LASER INTERFEROMETER GRAVITATIONAL WAVE OBSERVATORY
- LIGO -
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Pre-Stabilized Laser Control and Data System Software Requirements Specification

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1 INTRODUCTION

1.1. Purpose

The purpose of this document is to specify the requirements for the control system software to be developed for the Pre-Stabilized Laser (PSL) subsystem of the LIGO interferometers. As the software to be developed in accordance with this specification is a LIGO 'in-house' project, this document may lack some of the detail and boiler-plate which would be necessary for an outside contracted project.

The intent of this document is to:

- Provide a written starting point for software development and act as a guide to help reduce the number of functional/performance omissions.
- Help reduce the amount of code to be re-written in the future due to these omissions.
- Help the design process by giving an overall view of the system in one place.
- Help to ensure, before project start, that the end product will fit the needs of LIGO.
- Provide a history, through the revision process, of the project scope and definition changes.
- Provide a background to other staff who may pick up the project at a later date in the software lifecycle.
- Provide documented requirements from which a Software Test Plan (STP) can be developed to verify that the final product design and implementation is correct.

1.2. Scope

This specification covers all control and monitoring aspects for the PSL, including:

- Real-time Processing
- Operator Interfaces
- Alarm Management
- Slow Data Archival (<=10Hz)

This document does not cover what the CDS overall specification calls out as 'Remote Diagnostics' or 'Data Acquisition' for the PSL.

1.3. Definitions, Acronyms, and Abbreviations

1.3.1. Definitions

1.3.1.1 Physical Input/Output Channels

Physical I/O channels are defined as those software data channels which directly receive data from / send data to VME I/O module channels. The point of I/O reference is the control system software.

1.3.1.2 Virtual Input/Output Channels

Virtual I/O channels are ones which strictly communicate data between software modules.

1.3.1.3 CDS Diagnostic Data Channel

A CDS diagnostic data channel is one which is not required for operation of the system, other than to provide diagnostic information to allow verification of proper system operation.

1.3.1.4 Real-time Software

Real-time software is defined as that software which is deterministic in its task scheduling and duration. Throughout this document, this term refers to software which runs on the PSL VME uprocessor under control of a real-time operating system (VxWorks).

1.3.1.5 Non-Real-time Software

Non-real-time software refers, in this document, typically to that software which runs under the UNIX operating system. This is due to the non-deterministic scheduling and task duration under this operating system.

1.3.2. Acronyms

1. ADC. . . . Analog to Digital Converter
2. AOM . . . Acousto-Optic Modulator
3. CDS . . . . Control and Data System
4. CIM . . . . Computer Integrated Manufacturing
5. DAC. . . . Digital to Analog Convertor
6. EPICS . . Experimental Physics and Industrial Control System
7. FDR . . . . Final Design Review
8. FSS. . . . . Frequency Stabilization Servo
9. I/O . . . . . Input/Output
10. LANL. . . Los Alamos National Laboratory
11. LCU . . . . Logical Control Unit
12. LLA . . . . Laser Loop Amplifier
13. MEDM. . Motif EPICS Display Manager
14. PC . . . . . Pockels Cell
15. PDR . . . . Preliminary Design Review
16. PM . . . . . Phase Modulation
17. PSA . . . . Power Stabilization Amplifier
18. PSL . . . . Pre-Stabilized Laser
19. PSS. . . . . Power Stabilization Servo
20. RC . . . . . Reference Cavity
21. RF . . . . . Radio Frequency
22. SNL . . . . State Notation Language
23. TBD . . . . To Be Determined
24. VME . . . Versa Modular Eurocard

1.4. References

1. Pre-Stabilized Laser Controls Subsystem Requirement Specification LIGO-T950001-1-C

2. EPICS User's Manual, LANL

1.5. Overview

This document is divided into three primary sections:
1. Introduction
2. General Description, which provides general background information
3. Specific Requirements, which details the software specifications

1.6. Precedence

This document is highlighted in the following figure, which shows a portion of the specification tree for LIGO. In the event of conflicts between this and other LIGO documentation, those documents at higher levels shall take precedence.

The light back shaded boxes indicate documents not produced by the CDS group. The documents labelled as 'CDS Global' provide specifications/information pertinent to all CDS projects, not just the PSL.

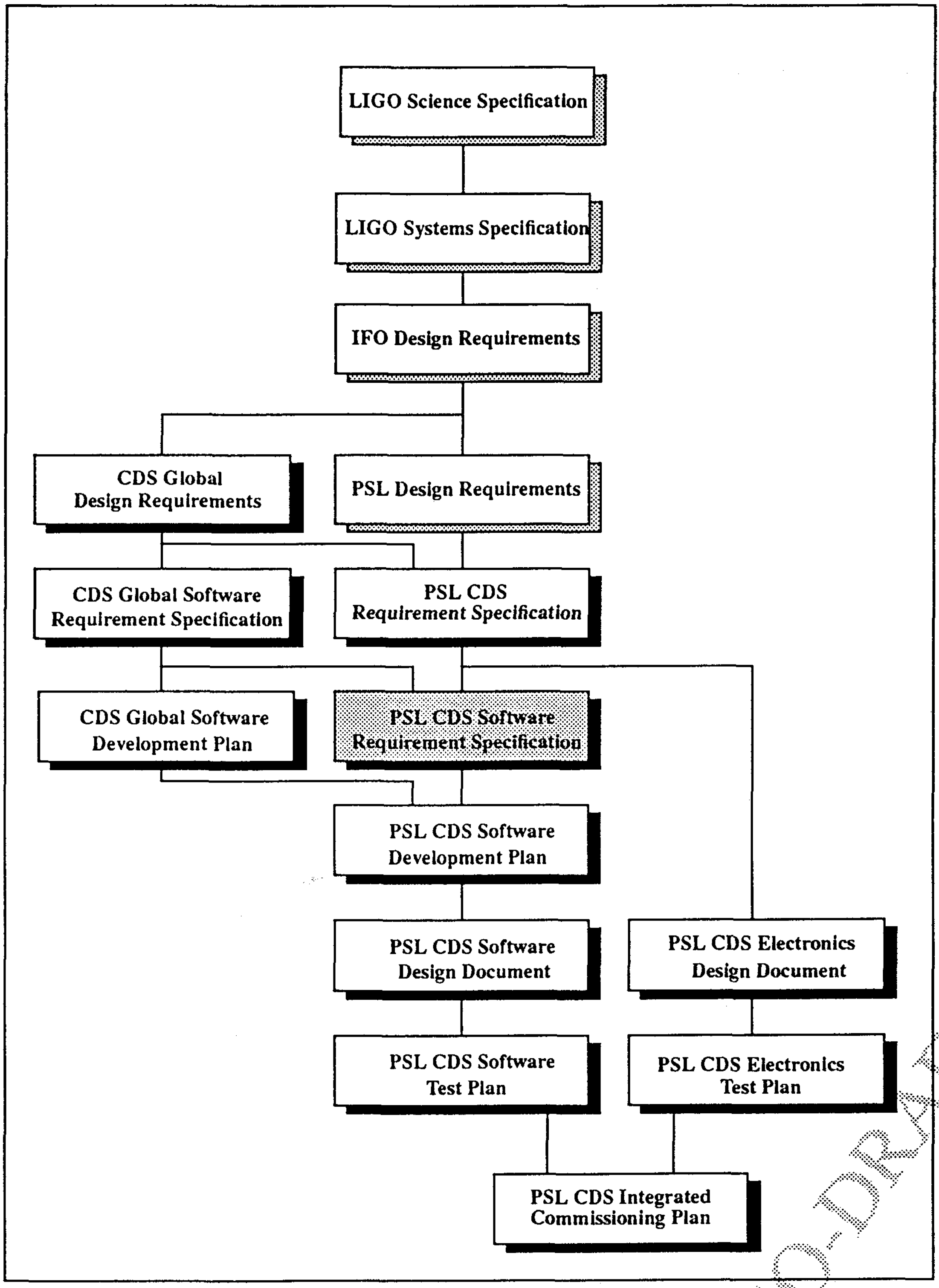

Figure 1: PSL CDS Document Tree

2 GENERAL DESCRIPTION

2.1. Product Perspective

The PSL is a subsystem of an interferometer, which is the scientific instrument of the LIGO project. For LIGO, this is only one small fraction of the overall CDS system. But, as a part of the larger system, it must be specified and designed to provide for a tight integration.

2.2. Product Functions

The primary function of this software is to provide real-time control and monitoring capabilities for the PSL within the overall framework of the LIGO Control and Data System (CDS). In Version 0 of the software (required to be complete by the time of the PSL Final Design Review), the software will be expected to provide, at minimum, Remote Manual operation capabilities. This is defined as having all the necessary capabilities to provide for remote operation and monitoring of the PSL via operator displays running on a UNIX workstation. Prior to start of LIGO commissioning at the various sites, this PSL software is intended to be extended to provide more automatic functionality as prescribed in this document. This will include such items as automatic start-up and shutdown of the PSL subsystem.

A basic layout of the software components are shown in the following figure. Predominantly, this specification, and ensuing development, will center around the PSL real-time control. Also specified are the appropriate setups and development of Unix workstation based software, such as operator interfaces, alarm managers, and data archivers.

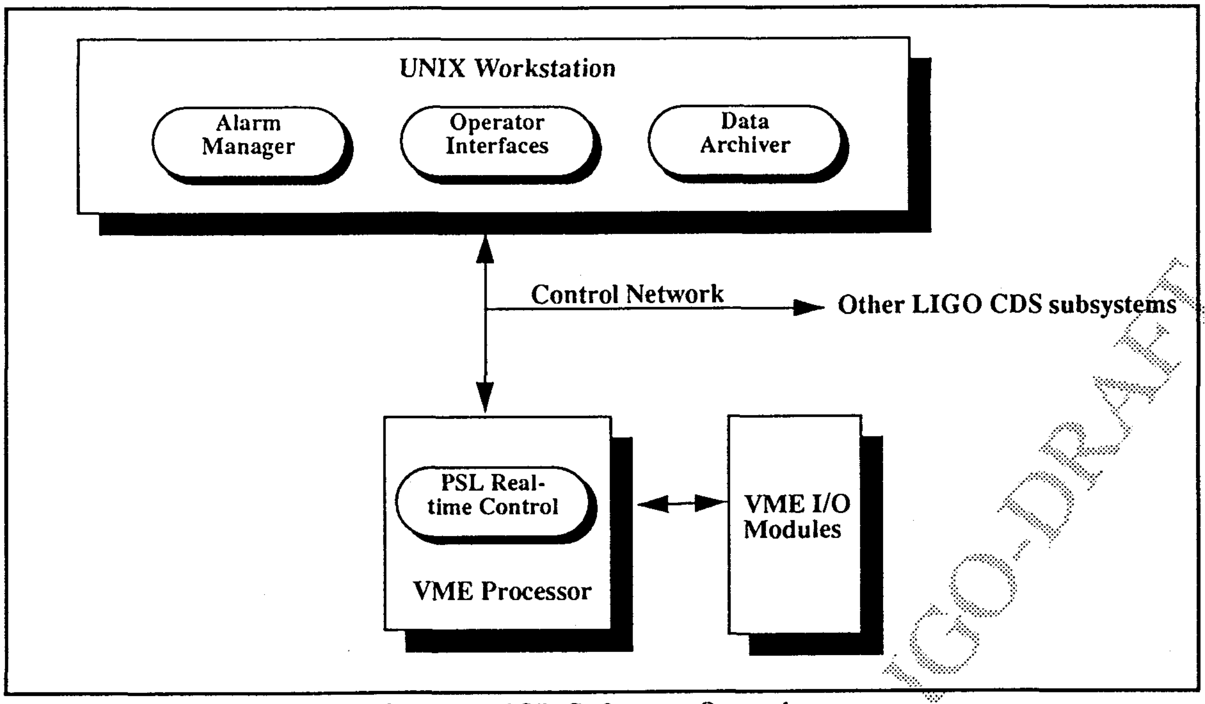

Figure 2: PSL Software Overview

2.3. User Characteristics

LIGO systems will evolve through various phases, with differing groups of staff involved.

Prototype development and Commissioning

CDS software and hardware engineers and technicians
Project lead scientists

LIGO Operation

Operating staff comprised of technicians, engineers, graduate students and scientific staff who were not necessarily involved with the PSL design and construction.

2.4. General Constraints

2.4.1. EPICS

All control and monitoring software for the LIGO project is to be developed within the framework of the Experimental Physics and Industrial Control System (EPICS) software developed by Los Alamos National Laboratory (LANL) and other laboratories and universities in the EPICS collaboration.

2.4.2. Naming Convention

A standard signal or tag name convention developed for LIGO will be used to identify all software channels. This channel identification convention is shown in the following figure. For purposes of this document, since the first system will be installed in the Caltech Mark II prototype, the channel designations are listed as CT:IF1-PL1_xxxx. Actual software developed for the various sites and interferometers will use the appropriate site designators.

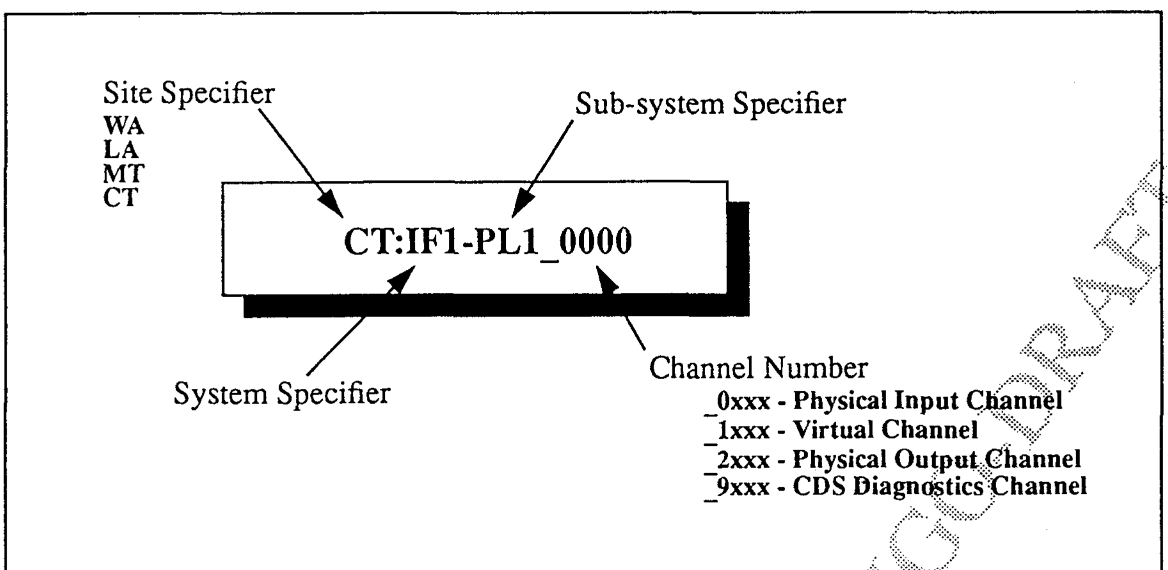

Figure 3: LIGO Data Naming Convention

Once loaded into EPICS, this data tag name is appended by a '.xxxx', where this describes the particular parameter of the data channel. For example, the actual channel value is located in 'ChannelName.VAL'. The engineering units of the data is located in 'ChannelName.ENG', and so on, depending on the data type. Refer to the EPICS User's Manual for more information on data tagging.

In addition to a unique name tag, each channel will be assigned a unique 'Short Description' field. This field is a plain text description of the data channel which is unique from all others. This field may be up to 30 characters in length.

Examples of the channel tag names and short description fields can be found in Appendix A.

2.5. Assumptions and Dependencies

2.5.1. Schedule

This document assumes that the present LIGO schedule will be followed for implementation, which begins with a prototype phase in the LIGO Optics Lab, and later is installed in the CalTech 40M interferometer prototype.

2.5.2. PSL Configuration

This document assumes that the present PSL optics layout is to be used with only possible minor modifications and that this design is consistent for the multiple PSL subsystems which are to be installed at LIGO sites. This specification does not take into account the possibility of multiple PSL subsystems per interferometer for redundancy.

2.6. Evolution

In a project such as LIGO, it is difficult to start with an original requirement specification at an early stage of design, and not expect requirements to change over time. Therefore, this document shall be kept updated throughout the project lifecycle, not just for the formal construction phase reviews. After this document's original release and review, an appendix will be added to note changes to the document to facilitate auditing and tracking requirement/scope changes.

3 SPECIFIC REQUIREMENTS

3.1. Introduction

The PSL Software Requirements are organized according to the CDS PSL Computer Integrated Manufacturing (CIM) model shown in the following figure. The shaded area indicates those levels covered by this document. This CIM model varies slightly from the CIM model in the PSL Subsystem Requirement Specification at level 1B and level 0. Since the software interfaces to sensors/electro-mechanical operators via VME I/O modules, Level 0 has been changed from 'Sensors' to VME Electronics. Level 1B has been changed to 'Device Drivers', which is that software which provides the actual interconnection between the VME I/O and the other PSL software.

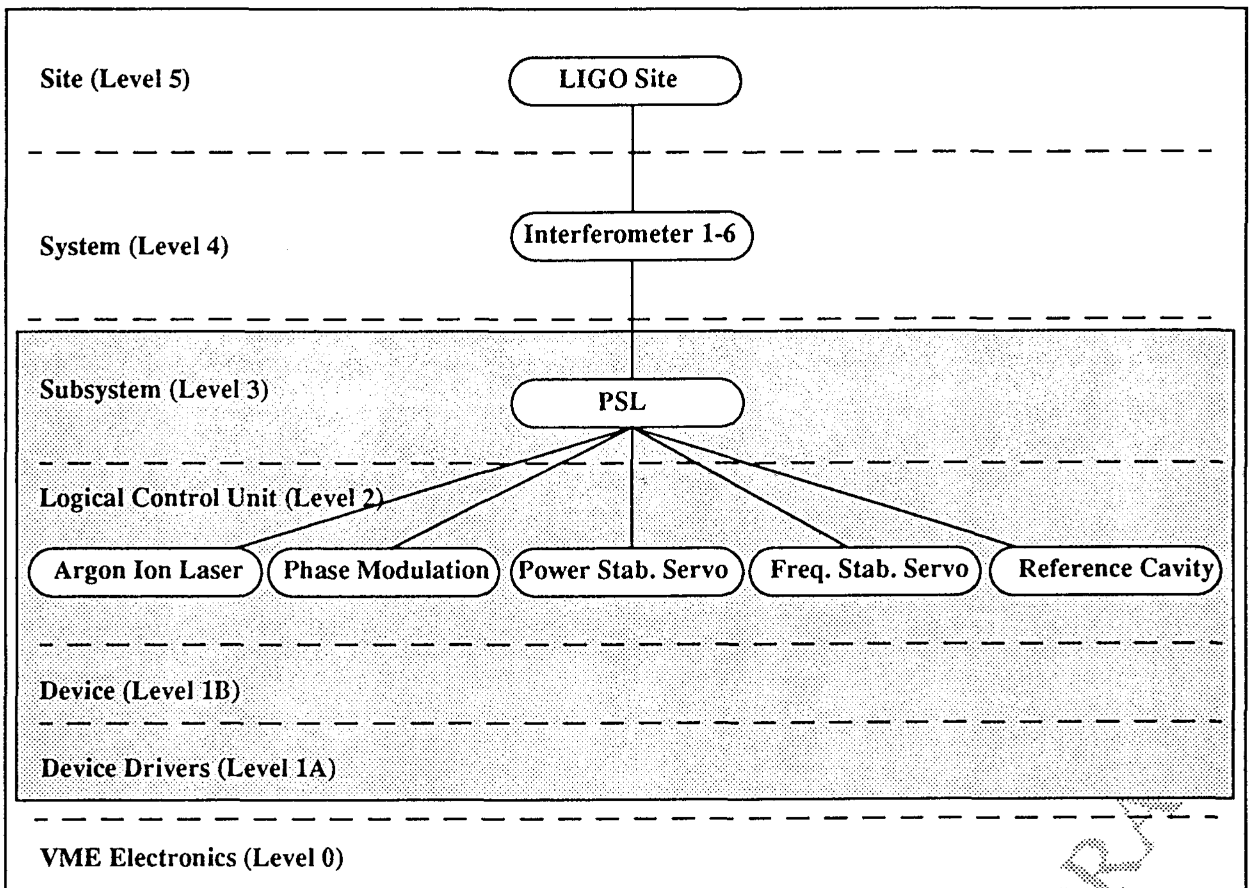

Figure 4: PSL CIM Model

Each of the subsections which follow specify the requirements for each level of software. Each section is divided up into the same categories, which are:

1. Introduction: Brief overview of the software to be developed and further breakout of the CIM model to give greater detail than allowed in the previous figure.
2. Real-time Software: That software which is to run within the VME uprocessor(s) associated

with the PSL. This section is further divided into:

- Virtual Inputs: Those software signals which are an input to the code to be developed.
- Normal Operations: Tasks to be performed by the software under 'Normal' operating conditions; this can include automatic sequences, control algorithms, etc. Normal Operation of the PSL, as a whole, is defined as:
  a) Laser 'ON', operating at maximum output power.
  b) Intensity (Power) Stabilization is ON and LOCKED.
  c) Frequency Stabilization is ON and LOCKED.
- Diagnostics: Automatic diagnostics to be performed by the software; this can cover a range of things, from CDS diagnostics to determine if the CDS components are operating correctly to setting up and taking spectrums of various PSL parameters.
- Machine Protection: The software shall work as a backup or second level to the CDS hardware protection systems.
- Abnormal Condition Detection and Response: Deals with the alarms to be generated by the software and response to be taken by the software when alarm conditions exist.
- Outputs: This software signals which are output by the software being defined in that particular section.

4. Non-Real-time Support Software: Software which operates on the UNIX workstations to provide interfaces to operations staff.
   - Operator Displays
   - Data Archival
   - Alarm Handler

3.2. General Requirements

For future SRS documents and later update of this document, this section will refer to the CDS Global Software Requirements Specification. This referred to document will cover general specifications to which all LIGO CDS software development must adhere. In the present absence of that document, some general system requirements are listed in the following paragraphs.

3.2.1. Input/Output (I/O) Sources

I/O to the real-time PSL control software is described in detail in following sections. Overall, I/O can come via the LIGO control ethernet or from VME modules . All I/O via the ethernet shall be through the Channel Access protocol of EPICS. If requirements dictate custom protocols due to EPICS limitations, that custom software shall, at minimum, provide control and status information through the general EPICS framework.

All I/O to/from the PSL VME modules shall be via EPICS module drivers, unless EPICS drivers can not meet the specified requirements. Under these circumstances, custom drivers may be developed, again within the control and monitoring framework of EPICS.

3.2.2. Processing

3.2.2.1 Data Conversions

All software which communicates with the VME hardware shall perform the necessary engineering to raw output and/or raw input to engineering units conversions prescribed for those physical interface channels. Where other specific data conversions are required, they will be listed in the appropriate software level sections which follow.

3.2.2.2 Automatic Sequencing

Various automatic sequences will be defined in the following sections. The general design philosophy shall be to provide intelligent or expert sequences at the lowest levels of the CIM structure as possible, i.e. the expert sequences to operate the laser should be within the Laser LCU software, not within software at the PSL Subsystem (Level 3) software. The intent is that higher levels of code need not have the expert knowledge of how to operate everything within the subsystem. Therefore, the higher levels can give simple commands, such as 'Laser On' to a lower level piece of code, which then contains the expertise to actually sequence the laser to the ON state.

3.2.2.3 Alarms

All alarms and warnings shall be presented to the operator via the EPICS Alarm Handler (ALH) whenever a data channel alarm/warning condition changes state. The alarm tree structure for ALH shall correspond to the PSL CDS CIM model.

3.2.2.3.1 Help Information

Within the ALH display, each channel shall have a 'Help' button, which causes the display of:
1. A text description of the channel.
2. At a minimum, one electrical layout drawing on which this signal appears, as a start to tracking of problems.
3. Information to assist in diagnosing the problem.
4. As applicable, procedures to correct the problem, or measures to take to prevent equipment damage.

3.2.2.3.2 Automatic Sequences

Where automatic sequences are built and suggested for use in response to alarms, an operator push-button shall be provided to begin that sequence (if it is not automatically run by the CDS).

3.2.2.4 Data Archival

3.2.2.4.1 PSL Control and Monitor Data

Slow data archival (10Hz or slower) shall be performed continuously on those data channels listed in Appendix C. Where addition data archival (such as for data arrays) exist, those requirements are listed in the 'Data Archival' paragraphs of the PSL Subsystem and LCU requirement sections which follow.

3.2.2.4.2 CDS messages

In general, all state/status messages produced by automatic sequencing software shall be archived to provide an audit trail for diagnostic purposes.

3.2.3. Operator Interfaces

3.2.3.1 Introduction

Operator interfaces are to be provided on remotely and/or locally positioned workstations to facilitate operation of the PSL.

3.2.3.2 Environment

All operator displays shall be developed with and function under the Motif EPICS Display Manager (MEDM) in X windows.

3.2.3.3 Hierarchy

The operator displays shall be supplied in a hierarchical fashion, following the CIM model, with more detail provided as one descends through the levels.

3.2.3.4 Control and Monitor / Monitor Only Displays

EPICS has no built-in security provisions, such as whether or not any particular person can adjust parameters. This is expected in future releases of EPICS. In the interim, in order to allow anyone to monitor the system, but not to operate it, each EPICS operator display built shall be replicated: one which has full control capabilities, and the other, which appears the same, but only has monitoring capabilities. These display files shall be maintained in two separate directories. One directory shall have restricted group access, while the monitor only directory will have public access.

3.2.3.5 Window Headers

The PSL Overview and LCU operator display window headers shall contain the name of the LCU or subsystem to establish the context of the data contained therein. The end of the name shall be followed by '_Control' or '_Monitor', indicating if it is an operational control screen or a monitor only screen.

3.2.3.6 Channel/Parameter Labelling

Care shall be taken in the labeling of dynamic data on display screens such that any signal labelled cannot be confused to be another signal in the CDS system. For example, a screen has a push-button labeled 'Control Mode'. Any number of devices have control modes, so which one is it? To avoid this situation, either:

1. A labeled signal is within an LCU or other specific display which allows identification of a signal as unique.
2. A signal is labelled with either its Channel name or its Short Description field, or both, as identified in Appendix A and B.

3.3. PSL Subsystem Requirements (Level 3)

3.3.1. Introduction

This section covers the level 3 (subsystem) requirements of the PSL. This would include all real-time software which oversees the various level 2 (Logical control units) of the PSL.

3.3.2. Real-time Software

3.3.2.1 PSL Subsystem Inputs

3.3.2.1.1 PSL Virtual Inputs

The PSL subsystem virtual inputs are shown in the following table.

Table 1: PSL Subsystem Virtual Inputs

Channel	*Short Description*	*Range*
TBD	PSL Operating Mode	Manual/Auto On/ Auto Off

3.3.2.1.2 PSL Physical Inputs

Connections, as necessary, to provide diagnostic information on the CDS (see diagnostics section).

3.3.2.2 Normal Operation

3.3.2.2.1 Initialization

On power up or system reboot, the software shall initialize to the Manual Mode. Additionally, this subsystem software shall ensure that the state of all PSL LCU goes to the defined 'Initialization' or 'OFF' state.

3.3.2.2.2 Modes of Operation

The PSL software shall provide for 'Manual' (operator controlled via EPICS displays), 'Auto On' and 'Auto Off' modes of operation. The Auto modes are described in the following paragraph.

3.3.2.2.3 Automatic Sequencing

The PSL software shall provide the capability to automatically sequence the PSL from an OFF state (all PSL LCU in their defined 'OFF' state) to a fully operational ON state (all PSL LCU in their defined 'ON' state) on operator request. This process, once started, shall be capable of completing this task without operator interaction (within limitations of hardware monitoring/ control). This process shall allow for the operator to return to a 'Manual' mode at any point, with the system maintaining the present status of the PSL. This software likewise shall allow an operator to return to the 'Automatic' mode at any point in the start-up/shutdown sequence.

3.3.2.3 Diagnostics

3.3.2.3.1 Transient Detection

The PSL subsystem level software shall provide for transient detection on various lower level PSL signals. These signals are:

1. HV Power Supply levels (5 ea)
2. Servo Error Points (2 ea)
3. Servo Actuator Monitor (5 ea)

Further detailed specification of processing of these signals is TBD. (Read from hardware threshold detector? Digitization of signal around the transient detection point?)

3.3.2.3.2 CDS Diagnostics

This level of software shall provide diagnostics to ensure that:

1. The PSL VME crate hardware and associated I/O modules are operating correctly.
2. The proper software has been downloaded and is functioning properly on the VME processor.

These diagnostics shall be performed on CDS start-up and on operator request thereafter. This information shall be available to the operator on request.

3.3.2.4 Abnormal Condition Detection and Response

In general, the lower levels of PSL software shall produce the alarm conditions. At this level, the software shall detect and produce alarms when:

1. The automatic sequence, described above, is not able to complete its functions, due to a system fault.
2. The PSL VME diagnostics have detected a fault within the CDS components.
3. Transients (as listed in Diagnostics) have occurred.

3.3.2.5 PSL Subsystem Outputs

3.3.2.5.1 PSL Virtual Outputs

Table 2: PSL Subsystem Virtual Outputs

Channel	*Short Description*	*Range*
TBD	PSL Subsystem Status	String, indicating status information about the PSL subsystem as a whole.
TBD	PSL Sequencer Status	String, indicating status of PSL sequencers

3.3.2.5.2 PSL Physical Outputs

The PSL subsystem software shall provide physical outputs, as necessary, to test the status of the CDS equipment, mentioned in the previous 'diagnostics' section.

3.3.3. Non-Real-time Support Software

3.3.3.1 Operator Displays

At this level, the CDS software shall provide an overview operator display of the PSL operation. This shall include:

1. Those items which give a quick indication of overall operation, such as:
    - Laser Power/Status
    - Intensity Stabilization Status
    - Frequency Stabilization Status
2. Push-button, which provide access to the high level sequences of starting up/shutting down or performing diagnostics on the PSL subsystem.
3. A menu select to move around to various other PSL related operator displays which provide greater detail / different functionality.

3.3.3.2 Data Archival

No special data archival requirements exist at this level.

NOTE: For prototype tests in the optics lab, extra sensors will be installed which will either not be installed in LIGO or be part of a separate system. These sensors will be connected to the PSL CDS during prototyping and must be archived. These are:

1. Room temperature - 1 channel
2. Seismometer RMS levels - 4 channels
3. Microphone RMS levels - 4 channels

Archiving rates/deadbands are TBD.

3.3.3.3 Alarm Handler

A separate alarm tree branch shall exist for PSL subsystem level 3 software alarms.

3.4. PSL LCU and Device Requirements (Level 2 & 1B)

3.4.1. Introduction

3.4.2. Argon Ion Laser LCU

3.4.2.1 Introduction

The Argon laser LCU consists of two devices: Laser and Temperature Controller. The temperature controller does not have remote I/O capabilities, therefore this LCU software only has requirements for laser device control and monitoring. The expanded CIM model for this LCU is shown in the following figure.

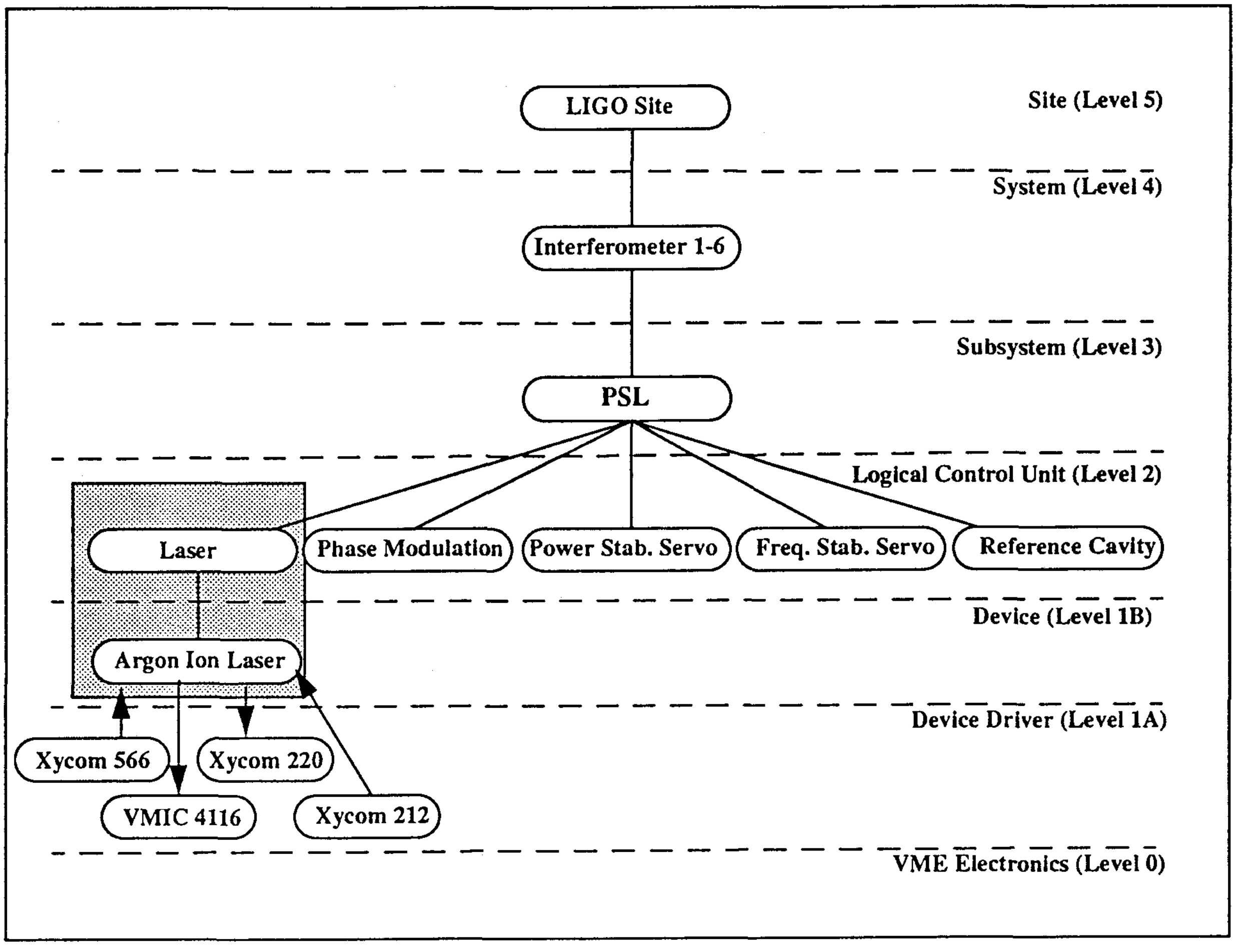

Figure 5: Laser LCU CIM Detail

3.4.2.2 Real-time Software

3.4.2.2.1 Laser LCU Inputs

3.4.2.2.1.1 Physical Input Channels

Physical input channels and module/channel assignments are shown in Appendix A (LCU = Laser).

3.4.2.2.1.2 Virtual Input Channels

The Laser LCU shall accept the virtual inputs as listed in Table 3: Laser LCU Virtual Inputs

3.4.2.2.2 Normal Operation

In normal LIGO operation, the PSL laser is set and adjusted for maximum power output.

Table 3: Laser LCU Virtual Inputs

Channel	*Short Description*	*Range*
TBD	Laser Power Control	Off/On
TBD	Laser Power Request	0-10W
TBD	LCU Mode Select	Manual/Auto

3.4.2.2.2.1 Power up initialization

Upon software initialization, the laser shall be brought to an 'OFF' state, as defined by the following table.

Table 4: Laser 'OFF' State Definition

Channel	*Description*	*Setting*
TBD	Laser Computer/IEEE488 Control	Computer
TBD	Laser Control Mode	Power
TBD	Laser Power Range	0-10 Watts
TBD	Laser Plasma Control	OFF
TBD	Laser Purge Gas Control	OFF
TBD	Laser Water Control	OFF

3.4.2.2.2.2 Data Conversion

The Laser Power Request shall be converted by this code to produce the proper power settings to the laser via the Laser Power Range outputs and Laser Power Control output.

Monitored laser power shall be derived by the software via the Laser Power Range Select Status bits and the Laser Tube Power readback.

3.4.2.2.2.3 Automatic Sequencing

The Laser LCU software shall provide automatic sequences which take the laser from an 'OFF' state to the 'ON' state (see Laser 'ON' State Definition), from the 'ON' state back to the 'OFF' state, or to either state from some intermediate state. These sequences shall be started/stopped via a single operator push-button, which is also accessible by other CDS software for later higher level sequencer development.

Table 5: Laser 'ON' State Definition

Channel	*Short Description*	*Setting*
TBD	Laser Computer/Remote	Remote
TBD	Laser Power Range	0-10 Watts
TBD	Laser Control Mode	Power
TBD	Laser Plasma On/off	ON
TBD	Laser Purge Gas Control	ON
TBD	Laser Power Adjust	Maximum / Operator Request

3.4.2.2.3 Diagnostics

There are no requirements on the Laser LCU software for laser diagnostics.

3.4.2.2.4 Machine Protection

The Laser LCU software shall not allow the laser to be cycled to the 'ON' state if any of the laser interlocks or Laser Key Switch are OPEN. OPEN is defined as not the normal indication for laser operation. Should an interlock become OPEN while the laser is transitioning to or in the 'ON' state, the automatic shutdown sequence shall be initiated (even though the opening of an interlock should have caused the PSL hardware to also shutdown the system).

3.4.2.2.5 Abnormal Condition Detection and Response

The Laser LCU software shall produce alarm conditions for its assigned I/O channels dependent upon the operational state of the laser (OFF/ON). During the transitions between those states, the sequencer, described previously, shall notify the operator of abnormal start-up/shutdown conditions.

3.4.2.2.5.1 Laser Alarms while laser is in ON state

Once in the ON state, the laser LCU shall turn on all alarm monitoring for the laser power supply produced interlocks, Laser Key Switch and the Purge Gas. In the case of all laser power supply interlocks (including the Laser Key Switch), the alarm severity shall be set to 'MAJOR'. Should one of these alarm conditions occur, the laser power supply will shut off due to hard interlocking. The PSL software shall automatically initiate the laser shutdown sequence.

The Purge Gas alarm (gas pressure reading <TBD) severity shall be set to MINOR. If a Purge Gas alarm should occur, and continue for > TBD minutes, the software shall raise the alarm severity to MAJOR and initiate the laser shutdown sequence.

3.4.2.2.5.2 Laser Alarms in the OFF state

When the laser has been requested to OFF:

The laser power supply interlock alarms shall be disabled, with the exception of the Low Water

Flow. If there is not a Low Water Flow indication within TBD minutes of Laser Cooling Return Water Temp being with TBD degrees of the Laser Cooling Supply Water Temp., an alarm of MINOR severity shall be issued. If this condition persists beyond TBD minutes, the severity shall be raised to MAJOR.

The Laser Key Switch alarm shall be reduced in severity to MINOR.

The Purge Gas alarm polarity shall be reversed, i.e. alarm condition if there is purge gas pressure > TBD. The alarm severity shall be set to MINOR.

3.4.2.2.6 Laser LCU Outputs

3.4.2.2.6.1 Physical Output Channels

Laser LCU shall provide physical output channels as listed in Appendix B (LCU = Laser).

3.4.2.2.6.2 Virtual Output Channels

.

Table 6: Laser LCU Virtual Outputs

Channel	*Short Description*	*Range*
TBD	Laser Power Monitor	0-10W

3.4.2.3 Non-Real-time Support Software

3.4.2.3.1 Operator Displays

A separate interactive display shall be provided which contains all of the control and monitor points available within the Laser LCU.

3.4.2.3.2 Data Archival

3.4.2.3.3 Alarm Handler

A separate alarm branch shall be developed below the PSL subsystem for the display of Laser LCU alarm states.

3.4.3. Power Stabilization Servo (PSS)

3.4.3.1 Introduction

Power stabilization is achieved by controlling the ratio of laser power in the zero order and first order beams at the output of an Acousto-Optic Modulator (AOM). The various devices which make up the PSS are (as defined in the CDS PSL Requirement Specification):

- Reference Photodiode
- Power Stabilization Amplifier (PSA)

- AOM Driver
- AOM

The PSL software only has direct control and monitor responsibilities for two of these devices, as shown in the following diagram.

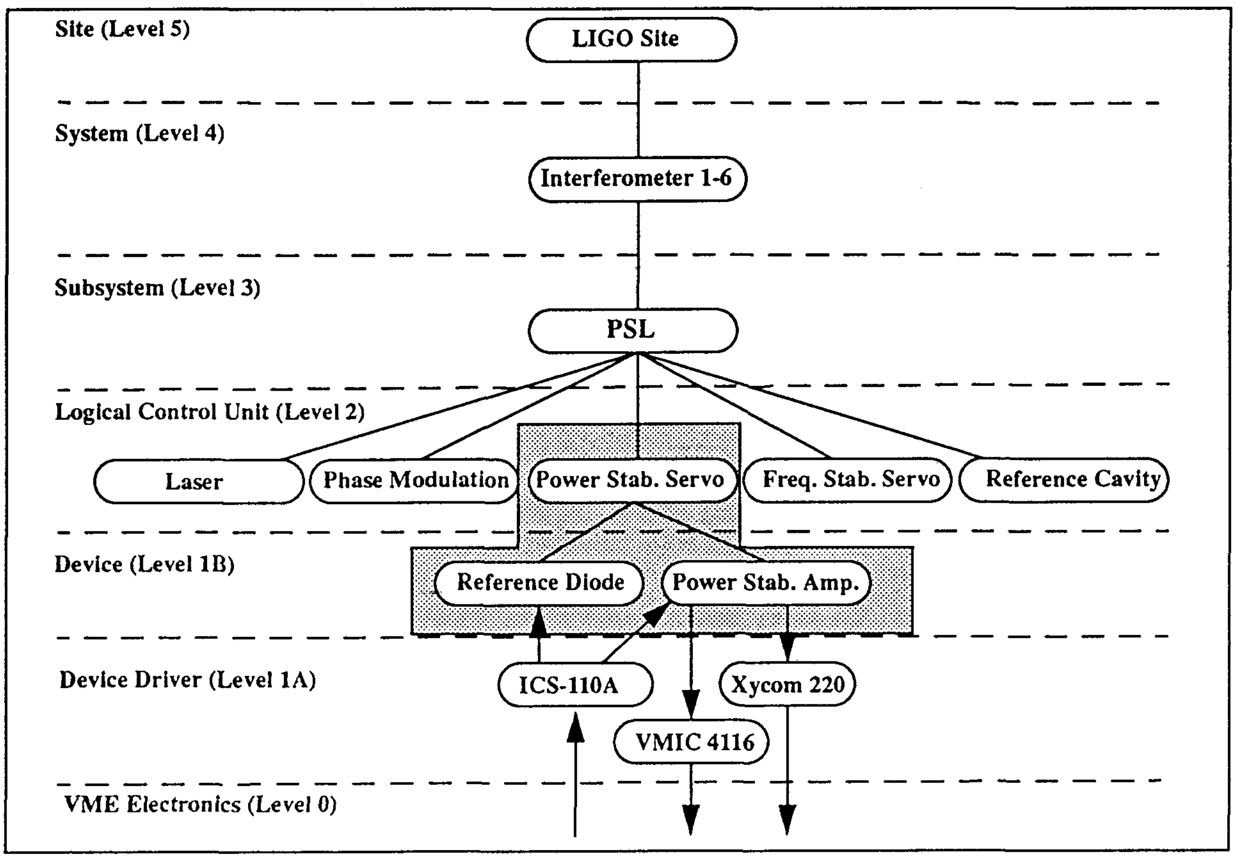

Figure 6: PSS LCU CIM Detail

3.4.3.2 PSS Real-time Software

3.4.3.2.1 PSS LCU Inputs

3.4.3.2.1.1 PSS Physical Inputs

All PSS physical input channels are listed in Appendix A (LCU=PSS).

3.4.3.2.1.2 PSS Virtual Inputs

The PSS LCU software shall accept virtual inputs as listed in Table 7: PSS LCU Virtual Inputs.

3.4.3.2.2 Normal Operation

Normal operation for the PSS is laser output power (intensity) stabilized and locked.

Table 7: PSS LCU Virtual Inputs

Channel	*Short Description*	*Range*
TBD	Laser Power Monitor	0-10W
TBD	PSS Manual/Auto Lock	Manual/Auto

3.4.3.2.2.1 Initialization

On software initialization, the PSS shall come up in the 'OFF' state, as defined in Table 8: PSS Operating Mode Characteristics.

3.4.3.2.2.2 Modes

The software shall support the following operating modes:

- PSS OFF
- PSS ON
- Cavity Ringdown

Channels associated with these modes and their states in each mode are shown in the following table.

Table 8: PSS Operating Mode Characteristics

Channel	*Description*	*PSS OFF*	*PSS ON*	*Ringdown*
TBD	PSA Output Enable	OFF	ON	OFF
TBD	PSA Ringdown Enable	OFF	OFF	ON

3.4.3.2.2.3 PSS LOCK Indication

The PSS LCU software shall provide a PSS LOCK indication. PSS LOCK is defined as:

1. PSS Operating Mode: PSS ON
2. PSA Output: < 40 mV

3.4.3.2.2.4 Automatic Sequences

The PSS software shall provide an automatic Power locking capability. In normal operation, this consists of:

1. Selecting the proper PSA attenuator which corresponds approximately with 10% less power (as read from the reference photodiode) than that read with the PSA mode set to OFF at the present laser output power.
2. Setting the PSA mode to ON.
3. Adjusting the PSA vernier until the PSA has a lock indication, PSA output is minimum, and PSL power output is maximum. Due to relatively long time constants in the PSA electronics, the slew rate for the PSA vernier shall be no faster than 10Hz, but not slower than 5Hz in order to achieve lock within a reasonable length of time.

The PSS software also needs to provide sequences for other operating modes (see Diagnostics section below).

3.4.3.2.3 Diagnostics

3.4.3.2.3.1 Ringdown Measurement

The PSS LCU software shall provide for ringdown measurements of the PSL reference cavity, mode cleaner, and interferometer arms.

This software shall:

1. Provide on/off selection of the ringdown test.
2. Provide an 80mV pp, 50% duty cycle signal to the PSA at three frequencies:
   - 200 Hz, for reference cavity measurements
   - TBD, for mode cleaner measurements
   - TBD, for the arm measurements
3. Set the appropriate switches within the PSA to disable the normal PSA output, and direct this test output signal to the AOM driver.
4. Read data from the cavity photodiode and perform the ringdown measurement.
5. Display the measurement results to the operator.

The ringdown measurement accuracy shall be TBD, with a resolution of TBD.

3.4.3.2.3.2 Intensity Noise Spectrum Measurement

One of the methods of determining proper PSL operation is to take a power (intensity) noise spectrum. The PSS software shall provide for one button execution of this test, with results to be displayed to the operator.

3.4.3.2.3.3 Operation Verification

The PSS software shall provide an automatic test procedure to verify, to the extent possible, that the PSS software and hardware is operating properly. Results of the test(s) shall be provided to the operator on request.

3.4.3.2.4 Abnormal Condition Detection and Response

The PSS software shall produce alarm conditions only after the PSS has achieved an ON and LOCKED state. At this point, the PSS software shall arm alarms for:

1. PSS inadvertently going to an OFF state.
2. PSS losing LOCK.
3. PSS hardware/software fault is detected.

3.4.3.2.5 PSS Outputs

3.4.3.2.5.1 PSS Physical Outputs

PSS physical output channels shall be as defined in Appendix B (LCU = PSS).

3.4.3.2.5.2 PSS Virtual Outputs

The PSS LCU shall provide virtual output channels as defined in Table 9: PSS LCU Virtual Outputs.

Table 9: PSS LCU Virtual Outputs

Channel	*Short Description*	*Range*
TBD	PSS LOCK Indication	$\overline{\text{LOCK}}$/LOCK

3.4.3.3 Non-Real-time Support Software

3.4.3.3.1 Operator Displays

A separate interactive display shall be provided which contains all of the control and monitor points available within the PSS LCU.

3.4.3.3.2 Data Archival

The PSL CDS software shall provide the capability to store results of the various PSS diagnostics as arrays of data in a ***TBD*** format suitable for retrieval by various LIGO analysis software packages.

3.4.3.3.3 Alarm Handler

A separate alarm branch shall be developed below the PSL subsystem for PSS LCU alarms.

3.4.4. Phase Modulation

3.4.4.1 Introduction

The phase modulation LCU uses Pockels Cells to phase modulate the laser light with amplitude ~1 rad and frequency of 10.7 MHz. It is made up of a master oscillator, RF power amplifier, and PC matching network. This section describes the software requirements to control and monitor this LCU.

3.4.4.2 Real-time Software

3.4.4.2.1 PM Inputs

3.4.4.2.1.1 PM Physical Inputs

PM physical input channels shall be as defined in Appendix A (LCU = PM).

3.4.4.2.1.2 PM Virtual Inputs

TBD

3.4.4.2.2 Normal Operation

3.4.4.2.2.1 Initialization

On software initialization, the PM shall be initialized in the 'OFF' state as defined in Table 10: PM 'OFF' State Definition.

Table 10: PM 'OFF' State Definition

Channel	*Description*	*Setting*
TBD	PM MO PS Control	OFF
TBD	PM RF Mod Control	OFF
TBD	PM RF Power Select	0W

3.4.4.2.2.2 Automatic Sequences

Automatic sequencing for the PM LCU is ***TBD***.

3.4.4.2.3 Diagnostics

TBD

3.4.4.2.4 Abnormal Condition Detection and Response

TBD

3.4.4.2.5 PM Outputs

3.4.4.2.5.1 PM Physical Outputs

PM LCU physical output channels shall be as defined in Appendix B (LCU = PM).

3.4.4.2.5.2 PM Virtual Outputs

TBD

3.4.4.3 Non-Real-time Support Software

3.4.4.3.1 Operator Displays

3.4.4.3.2 Data Archival

No special data archival requirements.

3.4.4.3.3 Alarm Handler

TBD

3.4.5. Frequency Stabilization Servo (FSS) LCU

3.4.5.1 Introduction

The FSS uses Pockels cells, piezo mounted laser mirrors and a rigid spacer Fabry-Perot cavity to prestabilize the laser light frequency.

The FSS is comprised of the following devices:

- Laser Loop Amplifier (LLA)
- Visibility Monitor
- Laser PZT Driver
- RF Photodetector

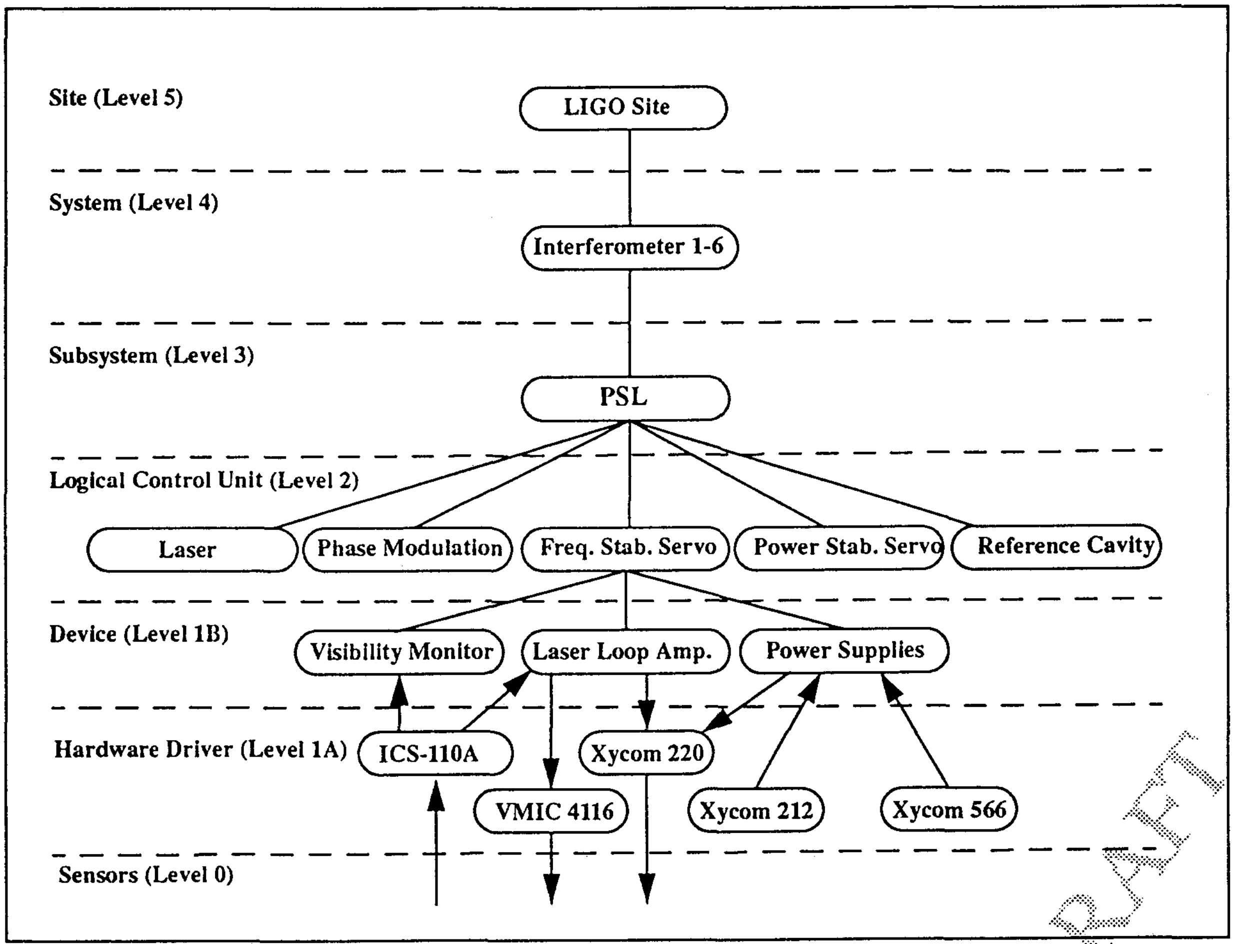

Figure 7: FSS LCU CIM Detail

3.4.5.2 Real-time Software

3.4.5.2.1 FSS Inputs

3.4.5.2.1.1 FSS Physical Inputs

FSS physical input channels shall be as defined in Appendix A (LCU = FSS).

3.4.5.2.1.2 FSS Virtual Inputs

The FSS LCU software shall have the virtual input channels as defined in Table 11: FSS Virtual Inputs.

Table 11: FSS Virtual Inputs

Channel	*Short Description*	*Range*
TBD	FSS Scan Mode Select	Off/Auto/On
TBD	FSS LLA Gain Select	Auto/Bypass off/ Bypass On
TBD	FSS Visibility Threshold	0-100%

3.4.5.2.2 Normal Operation

Normal operation for the FSS is in the ON and LOCKED state.

3.4.5.2.2.1 Initialization

On software initialization, the FSS shall be set to the 'OFF' state as characterized in the following table.

Table 12: FSS 'OFF' State Definition

Channel	*Description*	*Setting*
TBD	FSS Slow PZT Power Supply On/off	OFF
TBD	FSS Fast PZT Power Supply On/off	OFF
TBD	FSS RF Photodetector PS On/off	OFF
TBD	FSS PC Power Supply On/off	OFF
TBD	FSS LLA Test Enable	OFF

3.4.5.2.2.2 Scan Modes

The FSS software shall support three slow PZT scan modes as selected by the FSS Scan Mode Select Channel. These modes are:

SCAN OFF: Slow PZT is not allowed to SCAN but retains its present setting.

SCAN AUTO: FSS automatically attempts to gain 'LOCK', which is defined by visibility greater than threshold (see visibility monitor). When $\overline{\text{LOCK}}$, the Slow PZT shall be scanned through its range in 1VDC steps at 1msec time intervals until LOCK is indicated by the visibility monitor.

SCAN ON: Slow PZT is continuously scanned from 0-850VDC in 1VDC increments at 1msec time intervals. Scan ramp shall be from 0VDC to 850VDC, then back to 0VDC and continue.

3.4.5.2.2.3 Laser Loop Amplifier Gain Select

The LLA software shall support LLA gain selections via the FSS LLA Gain Select input. These settings are:

AUTO: LLA goes to wideband or bypass, depending on the LOCK indication from the visibility monitor.
WIDEBAND: Gain of LLA is set to wideband continuously.
BYPASS: Gain of LLA is set to bypass continuously.

3.4.5.2.2.4 Visibility Monitor Calibration

The FSS shall provide for calibration of the RF photodiode measurement to the Reference photodiode measurement upon operator request. This calibration shall be performed while the FSS is not locked to balance the photodiode readings. This calibration shall be:

$$K_{calibration} = I_{in} / I_{reflected}$$

Where:

I_{in} = Reference photodiode measurement in mA

$I_{reflected}$ = RF photodiode DC output measurement in mA

3.4.5.2.2.5 Visibility Calculation

The software shall calculate visibility as:

$$Visibility = \left(I_{in} - K_{calibration} \times I_{reflected}\right) / I_{in}$$

Where:

I_{in} = Reference photodiode measurement in mA

$K_{calibration}$ = Calibration factor calculated in 3.4.5.2.2.5

$I_{reflected}$ = RF photodiode DC output measurement in mA shall be developed for these modules.

In addition, a TPRO VME module is inserted into the crate for timing information.

3.5.1.1 ICS-110A Driver

The ICS-110A module driver must perform in three modes:

1. Slow or Standard Mode: Take synchronized data, one value for each of 32 channels, at a 10Hz rate.
2. Fast Mode: Take synchronized data at a 1KHz rate, one value for each of 32 channels. (Note: Needed to support the LLA slow PZT drive when analog loop loses lock indication)
3. Burst or Snapshot Mode: Take synchronized data sets at rates up to 100KHz for diagnostic purposes. This data is to be placed in waveform records for operator/other software analysis.

3.5.1.2 Timing Information

For normal data timestamping, the EPICS internal timestamping capabilities shall be used. This time of day information is provided by the VME TPRO module. In cases where PSL application software requires accurate timing/time of day information and cannot access the EPICS timestamping (such as when parts are developed in State Notation Language (SNL) or custom C code), that information shall be obtained from the TPRO module to ensure that time information is consistent with the rest of the system.

3.5.2. Module Base Addresses

The PSL software shall communicate with the VME modules set to the base addresses given in Table 16: PSL VME Module Base Addresses.

Table 16: PSL VME Module Base Addresses

VME Module	*Control Address Space*	*Data Address Space*
VMIC 4116 #1	***TBD***	***TBD***
VMIC 4116 #2	***TBD***	***TBD***
Xycom 212	***TBD***	***TBD***
Xycom 220	***TBD***	***TBD***
ICS-110A	***TBD***	***TBD***
TPRO Timing	***TBD***	***TBD***

3.5.3. Data Channel Connection

Individual physical input and output channels shall connect to the VME module and channel as defined in Appendix A and B.

3.5.4. CDS Network Interface

The PSL software shall operate on an MVME167 or MVME162 microprocessor. This processor shall be setup to boot from the LIGO CDS site server TBD. Processor network names and addresses shall be set as listed in Table TBD.

Appendix A: Physical Input Channels

This Appendix provides the database listings for all PSL physical input channels. Note: Those channels listed with a Device Type of 'Soft Channel' are to connect to the ICS-110A module.

PSL Physical Input Channels

27-Jun-95

Record	LCU	DESCRIPTION	SCAN	DEVICE TYPE	MOD/CHAN
CT:IF1-PL1_0013	UNA			Soft Channel	
CT:IF1-PL1_0016	UNA			Soft Channel	
CT:IF1-PL1_0015	UNA			Soft Channel	
CT:IF1-PL1_0001	PSA	PSA Output Monitor	Passive	Soft Channel	
CT:IF1-PL1_0014	UNA			Soft Channel	
CT:IF1-PL1_0012	UNA			Soft Channel	
CT:IF1-PL1_0011	UNA			Soft Channel	
CT:IF1-PL1_0010	UNA			Soft Channel	
CT:IF1-PL1_0008	UNA			Soft Channel	
CT:IF1-PL1_0007	UNA			Soft Channel	
CT:IF1-PL1_0006	UNA			Soft Channel	
CT:IF1-PL1_0005	PSA	PSS Ref Photo Diode		Soft Channel	
CT:IF1-PL1_0004	RC	PSL RC Vacuum Monitor		Soft Channel	
CT:IF1-PL1_0009	UNA			Soft Channel	
CT:IF1-PL1_0002	FSS	Ref. PD Monitor		Soft Channel	
CT:IF1-PL1_0003	FSS	RF PD Monitor		Soft Channel	
CT:IF1-PL1_0028	Laser	Laser Emission Indicator	1 second	XVME-210	#C1 S16 @

Record	LCU	DESCRIPTION	SCAN	DEVICE TYPE	MOD/CHAN
CT:IF1-PL1_0020	Laser	Laser Reg. Fault	1 second	XVME-210	#C1 S17 @
CT:IF1-PL1_0018	Laser	Laser Head Cover Intlk.	1 second	XVME-210	#C1 S18 @
CT:IF1-PL1_0024	Laser	Laser Premon 0	1 second	XVME-210	#C1 S19 @
CT:IF1-PL1_0025	Laser	Laser Premon 1	1 second	XVME-210	#C1 S20 @
CT:IF1-PL1_0026	Laser	Laser Premon 2	1 second	XVME-210	#C1 S21 @
CT:IF1-PL1_0027	Laser	Laser Tube Fill Status	1 second	XVME-210	#C1 S22 @
CT:IF1-PL1_0017	Laser	Laser Hi H2O Temp.	1 second	XVME-210	#C1 S23 @
CT:IF1-PL1_0019	Laser	Laser Low H2O Flow	1 second	XVME-210	#C1 S24 @
CT:IF1-PL1_0029	Laser	Laser Mode Monitor	1 second	XVME-210	#C1 S25 @
CT:IF1-PL1_0036	Laser	Laser Key Switch Monito	1 second	XVME-210	#C1 S26 @
CT:IF1-PL1_0021	Laser	Laser Voltage Monitor	.2 second	XYCOM-566 SE Scanned	#C0 S0 @
CT:IF1-PL1_0039	FSS	LLA -PC Output	.2 second	XYCOM-566 SE Scanned	#C0 S10 @
CT:IF1-PL1_0040	FSS	LLA PZT Out Monitor	.2 second	XYCOM-566 SE Scanned	#C0 S11 @
CT:IF1-PL1_0041	FSS	LLA Slow PZT Monitor	.2 second	XYCOM-566 SE Scanned	#C0 S12 @
CT:IF1-PL1_0042	FSS	LLS Fast PZT Monitor	.2 second	XYCOM-566 SE Scanned	#C0 S13 @
CT:IF1-PL1_0034	RC	Str. M2 X- Monitor	.2 second	XYCOM-566 SE Scanned	#C0 S16 @
CT:IF1-PL1_0035	RC	Str. M2 Y Monitor	.2 second	XYCOM-566 SE Scanned	#C0 S17 @
CT:IF1-PL1_0022	Laser	Laser Current Monitor	.2 second	XYCOM-566 SE Scanned	#C0 S2 @
CT:IF1-PL1_0023	Laser	Laser Power Monitor	.1 second	XYCOM-566 SE Scanned	#C0 S3 @
CT:IF1-PL1_0030	RC	Str. M1 X+ Monitor	.2 second	XYCOM-566 SE Scanned	#C0 S4 @

Record	LCU	DESCRIPTION	SCAN	DEVICE TYPE	MOD/CHAN
CT:IF1-PL1_0031	RC	Str. M1 X- Monitor	.2 second	XYCOM-566 SE Scanned	#C0 S5 @
CT:IF1-PL1_0032	RC	Str. M1 Y Monitor	.2 second	XYCOM-566 SE Scanned	#C0 S6 @
CT:IF1-PL1_0033	RC	Str. M2 X+ Monitor	.2 second	XYCOM-566 SE Scanned	#C0 S7 @
CT:IF1-PL1_0037	FSS	LLA Demod Monitor	.2 second	XYCOM-566 SE Scanned	#C0 S8 @
CT:IF1-PL1_0038	FSS	LLA +PC Output Monitor	.2 second	XYCOM-566 SE Scanned	#C0 S9 @

Appendix B: Physical Output Channels

This Appendix provides the database listings for all PSL physical output channels. NOTE: Those channels which are listed with a Device Type of "Soft Channel" are to connect to the VMIC4116 modules.

PSL Physical Output Channels

27-Jun-95

Record	LCU	DESCRIPTION	DEVICE TYPE	MOD/CHAN
CT:IF1-PL1_2001	FSS	FSS LLA Ins. Amp. DC adj.	Soft Channel	
CT:IF1-PL1_2002	FSS	FSS LLA Wideband DC Adj.	Soft Channel	
CT:IF1-PL1_2003	FSS	FSS LLA Gain Adj.	Soft Channel	
CT:IF1-PL1_2004	FSS	FSS LLA PZT Bias Adj.	Soft Channel	
CT:IF1-PL1_2005	FSS	FSS PZT Scan Control	Soft Channel	
CT:IF1-PL1_2006	UNA		Soft Channel	
CT:IF1-PL1_2007	UNA		Soft Channel	
CT:IF1-PL1_2008	PSA	PSA Vernier Bias Adj.	Soft Channel	
CT:IF1-PL1_2009	RC	Steering M1 X Control	Soft Channel	
CT:IF1-PL1_2010	RC	Steering M1 Y Control	Soft Channel	
CT:IF1-PL1_2011	RC	Steering M2 X Control	Soft Channel	
CT:IF1-PL1_2012	RC	Steering M2 Y Control	Soft Channel	
CT:IF1-PL1_2013	UNA		Soft Channel	
CT:IF1-PL1_2014	Laser	Laser Current Control	Soft Channel	
CT:IF1-PL1_2015	Laser	Laser Power Control	Soft Channel	
CT:IF1-PL1_2016	UNA		Soft Channel	
CT:IF1-PL1_2038	Laser	Purge Gas Valve Cntrl	Soft Channel	

Record	LCU	DESCRIPTION	DEVICE TYPE	MOD/CHAN
CT:IF1-PL1_2039	Laser	Cooling Water Cntrl	Soft Channel	
CT:IF1-PL1_2023	PSA	PSA Test Enable 1	XVME-220	#C1 S0 @
CT:IF1-PL1_2024	PSA	PSA Gain Select 3	XVME-220	#C1 S1 @
CT:IF1-PL1_2033	FSS	FSS PZT Scan Enable	XVME-220	#C1 S10 @
CT:IF1-PL1_2034	FSS	FSS PZT Test Enable	XVME-220	#C1 S11 @
CT:IF1-PL1_2037	FSS	FSS LLA RD Gain Sel.	XVME-220	#C1 S12 @
CT:IF1-PL1_2036	FSS	FSS LLA DAQ Gain Sel.	XVME-220	#C1 S13 @
CT:IF1-PL1_2035	FSS	FSS CDS Gain Sel.	XVME-220	#C1 S14 @
CT:IF1-PL1_2017	Laser	Laser computer/remote	XVME-220	#C1 S16 @
CT:IF1-PL1_2018	Laser	Laser Pre0	XVME-220	#C1 S17 @
CT:IF1-PL1_2019	Laser	Laser Pre1	XVME-220	#C1 S18 @
CT:IF1-PL1_2020	Laser	Laser Pre2	XVME-220	#C1 S19 @
CT:IF1-PL1_2025	PSA	PSA Gain Select 2	XVME-220	#C1 S2 @
CT:IF1-PL1_2021	Laser	Laser Control Mode	XVME-220	#C1 S20 @
CT:IF1-PL1_2022	Laser	Laser Plasma On/Off	XVME-220	#C1 S21 @
CT:IF1-PL1_2026	PSA	PSA Gain Select 1	XVME-220	#C1 S3 @
CT:IF1-PL1_2027	PSA	PSA Gain Select 0	XVME-220	#C1 S4 @
CT:IF1-PL1_2028	PSA	PSA Output Enable	XVME-220	#C1 S5 @
CT:IF1-PL1_2029	PSA	PSA Ringdown Enable	XVME-220	#C1 S6 @
CT:IF1-PL1_2030	PSA	PSA Test Enable 2	XVME-220	#C1 S7 @

Record	LCU	DESCRIPTION	DEVICE TYPE	MOD/CHAN
CT:IF1-PL1_2031	FSS	FSS LLA Bypass Enable	XVME-220	#C1 S8 @
CT:IF1-PL1_2032	FSS	FSS LLA Test Enable	XVME-220	#C1 S9 @

Appendix C: Data Archive Channels

This Appendix provides the database listings for all PSL data channels which are to be archived on a continuous basis, along with their archive deadband settings.

PSL Archive Channel List

28-Jun-95

Record	LCU	DESCRIPTION	Deadband
CT:IF1-PL1_0021	Laser	Laser Voltage Monitor	2 Volts
CT:IF1-PL1_0022	Laser	Laser Current Monitor	1 Amps
CT:IF1-PL1_0023	Laser	Laser Power Monitor	0.1 Watts
CT:IF1-PL1_1003	FSS	Visibility Monitor	0.5 %
CT:IF1-PL1_1021	FSS	Vismon Calibration Calc.	0.01