Facilities

1. High ϕ sensitivity prototyping: develop new high ϕ sensitivity concepts; certify optical systems for remote sites (from laser to beamsplitter).

2. High δx sensitivity prototyping: develop improved isolation, thermal/quantum noise performance concepts; certify isolation systems, beamsplitter and test mass modules for remote site.

3. Optics Research: conduct R & D, characterization, and testing of optics and lasers.

4. Mechanical Systems R & D: conduct background work on mechanical properties of materials, and characterization of isolation system transfer functions.

5. Vacuum/Outgassing Characterization.

6. Auxiliary Systems R & D: eg sharks, pointing, remote control, and environmental monitors.

7. Data Analysis: not analyzed by this committee.

Equipment List for Campus Facilities

AA, MB, FJR, MEZ

10-March-89, [redacted]

1 Summary of Tasks and Corresponding Equipment (A more complete List appears in Section 3

1.1 High Phase Sensitivity Interferometer Development

(see lay-out in Fig. 1)

- 4 × 4′ test mass chambers
- 1 × 4′beam splitter chamber
- 4-8 HAMs (for input and output optics)
- Electronics instrumentation
- Data aquisition system
- High power laser

1.2 High displacement sensitivity interferometer prototype development/ laser stabilization development

(see lay-out in Fig. 2)

- 8' end test mass tank with LIGO compatible interface, 8' beam splitter tank, $3 \times 5' - 6'$ test mass tanks, 4 HAMs (for input and output optics)
- Electronics instrumentation
- Data aquisition system
- High power laser system

2.3 Optical Research: R and D/Characterization/Testing of Optics and Lasers

(see lay-out in Fig. 3, 10'× 44', fits on the third floor in Bridge)

- Two 2' DIA, 3' high chambers, connected with a piece of pipe of length and diameter TBD
- Medium power (1 W) laser
- Clean bench(s)
- Electronics instrumentation
- Phase camera

2.4 Vibration Isolation Development/Certification

(see lay-out in Fig. 4, 10'×15')

- Will also use the 8' end test mass tank of the high displacement sensitivity interferometer
- One HAM for component testing (e. g. pendulum Q measurement, subassembly transfer function measurement,etc.)
- Shaker
- Electronics instrumentation

2.5 Component outgassing test/certification

(see lay-out in Fig. 5, 10'×15')

- Two 2' DIA, 3' high chambers
- Vacuum measuring equipment

2.6 Auxiliary Systems/Components Testing/Certification (Sharks, Pointing Systems, Remote Controls, Environmental Test Equipment)

- Two 2' DIA, 3'high chambers (to be shared with 1.5)
- Electronics instrumentation

2.7 Data Aquisition and Analysis System

- TBD

3 List of Big Equipment Items

3.1 Vacuum chambers

- Two 8' chambers, with LIGO compatible interfaces
- Three 5'-6' DIA tanks
- 9-13 HAMs
- 5 × 4′ chambers
- Four 2' DIA, 3' hich chambers
- Pumps and vacuum monitoring equipment to be determined by vacuum engineers

3.2 Electronics instrumentation

- Two RF spectrum analyzers/network analyzers
- Two lock-in analyzers
- Scopes/storage scopes
- Oscillators
- Function generators
- Frequency counters
- RF power meter
- HV power supplies

3.3 Vacuum Instrumentation

- Two RGA controllers with a total of 4 heads
- Gauges and controllers
- Furnace for component pre treatment

3.4 Optics instrumentation

- Zygo interferometer
- Phase camera
- Spinning table for mirror cleaning
- Optical tables
- Two optical spectrum analyzers
- Two laser power meters
- Fiber fusion splicer and other fiber handling equipment

3-5 [redacted] Other equipment

- One high power laser (ore more, if laser addition is considered)
- One 1 W laser
- Clean bench(s) - class 100

Section 5: Scenario's for Campus Facilities

5.1 Scenario: New interferometer scientific concept to R&D

A new large test mass interferometer with low frequency vibration isolation has been shown to be workable in a prototype. To get it to LIGO R&D:

1. Scientific requirements given to Engineering Team.
2. A less marginal and more turnkey system is engineered.
3. Industrial fabrication of parts.
4. Campus fabrication and assembly.
5. Electronics, hardware, software, etc., and test modules (stacks, suspension, test masses, everything) get tested in prototype, one-at-a-time, against old masses.
6. LIGO test masses/mirrors will not be used in campus facilities. Dummy mirror/masses will be used.
7. After complete checkout all modules get disassembled into sub-pieces and shipped to remote sites.

5.2 Scenario: Optics testing

A new optical material is developed which has potential for use as LIGO mirror.

1. Buy pieces of material.
2. Test Q and other relevant mechanical properties.
3. Send out for polishing.
4. Optical testing:
   - scattering
   - homogeneity
   - birefringence
   - thermo-optical characteristics
   - et cetera

5. Send out for coating.
6. Repeat relevant optical tests.
7. Conduct mode cleaner tests or prototype interferometer tests, as appropriate.

5.3 Scenario: Vacuum certification

Parts arrive on campus after being fabricated by industry.

1. Conduct whatever cleaning and degreasing operations are required.
2. Conduct whatever bakeout is required.
3. If parts are of questionable volatility, then they are tested for outgassing in vacuum test facility.

High δΦ-sensitivity interferometer

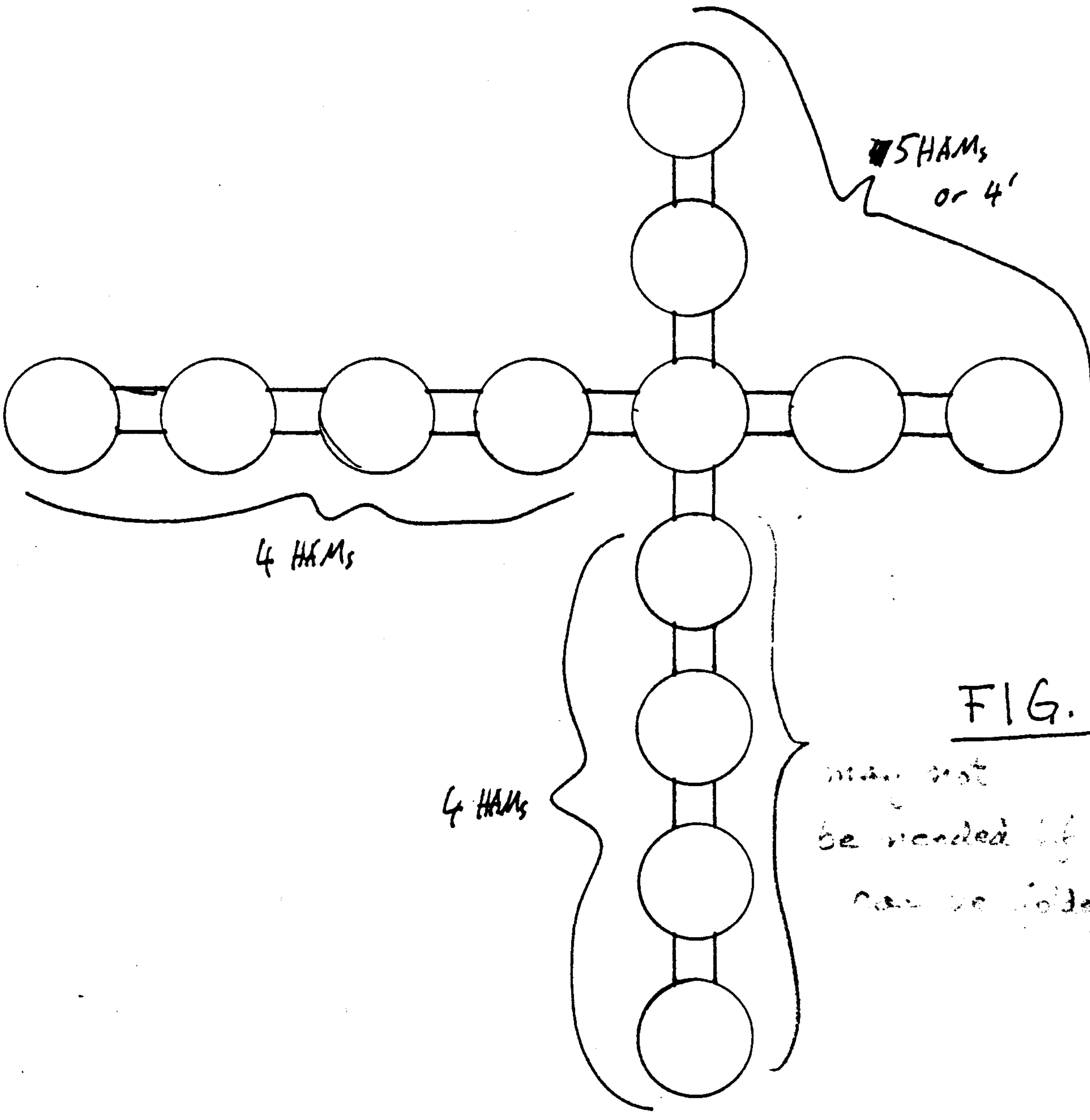

FIG. 1

High δx-sens intf.

- thermal noise
- quantum noise
- calibration
- materials testing
- Seismic isolation certification

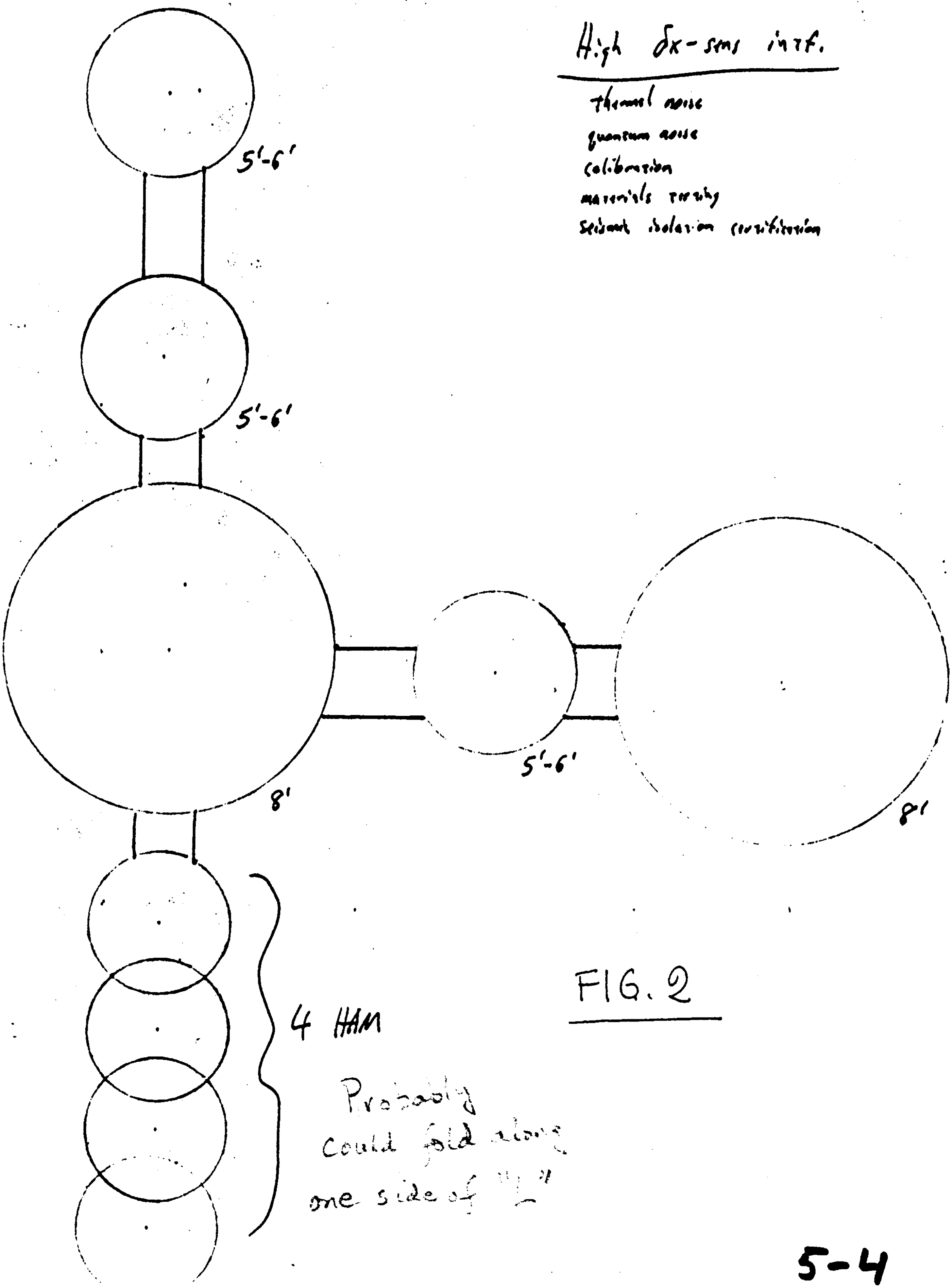

FIG. 2

OUTLINE OF OPTICS R&D FACILITY

10 x 44'

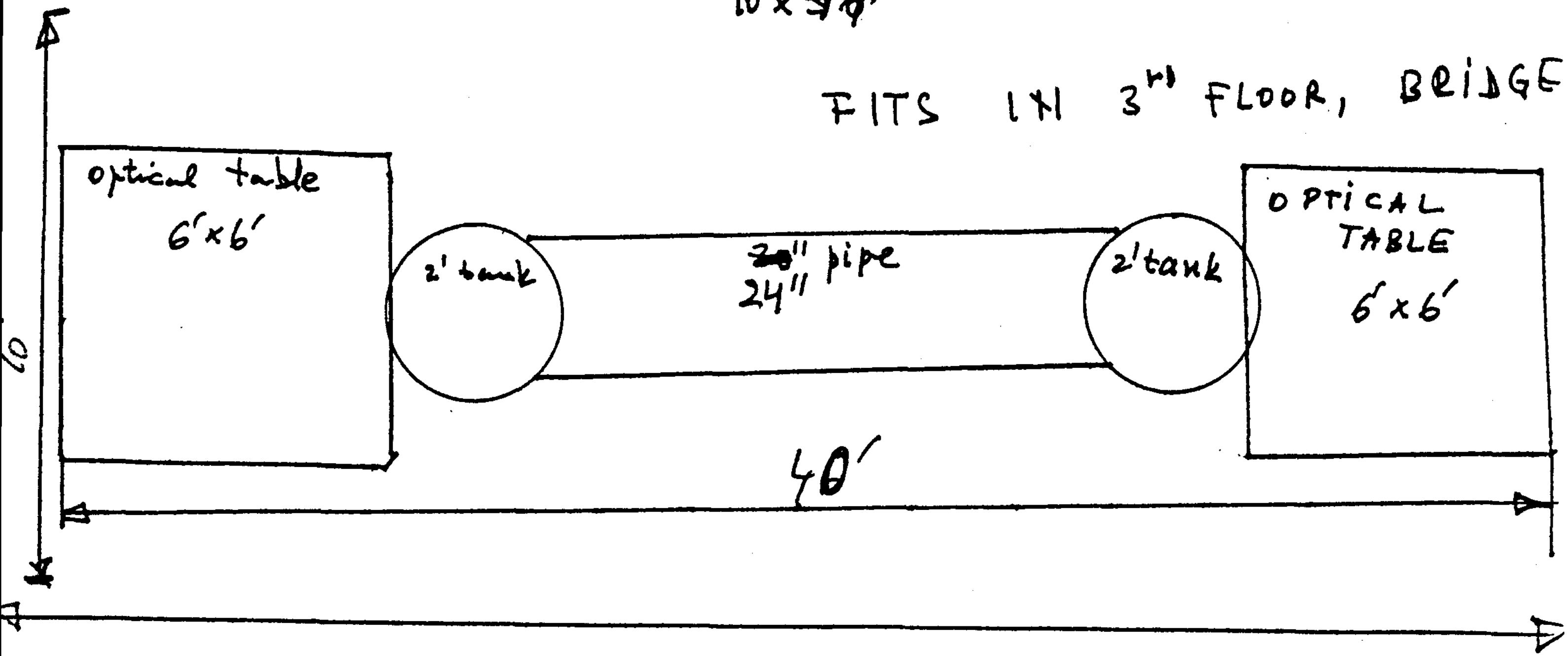

FIG. 3

VIBRATION ISOLATION DEVELOPMENT FACILITY

10' x 15'

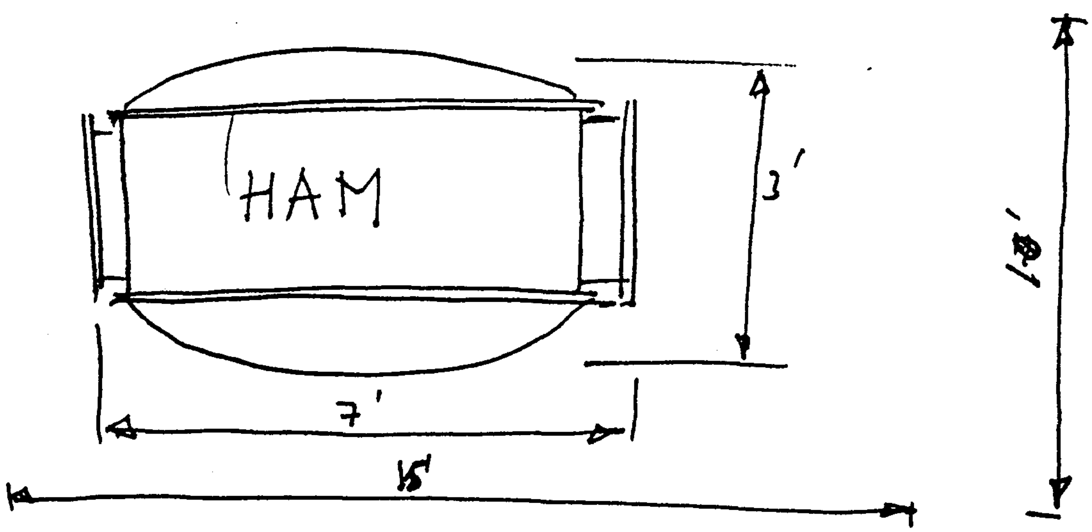

FIG. 4

COMPONENT OUTGASSING TEST FACILITY

10' x 15'

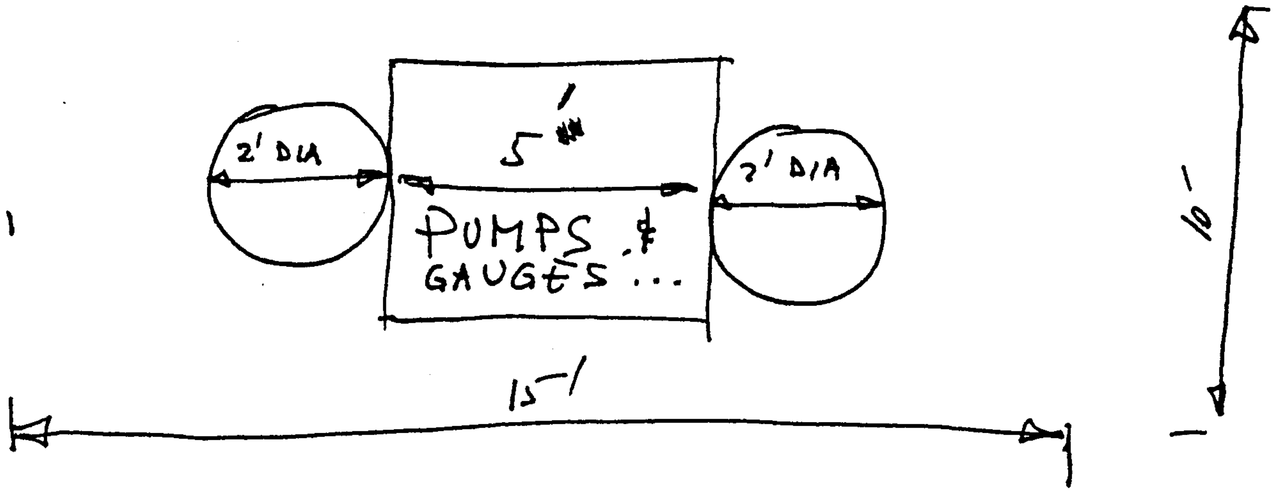

FIG. 5

6. Manpower Requirements (campus facilities)

1. High ϕ sensitivity prototype

   3 Ph.D's, 2 students

2. High δx sensitivity prototype

   3 Ph.D's, 2 students

3. Optical Research

   1 Ph.D's, 2 students

4. Mechanical Systems R & D

   1 Ph.D's, 1-2 students

5. Vacuum/Outgassing Characterization

   1/2 Eng., 1 technician (low duty factor)

6. Auxiliary Systems

   1/2 Eng., 1 Ph.D's, 2 students

7. Data Analysis

   1 Eng., 3 Ph.D's, 2 students

****

Total Ph.D's: 11* Engineers: 2+ Students: 12-13

+ Have not included engineering manpower associated with electronics and engineering of prototype--to--LIGO systems.

+ Same comment applies to technicians.

* Note: Does not include FTE's of remote sites.

7. Ancillary Facilities

Long Baseline Test Facility

There should be a 0.5-4km section of vacuum tube (capable of transporting a 6" ϕ optical beam) with one small vacuum chamber (2'ϕ x 3') at each end. This will be used for testing/certification of actual LIGO mirrors and alignment system testing. This is needed at only one site. (Site 2 already has vacant 4km clear aperture thru $\phi\beta$).

On Site Optical Testing

1 W air cooled Ar^+(or)Nd:YAG	
Optical table	Needed at both remote sites
Equipment rack	

8. LIGO Phase A Site, ~~Campus and Ancillary Facilities~~ Equipment and Instrumentation Requirements

Fred Raab Alex Abramovici Mike Burka
Mike Zucker

March 10, 1989
Version 1.1

Abstract

~~We consider possible goals for the campus and ancillary facilities and explore~~ the needs of ~~campus,~~ ancillary and LIGO sites for equipment ~~and~~ instrumentation.

1 Site Functions

2 LIGO Remote Site Equipment

2.1 Interferometer–Dedicated Electronic Equipment

This category comprises all the electronic equipment needed to control and operate the interferometer in routine service. Much of this equipment will be dedicated to controlling the various suspended components in the interferometer designs currently envisioned; the next largest fraction is actually the laser and cavity phase locking systems required for operation of each interferometer. To avoid dependence on a specific interferometer design we have attempted to modularize the component control functions according to the chamber–type guidelines outlined in the document "Electrical and

Function	Racks/Func.	Funcs./Site 1	Funcs./Site 2	Σ Racks
TM1	2	8	8	32
TM2	4	4	0	16
HAM	1	58	30	88
BS12	3	1	0	3
BS8	2	1	2	6
SAT	1	4	0	4
Laser/RF	7	4	2	42
TOTAL RECEIVER RACKS				191

Table 1: Number of electronic equipment racks associated with each receiver chamber type or function, with Phase A multipliers for each remote LIGO site. The bottom line reflects our estimate for the total number of equipment racks dedicated to routine operation of all interferometers specified in the "LIGO Mission" document at both sites during Phase A. Additional apparatus to enable monitoring, adjustment, control, repair or alteration of the interferometer systems is not included. Chamber types are defined as in "Electrical and Optical Feedthroughs for Phase A Vacuum Chambers" by Jeffries, Spero and Zucker.

Optical Feedthroughs for Phase A Vacuum Chambers" by Jeffries, Spero and Zucker (3/9/89, v.1.1). We similarly refer to the drawing 89L-307 as defining conceptually some chamber ~~chamber~~ types.

We employ a 19" standard relay rack filled with 5 NIM or CAMAC style electronics crates, two auxiliary (e.g. high voltage) power supplies and a digital control/readout/interface as an irreducible unit of receiver electronics. Here the digital control/readout/interface has the function of enabling remote (or local) control and readout of gains, switch settings, etc. as well as channeling any desired analog signal to remote or local monitoring equipment (scopes or computer displays or chart recorders, for example).

It is estimated that each chamber and laser locking/RF modulation system will have associated with it a number of such racks summarized in Table 1.

2.2 Interferometer–Dedicated Optical Equipment

At this writing no account of the in–vacuum optics or mechanics beyond that implicit in previous documents on the beam conditioning chain, beam-splitter layouts, and test mass chamber layouts has been completed. A partial listing of extra–vacuum receiver optical equipment, in rough order of their perceived cost impact, follows:

Lasers

Optical benches

Scanning optical spectrum analyzers

Pockels Cells

Faraday Isolators

Polarizers

Retarder Plates

Beamsteering Mirrors

Modematching Lenses

Photodetectors

2.3 Undedicated Electronic Equipment

To carry out R&D and debug interferometers, it will be necessary to supply each site with portable electronic test equipment appropriate to a state–of–the–art physics laboratory. Detailed lists are TBD, but a rough guide might be derived from the 40m and 5m prototype labs, with appropriate scaling for the number of scientific and technical personnel expected on each site.

2.4 Undedicated Optical Equipment

A guide similar to the preceding section may be adopted; again, detailed lists are TBD.

2.5 Data Acquisition, Computers, and Interferometer Controls

It is assumed that the Data Systems Working Group report will provide information on the expected scope of computer-related hardware requirements.

2.6 Control Room

The control room should be instrumented to provide for operation of interferometers, monitoring equipment, surveillance, safety and security operations.

2.7 Electronic Test/Repair Shop

The electronic shop should be equipped to diagnose and repair simple apparatus on-site and support ongoing R&D with limited small construction capabilities. J. Harman has produced a document on these requirements which we hope to find and include as an appendix.

2.8 Machine Shop

Vertical Mill

Drill Press

Lathe

Band Saw

Belt Sander

TIG Welder

Ultrasonic Cleaner(s)

Fume Hood

Sheet Metal Brake

Sheet Metal Shear

Shop Vacuum

Misc. Tooling

Misc. Hand Tools

2.9 Mechanical Assembly/Test Station

2.10 Laser Maintenance/Optics Testing/Clean Room Station

2.11 Mobile Dust Control

2.12 Vacuum Testing and Bakeout Station

Mass Spectrometers

Leak Detectors

Calibration Stand

Bakeout Chamber

2.13 Transportation and Lifting

Hoists, forklifts, cranes, jackstackers etc. should be provided to handle equipment and receiver components in the experimental areas, to load and unload trucks, and to transport personnel and equipment between vertex and end– or mid–stations.

a small truck will be needed

2.14 Equipment Storage

Appendix A Chamber Type Conventions

Here is a list of the chamber types, taken from the Jeffries/Spero/Zucker report.

TM1 Test mass chamber for one test mass.

TM2 Test mass chamber for two test masses.

HAM Horizontal axis ("pill box") module. This vacuum chamber appears in single and double form in the drawings.

BS8 8-foot diameter splitter chamber.

BS12 12-foot diameter splitter chamber

MAN Test mass chamber manifold, 6 feet in diameter in current concepts. The manifolds will house optical levers for control of test mass alignment.

SAT Satellite chamber.

9. Equipment List - Draft 1 (used for equipment lists in Section 8)

Michael Burka

27 Feb 89

1 Introduction

This is a list of the equipment that will be needed at each LIGO site. The list is intended to be as comprehensive as possible, but undoubtedly much has been overlooked. The next section contains the list proper, broken down into categories such as computer, vacuum, etc. Following are discussion and explanation of why various things have been included. No assumption has been made as to how many interferometers will be included at each site or whether there will be mid-stations. Thus, for some items in the equipment list, only the number per interferometer or the number per mid-station/end-station is listed. Aside from that caveat, I have attempted to be as concrete as possible.

2 LIGO site equipment list

2.1 Computer equipment

- 1 General purpose computer (Sun 4/260 or equivalent)
- 6 Workstations/terminals
- 2 Gigabytes disk storage
- 2 Telephone modems
- 1 High bandwidth network multiplexer
- 2 6250 bpi tapedrives
- 1 Color laser printer

- 1 B/W laser printer
- Large graphics workstations
  1. 1 for vacuum system
  2. 1 for environmental monitor
  3. 1 for each mid-station
  4. 1 for each end-station
  5. n for detectors (each detector requires one in central station)
- n VCR data logging and storage units
  1. 1 for each detector
  2. 1 for housekeeping
- Real-time boxes (680XX-based VME bus)
  1. 3 for environmental monitoring
  2. 4 for each interferometer
     - 1 for optical detector output
     - 9 for position servoes, alignment systems, etc.
  3. 2 Mobile workstations
- 1 Array processor (if on-site data analysis is contemplated)
- 1 Color pen plotter

2.2 Vacuum equipment

- 8 Mass spectrometers
- 2 Leak detectors
- 1 Calibration stand
- 1 Bakeout chamber

2.3 Optical equipment

- 1 Air-cooled argon laser
- 2 He-Ne lasers
- 1 Chopper
- 1 Laminar flow bench
- 2 Laser power meters
- 2 General purpose optical tables
- 1 Single mode fiber fusion splicer
- All manner of optical mounts, wrenches, small lenses, etc.

2.4 Test equipment

- 4 Oscilloscopes
- 1 Audio Fourier transform box
- 1 R.F. Fourier transform box
- 1 Waveform synthesizer
- 1 NIM crate
- 1 H.V. power supply
- 1 H.V. Op amp
- n Equipment racks
- 1 R.F. amplifier
- 8 V.O.M.
- 1 Lock-in amplifier
- 2 Strip-chart recorders
- 1 R.F. power meter
- 2 Capacitance meters

2.5 Machine shop

- 1 Drill press
- 1 Band saw
- 1 Belt sander
- 1 TIG Welder
- 1 Vented fume hood
- 1 Ultrasonic cleaner
- 1 Shop vacuum
- All manner of hand tools

2.6 General service

- 1 Pickup truck
- 1 Station wagon
- 1 Forklift
- 1 Jack stacker
- 1 Large LN_2 storage tank
- 1 Monorail crane
- 1 Bridge crane
- 2 Refrigerators
- 1 Telephone system
- 1 Xerox machine
- 1 Facsimile machine
- 1 Intercom system
- 1 Air compressor
- 5 Five drawer file cabinets

- 3 Stepladders
- n Storage cabinets
  1. 12 for central station
  2. 2 for each mid-station/end-station
- n First-aid kits (1 for each building)
- Drinking fountains, eyewash fountains
- Desks, chairs, tables, bookshelves, whiteboards, wastebaskets

3 Discussion

Most of the entries in the above list require no explanation. In this section we deal with the exceptions.

3.1 Computer equipment

The computer equipment list relies heavily upon Andrew Jeffries' thoughts about how the computing and data operations of the LIGO will be coordinated. The big picture is that there is to be one general purpose computer at each site, and numerous microcomputers attached to VME-bus or equivalent real-time boxes. The general purpose computer is attached to telephone modems and the network multiplexer to allow each site to communicate with the world. The network multiplexer is envisioned to be high bandwidth, and will serve as a data link with the other site and the campuses. The choice of 2 gigabytes of disk storage as opposed to 3 or 4 and 6 workstations as opposed to 5 or 7 is somewhat arbitrary. The array processor is only required if we intend to do data analysis at the sites.

3.2 Vacuum equipment

This list came from Boude Moore. The calibration stand is a test system closely resembling his vacuum test facility. The bakeout chamber should be able to reach 250°C.

3.3 Optical equipment, Test equipment, and Machine shop

The idea behind these lists is that one ought to have the capability to diagnose flaky components and fix them and to build minor circuits and such. It is not anticipated that there will be major design work or building of components on site. The lasers need not be high power, and the argon laser should be air-cooled and portable.

3.4 General service

The numbers chosen for cabinets and stepladders are off-the-cuff estimates. Two refrigerators are required; one for food and one for such things as epoxies and batteries.