LASER INTERFEROMETER GRAVITATIONAL WAVE OBSERVATORY
- LIGO -
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Interface Control Document (ICD): LIGO System & Detector (DET) - Civil Construction (CC)

Title

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TBDs/TBRs to be resolved by Detector/Systems Engineering:

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3.2.1.1.4 3.2.2.1.3 3.2.3.1.3	Specify number, locations and details of interior survey monuments	6/1/96
3.2.1.4.2 3.2.2.4.2 3.2.3.4.2	Revise/finalize power demand after VE FDR	5/25/96
3.2.1.5	Define the data/software interface between the FMCS logged state-vector data and the CDS Monitoring and Control System	10/1/96

TBDs/TBRs to be resolved by CC:

Section	*Subject*	*Due Date*
3.2.1.1.1 3.2.2.1.1 3.2.3.1.1	Review buried signal wire conduit stub-up locations	5/1/96
3.2.1.1.5	Review stay-clear zone for inter-building buried cabling	5/1/96
3.2.1.1.6	Review stay-clear zone for future building and interferometer expansion	5/1/96

1 SCOPE

This document defines the interfaces between the LIGO System & Detector (DET) and the Civil Construction (CC). This ICD takes precedence over previous interface definitions between these systems.

1.1 Purpose

The purpose of this document is to define the interfaces required to insure compatibility between the LIGO System & Detector (DET) and the Civil Construction (CC) and compliance with the LIGO System Specification.

1.2 Content

This document contains interface descriptions, definitions, drawings and requirements. The content is intended to be as concise as possible so as to convey requirements and not duplicate design information.

The intent is that this document be self-contained with little or no requirements included by reference to other documents or drawings. If it is necessary to include information by reference to another document or drawing, then that source must be:

- an approved document
- under configuration control
- cited by document number, date, and revision number

1.3 Interface Overview

There are four major subsystems involved in the design and construction of the LIGO project; the Detector (DET) system, the Civil Construction (CC) package, the Vacuum Equipment (VE) and the Beam Tube (BT). Since a quadripartite ICD is impractical, the interfaces have been approached in a pairwise fashion. As a consequence, the complete interface definition for any system is the ensemble of (at most) three ICDs. <u>This ICD is unique in that it addresses not only the interfaces between the DET and the CC, but also overall LIGO System considerations[1] which impose requirements on the CC</u>.

The interfaces between the Detector (DET) and the Civil Construction (CC) involve:

- mechanical
- thermal
- electrical
- software

For each of these areas, the detailed requirements are delineated in text supported with drawings as required; these drawings (each marked with a note indicating that they are part of an ICD) are

1. To date, the only LIGO Systems consideration incorporated into the Detector-CC ICD is the overall demand power (VE and Detector) by operational mode and the associated temperature control requirements.

an integral part of the ICD and subject to the same control procedures as the overall interface control document.

When an interface is site-specific, then the definition is provided separately for the Hanford, WA and the Livingston, LA sites; unless otherwise noted information applies to both sites.

2 APPLICABLE DOCUMENTS

The documents cited in Table 2-1 specifically relate to the interface defined and controlled in this ICD. In the event of discrepancies, this ICD takes precedence; Any conflicts should be pointed out to LIGO systems engineering.

Table 2-1: Relevant Documents

DOCUMENT TITLE	ID NUMBER
LIGO System Specification	LIGO-E950084 TBD-CIT-MIT
The Civil Construction (CC) Specification: Design Configuration Control Document (DCCD) augmented by: The Operations Support Building (OSB) Requirements	*PAR-FDCM010AB1B03* LIGO-E950098
Detector System Specification	TBD-CIT-MIT
LIGO Master Schedule	Latest Revision
Interface Control Document (ICD): Detector - Beam Tube	LIGO-E950093
Interface Control Document (ICD): Detector - Vacuum Equipment	LIGO-E950091
Interface Control Document (ICD): Vacuum Equipment - Civil Construction	LIGO-E950088
Interface Control Document (ICD): Beam Tube - Civil Construction	LIGO-E950089

3 REQUIREMENTS FOR INTERFACE

3.1 General Requirements

3.1.1 Responsibilities

The LIGO Integration and Systems Engineering group is responsible for maintaining this ICD and for resolving interface conflicts which may arise between the involved subsystems. The forum for interface conflict resolution is the Interface Control Working Group (ICWG) which is to be established upon initial release of the ICD. Members of the ICWG consist of Caltech and MIT personnel only; Representation of LIGO contractor interests is through the subsystem task managers. It is the responsibility of the subsystem task leaders to insure that they and their contractors design and implement in accordance with this interface specification.

3.1.2 Schedules

The LIGO program office is responsible for maintaining the master project schedule. Schedules often have significant interface impacts. Recognizing the often volatile and certainly evolving nature of project schedules, they are included only by reference.

3.1.3 Dimensioning

All interface drawings in this document shall be dimensioned in english units with metric units in parentheses.

3.1.4 Coordinate System

The common coordinate system to be used in global dimensioning for interfaces is a Cartesian system with its origin located at the corner station vertex (intersection of the projected beam tube centerlines) and with its:

- x-axis aligned along the northwest beam tube centerline in Hanford, WA and along the southwest beam tube centerline in Livingston, LA. These arms are also denoted "Right Arm" or "X-Arm".
- y-axis aligned along the southwest beam tube centerline in Hanford, WA and along the southeast beam tube centerline in Livingston, LA. These arms are also denoted "Left Arm" or "Y-Arm".
- z-axis aligned upwards along the normal to the x-y plane.

3.2 Specific Requirements

The requirements are organized on the basis of spatial location of the interfaces:

- Corner Station
- Mid-Station
- End-Station
- Service Entrance Enclosures (SEE) of the BTE

3.2.1 Corner Station

3.2.1.1 Mechanical Interfaces

3.2.1.1.1 Buried/Embedded Conduit for Signal Wiring

Buried/embedded conduit shall be provided for use by the Detector in running signal cables to/from the locations indicated in Table 3-1. The stub-up locations for the conduit are to be as indicated in drawing D960154. (*TBR-CC*)

Figure 3-1: Buried/Embedded Conduit for Signal Wiring

To/From	*Purpose*	*No.*	*Dia. in. [mm]*
OSB[a]/CMSR[b] <--> LVEA	Fiber-optic data cabling, phone lines, etc.	3	6 [152]
OSB/CSMR <--> Corner Station Mechanical Room	VE control signals, CT signals, etc.	2	6 [152]
OSB/CMSR <--> Chiller Support Building	CT signals	1	6 [152]
OSB/CMSR <--> Electrical Sub-station	CT signals	1	6 [152]
OSB/CMSR <--> Exterior Buried Vault with Man-hole cover access	fiber-optic cabling to the mid-stations[c] and end-stations	2[d]	4 [102]

a. Operations Support Building (OSB)
b. Computer and Mass Storage Room (CMSR)
c. at the Hanford, WA site only
d. one for each arm

3.2.1.1.2 Embedded Conduit for Laser Cooling Hose Lines

Conduit shall be embedded in (or run under) the LVEA slab for potential future use in running flexible coolant hose lines from the wall across to the Detector Pre-stabilized Laser (PSL) subsystems for use in cooling the laser. At each of the two PSL locations, two conduits (supply and return) shall be provided; the locations are to be as indicated in drawing D960155. Each conduit shall be terminated in a fitting flush with the floor surface and shall be 4 in [102 mm] in diameter. A pull cord shall be placed within each of the conduits for future use. Each embedded conduit shall have a straight run (only two 90 degree bends) with a total length no greater than 50 ft. The minimum bend radius is 2 ft. [610 mm]

3.2.1.1.3 Embedded Conduit for Electrical Power Distribution

The conduit used for electrical power distribution (see section 3.2.1.1.3.2) shall be terminated in a fitting flush with the floor surface which has provision for future conduit extension above the floor. The number of embedded conduit and their diameter(s) shall be sufficient for the required capacity of the Detector System (as defined in section 3.2.1.1.3.5) with 100% spare capacity for pulling future power cables (except that the spare capacity does not apply to the power for the PSL). A pull cord shall be placed within each of the conduits for future use. The embedded conduits shall have no more than two 90 degree turns with a wire length no greater than 50 ft. The minimum bend radius is 2 ft. [610 mm].

3.2.1.1.4 Survey Reference Monuments

Monuments shall be provided by the CC within the LVEA and are available for positioning the Detector systems. The number and locations of these monuments is given in drawing D960156 *TBD-Det.*

3.2.1.1.5 Stay-Clear for Inter-Building Buried Cabling

The area on the inside perimeter of the BTE, indicated in D960157 (*TBR-CC*), shall be reserved for use in burying cables between man-holes near the corner, mid- and end-stations along each arm.

3.2.1.1.6 Stay-Clear for Future Building and Interferometer Expansion

The area on the inside perimeter of the BTE, indicated in D960157 (*TBR-CC*), shall be reserved for future expansion of the building (and to accommodate long mode cleaner designs of the interferometer), with the exception of a BTE cross-over access road on the X-arm.

3.2.1.2 Thermal Interfaces

3.2.1.2.1 Chilled Water for Laser Cooling

Although laser cooling via the chilled water is not initially required, the CC shall make the following provisions for potential future use of the building chilled water for use in cooling advanced laser systems:

- The CC shall employ a modular chiller plant design such that additional capacity can be added at a later date in order to meet an anticipated increase in laser cooling requirements of up to 160 kW. The chilled water supply line diameter shall be of sufficient diameter to accommodate the increased heat load.
- Valved supply and return access points for the chilled water shall be provided in the corner bldg. mechanical room and in the OSB/Optics Lab.
- Embedded conduits in the slab at two locations (corresponding to the initial nominal locations of the PSL systems for the first two interferometers) to the adjacent wall for coolant water loop hoses (in case needed at a later date); These conduits are defined in section 3.2.1.1.2.

3.2.1.3 Electrical Interfaces

3.2.1.3.1 Building/Equipment Current Sensing

The current draw of all major facility electrical loads and moving/rotating machinery (with the exception of overhead cranes) must be detectable (resolved) via Current Transducers (CT) to be placed by the CC. The CTs can monitor the composite current draw of a number of equipment items, but must be capable of detecting (resolving) the smallest current change due to a change in equipment state (on-off, off-standby, etc.). The CTs shall have a response bandwidth > 5 kHz. These CTs will be accessed for signal processing, monitoring and recording via the Detector/ CDS; The CC is only responsible for providing the CTs, a pigtail for connection, locations, and a list of the equipment and circuits which the CT monitors. [CDS access between the OSB/CMSR and the sensor locations shall be provided by the CC, via a conduit, per section 3.2.1.1.1.]

3.2.1.3.2 Power Distribution

Individual circuit breakers shall be provided in wall panels within the LVEA and the Mechanical Room at one or more locations. All breakers shall have provision for lock outs (for lock and tag maintenance procedures). The LVEA electrical power and "green wire" safety ground for use by CDS racks in the LVEA will be provided via conduits embedded in the LVEA slab with riser locations in the regions indicated in drawing LIGO-D950145. The CC contractor shall not pull electrical cables through the conduit.

In the Mechanical Room, the CDS power shall be provided at a wall-mounted CB panel, as indicated in drawing D950145.

3.2.1.3.3 Technical Power Isolation

All power provided to the Detector system shall be isolated from the power bus used for facility power by at least two isolation transformers and designated "technical power" (to distinguish it from the "facility power").

3.2.1.3.4 Technical Ground Distribution

In accordance with the civil construction Design Configuration Control Document, there is a quiet technical (signal) ground separate from the "green wire" safety ground. The Detector shall be provided with access to the technical ground at each power distribution locations (per 3.2.1.3.2). The "island grounding" scheme shall be employed with separate technical ground wires to each of the rack cluster or "island" locations designated in drawing LIGO-D950145.

3.2.1.3.5 Electrical Load Capacity

The voltages, number of circuits and their capacities required at each of the conduit riser locations, referred to in section 3.2.1.3.2, with locations labeled in drawing LIGO-D950145, are as indicated in the Table 3-2. Table 3-2 provides the total potential connected load; The maximum demand loads, as a function of operational scenario, is given in section 3.2.1.4.2.

3.2.1.3.6 CDS Network Provided Inter-Building Communication for the FMCS

The FMCS systems in the mid- and end-stations will communicate with the central FMCS system in the corner station via the CDS system (by way of the CDS fiber-optic cabling between the station buildings). The FMCS in each building shall be stand-alone (i.e. can be tested and can function independently of the CDS provided communication link) except for central data logging and remote monitoring functions. The FMCS shall interface with the CDS system via a 10baseT network connection at a single RJ11 jack at each station. The location of the RJ11 jack shall be provided by CC in the building documentation package.

3.2.1.4 HVAC

3.2.1.4.1 Temperature Control

The HVAC must maintain 72 +/- 3.5F within all occupied spaces under "nominal LIGO operations". During off-nominal operational conditions (i.e. all operational conditions other than "nominal LIGO operations"), the internal environment should not be uncomfortable for working and should be maintained at about 72 +/- 6F. In this context, "nominal LIGO operations" means maintaining a low vacuum (low VE power dissipation) and the Detector equipment drawing between zero and its maximum demand load. For each of the operational modes listed in Table 3-3, the temperature requirements are indicated.

3.2.1.4.2 Power Dissipation

Electrical demand load and power dissipation for various operational scenarios are given in Table 3-3 as representative of LIGO needs and is provided for use in circuit load balancing and HVAC design for thermal load swings/extremes and spatial non-uniformity; as such, not all of the details of the individual loads are part of the controlled interface. The loads given in Table 3-3 include both VE and Detector loads (i.e. all non-building loads). Table 3-3 applies to the Hanford, WA site; Although the Livingston, LA site will not initially require as much power, it should be designed to accommodate the same power dissipation as Hanford, WA for future expansion capability.

3.2.1.5 Software

The state-vector history of the facility system is logged by the FMCS. A network interface to transfer the data from the FMCS to the CDS Monitoring and Control System is required. Data, message formats and protocols are *TBD-Det*.

Table 3-2: Detector Power Required[a] in the Corner Station Building (LVEA and Mechanical Room)

Voltage	*208Y/120V, 3φ*							*480Y/277V, 3φ*						
Location[b]	*# C[c]*	*φ*	*KVA d*	*CB (A)*	*# R[e]*	*Recepticle*	*nominal use*	*# C*	*φ*	*KVA*	*CB (A)*	*# R*	*Recepticle*	*nominal use*
C-CC-PD-CDSAC_01	**6**	**1**	**1.9**	**20**	**0**	**direct**	**CDS/PSL IFO#1**	**1**	**3**	**60**	**90**	**0**	**direct**	**Laser (future use)**
C-CC-PD-CDSAC_02	**12**	**1**	**1.9**	**20**	**0**	**direct**	**CDS/Input Optics IFO#1**	-	-	-	-	-	-	-
C-CC-PD-CDSAC_03	**8**	**1**	**1.9**	**20**	**0**	**direct**	**CDS/Output Optics IFO#1**	-	-	-	-	-	-	-
C-CC-PD-CDSAC_04	**12**	**1**	**1.9**	**20**	**0**	**direct**	**CDS/Output Optics IFO#1**	-	-	-	-	-	-	-
C-CC-PD-CDSAC_05	**12**	**1**	**1.9**	**20**	**0**	**direct**	**CDS/VE X-arm** **CDS/Beam Splitter IFO#1** **CDS/Test Mass IFO#1**	-	-	-	-	-	-	-
C-CC-PD-CDSAC_06	-	-	-	-	-	-	**none**	-	-	-	-	-	-	-
C-CC-PD-CDSAC_07	**6**	**1**	**1.9**	**20**	**0**	**direct**	**CDS/PSL IFO#2**	**1**	**3**	**60**	**90**	**0**	**direct**	**Laser (future use)**
C-CC-PD-CDSAC_08	**12**	**1**	**1.9**	**20**	**0**	**direct**	**CDS/Input Optics IFO#2**	-	-	-	-	-	-	-
C-CC-PD-CDSAC_09	**12**	**1**	**1.9**	**20**	**0**	**direct**	**CDS/Output Optics IFO#1**	-	-	-	-	-	-	-
C-CC-PD-CDSAC_10	**8**	**1**	**1.9**	**20**	**0**	**direct**	**CDS/Output Optics IFO#1**	-	-	-	-	-	-	-

Table 3-2: Detector Power Required[a] in the Corner Station Building (LVEA and Mechanical Room)

Voltage	*208Y/120V, 3φ*							*480Y/277V, 3φ*						
Location[b]	*# C[c]*	*φ*	*KVA d*	*CB (A)*	*# R[e]*	*Recepticle*	*nominal use*	*# C*	*φ*	*KVA*	*CB (A)*	*# R*	*Recepticle*	*nominal use*
C-CC-PD-CDSAC_11	-	-	-	-	-	-	**none**	-	-	-	-	-	-	-
C-CC-PD-CDSAC_12	**12**	**1**	**1.9**	**20**	**0**	**direct**	**CDS/VE X-arm** **CDS/Beam Splitter IFO#1** **CDS/Test Mass IFO#1**	-	-	-	-	-	-	-
C-CC-PD-CDSAC_13	**2**	**1**	**1.9**	**20**	**0**	**direct**	**CDS/VE Mechanical Room**	-	-	-	-	-	-	-

a. All power to the Detector is "technical power", with the exception of the 480V laser supply which is "facility power".

b. Locations are indicated in drawing LIGO-D950145. The nomenclature is as follows:

station-system-subsystem-unit

where in this case, C = corner station, CC = Civil Construction, PD = Power Distribution, CDSAC_n = n'th Detector AC location

c. Number of separate circuits and circuit breakers.

d. Maximum continuous KVA per circuit.

e. Number of receptacles (duplex receptacles for single phase locations).

Table 3-3. POWER CONSUMPTION VS. OPERATIONAL MODE: Corner Station [Not including the OSB]

					max.	max.	heat sink factor			MODES OF OPERATION (KW)						Purge+	
			Total	Power	demand	diversity	room	chiller			Regen+	Nominal Op.				Regen +	Purge+
Subsys.	**Location**	**Use**	**Qty**	**KW**	**factor**	**factor**	**air**	**water**	**external**	Rough Pump	Final Pump	Maintain Vac	VE Bake-Out	Vent	Regen	1 Clean Rm	3 Clean Rm
VE	LVEA	Aux. Turbo Pump Sys	2	1.9	1	1		1		3.8	3.8		3.8	3.8	3.8	3.8	
		Gate Valves	8	1.4	1	0	1			0.0	0.0	0.0	0.0	0.0	0.0	0.0	0
		Cryopump regenerator	2	20	1	1	0.15		0.85		20.0				20.0	20.0	
		Heating Blkt Cart	6	27	1	1	1				27.0		162.0		27.0	27.0	
		Portable Clean Rms	4	10	1	1	1									10.0	30
		Chamber Annulus Ion Pumps	18	1	1	1	1				18.0	18.0	18.0	18.0	18.0	18.0	18
		Valve Annulus Ion Pumps	8	1	1	1	1				8.0	8.0	8.0	8.0	8.0	8.0	8
		Main Roughing Pumps	2	3.7	1	1		1		7.4	7.4						
		Main Turbo Pumps	2	0.4	1	1		1		0.8	0.8		0.8				
		VE Racks	4	3.8	0.5	1	1			7.6	7.6	7.6	7.6	7.6	7.6	7.6	7.6
	Mech Rm	Roughing Pump Backing	2	52	1	1		1		104.0							
		Turbo Pump Backing	2	8	1	1		1		16.0	16.0		16.0	16.0	16.0	16.0	
		Vent/Purge Compressor	1	61	1	1		1						61.0		61.0	61
		Main Ion Pump PS	8	1.4	1	1	1				11.2	11.2	11.2	11.2	11.2	11.2	11.2
		Vacuum Gauge PS	1	1	1	1	1			1.0	1.0	1.0	1.0	1.0	1.0	1.0	1
		VE Racks	2	3.8	0.5	1	1			3.8	3.8	3.8	3.8	3.8	3.8	3.8	3.8
Detector	LVEA	CDS-VE Interface Racks	2	3.8	0.5	1	1			3.8	3.8	3.8	3.8	3.8	3.8	3.8	3.8
		CDS Racks + Detector	50	3.8	0.5	1	1			47.5	47.5	95.0	0.0	47.5	47.5	47.5	47.5
		PSL	2	4	1	1	1			8.0	8.0	8.0	0.0	8.0	8.0	8.0	8.0
	Mech Rm	CDS-VE Interface Racks	2	3.8	0.5	1	1			3.8	3.8	3.8	3.8	3.8	3.8	3.8	3.8
									Approx. Duration (hr)	4	100	Indef	~100	Indef	8	Indef	Indef
									Max. Electrical Power (kW)	**207.5**	**187.7**	**160.2**	**239.8**	**193.5**	**179.5**	**250.5**	**203.7**
									Min. Electrical Power (kW)	152.0	132.2	57.2	239.8	138.0	124.0	195.0	148.2
									Heat to Water (kW)	132.0	28.0	0.0	20.6	80.8	19.8	80.8	61.0
									Max. Heat to Air (kW)	**75.5**	**142.7**	**160.2**	**219.2**	**112.7**	**142.7**	**152.7**	**142.7**
									Min. Heat to Air (kW)	20.0	87.2	57.2	219.2	57.2	87.2	97.2	87.2
									External (kW)	0.0	17.0	0.0	0.0	0.0	17.0	17.0	0.0
									Temperature Requirement	72 +/-6F	72 +/-6F	72 +/-3.5F	none	72 +/-6F	72 +/-6F	none	72 +/-6F

Notes:

(1) The cryopump regeneration requires bake-out of the pump walls with one heater blanket per pump.

(2) Cryopump regeneration is constrained to one pump at a time. Total duration of each cryopump regeneration is ~ 4 hr. heating and ~4 hr cooling, or 12 hr total if the heating for two cryopumps is done serially.

(3) Diversity factor is set to zero for the gate valves since power draw is only *during brief close/open period -- never all simultaneously.*

(4) Max. and Min. for the Detector taken as full demand power and no power, respectively.

(5) The "nominal operations/maintain vacuum" mode has a firm temperature requirement of 72 +/- 3.5F. There is no temperature control requirement for some modes; Temperature control for the balance of modes should be such that conditions are not uncomfortable for working.

(6) Laser cooling is either to air or to water -- shown as air above.

(7) The power dissipation (kW) is taken to be equal to the apparent power (kVA) since then error is within the estimation accuracy and is conservative, e.g. the error for induction motors from 1 to 100 HP and 0.5 to full load is +20% to -3%.

3.2.2 Mid-Station

This section applies only to the Hanford, WA site.

3.2.2.1 Mechanical Interfaces

3.2.2.1.1 Buried/Embedded Conduit for Signal Wiring

Buried/embedded conduit shall be provided for use by the Detector in running signal cables to/from the locations indicated in Table 3-4. The stub-up locations for the conduit are to be as indicated in drawing D960154.

Table 3-4: Buried/Embedded Conduit for Signal Wiring

To/From	*Purpose*	*No.*	*Dia. in. [mm]*
VEA <--> Chiller Support Building	CT signals	1	6 [152]
VEA <--> Electrical Sub-station	CT signals	1	6 [152]
VEA <--> Exterior Buried Vault with Manhole cover access	fiber-optic cabling to the corner station[a]	2	4 [102]

a. at the Hanford, WA site only

3.2.2.1.2 Embedded Conduit for Electrical Power Distribution

Refer to section 3.2.1.1.3.

3.2.2.1.3 Survey Reference Monuments

Refer to section 3.2.1.1.4.

3.2.2.2 Thermal Interfaces

None.

3.2.2.3 Electrical Interfaces

3.2.2.3.1 Building/Equipment Current Sensing

Refer to section 3.2.1.3.1.

3.2.2.3.2 Power Distribution

Refer to section 3.2.1.3.2.

3.2.2.3.3 Technical Power Isolation

Refer to section 3.2.1.3.3.

3.2.2.3.4 Technical Ground Distribution

Refer to section 3.2.1.3.4.

3.2.2.3.5 Electrical Load Capacity

The voltages, number of circuits and their capacities required at each of the conduit riser locations, referred to in section 3.2.2.3.2, with locations labeled in drawing LIGO-D950145, are as indicated in the Table 3-5. Table 3-5 provides the total potential connected load; The maximum demand loads, as a function of operational scenario, is given in section 3.2.2.4.2.

3.2.2.3.6 CDS Network Provided Inter-Building Communication for the FMCS

Refer to section 3.2.1.3.6.

3.2.2.4 HVAC

3.2.2.4.1 Temperature Control

Refer to section 3.2.1.4.1. For each of the operational modes listed in Table 3-6, the temperature requirements are indicated.

3.2.2.4.2 Power Dissipation

Refer to section 3.2.1.4.2 for general comments. Electrical demand load and power dissipation for the mid-station for various operational scenarios are given in Table 3-6 as representative of LIGO needs. The loads given in Table 3-6 include both VE and Detector loads (i.e. all non-building loads).

Table 3-5: Detector Power Required[a] in the Mid-Station Building

Voltage	*208Y/120V, 3φ*							*480Y/277V, 3φ*						
Location[b]	*# C[c]*	*φ*	*KVA d*	*CB (A)*	*# R[e]*	*Recepticle*	*nominal use*	*# C*	*φ*	*KVA*	*CB (A)*	*# R*	*Recepticle*	*nominal use*
Ma-CC-PD-CDSAC_01	**4**	**1**	**1.9**	**20**	**0**	**direct**	**CDS/Test Mass IFO#2**	-	-	-	-	-	-	-
Ma-CC-PD-CDSAC_02	**2**	**1**	**1.9**	**20**	**0**	**direct**	**CDS/VE Interface**	-	-	-	-	-	-	-
Ma-CC-PD-CDSAC_03	-	-	-	-	-	-	**none**	-	-	-	-	-	-	-

a. All power to the Detector is "technical power".

b. Locations are indicated in drawing LIGO-D950145. The nomenclature is as follows:

station-system-subsystem-unit

where in this case, Ma = mid-station on arm "a", where $a \in \{x, y\}$; CC = Civil Construction, PD = Power Distribution, CDSAC_n = n'th Detector Equipment AC location

c. Number of separate circuits and circuit breakers.

d. Maximum continuous KVA per circuit.

e. Number of receptacles (duplex receptacles for single phase locations).

Table 3-6. POWER CONSUMPTION VS. OPERATIONAL MODE: Mid-Station (WA) [Not Including support rooms]

Subsys.	Location	Use	Total Qty	Power KW	max. demand factor	max. diversity factor	heat sink factor: room air	heat sink factor: chiller water	heat sink factor: external	MODES OF OPERATION (KW): Rough Pump	Regen+ Final Pump	Nominal Op. Maintain Vac	VE Bake-Out	Vent	Regen	Purge+ 1 Clean Rm	Regen+ Purge+ 1 Clean Rm
VE	VEA	Aux. Turbo Pump Sys	1	1.9	1	1		1		1.9	1.9		1.9		1.9		1.9
		Gate Valves	4	1.4	1	0	1			0	0	0	0	0	0	0	0
		Cryopump regenerator	2	20	1	1	0.15		0.85		20				20		20
		Heating Blkt Cart	2	27	1	1	1				27		54		27		27
		Portable Clean Rms	1	10	1	1	1									10	10
		Chamber Annulus Ion Pumps	1	1	1	1	1				1	1	1	1	1	1	1
		Valve Annulus Ion Pumps	4	1	1	1	1				4	4	4	4	4	4	4
		Main Roughing Pumps															
		Main Turbo Pumps	1	0.4	1	1		1		0.4	0.4		0.4				
		VE Racks	1	3.8	0.5	1	1			1.9	1.9	1.9	1.9	1.9	1.9	1.9	1.9
	Mech Rm.	Roughing Pump Backing															
		Turbo Pump Backing	1	8	1	1		1		8	8		8		8		8
		Vent/Purge Compressor	1	25	1	1		1						25		25	25
		Main Ion Pump PS (in Rack)	1	1.4	1	1	1				1.4	1.4	1.4	1.4	1.4	1.4	1.4
		Vacuum Gauge PS (in Rack)	1	1	1	1	1			1	1	1	1	1	1	1	1
Detector	VEA	CDS-VE Interface Racks	1	3.8	0.5	1	1			1.9	1.9	1.9	1.9	1.9	1.9	1.9	1.9
		CDS Racks + Detector	2	3.8	1	1	1			7.6	7.6	7.6	7.6	7.6	7.6	7.6	7.6
	Mech Rm	CDS-VE Interface Rack	1	3.8	0.5	1	1			1.9	1.9	1.9	1.9	1.9	1.9	1.9	1.9
Duration (hr)										4	100	Indef	~100	Indef	8	Indef	Indef
Max. Electrical Power (kW)										**24.6**	**78.0**	**20.7**	**85.0**	**45.7**	**77.6**	**55.7**	**112.6**
Min. Electrical Power (kW)										17.0	70.4	13.1	77.4	38.1	70.0	48.1	105.0
Heat to Water (kW)										10.3	10.3	0.0	10.3	25.0	9.9	25.0	34.9
Max. Heat to Air (kW)										**14.3**	**50.7**	**20.7**	**74.7**	**20.7**	**50.7**	**30.7**	**60.7**
Min. Heat to Air (kW)										6.7	43.1	13.1	67.1	13.1	43.1	23.1	53.1
External (kW)										0.0	17.0	0.0	0.0	0.0	17.0	0.0	17.0
Temperature Requirement										72 +/-6F	72 +/-6F	72 +/-3.5F	none	72 +/-3.5F	72 +/-6F	72 +/-3.5F	none

Notes:

(1) The cryopump regeneration requires bake-out of the pump walls with one heater blanket per pump.

(2) Cryopump regeneration is constrained to one pump at a time. Total duration of each cryopump regeneration is ~ 4 hr. heating and ~4 hr cooling, or 12 hr total if the heating for two cryopumps is done serially.

(3) Diversity factor is set to zero for the gate valves since power draw is only during brief close/open period -- *never all simultaneously.*

(4) Max. and Min. for the Detector taken as full demand power and no power, respectively.

(5) The "nominal operations/maintain vacuum" mode has a firm temperature requirement of 72 +/- 3.5F. There is no temperature control requirement for some modes; Temperature control for the balance of modes should be such that conditions are not uncomfortable for working.

(6) The power draw and dissipation in the mid- and end-stations is taken to be essentially the same. Conservative for mid-station and allows for expansion at end for 2nd BSC at a later date.

(7) The power dissipation (kW) is taken to be equal to the apparent power (kVA) since then error is within the estimation accuracy and is conservative, e.g. the error for induction motors from 1 to 100 HP and 0.5 to full load is +20% to -3%.

(8) The demand factor for the CDS Rack power (incl. the Detector Sys. power) is set to 1.0 (instead of 0.5 as in the corner station) since there are only 2 racks in which to spread the demand uncertainty.

3.2.3 End-Station

3.2.3.1 Mechanical Interfaces

3.2.3.1.1 Buried/Embedded Conduit for Signal Wiring

Refer to section 3.2.2.1.1.

3.2.3.1.2 Embedded Conduit for Electrical Power Distribution

Refer to section 3.2.1.1.3.

3.2.3.1.3 Survey Reference Monuments

Refer to section 3.2.1.1.4.

3.2.3.2 Thermal Interfaces

None.

3.2.3.3 Electrical Interfaces

3.2.3.3.1 Building/Equipment Current Sensing

Refer to section 3.2.1.3.1.

3.2.3.3.2 Power Distribution

Refer to section 3.2.1.3.2.

3.2.3.3.3 Technical Power Isolation

Refer to section 3.2.1.3.3.

3.2.3.3.4 Technical Ground Distribution

Refer to section 3.2.1.3.4.

3.2.3.3.5 Electrical Load Capacity

The voltages, number of circuits and their capacities required at each of the conduit riser locations, referred to in section 3.2.3.3.2, with locations labeled in drawing LIGO-D950145, are as indicated in the Table 3-7. Table 3-7 provides the total potential connected load; The maximum demand loads, as a function of operational scenario, is given in section 3.2.3.4.2.

3.2.3.3.6 CDS Network Provided Inter-Building Communication for the FMCS

Refer to section 3.2.1.3.6.

3.2.3.4 HVAC

3.2.3.4.1 Temperature Control

Refer to section 3.2.1.4.1. For each of the operational modes listed in Table 3-6, the temperature requirements are indicated.

3.2.3.4.2 Power Dissipation

Refer to section 3.2.1.4.2 for general comments. Electrical demand load and power dissipation for the end-station for various operational scenarios are given in Table 3-8 as representative of LIGO needs. The loads given in Table 3-8 include both VE and Detector loads (i.e. all non-building loads).

3.2.4 Service Entrance Enclosure (SEE)

3.2.4.1 Mechanical Interfaces

None.

3.2.4.2 Thermal Interfaces

None.

3.2.4.3 Electrical Interfaces

3.2.4.3.1 Power Distribution

Electrical power shall be made available at each SEE for use by the Detector (e.g. Physics and Environment Monitoring (PEM) equipment, CDS supporting equipment/racks) and future ion or getter vacuum pumps and any lighting. The power shall be 120 volts and 5 KW capacity at each SEE.

3.2.4.4 HVAC

None.

Table 3-7: Detector Power Required[a] in the End-Station Building

Voltage	*208Y/120V, 3φ*							*480Y/277V, 3φ*						
Location[b]	*# C[c]*	*φ*	*KVA d*	*CB (A)*	*# R[e]*	*Recepticle*	*nominal use*	*# C*	*φ*	*KVA*	*CB (A)*	*# R*	*Recepticle*	*nominal use*
Ea-CC-PD-CDSAC_01	**4**	**1**	**1.9**	**20**	**0**	**direct**	**CDS/Test Mass IFO#2**	-	-	-	-	-	-	-
Ea-CC-PD-CDSAC_02	**2**	**1**	**1.9**	**20**	**0**	**direct**	**CDS/VE Interface**	-	-	-	-	-	-	-
Ea-CC-PD-CDSAC_03 see note[f]	**2**	**1**	**1.9**	**20**	**0**	**direct**	**CDS/Test Mass IFO#3**	-	-	-	-	-	-	-

a. All power to the CDS is "technical power".

b. Locations are indicated in drawing LIGO-D950145. The nomenclature is as follows:

station-system-subsystem-unit

where in this case, Ea = mid-station on arm "a", where $a \in \{x, y\}$; CC = Civil Construction, PD = Power Distribution, CDSAC_n = n'th Detector Equipment AC location

c. Number of separate circuits and circuit breakers.

d. Maximum continuous KVA per circuit.

e. Number of receptacles (duplex receptacles for single phase locations).

f. The Ea-CC-PD-CDSAC_03 location is for use in future expansion of the End-Station.

Table 3-8. POWER CONSUMPTION VS. OPERATIONAL MODE: End-Station [Not Including Support Rooms]

					max.	max.	heat sink factor			MODES OF OPERATION (KW)							Regen+
			Total	Power	demand	diversity	room	chiller			Regen+	Nominal Op.				Purge+	Purge+
Subsys.	**Location**	**Use**	**Qty**	**KW**	**factor**	**factor**	**air**	**water**	**external**	Rough Pump	Final Pump	Maintain Vac	VE Bake-Out	Purge	Regen	1 Clean Rm	1 Clean Rm
VE	VEA	Aux. Turbo Pump Sys	1	1.9	1	1		1		1.9	1.9		1.9		1.9		1.9
		Gate Valves	2	1.4	1	0	1			0	0	0	0	0	0	0	0
		Cryopump regenerator	1	20	1	1	0.15		0.85		20				20		20
		Heating Blkt Cart	2	27	1	1	1				27		54		27		27
		Portable Clean Rms	1	10	1	1	1									10	10
		Chamber Annulus Ion Pumps	1	1	1	1	1				1	1	1	1	1	1	1
		Valve Annulus Ion Pumps	2	1	1	1	1				2	2	2	2	2	2	2
		Main Roughing Pumps															
		Main Turbo Pumps	1	0.4	1	1		1		0.4	0.4		0.4				
		VE Racks	1	3.8	0.5	1	1			1.9	1.9	1.9	1.9	1.9	1.9	1.9	1.9
	Mech Rm	Roughing Pump Backing															
		Turbo Pump Backing	1	8	1	1		1		8	8		8		8		8
		Vent/Purge Compressor	1	25	1	1		1						25		25	25
		Main Ion Pump PS (in Rack)	1	1.4	1	1	1				1.4	1.4	1.4	1.4	1.4	1.4	1.4
		Vacuum Gauge PS (in Rack)	1	1	1	1	1			1	1	1	1	1	1	1	1
Detector	VEA	CDS-VE Interface Racks	1	3.8	0.5	1	1			1.9	1.9	1.9	1.9	1.9	1.9	1.9	1.9
		CDS Racks + Detector	2	3.8	1	1	1			3.8	3.8	7.6	0	3.8	3.8	3.8	3.8
	Mech Rm	CDS-VE Interface Racks	1	3.8	0.5	1	1			1.9	1.9	1.9	1.9	1.9	1.9	1.9	1.9
									Duration (hr)	4	100	Indef	~100	Indef	8	Indef	Indef
									Max. Electrical Power (kW)	**20.8**	**72.2**	**18.7**	**75.4**	**39.9**	**71.8**	**49.9**	**106.8**
									Min. Electrical Power (kW)	17.0	68.4	11.1	75.4	36.1	68.0	46.1	103.0
									Heat to Water (kW)	10.3	10.3	0.0	10.3	25.0	9.9	25.0	34.9
									Max. Heat to Air (kW)	**10.5**	**44.9**	**18.7**	**65.1**	**14.9**	**44.9**	**24.9**	**54.9**
									Min. Heat to Air (kW)	6.7	41.1	11.1	65.1	11.1	41.1	21.1	51.1
									External (kW)	0.0	17.0	0.0	0.0	0.0	17.0	0.0	17.0
									Temperature Requirement	72 +/-6F	72 +/-6F	72 +/-3.5F	72 +/-6F	72 +/-6F	72 +/-6F	72 +/-6F	72 +/-6F

Notes:
(1) The cryopump regeneration requires bake-out of the pump walls with one heater blanket per pump.
(2) Cryopump regeneration is constrained to one pump at a time. Total duration of each cryopump regeneration is ~ 4 hr. heating and ~4 hr cooling, or 12 hr total if the heating for two cryopumps is done serially.
(3) Diversity factor is set to zero for the gate valves since power draw is only during brief close/open period -- never all simultaneously.
(4) Max. and Min. for the Detector taken as full demand power and no power, respectively.
(5) The "nominal operations/maintain vacuum" mode has a firm temperature requirement of 72 +/- 3.5F.
There is no temperature control requirement for some modes; Temperature control for the balance of modes should be such that conditions are not uncomfortable for working.
(6) The power draw and dissipation in the mid- and end-stations is taken to be essentially the same. Conservative for mid-station and allows for expansion at end for 2nd BSC at a later date.
(7) The power dissipation (kW) is taken to be equal to the apparent power (kVA) since then error is within the estimation accuracy and is conservative, e.g. the error for induction motors from 1 to 100 HP and 0.5 to full load is +20% to -3%.
(8) The demand factor for the CDS Rack power (incl. the Detector Sys. power) is set to 1.0 (instead of 0.5 as in the corner station) since there are only 2 racks in which to spread the demand uncertainty.

4 INTERFACE VERIFICATION

Verification of the interface is to be performed by one or more of the following methods:

- Test
  A test (wherein the specific test is to be specified) is conducted to insure compliance with the ICD requirements. In some cases this test may be part of a planned component or subsystem test program and not required specifically for verification of the interface.
- Inspection
  In some cases verification may be accomplished by an inspection of the physical article (e.g. measurement of critical dimensions).
- Analysis
  Verification by analysis (wherein the specific analysis is to be specified) may be appropriate in instances where verification by test is expensive or impractical.
- Demonstration
  Demonstration may be used for qualitative determination of properties and performance of an item. Demonstration is accomplished by observation of the item in the performance of its function.
- Similarity
  Arguments of similarity of design may be invoked to verify compliance with interface requirements (e.g. lifetime of a component based upon demonstrated lifetime of similar component designs).

The specific verification method is called out for each of the requirements in the following table.

Table 4-1: Verification Matrix

Para.	*Requirement Title*	*Test*	*Inspection*	*Analysis*	*Demonstration*	*Similarity*
3.2.1.1.1 3.2.2.1.1 3.2.3.1.1	Buried conduit for signal wiring		✓			
3.2.1.1.2	Embedded conduit for laser coolant lines		✓			
3.2.1.1.3 3.2.2.1.2 3.2.3.1.2	Embedded conduit for electrical power distribution		✓			
3.2.1.1.4 3.2.2.1.3 3.2.3.1.3	Interior survey reference monuments	✓				
3.2.1.2.1	Chilled water for laser cooling		✓			

Table 4-1: Verification Matrix

Para.	*Requirement Title*	*Test*	*Inspection*	*Analysis*	*Demonstration*	*Similarity*
3.2.1.3.1 3.2.2.3.1 3.2.3.3.1	Facilities equipment current sensing				✓	
3.2.1.3.2 3.2.2.3.2 3.23.3.2	Electrical power distribution		✓			
3.2.1.3.3 3.2.2.3.3 3.2.3.3.3	Technical power isolation		✓			
3.2.1.3.4 3.2.2.3.4 3.23.3.4	Technical ground distribution		✓			
3.2.1.3.5 3.2.2.3.5 3.2.3.3.5	Electrical load capacity		✓	✓		
3.2.1.4.1 3.2.2.4.1 3.2.3.4.1	Temperature control			✓	✓	
3.2.1.4.2 3.2.2.4.2 3.2.3.4.2	Power dissipation			✓		
3.2.4.3.1	SEE power distribution		✓	✓		

5 NOMENCLATURE AND ACRONYMS

Table 5-1: Nomenclature and Acronyms

Acronym	*Meaning*
BT	Beam Tube
BTE	Beam Tube Enclosure
Caltech	California Institute of Technology
CB	Circuit Breaker
CC	Civil Construction
CDS	Control & Data System; a subsystem of the Detector
CIT	California Institute of Technology
CMSR	Computer and Mass Storage Room; a room within the OSB
CT	Current Transducer
DCCD	Design Configuration Control Document -- the requirements document for the Civil Construction design
Det	Detector; a major LIGO System
FMCS	Facility Monitoring and Control System
FO	Fiber-Optic
HVAC	Heating, Ventilation and Air Conditioning
ICD	Interface Control Document
ICWG	Interface Control Working Group
IFO	Interferometer
LIGO	Laser Interferometer Gravitational Wave Observatory
LVEA	Laser and Vacuum Equipment Area (part of the corner station)
MIT	Massachusetts Institute of Technology
OSB	Operations Support Building
PSL	Pre-stabilized Laser subsystem (part of the Detector System)
Pump Ports	Access ports/flanges used to connect vacuum pumps and instrumentation to the Beam Tube
SEE	Service Entrance Enclosure; a component of the BTE

Table 5-1: Nomenclature and Acronyms

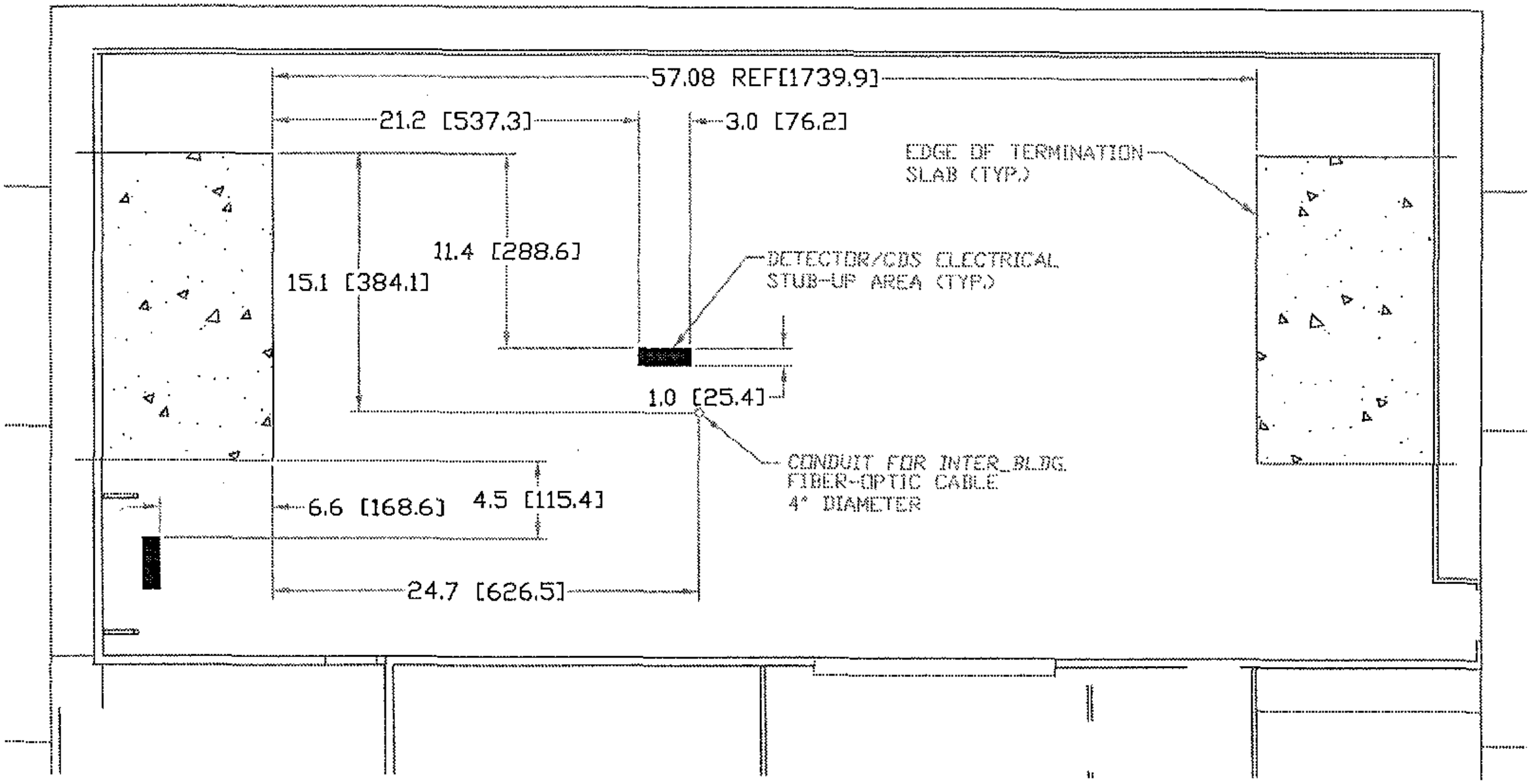
Acronym	*Meaning*
TBD	To Be Determined
TBR	To Be Resolved
VE	Vacuum Equipment
VEA	Vacuum Equipment Area (part of the mid- and end-stations)

6 DRAWINGS:

LIGO Dwg	*Title* *Subtitle*	*No. of Sheets*	*Approved/ Released?*
D960156	Interior Survey Reference Monuments for the Detector		
	Corner Station	1	*TBD-Det*
	Mid- and End-Station	2	*TBD-Det*
D960157	Stay-Clear Zones for Inter-Station Buried Cabling and Future Building Expansion	1	*TBR-CC*
D950145	Conduit Stub-Up Locations for the Detector System (Power, Signal, Coolant)		
	Corner Station	1	*TBR-CC*
	Mid- and End-Station	2	*TBR-CC*

NOTES:

1. POSITIONS ARE MIRROR-IMAGED (LEFT/RIGHT) FOR Y_ARM (LEFT ARM) MID- AND END-STATION BLDGS.



PRELIMINARY

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REFERENCE DRAWINGS

ISSUE DESCRIPTION

CURRENT REVISION APPROVAL

DRAWN	GROUP	SIGNATURE	DATE
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LIGO CALIFORNIA INSTITUTE OF TECHNOLOGY / MASSACHUSETTS INSTITUTE OF TECHNOLOGY

CONDUIT STUB-UP LOCATIONS FOR DETECTOR SYSTEM (POWER, SIGNAL, COOLANT): MID- AND END- STATIONS (X-ARM)

SCALE	SIZE	DWG. NO.	REV.
NTS	B	D950145-00-E	A

SHEET 2 OF 2