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Contract PP150969
Control No. 950324-0

March 24, 1995

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Ms. Linda Turner
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California Institute of Technology
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Dear Linda,

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As discussed with Fred Asiri, we will discuss the changes in this document and back-check previous comments from LIGO today or no later than March 28, 1995

Very truly yours,

Tyler M. Jackson, PE
Project Manager

JVH/TMJ/jvh

cc: Jeff Hermann
Administration File 5.2.1
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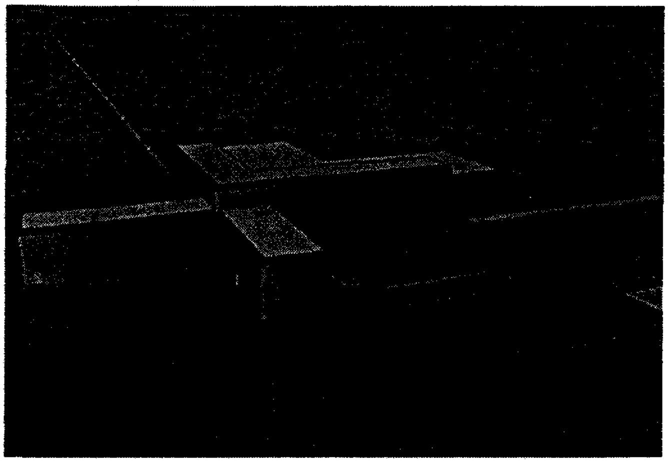
PARSONS



Design Configuration Control Document

Working Draft

March 24, 1995

LIGO
Laser Interferometer Gravity Wave Observatory
California Institute of Technology
The Ralph M. Parsons Company
Contract Number: PP150969

LIGO Document	____
CDRL Number	06
DRD Number	03

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APPROVAL STATUS

YES NO (NOT REQUIRED)

Project Manager, Parsons

Technical Representative, Caltech

Parsons–LIGO

Laser Interferometer Gravity Wave Observatory

Foreword

This document is a "working draft". This document is not yet finalized but has been reviewed and commented on by both the Client and our own Staff, and these comments have been incorporated into the document. This document will continue to evolve as criteria is further developed and adjusted. The final version of the document will be submitted at the end of the Concept Design -- Phase A. During Final Design -- Phase B, it will be revised as needed and issued as a revision.

Revisions from the previous submittal are indicated. Deletions are indicated by a strike-through and a revision bar in the margin, and additions are indicated by an underline and a revision bar in the margin.

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1. Scope

The purpose of this document is to establish baseline design criteria for the Laser Interferometer Gravitational-Wave Observatory (LIGO) Facility Design. The baseline design criteria is developed from the LIGO Facility Request for Proposal No. YM 193, the LIGO Vacuum Equipment Request for Proposal No. MH 178, our understanding of LIGO Project needs, and industry standard design and construction practices that will meet or exceed these needs.

This document serves as a facility design criteria from which the configuration of the facility will evolve. As it evolves, this document will be updated. This document will continue to be the source for configuration control information for the direction of the design process. It is also the baseline for the design effort.

By reference, criteria provided in Appendix A, B, and C of the LIGO Facility Request for Proposal Number YM 193, and the LIGO Vacuum Equipment Request for Proposal Number MH 178 constitute an element of this document and are therefore considered an element of the Facility's controlled design configuration. Concept strawman design approaches presented in these RFPs are not an element of the controlled design configuration; however, the layouts of the Vacuum Equipment in the LVEAs are considered a controlled design configuration.

2. Facility Overview

The LIGO project is a pioneering effort to design and construct a novel scientific facility -- a gravitational-wave observatory -- that will open a new observational window on the universe.

LIGO will consist of two observatory facilities located at Hanford, Washington, and Livingston, Louisiana. These facilities will incorporate L-shaped vacuum systems with arms of 4 km length. The vacuum systems (by others) will house laser interferometer detectors sensitive to gravitational waves from astrophysical sources. Initial detector sensitivity will detect strains as small as 10^{-22}~~; the existing 1/100 scale prototype has measured strains to 10^{-17}~~. Correlation of data from interferometers at the two sites will allow identification of gravitational waves, their sources and origin in space. LIGO will become the first part of a planned worldwide network of gravitational-wave detectors coordinated to operate as a single observatory complex. Current plans are to begin observatory operations by the year 2000.

Constructed facilities at each site include the main corner station, with the large laser and vacuum equipment area, ~~end and corner buildings on each beam tube leg~~End, Mid and Corner Stations on each beam tube arm, and a central plant. Building work includes, but is not limited to, power distribution, lighting, security systems, fire protection, communications, control system, access platforms, clean rooms, cranes, heating ventilating and air conditioning, and cable raceways. Each site will have two beam tube enclosure structures, each 4 km long. Sitework for the virgin sites includes site grading, drainage, roads, parking, landscaping, water supply developed from wells, sanitary facilities, waste water treatment and disposal and power distribution from area utilities.

Facility design will address special building requirements for the laser and vacuum equipment areas located at the corner, mid and end stations. Vibration isolation and reduction is required in order that transmitted vibration energy is no more than a factor of two above natural ambient levels. Both sites were selected based on their low ambient background noise and vibration levels. This requires seismic mass type foundations for critical scientific equipment and separate foundations and remote locations for vibration producing equipment and occupancy. Laser and vacuum equipment will be located in a large open space of high volume (3.5 million cubic feet) designed as a clean room to Class 50,000. Smaller support areas for scientific equipment will require clean room conditions to Class ~~1~~5000 or better. The laser interferometer detector is sensitive to EMI effects and will require special design for power, lighting, and control circuits to minimize disturbances. The laser interferometer detector is also sensitive to local gravity field gradients which requires special provisions for people and equipment movements.

3. Systems Provided by Others

These systems are designed, provided, and installed by Others and, in general, consist of the following items

3.1 Beam Tube System

- Beam Tube Segments with Expansion Joints
- Baffles
- Beam Tube Support and Leveling Subsystem
- Bakeout Subsystem

3.2 Vacuum Equipment System

- Vacuum Chamber Subsystem
- Pumping Subsystem
- Valve Subsystem
- Vent and Purge Subsystem
- Bakeout Subsystem
- Monitor and Control Subsystem

3.3 Detector System

- Lasers
- Optics
- Coarse Alignment
- Detectors
- Control and Data System

4. Functional Description

4.1 Laser and Vacuum Equipment Area (LVEA)

This area is designed to house the high precision, sensitive interferometer components. The interferometers require a clean controlled environment with a minimum of disturbance from acoustic noise, ground vibrations, electromagnetic interference and other localized disturbances. Each interferometer uses one or more high power lasers which will be located within this area. Power and cooling must be provided for these lasers. The electro-optic interferometer components are contained within a high vacuum envelope generally referred to as the "vacuum equipment".

The vacuum equipment comprises a network of chambers, which house the sensitive interferometer components, and interconnecting beam-tubes which transmit laser beams between the chambers. High vacuum gate valves are provided between segments of the interconnecting tubing to isolate different portions of the vacuum system for diagnostics, maintenance, or upgrades while other portions remain operable.

Re-locatable vacuum pumps are deployed where needed by overhead crane and coupled locally to valved pumpout ports for initial pumpdown. Electrical power, compressed air, monitor/control system, and pump exhaust lines are provided near the pumpout ports. Stationary high-vacuum ion pumps attached to the individual chambers contend with normal outgassing, porosity and leakage. Liquid nitrogen (LN_2) pumps at the ends of the adjacent beam-tube modules provide additional capacity for removing condensable gases.

The vent/purge subsystem generates and distributes filtered, dry air for backfilling chambers when they are to be opened and provides internal filtered air showers to maintain cleanliness while working inside the chambers. A bakeout subsystem, comprising of relocatable heaters, insulation and power connections, allows optional vacuum baking of individual valved-off sections of the vacuum equipment. This permits removal of contaminants and reduction of outgassing when required.

In addition to lasers and vacuum equipment, this area contains the electronics racks and cabling for the interferometers. The racks house the servo loop electronics, control and monitoring electronics, and computer networking electronics. Cable raceways will each serve each chamber, pump or valve location.

4.2 Operation Support Building (OSB)

4.2.1 Staff Offices, Lobby, and Visitor Accommodations

This area includes offices and common areas such as rest rooms, break room, conference room, suitable for a permanent staff of 21 employees. This staff will consist of 8 professionals and 13 technicians/operators. Approximately 15 visiting scientists and interns are anticipated during the year, each with a stay of one week to six months. Other visitors will include tour groups of students, educators, scientists, and dignitaries who may be accommodated with a facility at a remote location with displays, models, and CCTV monitors for viewing the facility operations. The facility entrance for employees, users, and visitors is through a lobby and controlled by a receptionist/secretary area. The conference room, all workspaces, and all offices shall have provisions for computer networking.

4.2.2 Control Room

The Control Room is the operational center of the facility. It will provide an office quality environment for the operations crew. Physical plant control and monitoring is executed from this room. The Control Room equipment consists mainly of desktop computing workstations and rack mounted electronics. This room also provides space for the central monitoring panels of facility services such as fire protection, personnel access control, and building surveillance via a low-light level closed circuit television system.

4.2.3 Computer Users Room

The Computer Users Room is similar to the Control Room for the facility with the exception of monitoring the building controls systems. The space will provide an office quality environment for the operations crew for the purpose of data analysis, software development, and communications. The Computer Users Room equipment consists mainly of desktop computing workstations, printers, plotters, scanners, and reference areas.

4.2.4 Computer and Mass Storage and TapeData Archives Rooms

These areas house rack-mounted computing equipment, mass storage units, and peripherals (disk and tape drives, etc.) as well as storage cabinets for magnetic tapes. Portions of this area will have a access flooring to allow for easy cabling. The equipment for these areas consists mainly of desktop computing workstations for the Diagnostics portion of the operation. - The room will be provided with a fire suppression systemequipment. The Tape Room will be the on-site repository for all data tapes. A duplicate, offsite storage space shall also exist.

4.2.5 Change/Smock Function

All personnel will enter the LVEA via this space. This space will contain small lockers and benches to facilitate the gowning-up process prior to entering the LVEA.

~~4.2.6 Experiment Equipment Area~~

~~This room will house equipment being developed for use in association with the LIGO experiments. It will also serve as the area where new equipment for use with or as replacements for equipment used in LIGO is assembled. This room will contain a small laser, vacuum chambers for performance testing, and a vacuum bakeout chamber.~~

~~4.2.6 Testing Area~~

~~A testing area is provide for setup and checkout of interferometer components before installing them into the vacuum equipment. This room will contain a small laser, vacuum chambers for performance testing, and a vacuum bakeout chamber.~~

4.2.6 Vacuum Prep / Assembly Lab

This lab is designated to enable the assembly and disassembly of vacuum components and subsystems for cleaning with solvents and detergents, bakeout and outgassing certification of new components,. Specific areas shall have Class 100 workbenches for work on the components for the LVEA. This will also be the location of a mechanical engineer and technician with workstations and workbenches.

4.2.7 Electronics / Data Lab

This lab is designated to enable the repair and assembly of electronics and cabling, perform measuring, calibration and troubleshooting of the electronic components of the lasers and interferometers, both new and existing. Other activities will include the design and repair of new or existing electronics necessary to support the testing and experiments. This will also be the location of an electronics engineer and technician.

4.2.8 Optics Lab

This lab is designated to provide support for inspections, cleaning, testing, and storing of the optics required for the operation of the experiments. This lab will be classified as a minimum Class 5000 clean room with designated work areas and benches with a Class 100. This will also be the location of an optics technician.

4.2.9 Mechanical ~~and Electronic~~ Shop

This shop is provided for checking, maintaining and repairing interferometer and facility equipment. ~~The electronics shop contains electronic service instrumentation and calibration equipment for vacuum instrumentation, auxiliary physics monitoring instrumentation, computers, and interferometer electronics.~~ The mechanical shop contains small scale machining and welding equipment such as drill presses and lathe/milling machines, for maintaining or modifying interferometer components and vacuum chambers.

4.2.10 Active ~~Storage~~ and Long Term Storage

These areas will be used to store the parts and components integral to the common maintenance of the facility and the equipment. Storage of large bulky items or items that are seldom used (i.e., bake-out insulation for the vacuum equipment vessels or beam tubes, etc.) will be stored off-site in commercially available storage facilities.

4.2.11 Receiving and Shipping, and Inspection Area,

Equipment that arrives at the LIGO facility loading dock and will be processed through this area in a manner which ensures the integrity of the clean environments. Packages that arrive at the loading dock will be cleaned externally before being moved into the receiving and shipping area. There, they are unpacked from the outer shipping container and moved to the inspection area, where the inner packaging is removed and the contents are inspected.

4.2.12 Cleaning Area

Equipment destined for the vacuum equipment area is moved from the Inspection Area through the Cleaning Area for removal of dust or contamination. The doors connecting through this area will be opened one at a time to prevent outside dust or particulate contamination riding on packaging from reaching the clean LVEA. Environment will be equal to the LVEA when components are transferred between the two spaces.

~~4.2.13 Cleanroom~~

~~This room is a Class 1000 cleanroom with ceiling supply and wall return air flow. The room will be used for the installation of the laser components into the argon ion lasers and the test mass chambers. It will also contain Class 100 laminar flow work benches. This room will also be used to setup any developmental devices needed in association with the LIGO project. The cleanroom will be accessed through an air shower type airlock anteroom to accommodate the large lasers and chambers.~~

4.3 Mechanical/Utility Buildings

This building, or buildings, provides space for equipment such as heating, ventilation, and air conditioning (HVAC), and other mechanical and electrical equipment associated with the facility operations. It also provides areas such as a workshops and storage for functions related specifically to facility maintenance.

The Mechanical/Utility Building is vibrationally isolated from the LVEA and is serviced by a remotely located chiller plant to minimize vibration transfer to the LVEA. Air handling units are designed for minimum induced vibration and acoustic noise. Cooling for the lasers is provided by individual closed-loop de-ionized water cooling systems with heat exchangers located in the utility building and coupled to a facility chilled-water line.

4.4 Chiller PlantsBuilding

The Corner, Mid, and End Station chilled water plants provides chilled water to the HVAC systems, and, at the Corner Station, the closed loop cooling systems for the lasers. The plant utilizes air cooled refrigeration units. The chilled water plant is remotely located from the Corner Station to minimize transmitted vibration and is isolated acoustically to minimize acoustic energy transmission to the LVEA. It also provides areas such as a workshops and storage for functions related specifically to facility maintenance at the Corner Station chiller building to service the entire site.

4.5 Mid Station and End Station

The buildings for the end stations at both sites and the mid stations at the Washington site are of similar design, but differ in their vacuum equipment layout. The functional requirements and designs are similar to those of the corner stations, except that the vacuum equipment in these stations is much simpler and there is no need for personnel offices. These stations include a vacuum equipment area, a support services area, a utility room, and a remote chilled water plant. Access to the buildings and the vacuum chamber areas is controlled and monitored from the corner station control room by the facility operator.

4.5.1 Vacuum Equipment Areas

The design and construction approaches of vacuum equipment area are similar to those used in the LVEA in the corner station. These areas contain vacuum chambers, pumps, and valves which are serviced by an overhead bridge crane with a minimum 50 foot hook height. It also encloses electronics racks and associated cabling for control and data acquisition.

4.5.2 Operation Support Area

The design and construction approaches of the Operation Support Area are the same as those of the corner station. It includes space for interferometer and facility electronics equipment, areas for unpacking, inspection, and cleaning of interferometer and vacuum equipment. It also includes a small work area for maintenance and a Class ~~1~~5000 cleanroom for servicing interferometer components and optics.

4.5.3 Utility Area

An attached utility room, with separate foundation for vibration control, houses mechanical (i.e., HVAC air handler units, etc.), and electrical (i.e., motor control centers, etc.). Chillers are housed in a separate and remote plant.

4.5.4 Chilled Water Plant

This plant is separate from the mid and end stations and is of similar design to the corner station plant. Chilled water will be required for the HVAC system only since there are no high-power lasers in these stations.

4.6 Midpoint Pump Stations

This station is for the Louisiana site only. It replaces the Mid Station Vacuum Equipment area and, as a minimum, will provide access for~~contain~~ beam tube rough vacuum pumps. Further~~pumps. In addition to the pumps, it will house associated mechanical and electrical equipment.Further~~ functional details to be provided.

4.7 Beam Tube Foundation and Enclosure

The beam tube enclosures at each site are made up of four identical 2 kilometer long modules. The beam tube enclosure protects the high-vacuum beam tube walls from vibration induced by wind. In addition, it protects the tube walls from mechanical impacts which could release bursts of gas into the interferometer beams, thereby contributing noise. The enclosure provides an moderate amount of thermal stability for the beam tubes, reducing the variation in residual gas pressure. It also provides protection against damage to the beam tubes from stray bullets. A potential configuration is shown in the Figure 4.7-1

The foundation at the beam support must be constructed to a vertical tolerance of ±1/2 inch between the successive supports (about 65 ft apart). Beam tube supports will be attached to the foundation with anchor bolts. The foundation must be designed to minimize settlement and to take static and vacuum related loading of the beam tubes and their various components. See Section 7.3.2.8 for additional criteria on this subject.

The beam tube enclosures are not normally occupied. The enclosure configuration provides adequate room for access to repair leaks, adjust alignment of the beam tube and conduct occasional beam tube bakeouts.

Entries to the beam tube enclosure are required at about 250 meter intervals for installing and servicing the future ion getter pumps. The enclosure provides space for internal cableways for distribution of signal and power cables. Minimal permanent lighting is required. Utility outlets are provided at the 250 meter entries. The foundation is transversely sloped to drain accumulated water from the floor of the beam tube enclosure.

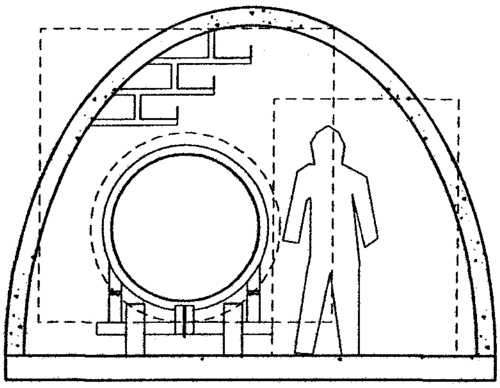

Figure 4.7-1

Potential growth of fungi at the Louisiana site due to water intrusion is a serious consideration. Dehumidification may be required to control the growth.

5. Growth and Flexibility

5.1.1 Laser and Vacuum Equipment Area

The vacuum equipment is of a modular design to permit phased expansion. The initial installation at Hanford will serve two interferometers but will be expandable to a total capacity of six by addition of chamber modules at the end, mid, and corner stations. At Livingston, one interferometer is planned initially with capacity for an additional two provided by adding chambers at the end and corner stations. Due to the cleanliness required in the vacuum equipment area and the need to maximize continuous observation capability through the life of the facility, LIGO has elected to construct stations and infrastructure consistent with the final configuration without phasing the construction.

~~Currently the configuration of interferometers is in an orthogonal orientation, however there is the possibility that a future interferometer may need to be angled.~~

To accommodate future interferometers, the LVEA foundation and structure will not preclude placement of vacuum chambers at any location within the Client accepted bridge crane hook envelope.

5.1.2 Operations Support Building

The operations will require expansion of the office and shop facilities at some future time. The initial construction should facilitate this expansion with minimum impact to the existing facility. This maybe accomplished by adding temporary trailers in a designated area near the Operations Support Building (OSB).

6. Referenced Documents

6.1 Federal Standards

Number	Title
FEDERAL STANDARDS	
FED-STD-209	Clean Room and Work Station Requirements, Controlled Environment
FED-STD-595	Color and Number Identification
Title 29 CFR	**Federal Occupational and Health**
OSHA 2207	Construction Industry -- OSHA Safety and Health Standards

6.2 Military Standards

Number	Title
MILITARY STANDARDS	
MIL-STD-461D	**Grounding, Bonding, and Shielding for Electronics Equipment and Facilities Applications**
MIL-STD-1246	**Product Cleanliness Levels and Contamination Control Program**
MIL-V-18436	**Valves, Check: Bronze, Cast-Iron and Steel Body**

6.3 Industry Standard Codes

Number	Title
Industry Standard Codes	
ASME Codes	**Pressure Vessel Codes, Section VIII & IX**
-B16.29	Wrought Copper and Wrought Copper Alloy Solder Joint Drainage Fittings
-B31.1	Power Piping
-Section VIII	Rules for Construction of Pressure Vessels
-Section IX	ASME Boiler and Pressure Vessel Code
BOCA	**Building Officials and Code Administrators -- Standard for the Design and Installation of the Fire Suppression System for Life Safety**
SBC	**Standard Building Code**
UBC	**Uniform Building Code**
UFC	**Uniform Fire Code**
UMC	**Uniform Mechanical Code**
UPC	**Uniform Plumbing Code**

6.4 Industry Standard Specifications, ~~Codes,~~ and Guidelines

Number	Title
	Industry Standard Specifications, ~~Codes,~~ and Guidelines
AASHTO	**American Association of State Highway and Transportation Officials**
Manual	Guide for Design of Pavement Structures
Specification	Standard Specifications for Highway Bridges
Specification	Standard Specifications for Transportation Materials
Specification	Standard Specifications for Methods of Sampling and Testing
ACCA	**Air Conditioning Contractor's of America**
Manual D	Equipment Selection and System Design Procedures
Manual Q	Equipment Selection and System Design Procedures for Commercial Summer and Winter Air Conditioning
ACGIH	**American Conference of Governmental Industrial Hygienists**
-Chapter 2	General Ventilation
ACI	**American Concrete Institute**
-117	Standard Specification for Tolerances for Concrete Structures and Materials
-318	Building Code Requirements for Reinforced Concrete and Commentary 60
-530	Building Code Requirements for Concrete Masonry Structures and Commentary
AEIC	**Association of Edison Illuminating Companies**
-CS 5	Specification for Thermo Plastic and Cross-linked Polyethylene Insulated Shielded Power Cable Rated 5 through 69 kV
-CS 6	Specification for Ethylene Propylene Rubber Insulated Shielded Power Cables Rated 5 through 69 kV
-S-68-516	Ethylene Propylene Rubber Insulated Wire and Cable for Transmission and Distribution of Electrical Energy
AFBMA	**Anti-Friction Bearing Manufacturers Association**
-9	Load Rating and Fatigue Life for Ball Bearings
-11	Load Rating and Fatigue Life for Roller Bearings
AISC	**American Institute of Steel Construction -- Specification for Structural Steel Buildings, Allowable Stress Design and Plastic Design Code of Standard Practice -- Standard Practice for Steel Buildings and Bridges**
AISI	**American Iron and Steel Institute**
AMCA	**Air Movement Control Association**
-99	Standard Handbook
-211	Certified Ratings Program, Error Performance
-311	Certified Sound Ratings Program for Air Moving Devices
-500	Test Methods of Louvers, Dampers and Shutters

Number	Title
	Industry Standard Specifications, ~~Codes,~~ and Guidelines
ANSI	**American National Standards Institute**
-A13.1	Scheme for the Identification of Piping Systems
-A53	Specification for Pipe Steel, Black and Hot Dipped, Zinc Coated, Welded and Seamless
-B16.3	Malleable Iron Fittings
-B16.5	Pipe Flanges and Flanged Fittings
-B16.9	Factory Made Wrought Steel Butt Welding Fittings
-B16.29	Wrought Copper and Wrought Copper Alloy Solder Joint Drainage Fittings
-B30.2	Safety Code for Overhead and Gantry Cranes
-B30.10	Hooks
-B31.1	Power Piping
-B32	Standard Specification for Solder Metal
-B88	Specification for Seamless Copper Water Tube
-C2	National Electrical Safety Code (NESC)
-Z358.1	Eyewashes and Showers Equipment, Emergency
-900	Test Performance of Air Filter Units
ARI	**Air Conditioning and Refrigeration Institute**
-410	Force Circulation Air Cooling and Air Heating, Coils
-430	Central Station Air Handling Units
-530	Method of Measuring Sound And Vibration of Refrigerant Compressors
-540	Method for Presentation of Compressor Performance Data
ASCE	**American Society of Civil Engineers**
-7-88	Minimum Design Loads for Buildings and Other Structures
ASHRAE	**American Society of Heating, Refrigerating and Air Conditioning Engineers**
-15	Mechanical Code for Refrigeration
-52	Method of Testing Air-Cleaning Devices Used in General Ventilation for Removing Particulate Matter
-34	Number Designation and Safety Classification of Refrigerants
-1989 HDBK	Fundamentals
ASME Codes	**Pressure Vessel Codes, Section VIII & IX**
-B16.29	Wrought Copper and Wrought Copper Alloy Solder Joint Drainage Fittings
-B31.1	Power Piping
-Section VIII	Rules for Construction of Pressure Vessels
-Section IX	ASME Boiler and Pressure Vessel Code
ASSE	**American Society of Sanitary Engineers**
-1013	Reduced Pressure Principle and Pressure

Number	Title
Industry Standard Specifications, ~~Codes,~~ and Guidelines	
ASTM	**American Society for Testing and Materials**
-A36	Standard Specification for Structural Steel
-A53	Specification for Pipe, Steel, Black & Hot Dipped, Zinc Coated Welded and Seamless
-A123	Standard Specification for Zinc (Hot Dipped Galvanized) Coatings in Iron and Steel
-A126	Specification for Gray Iron Coatings for Valves, Flanges
-A278	Standard Specification for Gray Iron Castings and Pressure, Containing Parts for Temperature
-B32	Standard Specification for Solder Metal
-B88	Standard Specification for Seamless Copper Water Tube
-B280	Specification for Seamless Copper Tube and Air Conditioning and Refrigeration Field Service
-C553	Standard Specification for Mineral Fiber Blanket and Felt Insulation
-D2737	Specification for Polyethylene Plastic Tubing
-E84	Surface Burning characteristics of Building Materials
-F50	Standard Practice for Continuous Sizing and Counting of Airborne Particles in Dust-Controlled Areas Using Instruments Based Upon Light Scattering Principles
-F328	Standard Practice for Determining Counting and Sizing Accuracy of an Airborne Particle Counter Using Near-Monodisperse Spherical Particulate Materials
-F649	Standard Practice for Secondary Calibration of Airborne Particle Counter Using Comparison Procedures
AWS	**American Welding Society**
-A2.4	Symbols for Welding, Brazing and Nondestructive Examination
-A3.0	Standard Welding Terms and Definitions
-B2.1	Standard for Welding Procedure and Performance Qualification
-D1.1	Structural Welding Code -- Steel
-D14.1	Specification for Welding Industrial and Mill Cranes
BOCA	**Building Officials and Code Administrators -- Standard for the Design and Installation of the Fire Suppression System for Life Safety**
CGA	**Compressed Gas Association**
-4.1	Cleaning Equipment for Oxygen Service
CMAA	**Crane Manufacturers Association of America**
-70	Specification for Electric Overhead Traveling Cranes
CTI (TBS)	**Cooling Tower Institute Standards**
DHI	**Door Hardware Institute**
FIPS Pub 94	**Guideline on Electrical Power for ADP Installations**

Number	Title
Industry Standard Specifications, ~~Codes,~~ and Guidelines	
IEEE	**Institute of Electrical and Electronic Engineers**
-43	Recommended Practice for Testing Insulation Resistance of Rotating Machinery
IESNA HDBK	**Illuminating Engineering Society North America Handbook**
IES	**Institute of Environmental Sciences, Recommended Practices**
-RP-CC-001	HEPA Filters
-RP-CC-006	Testing Clean Rooms
-RP-CC-013	Recommended Practice for Equipment Calibration or Validation Procedures
MSS	**Manufacturers Standardization Society**
-SP58	Pipe Hangers and Supports
-SP67	Butterfly Valves
-SP69	Pipe Hanger and Supports, Selection and Application
-SP70	Cast Iron Gate Valves, Flanged, and Threaded Ends
-SP72	Ball Valves with Flanged Butt Welded Ends for General Service
-SP80	Bronze Gate, Globe, Angle and Check Valves
NACE-STD	**National Association of Corrosion Engineers Cathodic Protection**
-RP-02-75	Application of Organic Coating to External Surface of Steel Pipe for Underground Service
NASA	**National Aeronautics and Space Administration**
-NSS/GO-1740.9	NASA Safety Standard for Lifting Devices and Equipment
NEMA	**National Electrical Manufacturers Association**
-MG1	Motors and Generators
NFPA	**National Fire Protection Association**
-13	Installation of Sprinkler Systems
-13A	Inspection, Testing and Maintenance of Sprinkler Systems
-54	National Fuel Gas Code
-70	National Electrical Code
-72E	Automatic Fire Detectors
-78	Lightning Protection Code
-80	Fire Doors and Windows
-85B	Standard for Prevention of Furnace Explosions in Natural Gas-Fired Multiple Burner Boiler
-90A	Installation of Air Conditioning and Ventilating Systems
-99	Standards for Health Care Facilities
NIOSH	**Technical Report: Guide to Industrial Respiratory Protection**
NIST	**National Institute of Standards and Technology**
NSS	**National Safety Standards**
SBC	**Standard Building Code**

Number	Title
	Industry Standard Specifications, ~~Codes,~~ and Guidelines
SMACNA	**Sheet Metal and Air-Conditioning Contractors National Association**
-	High Pressure Duct Construction Standards
-	Low Pressure Duct Construction Standards
-	Guidelines for Seismic Restraints of Mechanical Systems
-	Round and Oval Duct Construction Standards
-	Architectural Sheet Metal
SSPC	**Steel Structures Painting Council**
-SP-2	Surface Preparation, Hand Tool Cleaning
-SP-3	Surface Preparation, Power Tool Cleaning
-SP-10	Surface Preparation, Near-White Blast Cleaning
UBC	**Uniform Building Code**
UFAS	**Uniform Federal Accessibility Standards**
UFC	**Uniform Fire Code**
UL	**Underwriter's Laboratories**
-96	Lightning Protection Systems
-181	Factory Made Air Ducts and Connectors
-467	Grounding and Bonding of Equipment
-555	Leakage Rated Dampers for Use In Smoke Control Systems
-586	High Efficiency Particulate, Air Filter Units
-900	Test Performance of Air Filter Units
-1072	Medium Voltage Power Cables
UMC	**Uniform Mechanical Code**
UPC	**Uniform Plumbing Code**
USGSA	**United States General Services Administration**
-	Certification Test for Air Flow Measuring Stations

6.5 Site Specific Reference Documents -- General

Number	Title
SITE SPECIFIC REFERENCE DOCUMENTS	
RFP-YM 193	Appendices A, B, and C of the Request for Proposal No. YM 193 for LIGO Facility Design and Construction Management Support
ashington DOT	Standard Specifications for Road and Bridge Construction
ashington DOT	Standard Plans for Road and Bridge Construction
941208-01	Exhibit I, Vacuum Equipment Specification, LIGO Facility, LIGO Document 1100003 of the LIGO Vacuum Equipment Request for Proposal No. MH 178
941220-02	Beamtube Module Specification
941223-01	Information for Potential Contractors -- Facilities Contract
941228-11	Beam Tube Enclosure Statement of Work and Beam Tube Support Details
950104-01	Utility Conduit Design Calculations and Drawing
950112-03	Proposed Layout of LIGO Office and Shop Areas

6.6 Site Specific Reference Documents -- Hanford

Number	Title
SITE SPECIFIC REFERENCE DOCUMENTS	
ashington DOT	Standard Specifications for Road and Bridge Construction
ashington DOT	Standard Plans for Road and Bridge Construction
941219-01	Hanford -- Land Use Permit
941219-02	Hanford -- Memorandum of Understanding
941219-03	Hanford -- Environmental Assessment
941219-04	Hanford -- Finding of No Significant Impact
941219-05	Hanford -- Report of Geotechnical Survey/Letters of Clarification
941219-06	Hanford -- Staking Survey
941219-07	Hanford -- Topographical Survey/Including Back-up Data and Seven Diskettes
941219-08	Hanford -- Specification and Contract Documents for Rough-Grading
941219-09	Hanford -- Drawings for the Rough-Grading
941219-10	Hanford -- Ground Water-Temporary Permit
950104-01	Utility Conduit Design Calculations and Drawing
950113-01	Hanford -- LIGO Rough Grading (with 12 diskettes)
950201-01	Hanford -- Water Well Drilling Log

6.7 Site Specific Reference Documents -- Livingston

Number	Title
SITE SPECIFIC REFERENCE DOCUMENTS	
Louisiana DOTC	Standard Specifications for Road and Bridge Construction
Louisiana DOTC	Standard Plans for Road and Bridge Construction
941228-01	Livingston -- Act of Cash Sale (Draft)
941228-02	Livingston -- Lease Agreement (Draft)
941228-03	Livingston -- Environmental Assessment (Draft Final, One Copy) Finding of No Significant Impact (Appendix B)
941228-04	Livingston -- Section 404 Permit
941228-07	Livingston -- Staking Survey
941228-08	Livingston -- Drainage Plan with Hydrologic and Hydraulic Report
941228-10	Livingston -- Conceptual Designs for Pipeline Crossings of the LIGO Embankment
950112-04	Livingston -- Lease Agreement
950112-05	Livingston -- Geotechnical Investigation, Final Report

7. Design Criteria and Interface Requirements

7.1 General Facility Requirements

A. Units of measurement are in English units.

B. "Master Spec" will be used as the Guideline Construction Specification.

7.1.1 Fabrication and Construction Tolerances

The A-E will provide, in the drawings and specifications, all tolerances for fabrication, construction, and installation.

7.1.1.1 Structural Steel

Minimum tolerances for structural steel construction will be per the AISC "Code of Standard Practice for Steel Buildings and Bridges".

7.1.1.2 Concrete

Minimum tolerances for concrete construction and materials will be per ACI 117, "Standard Specification for Tolerances for Concrete Structures and Materials".

7.1.1.3 Installed Equipment

Tolerances for equipment interfaces specified by the A-E will not exceed the manufacturer's tolerance requirements.

7.1.2 Service Life

7.1.2.1 Facility Design Life

Facility design will be for a 30 year service life.

7.1.2.2 Systems and Equipment Design Life

Operating systems and equipment design will be for a 20 year service life.

7.1.3 Construction Category

The LIGO project is~~will be~~ categorized as permanent construction~~, noncombustible construction, Type II, 1 hour fire rated~~desistant, in accordance with the UBC and SBC.

7.1.4 Occupancy

Each LIGO project site will be designed for a maximum shift population with 40 personnel at both sitesthe Hanford, Washington, and for 30 at the Livingston, Louisiana. The breakdown of anticipated personnel and their classification is as follows:

Staff	Quantity
Technician and/or Operators	10
Technician Specialists	3
Engineers	3
Site Administration	2
Scientific Staff	3
Visiting Scientists	6
Interns and/or Visitors	9
Maintenance Personnel	4

7.1.5 Design

Design of the facility will comply with the Industry Standards and Specifications referenced hereintherein and good design principles. The Facility will be designed for moderate cost, low risk, and ease of maintenance and operability.

7.1.6 Safety

Construction of the facilities will comply with OSHA Title 29 CFR, and applicable local codes.

7.1.7 Security

Security of the facilities will comply with good industrial practice. The major security effort will be to design for minimum potential intrusion particularly along the beam tube enclosures into the Station buildings and beam tube enclosure.

~~7.1.7.1 Perimeter Penetrations~~

~~Vents, ducts, louvered openings, pipes, conduit, etc., that penetrate the facility's perimeter (i.e. exterior walls and roof) will receive the following special treatment.~~

~~A. Air handling ducts that penetrate the perimeter (roof or exterior walls) will contain non-conductive sections positioned within 6 inches of the inner (secure) side of the wall or roof.~~

~~A. Wireways, raceways, and conduit will contain non-conductive sections within 6 inches of the inner (secure) side of a wall and roof.~~

A. ~~Metal pipe penetrations will be treated with lead wrap foil, 1/8 inch thick for a distance of 12 inches, on the inner (secure) side of a wall or roof (Section~~

7.1.8 Material Selection

7.1.8.1 Flame Spread

All materials will be noncombustible or have a flame spread rating of 25 or less in accordance with ASTM E84.

7.1.8.2 Cleanliness/Contamination

A. Design will use non-corrosive and/or corrosion resistant material as required.

B. Exclude use of fraying or other material that could contribute to contamination in the LVEA and all other Clean Rooms.

C. Preclude ledges that may trap dirt and minimize oil leakage from mechanisms and mechanical equipment.

D. Consideration will be given to out-gassing and particle generation of the materials.

E. All materials will be compatible with the cleanliness requirements of the room's classification (e.g., Class 5,000~~1,000~~, Class 50,000, etc.).

7.1.8.3 Material Compatibility

As a design goal, all material selections should be made such that Non Volatile Residue (NVR) deposition, in the LVEA, does not exceed 0.5 mg/square foot/month in accordance with MIL-STD-1246.

7.2 Civil

7.2.1 General Civil Requirements

CivilThis section addresses the requirements includefor site preparation and earthwork, hydrology and drainage, roads and paving, parking, utilities, wastewater treatment and other site improvements. The A-E shall determine whether existing drainage, soil conditions, and subsurface conditions are adequate; or, how best to ensure adequacy for the least cost. Area contours shall be provided by Caltech's surveying Consultant for each site..

Careful attention will be paid in development of the site to the special needs of LIGO and of the individual site characteristics. Establishing and maintaining alignment are important considerations at both sites.

Caltech's Consultant shall provide soil conditions and allowable design parameters, through examination of existing records and performance of geotechnical investigations.

7.2.2 Coordinate Control

7.2.2.1 Global and Local Coordinate Systems

At each site their will be both a "Global Coordinate System", and five "Local Coordinate Systems". A Local Coordinate System will be established for each of the five Station Locations (i.e., Corner Station, 2 Mid Stations, and 2 End Stations). The Global Coordinate System (i.e., X_G, Y_G, Z_G) is dependent on the X_G, Y_G, Z_G system defined by the beam tube arms with the Z_G axis up.

Local coordinates (i.e., X_L, Y_L, Z_L) are determine by Z_L being plumb at each station, and the X_L and Z_L axes are in the same vertical plane as the longitudinal axis of the respective beam tube and Z_G.

7.2.2.2 Hanford

The intersection of the two beam tube arms is located at latitude 46° 27' 18.5"N and longitude 119° 24' 27.1"W. The northwesteast arm is at a bearing of N36.8°W and the southwest arm is at a bearing of S53.2°W from the corner station (LVEA). For further coordinate and site boundary information see Figure 7.2-1.

7.2.2.3 Livingston

The intersection of the two beam tube arms is located at latitude 30° 33' 46.0"N and longitude 90° 46' 27.3"W. The southeastnortheast arm is at a bearing of NS18°EW and the southwestwest arm is at a bearing of S72°W from the corner station (LVEA). For further coordinate and site boundary information see Figure 7.2-2.

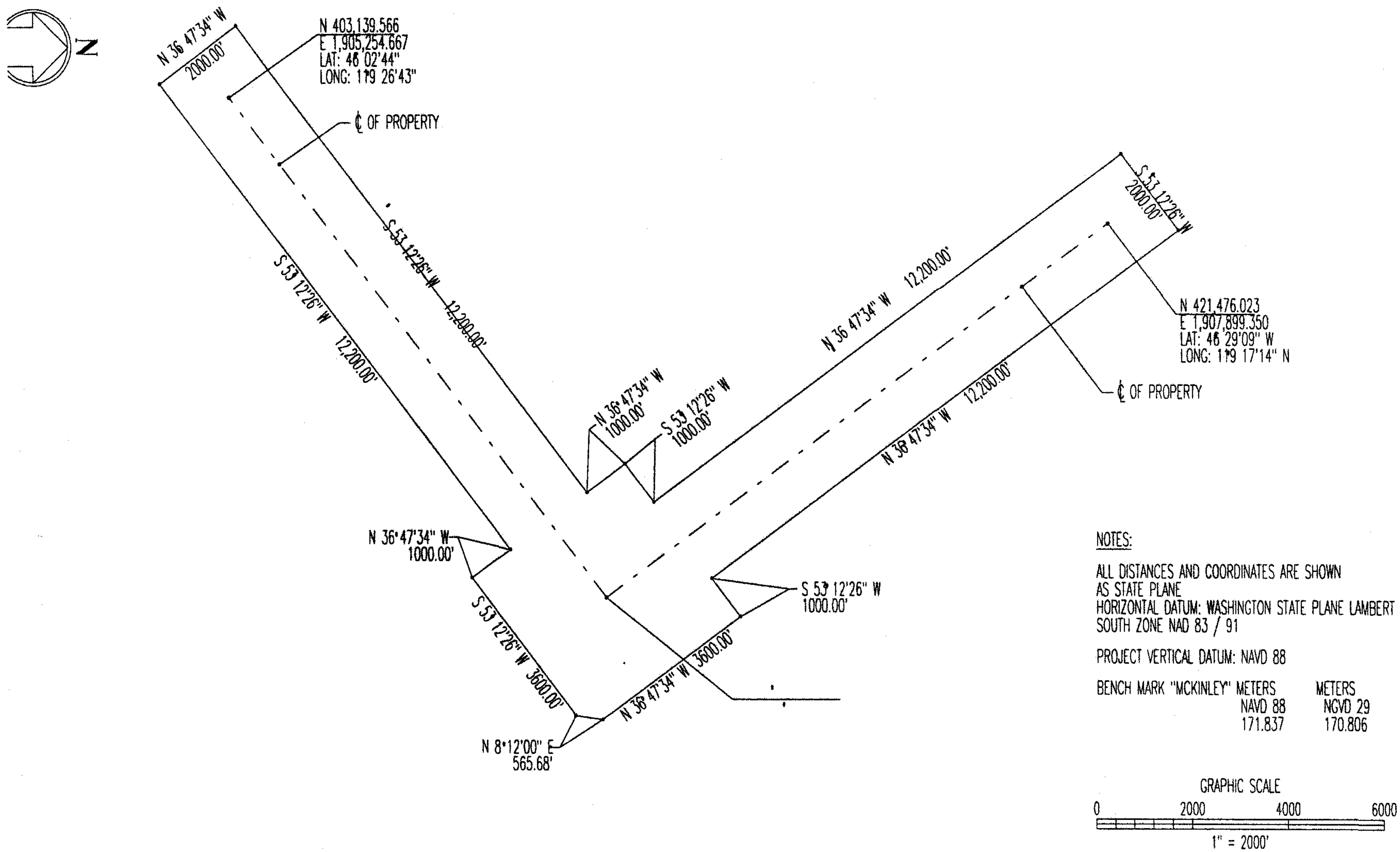

Figure 7.2-1 -- Hanford Property Boundaries (For Reference Only)

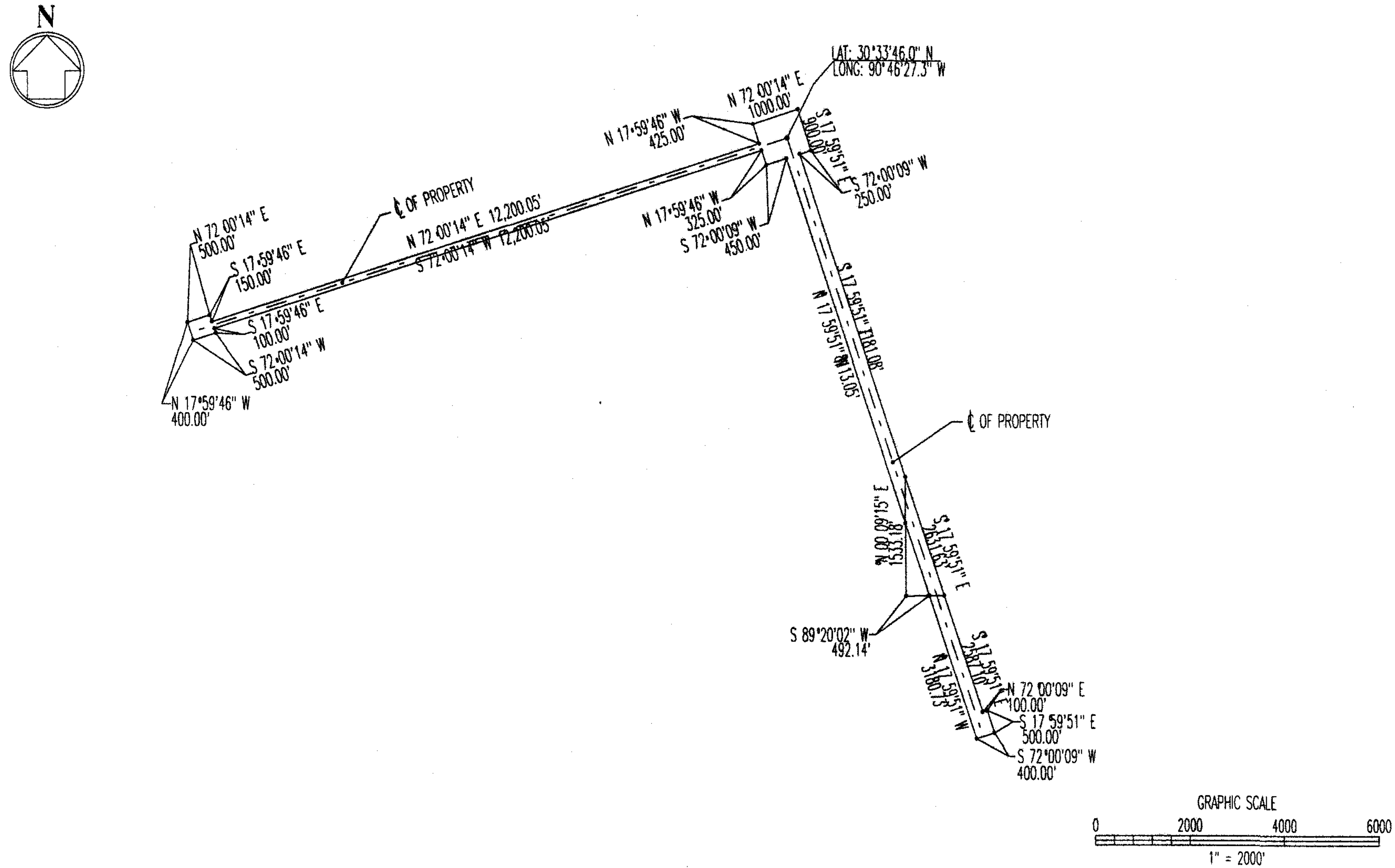

Figure 7.2-2 -- Livingston Property Boundaries (For Reference Only)

7.2.3 Site Preparation and Earthwork

Roads and graded areas shall be laid out to minimize environmental damage. Natural drainage patterns shall be maintained to the maximum extent possible. All site areas will be graded away from buildings.

Earthwork slopes and grading shall be in accordance with the recommendations of the geotechnical reports and the following:

A. Cut slopes shall be 1:2:1 for Hanford and 3:1 for Livingston Sites

B. Fill slopes shall be 2:1 for Hanford and 3:1 for Livingston Sites

C. Graded area pads shall be sloped 2% minimum for drainage

D. At Livingston a minimum freeboard of 3 feet shall be used above the 100 year storm level

E. The beam tube arm embankments form an "L" shape that will accommodate the LIGO interferometer arms. The two arms lie along two intersecting lines oriented perpendicular to one another, and which, in turn, define the plane of the interferometer. The beam tube arm embankments shall be flat graded with respect to this plane (as opposed to the normal grading practice that is relative to the earth's curvature). The orientation of this plane may be modified by $\pm 0.31 \times 10^{-3}$ radians with reference to a point within the square plane of the beam tube arms at which the local vertical is aligned along the normal to the interferometer plane in order to accommodate local topography and minimize earthwork. The direction of the component of the interferometer normal which lies in the local horizontal plane (at the center of the square) can point in any compass direction.

F. The beam tube embankment shall be designed to minimize settlement

7.2.4 Roads, Paving and Parking

The project roads shall consist of a main access road to the facilities and a perimeter road around the facilities that also tie-in to and the beam tube enclosure(s) service roads. Paved service roads along each arm provide access to the beam tube at 780 foot (237.74250 meter) intervals as well as access to the end and mid stations. For fire department access as well as access to the "backside" of the facilities during construction a road bridging of at least one beam tube will be required.

Parking for permanent staff and visitors will be provided. A frost penetration depth of 24 inches maximum and 12 inches average shall be considered for the Hanford design.

7.2.4.1 Roads

The road geometrics and cross-sectional design shall be in accordance with the following:

A. Roads shall be designed to positively drain with a minimum cross slope of 2% whenever possible.

B. Roads shall have a shoulder width of 4 feet (3 feet for beam tube service roads) with a cross slope of 4%.

C. Roads shall be two-lanes where possible

D. Road side slopes shall generally be 2:1 for Hanford and 3:1 for Livingston.

E. ~~Road~~ Corner radii shall be no less than 35 feet.

F. Road centerline radius shall be as required for site vehicles and construction equipment and deliveries (i.e. beam tube segments)

G. Road profile grades shall not exceed 6% whenever possible.

7.2.4.2 Paving

Paving design for the facility roads and parking areas shall be in accordance with the following:

A. The pavements shall be designed to provide ~~two-lane~~ all weather access.

B. All access and service roads shall be flexible pavement unless operational considerations dictate otherwise.

C. Axle loading for roads shall be AASHTO H-20.

D. California Bearing Ratio (CBR) value for pavement design shall be [per geotechnical reports]

E. Paving shall be as flat and smooth as possible. No speed bumps, manholes, lane divider bumps, grating, etc.

7.2.4.3 Parking

Parking spaces shall be provided and designed in accordance with the following:

A. Parking for the LVEA/OSB ~~main~~ facilities (corner station) shall be for:

1. 40~~{TBD}~~ employees (including maintenance vehicles)

2. 7{TBD} visitors

3. 2{TBD} handicap

4. 1{TBD} buses

B. Parking for the end station shall be for:

1. 5{TBD} employees (including maintenance vehicles)

2. {TBD} visitors

2. {TBD} handicap

C. Parking for the mid station shall be for:

1. 5{TBD} employees (including maintenance vehicles)

2. {TBD} visitors

2. {TBD} handicap

7.2.5 Site Drainage

All drainage systems shall be designed to properly drain all surface water that can cause damage to the facilities, property, and adjoining land. A storm frequency of 50100 years will be used for the design of all drainage structures.

7.2.5.1 Ditches

Sheet drainage to open ditches will be used to the maximum extent possible. Ditches side slopes at Livingston shall be no steeper than 3:1 to facilitate mowing and minimize erosion where required. Primary ditch work at Hanford has already been accomplished with ditch slopes at 2:1.

7.2.5.2 Pipes

Pipes or closed conduits will be used for drainage when open ditches interfere with the intended use of the area. Pipes shall be reinforced concrete.

7.2.5.3 Culverts

Culverts shall be provided under roads or the beam tube embankment and whenever the natural drainage pattern is interrupted. Culverts shall comply with the following requirements:

A. Minimum diameter = 24 inches

B. Preferred minimum gradient = 1%

C. Alignment shall be in the direction of storm flow and as nearly perpendicular to roads, embankments or obstructions as possible

D. The preferred culvert material shall be reinforced concrete pipe or concrete box sections

7.2.6 Utilities

The domestic water supply and the sanitary sewer system for the corner station (LVEA/OSB) shall be designed for a total work force of 40 {TBD} on day shift and 10 each on swing and graveyard {TBD} shifts. Fifty gallons per person per day shall be used as a basis.

Water and sanitary sewer requirements for the Mid-Stations and End Stations are 10 personnel (not concurrent with 40 at the Corner Station{TBD}. The firewater system will be designed in accordance with NFPA and local requirements.

7.2.6.1 Potable Water

A. Potable Water shall be provided from a well(s) located within the property limits {TBD} for Livingston and an existing well located near the end station of the southern arm for Hanford.

B. Potable Water shall be pumped to a pneumatic storage tank to accommodate facility requirements and to minimize well pump start/stops.

C. Based on water quality data from well tests the water may require treatment for potable use

D. Potable water shall be distributed from the tank to all facilities via an underground system.

E. The potable water distribution system shall be in accordance with the following:

1. Design velocity shall be 5 fps, with a maximum of 10 fps

2. Minimum earth cover of 3 feet

3. Backflow preventers will be provided at connections with the possibility of contamination.

4. Water supply shall be designed for the combined peak flow requirement

7.2.6.2 Firewater

A. Firewater shall be provided from a well(s) located within the property limits {TBD} for Livingston and an existing well located near the end station of the southern arm for Hanford.

B. Firewater shall be pumped to a storage tank to accommodate facility requirements and to minimize well pump start/stops and to provide the required fire water reserve necessary per code.

C. A standby diesel engine driven firewater pump shall be provided in case a complete power outage occurs

D. Fire hydrants will be strategically placed around the facility Corner, Mid and End Station Buildings. Hydrant spacing shall be 300 feet maximum. At branch lines to fire hydrants gate valves shall be provided. Fire hydrants are not required along the beam tubes.

E. If the buildings are equiped with sprinklers, post indicator valves will be provided at each building sprinkler connection.

F. Valving for fractional isolation of the fire water system will be provided if necessary.

7.2.6.3 Sanitary Sewer

Sanitary sewer pipelines will be designed in accordance with the following:

A. The minimum line size will be 6 inches diameter

B. Design velocity will be a minimum of 2 fps flowing at half depth or 3 fps when cleaning is difficult

C. Sewers will have straight runs between manholes (if manholes are needed)

D. Cleanouts will be used for changes in direction of minor sewer laterals and building connections

E. To help eliminate vibration sources, man holes shall not be located in road or parking lot surfaces or other traffic areas.

7.2.7 Wastewater Treatment Facilities

Federal, State, and local codes regarding collection, treatment and discharge of sanitary wastes will be met. Sewage collected from the LIGO facilities at Hanford will be treated by a septic tank system with disposal through a leach field system. Sewage collected from the LIGO facilities at Livingston will be processed through a package tertiary wastewater treatment plant with discharge to natural waterways. Sludge from both cases will be picked up by local contractors.

7.2.8 Miscellaneous Sitework

7.2.8.1 Solid Waste Disposal

Solid waste (trash) shall be collected by a locally contracted solid waste disposal firm from a facility location near the main road .{TBD}outside the 200 foot non critical traffic exclusion zone.

7.2.8.2 Security Fencing

Security fencing shall be limited to the area around the Corner, Mid, and End Stations and will consist of a 6 foot chain link fence (with 3 strands of barbed wire at the top at the Mid and End Stations only). Gated access from the main access road shall be provided. No guard station is required.

A standard "range" fence will be provided around the perimeter of the Livingston Site to keep out cattle and to some extent people. This will be simple metal T-posts with 3 strands of barb wire.

7.2.8.3 Pipeline Crossings

There are two oil company pipelines crossing the Livingston site. These pipelines will be protected or rerouted in a method in a manner acceptable to the oil companies and LIGO. {TBD}.

7.3 Structural

7.3.1 General Structural Requirements

7.3.1.1 Steel Design and Construction

Steel structures and components will be designed and constructed in accordance with the AISC Specification for Structural Steel Buildings, Allowable Stress Design and Plastic Design, and the AISC Code of Standard Practice for Steel Buildings and Bridges. All structural welding will be in accordance with AWS D1.1, A2.4 and A3.0.

7.3.1.2 Concrete Design and Construction

Concrete structures and components will be designed and constructed in accordance with ACI 318.

7.3.1.3 Concrete Reinforcing Steel

Steel reinforcement will conform to the requirements of ASTM A615, Grade 60. Detailing, fabrication and placement will be in accordance with CRSI-1.

7.3.1.4 Masonry Design and Construction

Masonry structures and components will be designed and constructed in accordance with ACI 530.

7.3.1.5 Inspection Requirements

Inspection requirements, along with acceptance criteria, for steel and concrete structures and components will be clearly specified by the A-E in the drawings and specifications.

7.3.2 Loading Conditions

Structural systems and components will meet or exceed the requirements of both ASCE 7-88 (formerly ANSI A58.1) and the UBC code for Hanford or Standard Building Code (SBCCI) for Livingston.

7.3.2.1 Minimum Floor Live Load

The minimum floor live load will be as follows:

A. 250 psf for storage and receiving areas

B. 100 psf for control room, shops and LVEA areas

C. 50 psf for office area

7.3.2.2 Seismic Load

A. Seismic loads will be applied and the structure analyzed using one of the methods described in the UBC for the Hanford site. Seismic loads will be applied and the structure analyzed using the equivalent static method per SBCCI for the Livingston site.

B. At the Hanford site, the structure is located in seismic zone 2B per UBC. At the Livingston site, the seismic classification is Hazard exposure group I, performance category A, per SBCCI.

7.3.2.3 Wind Loads

Wind loads, for the Hanford site, will be determined in accordance with UBC using a design wind speed of 70 MPH, exposure C and importance factor I. Wind loads, for the Livingston site will be determined in accordance with SBCCI using a design wind speed of 100 MPH, exposure C and importance factor I.

7.3.2.4 Forklift Loads

A 10~~25~~,000 pound capacity forklift will operate anywhere within the following areas of the Corner, Mid, and End Stations. ~~boundaries of the facility~~.

~~7.3.2.5 Interior Vehicular Surface Loads~~

~~The following interior areas will be designed per AASHTO H-20.~~

- Shipping and Receiving
- Inspection Area
- Cleaning Area
- LVEA

7.3.2.5 Volcanic Ash Loads

The Hanford site structures will be designed for a volcanic ash load of TBD psf.

7.3.2.6 Load Combinations

Load combinations will be in accordance with the UBC for the Hanford site and SBCCI for the Livingston site.

7.3.2.7 Serviceability Requirements

A. Deflections due to live load, wind or seismic will be limited as follows:

1. Maximum allowable live load deflection will be L/240, except for elements supporting plaster ceilings or wall in which case the maximum will be L/360.

2. Seismic lateral drift will meet or exceed the requirements 0.005 times the story height.

B. Vibration Transmission: The structure will be designed so as to minimize transmission of vibration to the LVEA foundation. See Section 7.7 for additional information on Vibration.

7.3.2.8 Beam Tube Foundation and Enclosure Requirements

A. Initial beam tube slab "straight line" variance of finish floor will be limited to ±1/2 inch for the entire length of all beam tube arms (Distance = 4 km).

B. Initial slab "straight line" variance of finish floor will be limited to ±1/4 inch in 10 feet.

C. The foundation at the beam support must be constructed to a tolerance of ±1/2 inch between the successive supports (about 65 ft).

D. The long term differential settlement is limited to ±0.8 inches with reference to the beam tube axis~~laser line~~. Any excessive differential settlement above the 0.8 inches may have to be taken care of by adjustments in the beam tube supports.

~~E. Any excessive differential settlement above the 0.8 inches may have to be taken care of by adjustments in the beam tube supports.~~

E. End flanges or valves were atmospheric~~vacuum~~ pressure can exist on one side only, will require support from the foundation to react to the entire force due to the differential pressure.

F. Beam Tube Enclosure and doors at entrances to the beam tube enclosure will be capable of stopping penetration of a stray bullet. The parameters to be used are as follows.

Item	Property
Caliber:	308
Weight:	180 Grains
Velocity at Impact:	2900 Feet Per Second
Energy at Impact:	2800 Foot-Pounds
Material:	Lead Core, Fully Jacketed with Copper

7.4 Architectural

The LIGO Project is comprised of a facility for the Corner Station containing a cleanroom for the Laser Vacuum Equipment Area (LVEA), with support areas for maintenance and administrative functions. Other facilities are the beam tube enclosures, Mid and End Stations, and utility buildings for conditioned air, power and water/waste treatment. These structures are to be located at both Hanford, Washington and Livingston, Louisiana. ~~The only difference is~~ The Mid Station at Livingston will be replaced with a mid-point Pump Station that does not house any special vacuum equipment chambers.

7.4.1 Life Safety

The LIGO Project will be designed in accordance with ~~UBC, SBC, and NFPA 101. These codes and standards ar~~the Uniform Building Code (UBC) for the Washington facilities, and the Standard Building Code (SBC) for the Louisiana facilities. These codes will be followed to provide emergency exits and exit access ways as applicable for all facilities including the beam tube enclosures.

7.4.2 Finishes

A. All architectural finishes shall be compatible with internal and external environments described in Section 7.4.2.1 and 7.1.8.3

B. All paints and coatings shall conform to the States of Washington and Louisiana local Air Pollution Control District requirements respectively.

7.4.2.1 Floor Finishes

A. Interior concrete floor surfaces for LVEA shall have seamless flooring which meet the clean environment requirements.

B. Other exposed interior concrete floor surfaces ~~have a smooth steel trowelled finish,~~ shall have a smooth, steel trowelled finish with a surface hardener.

C. Control room and computer spaces shall have anti-static access flooring with carpet.

D. Offices, lobby and receptionist areas shall have carpet.

E. All other interior spaces shall have resilient floor tile~~. T~~ except the toilet facilities which shall have ceramic tile.

F. Exterior concrete floor surfaces shall have a broom finish. Special concrete finishes shall be designated for the main entry to the ~~Corner Station~~Operations Support Building.

G. Joint filler and sealer materials are resistant to the effects of the induced environment as required shall be used.

H. Areas housing computer racks shall have non-conductive flooring.

7.4.2.2 Walls

A. Exterior walls will be proven architectural materials and will be insulated, weather resistant materials providing an air- and water-tight, maintenance free enclosure.

B. Exterior walls are TBDshall durable, minimally maintenance materials with an expected minimum life expectancy of 30 years.

C. Precast concrete arches shall be used for the beam tube enclosures.

D. Interior walls for the "clean areas" are smooth, non-sheashall be smooth, non-shedding, and compatible with Class 5,0001,000 and 50,000 clean environments respectively.

E. Interior walls for administrative and maintenance areas are standard gypsum board and metal stushall be a standard demountable wall system. metal stud and gypsum board construction with a three coat paint finish.

F. Interior walls for toilet areas are Water Rshall be water resistant (WR) gypsum board and metal stud construction with ceramic tile.

7.4.2.3 Ceiling Finishes

A. Ceilings shall be suspended type or acoustical tile in general areas such as offices, lobby and computer rooms.

B. Suspended hard-surfaced ceilings shall be used in the clean areas will be in areasto be compatible with Class 5,0001,000 or 50,000 clean environments respectively. Materials shall be selected as required to meet acoustic requirements as described in Section 7.8 Acoustics.

C. Other areas, such as toilet facilities, locker rooms, and janitors rooms, shall be suspended hard surfaced ceilings.

D. Exposed ceiling/roof structure shall be used in other areas such as shopas Shipping/Receiving, shop areas, and utility spaces.

E. WRater resistant (WR) gypsum board will not be used for ceiling applications.

7.4.2.4 Painting -- General

A. All exposed and untreated materials requiring protection shall be field painted.

B. Surfaces shall be finished, cleaned and dry prior to receiving painting.

C. Materials shall be primed with one coat 0.5 mils dry film thickness of paint primer.

D. Materials shall receive one intermediate coat and one finish coat of paint. The intermediate coat shall be a different color than the finish coat. Each coat shall be a minimum of 3 mils dry film thickness.

E. Surfaces not to be painted:

1. Concrete floors

2. Glass

3. Masonry, unless specified

4. Precast concrete, unless specified

5. Factory finished items

6. Items specified in construction documents as surfaces not to be painted

F. All colors shall be selected in accordance with the color palette as established by the architect and the Caltech Technical Representative. The finish coat of all painted interior clean room surfaces shall be white.

7.4.2.5 Painting (Metals), Shop and Field

A. All exposed ferrous and nonferrous metal such as used for flashing, railings, louvers, doors and frames (including copper and galvanized surfaces) to be installed shall be shop or field painted.Ferrous metal surfaces preparation shall be in accordance with Steel Structures Painting Council (SSPC) specifications.

B. Blast cleaning shall be in accordance with SSPC-SP-10. In areas where sand blasting is not allowed, surfaces shall be prepared in accordance with SSPC-SP-2 and/or SSPC-SP-3.

C. Ferrous metals shall be painted with one coat, 3 mils dry film thickness

D. Nonferrous metals shall be prime coated with 0.5 mils dry film thickness of primer.

E. All ferrous and nonferrous metals shall receive one intermediate coat and one finish coat. The intermediate coat shall be a different color than the finish coat. Each coat shall be a minimum of 3 mils dry film thickness.

F. Surfaces not to be painted:

1. Air terminals (Lightning Protection System)
2. Ladder rungs
3. Chain rails and hoist points
4. Bridge crane wheel/wire rope/rail interfacing surfaces
5. Lightning connectors/down cable isolation blocks
6. Stainless steel, brass and bronze
7. Top surface of aluminum floor plates
8. Aluminum handrails
9. Handrail post sockets
10. Wear surfaces of hinges or mechanisms
11. Winch cable drums
12. Factory finished items

~~7.4.2.5.1 Colors~~

A. ~~All colors will be in accordance with the color palette as established by the architect and the Caltech Technical Representative. The finish coat of all painted interior clean room surfaces is white~~All colors shall be compatible with the color palette established as stated in the Section for Painting - General.

7.4.2.6 Caulk and Sealant

Caulk/tape/sealant used in each type of cleanroom shall be compatible with the classification of the cleanroom environment.

7.4.3 Clean Room Interior Design

To ensure that the LVEA meets clean environment requirements of Section 7.5.2.1 the interior surfaces of these areas will be designed to the following criteria:

A. Minimize horizontal ledges and surfaces

B. Fully enclose all structural shapes

C. Line all necessary pockets and recesses with cleanable shapes

D. Cove all inside corners

E. Provide seams that will not retain soil or dust

F. Provide smooth, non-flaking and washable surfaces and finishes

G. Provide closed chases for pipes and conduits where possible

H. Provide access for cleaning all surfaces

I. Provide flush/surface mounted lighting fixtures

7.4.4 Doors - General

A. The clean room door opening mechanisms design will minimize the amount of contaminants generated by their operation.

B. All doors in the clean room perimeter walls will be equipped with weather-strips and seals in order to minimize air leakage/loss from clean environments and contamination.

7.4.4.1 Equipment Doors

A. All equipment doors will be 6'-0" wide by 7'-0" high, 1-3/4" thick, insulated hollow metal doors

7.4.4.2 Large Access Doors

A. All large access doors will be power actuated (with provisions for manual override), insulated at exterior exposures, and~~exposures, and~~ will provide a finished clear opening of 14'~~1'-0"~~ ~~TBD~~ wide by 14'~~and 18~~30'~~-0"~~ high inside the OSB or between the OSB and LVEA; and 16' by 24' high from the LVEA to the outside~~TBD wide~~. See Section 7.6.11 for door control requirements.

B. Large access doors to the cleaning area and LVEA shall be rapid close type to reduce loss of "clean" environment.

C. All large access doors will be installed per NFPA 80.

D. In closed position, all edges of large access doors shall be sealed to prevent infiltration of outside air, insects, animals, and dust; and prevent pressure loss from interior spaces.

7.4.4.3 Personnel Doors

A. Personnel doors will be 3'-0" wide x 7'-0" high insulated hollow metal doors.

B. All doors will be 1-3/4" thick.

C. UBC, SBC, and NFPA requirements will be applied when fire rated doors are required.

D. Door hardware will comply with Industry Codes and Standards.

E. Specialized door hardware will include automated entry control and intrusion detection devices, door mounted combination locks, deadbolts and padlocks, lever type hardware, exit hardware, electric strikes/latches, electric power transfers, heavy duty door closers meeting vibration requirements, lock cylinders, sound or weather seals, automatic door bottoms, hinges with non- removable pins, and associated equipment.

~~F. Lever type door handles shall be used.~~

~~F. "Soft close" mechanisms shall be used where required to meet vibration requirements.~~

7.4.4.4 Thresholds

Thresholds will be flush with the floor.

7.4.5 Roofs and Gutters

Roofing design for structures will meet the requirements of UBC and SBC. Roof penetrations will be eliminated if at all possible. Rain gutters and/or roof drains with overflow drains will capture all roof runoff and direct it to an appropriate storm drain system. Precautions shall be taken to guard against effects of rain water runoff in gutters causing vibration transfer to the LVEA area.

7.4.6 Energy Conservation

"U" values for roofs and exterior walls will be determined in accordance with the governing state codes for energy conservation, or with ASHRAE design guidelines.

7.4.7 Specific Area Requirements

7.4.7.1 Laser and Vacuum Equipment Area

~~A.~~ ~~The Laser and Vacuum Equipment Area (LVEA) is approximately 65,000 square feet for the Hanford, Washington site and 40,000 square for the Livingston, Louisiana site.~~

A. The LVEA is accessible via the Change Room for staff and through the Cleaning Area for equipment.

B. The LVEA ceilings have heights to accommodate overhead crane systems to facilitate movement of equipment components for repair, maintenance, and replacement.

C. LVEA floors have a durable surface to withstand occasional fork~~high~~lift traffic, a noise reduction capability, reduce vibration, and a seamless covering to maintain the cleanroom classification.

D. LVEA walls have a durable, cleanable surface of an inorganic, and a non-gassing finish to maintain the cleanroom classification.

E. Catwalks, platforms, and other surfaces that have traffic will be made of material, or be surfaced with material, that will help mitigate production of acoustic or vibration transmissions to the laser or vacuum equipment.

~~7.4.7.2 Cleanroom~~

~~A.~~ ~~The Cleanroom is approximately 500 square feet (minimum), and directly accessible to the LVEA via the Inspection and Cleaning Area and an airlock/anteroom.~~

~~A.~~ ~~The room has a Class 1000 cleanroom rating.~~

~~A.~~ ~~An access door with a minimum size of TBD wide x TBD high is provided to allow direct access from the Inspection and Cleaning Area to the Clean Room.~~

~~A.~~ ~~The flooring is seamless sheet vinyl or liquid epoxy coating. Walls are gypsum board with an epoxy coating.~~

~~A.~~ ~~The ceiling height is TBD (maximum). The ceiling material is suspended gypsum board with an epoxy coating.~~

A. Provision will be made for installation of laminar flow workstations within these spaces which will maintain local workspaces at Federal Standard 209D Class 100 or better conditions.

7.4.7.2 Optics Lab

A. The Experimental Equipment Area is approximately 1600 square feet and adjacent to the TestOptics Lab 600 square feet and adjacent to the Vacuum Prep and Assembly Lab, and Cleaning Area.

B. Materials and finishes are durable and cleanable. Floors are resilient flooring. Walls and ceilings are painted gypsum board.

C. The lab will be a Class 5000 cleanroom with a Class 100 vertical laminar flow bench(s) for assembly of objects up to 1 meter cubed and weighing up to several hundred kilograms

7.4.7.3 Vacuum Prep and Asssembly Lab

A. The Testing Area (TA) is approximately 1200 square feet Vacuum Prep and Assembly Lab Area is approximately 600 square feet adjacent to the Optics Lab and accessible to the Inspection and Cleaning Areas.

B. Materials and finishes are durable and cleanable. Floors are resilient flooring. Walls and ceilings are painted gypsum board.

C. The lab will be a Class 5000 cleanroom with a Class 100 vertical laminar flow bench for assembly of objects up to 1 meter cubed and weighing up to several hundred kilograms

7.4.7.4 Receiving, Shipping, and Inspection, and Cleaning Areas

A. Receiving, Shipping, and Inspection, and Cleaning Areas are approximately 850800 square feet each in size and immediately adjacent to the LVEA.

B. The ceiling height is 30'-0". TBD (maximum)(minimum).

C. An overhead equipment door is provided to allow direct access to the LVEA from the Inspection and Cleaning Area with access to the Cleanroom via an anteroom/airlock.

D. An additional overhead equipment door is provided from outside the LIGO facilities for access and deliveries via the loading dock.

E. Materials and finishes are durable and cleanable. Concrete floors are sealed. Walls and ceilings are painted gypsum board.

F. Movement of large objects from the loading dock to the Cleaning Area shall be by an overhead monorail and crane.

7.4.7.5 Computer and Mass Storage Room and Computer Users Room

~~A. The Computer Room and Computer Users Room is adjacent and accessible to the Control Room and Experimental Testing Area.~~

A. The Computer Room and Mass Storage Room, Tape Room, and Computer Users Room are a approximately 500 square feet each and accessible to the Control Room.

B. Floors are 24" raised access floor system and carpeted for control of noise.

C. Walls are painted gypsum board. Ceiling height is 10'-0" minimum and suspended acoustical tile system.

D. A single door is provided to allow access for personnel and equipment to each space.

7.4.7.6 Control Room

A. The Control Room is ~~djacent and accessible to the LVEA via the Clothing Change Room~~approximately 850 square feet, located near the LVEA.

B. Floor shall be a 24" raised- access floor system~~.~~ and carpeted for noise control.

C. Walls are painted gypsum board. Ceiling height is 10'-0" minimum and suspended acoustical tile system.

D. A single door is provided to allow access for personnel and equipment.

E. Control Room is provided with a fire detection and suppression system that will use a gaseous suppression system that is compatible with the occupancy and type of equipment installed.

7.4.7.7 ~~Clothing~~ Change/Smock Room

A. The ~~Clothing~~ Change Room accommodates 10 personnel, shall be approximately 150 square feet (minimum), and is directly accessible to the LVEA as controlled by the Control Room.

B. The room is equipped with ~~40 lockable 12" wide x 24" deep x 36"~~ storage cubicles and portable benches. Cubicles shall be used for clean smocks, booties, gloves and other necessities for cleanroom entry and work. Disposal bins shall also be provided.

C. A single door is provided to allow access for personnel and a pass-through for "clean" objects.

D. The flooring is sheet vinyl with a coved base.

E. The ceiling height is 8'-0" minimum and is painted gypsum board.

7.4.7.7 Beam Tube Enclosures

A. Enclosures are archedis ~~arched~~, precast concrete structures cast in ten feet long modules, approximately 6 inches thick and with a radius of approximately ~~TBD~~9'-0".

B. Service access to the enclosure is at a maximum of every 850 feet (250 m).

C. Emergency access to the enclosure is at a maximum of every 300 feet (90 m) ~~(300 ft)~~ as required by the UBC Section 1003.4, Travel Distance.

D. The enclosure is ventilated to control excess humidity and is provided with utility power.

E. Floors are sealed concrete and sloped to a floor drain.

F. The structure is water tight, vermin and insect proof, and resistant to bullets (see section 7.3.2.8).

7.4.7.8 Mid-Station Facilities

Facility areas shall follow height and material criteria for like spaces of the Corner Station.

7.4.7.9 End-Station Facilities

Facility areas shall follow height and material criteria for like spaces of the Corner Station.

7.5 Mechanical

7.5.1 General Mechanical Requirements

7.5.1.1 Mechanical System and Component Identification

Mechanical system and component identification comply with the requirements stated in ANSI A13.1 for lettering, colors, band widths, marker locations, and viewing angles.

7.5.1.2 Wind Loads

All exposed mechanical equipment and plumbing piping systems are to be designed to withstand wind loads as specified in ASCE 7-88.

A. For non-critical systems, the Importance Factor equals unity.

B. For critical systems, the Importance Factor equals 1.1~~1~~.

7.5.1.3 Corrosion Control

Corrosion control measures include cathodic protection systems, copper-finned coils and tubes, as well as, the use of protective coatings.

A. The use of protective coatings will be in accordance with NACE-RP-02-75.

B. Protection will be provided against corrosion caused by galvanic action due to physical contact of dissimilar metals.

7.5.1.4 Factory Paint

A. Unless otherwise specified, all ferrous and nonferrous metal to be installed inside the facility will have surfaces prepared in accordance with SSPC-SP-10 and shop primed with two-part, organic zinc rich epoxy for ferrous metals, or organic zinc rich chromate primer for non ferrous metals.

B. Field painting will be in accordance with Section 7.4.2.4.

7.5.1.5 Vibration Control

A. All major pieces of rotating ~~pieces of~~ equipment will be statically and dynamically balanced as a complete assembly.

B. Maximum displacement amplitude of any major piece of rotating ~~piece of~~ equipment will be 2 mils peak-to-peak, at all steady state operating speeds.

7.5.1.6 Motors

All motors will be high-efficiency type, non-overloading in accordance with Section 7.6.2. The HVAC fan motors will be synchronous type motors with position/phase control between the motors located within a single mechanical room. The fans will have adjustable pitch blades to control air flow velocity. The HVAC fans and motors will be skid mounted to permit each fan and motor pair to be vibration isolated from the mechanical room foundation.

7.5.1.7 Safety Requirements

Provide the following safety requirements:

A. Belts, pulleys, chains, gears, protruding set screws, keys and other rotating parts will be fully enclosed or properly guarded in accordance with OSHA 29 CFR 1910.219.

B. High temperature equipment and piping so located as to endanger personnel or create a fire hazard will be properly guarded or covered with insulation.

C. Where required for safe operation and maintenance of equipment, provide such items as catwalks, platforms, ladders, and guard rails.

7.5.1.8 Redundancy

A. Provide redundancy by including a standby unit for all critical areas which are served by only one air handling system.

B. For air handler units (AHUs) supplying air to Clean Rooms (i.e., LVEA, Clean Room, etc.), there will be one standby for each area. Redundant critical components are an acceptable alternative to providing complete redundant AHUs.

C. For chillers, boilers, pumps and air compressors, there will be at least one standby unit.

D. All redundant equipment will be provided with automatic start capability, with manual override.

7.5.2 Heating, Ventilating, and Air Conditioning Systems

The Heating, Ventilation and Air Conditioning (HVAC) systems will be designed for optimum energy conservation and operational cost. Centralized automatic control and system surveillance will be provided by the facility control and data acquisition system. In response to the strict vibration and acoustic requirements imposed by the interferometers, the HVAC system will incorporate the following features:

A. The location of machinery, chiller plants, high-velocity exhausts, etc. will be chosen to limit ~~atmospheric~~ transmission of vibration and noise.

B. Equipment will be provided with vibration isolators and flexible connectors for ducts, electrical conduits, and piping to avoid structural transmission of vibrations and acoustic noise.

C. Diffusers, grills, fans, heating and ventilating units, and other equipment will be carefully selected to meet or exceed the noise criteria for the serviced area

D. Excessive velocity and turbulence in ducts and piping will be avoided everywhere.

E. To limit noise transmission through the ventilating ducts, intra-duct acoustic attenuators will be installed, where necessary.

7.5.2.1 Design Conditions

7.5.2.1.1 Climatic Design Criteria

Environment	Hanford	Livingston
Nearest Town	Richland, WA	Baton Rouge, LA
Latitude	47 N	30 N
Longitude	119 W	91 W
Elevation	532 ~~392~~ ft above sea level	60 ~~65~~ ft above sea level
Summer Outdoor Design Temp	96 °F_{db}, 68 °F_{wb}	93 °F_{db}, 80 °F_{wb}
Daily Temp Range	30 °F	19 °F
Winter Outdoor Design Temp	5 °F_{db}	25 °F_{db}
Clearness Number, Summer Clearness Number, Winter	1.05 0.95	0.9 0.9
Design Wind Velocity, Summer Design Wind Velocity, Winter	3.6 mph 15 mph	7.5 mph 15 mph

Table 7.5-1 -- Climatic Design Criteria

7.5.2.1.2 Inside Design Conditions

Space	Design temperature	Air flow rate
Vacuum equipment operating (HI- and Lo-bay areas)	72 ± 2 °F, 40 ±5% RH 0.15" wg above outside ambient	10 to 15 Ach/Hr (clean air class 50,000)
Laminar flow work benches	72 ±2 °F, 40 ±5% RH 0.05" wg above adjeacent area	45 Ach/Hr (clean air class 100)
Operation area clean rooms	72 ±2 °F, 40 ±5% RH 0.05" wg above adjeacent area	30 Ach/Hr (clean air class 5,0001,000)
Interferometer Optic work and electronic shop areas.	72 ±2 °F, 40 ±5% RH 0.05" wg above adjacent area	30 Ach/Hr (clean air class 5,0001,000)
Interferometer optic work and electronic shop areas.	72 ±2 °F, 40 ±5% RH 0.05" wg above adjecent area	30 Ach/Hr (clean air class 1,000)
Electronic shop areas.	72 ±2 °F, 40 ±5% RH adje0.05" wg above adjacent area	30 Ach/Hr (clean air class 5,0001,000)
Inspection Area, Cleaning Room, and Smock Room	72 ± 3 °F, 40 ±5% RH 0.01" wg above adjeacent area	2 cfm / sf
Central Control Room, Racks, and Data Archives Room	72 ± 3 °F, 40 ±10% RH,	1.5 cfm / sf
Receiving and Shipping Area	75 ±5 °F	1 cfm / sf
Offices	72 ±3 °F	1.5 cfm / sf
Main Lobby	72 ±3 °F	1.5 cfm / sf
Conference Room	72 ±3 °F	1.5 cfm / sf
Electrical Equipment Room	80 to 60 °F	As required
Utility and Mechanical Rooms	80 to 60 °F	As required
Boiler Room	10° F above ambient summer max; 55 °F min winter	As required
Break Room	75 ±5 °F	1 cfm / sf
Toilets	72 °F	2 cfm / sf exhaust
Beam Tube Enclosure	No special temperature required, maintain less than 70% 30 to 50% RH and 0.101" wg above ambient	Minimal

Table 7.5-2 -- Inside Design Conditions

7.5.2.2 Space Humidity Requirements

A. All occupied spaces inside the facilities at Hanford will have a humidity range from 0 to 60% RH.

B. All occupied spaces inside the facilities at Hanford will have a humidity range from 0 to 70% RH.

7.5.2.3 Insulation Systems

All thermal insulation systems materials will be noncombustible as defined by ANSI/NFPA 220.

7.5.2.4 Penetrations

A. Perimeter (exterior walls and roof) penetrations will be protected in accordance with Section 7.1.7.1.

B. Effective sound stopping, vapor, dust, and vermin sealing, and adequate operating clearances will be provided to prevent structure contact where ducts and pipe penetrate walls, floors, or ceilings into occupied spaces.

7.5.2.5 HVAC Air Systems

HVAC air systems design will comply with the Uniform Mechanical Code (UMC) for Hanford and the Standard Mechanical Code (SMC) for Livingston; applicable SMACNA publications, including but not limited to, HVAC Duct Construction Standards - Metal and Flexible; Rectangular Industrial Duct Construction Standards; Round Industrial Duct Construction Standards; Accepted Industry Practice for Industrial Duct Construction; HVAC Systems Duct Design; and HVAC Air Duct Leakage Test Manual.

7.5.2.5.1 Air Handling Units

A. Air handling units will have automatic restart capability in the event of site power failure.

B. Air handling units will not be mounted on the roof, and other roof penetrations will be avoided.

C. Refrigerant coils will not be used in clean room system, since CFC is a contaminant itself.

7.5.2.5.2 Ductwork

Ductwork (See Section 7.1.8.3) will conform to the following requirements:

A. Duct system will be capable of withstanding static pressure variation +10%, and without pulsating.

B. Waveguide devices will be provided at duct penetrations through all EMI shielded walls, ceilings, and partitions.

C. Fire dampers will be provided at duct penetrations through fire rated walls, ceilings, and partitions.

7.5.2.5.3 Air Filters

A. All filters will be fire resistant type, nonallergenic, and nontoxic, with no detectable odors.

B. Dry filter gaskets will be closed-cell foamed neoprene or urethane elastomer of sufficient hardness to compress not more than 40 percent of original thickness when the filter is in position.

C. High-Efficiency Particulate Air (HEPA) Filter:

   1. HEPA filters will be capable of withstanding minimum 90% relative humidity determined dynamically between 70 and 100 degrees.

   2. HEPA filters will bear numbered Underwriter's Laboratories label certifying the filter is UL 586 classified.

   3. HEPA filters will provide, as a minimum, a 99.97% overall efficiency on 0.3 micron particles.

   4. Dioctylphalate (DOP) tested HEPA filters are not acceptable. DOP mist is a contaminant.

   5. HEPA filters will be located downstream of supply air fan system.

7.5.2.5.4 Humidifiers

A. Humidifiers may be electric, evaporative, or clean steam.

B. Electric and evaporative humidifiers will utilize reverse osmosis water as water source.

C. Electrode/jug type humidifiers are not acceptable.

7.5.2.6 HVAC Hydronic Systems

7.5.2.6.1 Chillers

A. In general, each chiller will be a complete, factory tested, water chilling package consisting of compressors, capacity control system, water cooler, refrigerant condenser, starters, disconnect, and steel base.

B. Chillers will be rated in accordance with ARI 540.

C. Chillers will comply with the ASME Code, Section VIII.

D. Control panels will be provided integral to the chiller unit.

E. Control panels will have the capability to interface with the HVAC and Control System (See Section 7.5.6.2).

F. The chillers will operate smoothly within the 15% to 100% capacity range without surge or vibration.

G. The chillers will have an automatic restart capability in the event of site power failure.

7.5.2.6.1.1 Chlorofluorocarbon Limitation

A. The contractor will supply the most cost-effective chiller type using an acceptable alternate refrigerant (No CFCs) as allowed by the Clean Air Act.

B. Comply with the refrigeration equipment room requirements specified in ASHRAE Standard 15-1992, and safety classification of refrigerants based on ASHRAE Standard 34-1992.

C. No refrigerant will be present inside the clean air flow stream, by design, single point failure, or accident.

7.5.2.6.1.2 Condensers and Cooling Towers

A. Air or water cooled condensers are acceptable.

B. Water cooled condensers will reject heat through induced draft type cooling towers.

C. Towers will be of noncombustible construction and conform with NFPA Standard 220 requirements.

D. Design and construction of steel members will conform to AISC S326.

7.5.2.6.2 Boilers

A. Provide packaged, steel water tube boilers for producing hot water including all necessary Local Code trim and appurtenances.

1. Boilers will have State approval, UL listed and be designed, constructed, and labeled for the design working pressure in accordance with the latest edition of the ASME Power Boiler Code.

2. Boilers will be factory assembled, factory tested, self-contained, easily transported, ready for automatic operation except for connection of water, fuel, electrical and vent service.

3. Diesel fuel is not an acceptable energy source.

4. Provisions will be made for collection and storage of boiler blowdown water.

5. Boilers will have an automatic restart capability in the event of site power failure.

6. Boilers will be of the multiple quick recovery type producing hot water.

B. Locate boilers separately from the rest of the HVAC equipment as required by the UBC for Hanford and the SBC for Livingston.

7.5.2.6.3 Water Treatment

Water treatment system, equipment to be based on site water tests, will be furnished to provide a source of treated water for boiler, humidifier, condenser and chilled water makeup.

7.5.2.6.4 Pumps

A. Pump will be capable of accommodating static pressure variations of plus or minus 10%.

B. Pumps will have an automatic restart capability in the event of site power failure.

7.5.2.6.5 Chilled Water, Condenser Water, and Heating Water Piping

A. Piping will be as a minimum Schedule 40 black steel conforming to ASTM/ANSI A53.

1. Fittings will conform to:

a. ANSI B16.3, minimum Class 150; and,

b. ANSI B16.9; ANSI B16.5; or, ASME Boiler and Pressure Code, Section VIII.

2. Fittings 2" and smaller may be threaded.

B. Piping 4" and smaller will be copper ASTM/ANSI B88, hard drawn, Type K (underground and exposed use) and Type L (aboveground and concealed use).

C. Copper fittings will comply with ANSI/ASME B16.29; joints, ANSI/ASTM B32, solder grade 95TA.

D. Route piping parallel with building lines with branch runs extended from the top of the mains and with pipe transitions in the eccentric to avoid cavitation and facilitate venting of air.

E. Provide vents at high points and drains at low points.

F. Provide unions or flanges at equipment connections to facilitate removal and maintenance.

7.5.2.6.6 Valves

A. Valves will be angle, ball, check, gate, globe, and automatic or manual balancing types.

1. Valves will have rising stems and open when turned counterclockwise.

2. Provide valves to permit isolation of branch piping and each equipment item to permit balancing of the system.

3. All valves 2" or smaller will be ball valves.

B. As a minimum, manual and control valves will conform to the following:

1. Bronze Gate, Check: MSS SP80.

2. Cast Iron Gate: MSS SP70.

3. Butterfly: MSS SP67, ASTM A126, and ANSI B16.1.

4. Ball: FED-STD WW-V-35 or MSS SP72, Class 150, flanged.

5. Cast Iron Check: MIL-V-18436, Class 125.

6. Globe and Angle: MSS SP80.