LASER INTERFEROMETER GRAVITATIONAL WAVE OBSERVATORY
- LIGO -
CALIFORNIA INSTITUTE OF TECHNOLOGY
MASSACHUSETTS INSTITUTE OF TECHNOLOGY

Document Type **LIGO-T960037-00- CCD** 7/17/96	

Vacuum Control and Monitoring System (VCMS) Design

R. Bork

Distribution of this draft:

This is an internal working note
of the LIGO Project.

California Institute of Technology
LIGO Project - MS 51-33
Pasadena CA 91125
Phone (818) 395-2129
Fax (818) 304-9834
E-mail: info@ligo.caltech.edu

Massachusetts Institute of Technology
LIGO Project - MS 20B-145
Cambridge, MA 01239
Phone (617) 253-4824
Fax (617) 253-7014
E-mail: info@ligo.mit.edu

WWW: http://www.ligo.caltech.edu/

LIGO-DRAFT

1 INTRODUCTION

1.1. Purpose

The purpose of this document is to present the conceptual design for the LIGO Vacuum Control and Monitoring System (VCMS).

1.2. Scope

The primary function of the VCMS is to provide for remote operation and monitoring of LIGO vacuum equipment during LIGO operations. Included in this scope is:

- Hardware and software applications specific to Vacuum Equipment (VE) control and monitoring, including digital processing equipment, Input/Output (I/O) interfaces, interactive operator interfaces, data collection, conversion and logging, signal conditioning, closed loop control, automatic sequences, interlocks and all necessary equipment housings.
- Hardware and software, as necessary, to interface the VCMS to the VE provided by the VE vendor and to the infrastructure of the LIGO CDS.

The VCMS is to be developed as an integrated subsystem of the LIGO CDS. As such, the system infrastructure and operational support components will be provided by the LIGO CDS and are not included in the scope of the VCMS. This includes such items as the data communication networks, operator consoles, compute servers, mass storage systems, and software development tools and general services.

Also not in the scope of the VCMS are control functions associated with equipment, such as roughing, turbo pumps and bake out systems, used for initial pumpdown of LIGO vacuum spaces. This function is to be provided by stand-alone control and monitoring systems associated with portable “pumpdown carts”, which are to be provided by the Vacuum Equipment (VE) vendor, Process Systems International (PSI).

1.3. Document Overview

The conceptual design described by this document is primarily based on the system to be developed for the LIGO Hanford site. The Livingston VCMS will be similar, the primary difference being the reduced number of I/O points due to only one interferometer at that site.

To describe the design, this document is organized by sections as follows:

- Introduction, of which this subparagraph is a part, which gives the scope and definitions of the VCMS.
- VCMS Overview, which gives a brief overall description of the VCMS architecture.
- System Architecture, which describes primarily the standard hardware systems.
- System, subsystem and assembly levels, which give the details of the implementation.

1.4. Definitions

1.5. Acronyms

- A - Amps
- ADC - Analog to Digital Convertor
- BSC - Beam Splitter Chamber
- BT - Beam Tube
- CDS - Control and Data System
- D/A - Digitial to Analog
- EPICS - Experimental Physics and Industrial Control System
- FCR - Facility Control Room
- GPS - Global Positioning System
- HAM - Horizontal Access Module
- Hz - Hertz
- I/O - Input/Output
- LN2 - Liquid Nitrogen
- l/s - liters/second
- mA - milliampere
- mm - millimeters
- P&ID - Piping and Instrumentation Diagram
- PLC - Programmable Logic Controller
- PSI - Process Systems International
- SNL - State Notation Language
- TBD - To Be Determined
- UPS - Uninterruptable Power Supply
- VCMS - Vacuum Control and Monitoring System
- VDC - Volts Direct Current
- VE - Vacuum Equipment
- VME - Versa Modular Eurocard

1.6. Applicable Documents

1.6.1. LIGO Documents

LIGO T960024-C VCMS Design Requirements Document

LIGO T960120-C LIGO CDS Control and Monitoring Conceptual Design

LIGO E950091-E Interface Control Document: LIGO System & Detector - Vacuum Equipment

1.6.2. Non-LIGO Documents

- Process Systems International (PSI) Piping and Instrumentation Drawings (P&ID), dated March 20, 1996, as listed in the following table:

Table 1: PSI P&ID Listing

PSI Number	*LIGO Number*	*Rev*	*Description*	*Sheets*
V049-0-001	D960107-00-V	0	Vac Equip Legend	3
V049-0-002	D960108-00-V	0	BSC Mid Stations	1
V049-0-003	D960109-00-V	0	BSC Corner Vertex Arms	1
V049-0-004	D960110-00-V	0	Horizontal Access Module	1
V049-0-005	D960111-00-V	0	112cm and 122cm Gate Valves	1
V049-0-006	D960112-00-V	0	80K Cryopump	1
V049-0-010	D960113-00-V	0	Washington LT End Station	1
V049-0-011	D960131-00-V	0	Washington LT Mid Station	1
V049-0-012	D960114-00-V	0	Washington LT Beam Manifold	1
V049-0-013	D960115-00-V	0	Washington Vertex Section	1
V049-0-014	D960116-00-V	0	Washington Diagonal Section	1
V049-0-015	D960117-00-V	0	Washington RT Beam Manifold	1
V049-0-016	D960118-00-V	0	Washington RT Mid Station	1
V049-0-017	D960119-00-V	0	Washington RT End Station	1
V049-0-018	D960120-00-V	0	Washington Crnr St Mechanical Rm	1
V049-0-020	D960121-00-V	0	LA Left End Station	1
V049-0-021	D960122-00-V	0	LA Left & Right Mid Joints	1
V049-0-022	D960123-00-V	0	LA Left Beam Manifold	1
V049-0-023	D960124-00-V	0	LA Vertex Section	1
V049-0-024	D960125-00-V	0	LA Right Beam Manifold	1
V049-0-025	D960126-00-V	0	LA Right End Station	1
V049-0-026	D960127-00-V	0	LA Corner St Mechanical Rm	1

- PSI transmittal V049-1-013, Approximate Total I/O Count for WA site, dated December 1, 1995
- PSI transmittal V049-1-036, Rev. 1, Instrument List, dated March 11, 1996

2 VCMS OVERVIEW

The basic design of the VCMS calls for the use of standard CDS VME-based systems to provide process controls and monitoring. A total of seven VME units will be employed at each site, as shown in Figure 1: VCMS Processing System. These units will all be interconnected via ethernet to the LIGO CDS networking infrastructure, allowing central control and monitoring from the site Facility Control Room (FCR).

LIGO CDS standard EPICS software tools will be used for software development, as well as to provide the runtime control and monitoring functions. This will be true for all but the low level isolation valve interlocks, which will be provided by embedded Programmable Logic Controllers (PLC) and programmed separately using the applicable PLC software tools.

3 SYSTEM ARCHITECTURE

In the VCMS design, it has been broken down into seven subsystems, each with its own VME unit. These seven subsystems are:

- Right and Left End Stations
- Right and Left Mid Stations
- Corner Station - Left Arm
- Corner Station - Right Arm
- Corner Station - Mechanical Room

Each VCMS will have its own rack enclosure and VME-based process controller. The architecture and layouts of the VME crates for each subsystem are shown in Figure 1: VCMS Processing System.

3.1. Standard Rack layout

A VCMS equipment rack is shown in Figure 2: VCMS Standard Rack Configuration. The rack itself is a CDS standard 19” mounting enclosure with a footprint of 800mm wide by 900mm deep. The front of this rack houses:

- 24VDC power supply (provided by PSI)
- Service Panel
- VME crate
- VME cable access panel
- Uninterruptable Power Supply (UPS)

Interconnecting cable is terminated on terminal blocks mounted on two DIN rails on the side of the rack, accessible via a side removable panel. Cables enter through the base via a side cutout, run up through 4” Panduit cable trays to the right of each DIN rail, and terminate at their designated terminal block. Interconnect cabling between these field devices and VCMS interfaces is done on the left side of each DIN rail, with cables run through the left side Panduit.

At the top of each DIN rail are shown mass termination blocks, which connect the signals to/from the VME I/O modules. A rolled ribbon cable interconnects these blocks to the front of the appropriate VME module.

The PLC, which will provide the isolation valve interlocks functions, will also mount to the DIN rails.

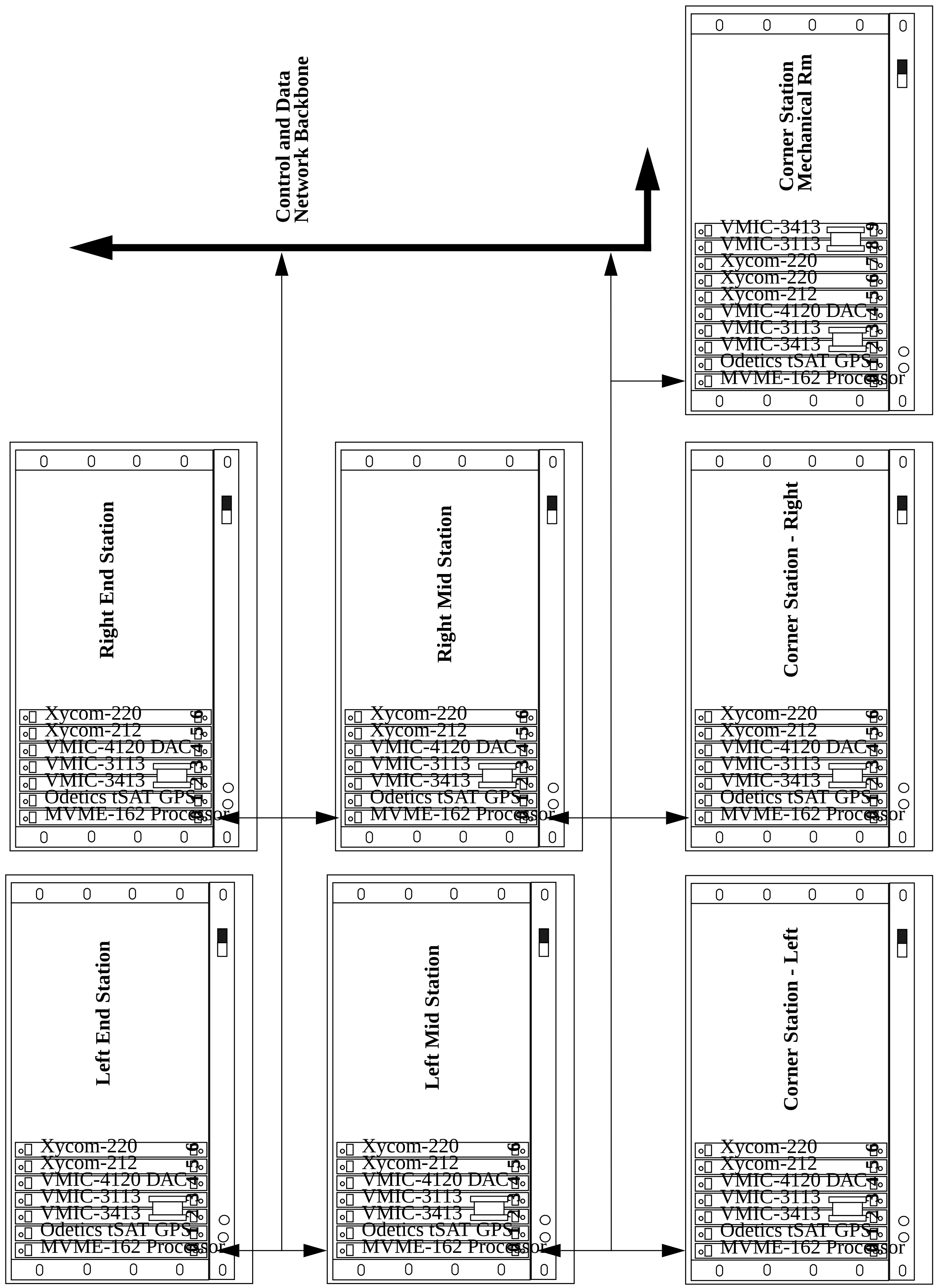

Figure 1: VCMS Processing System

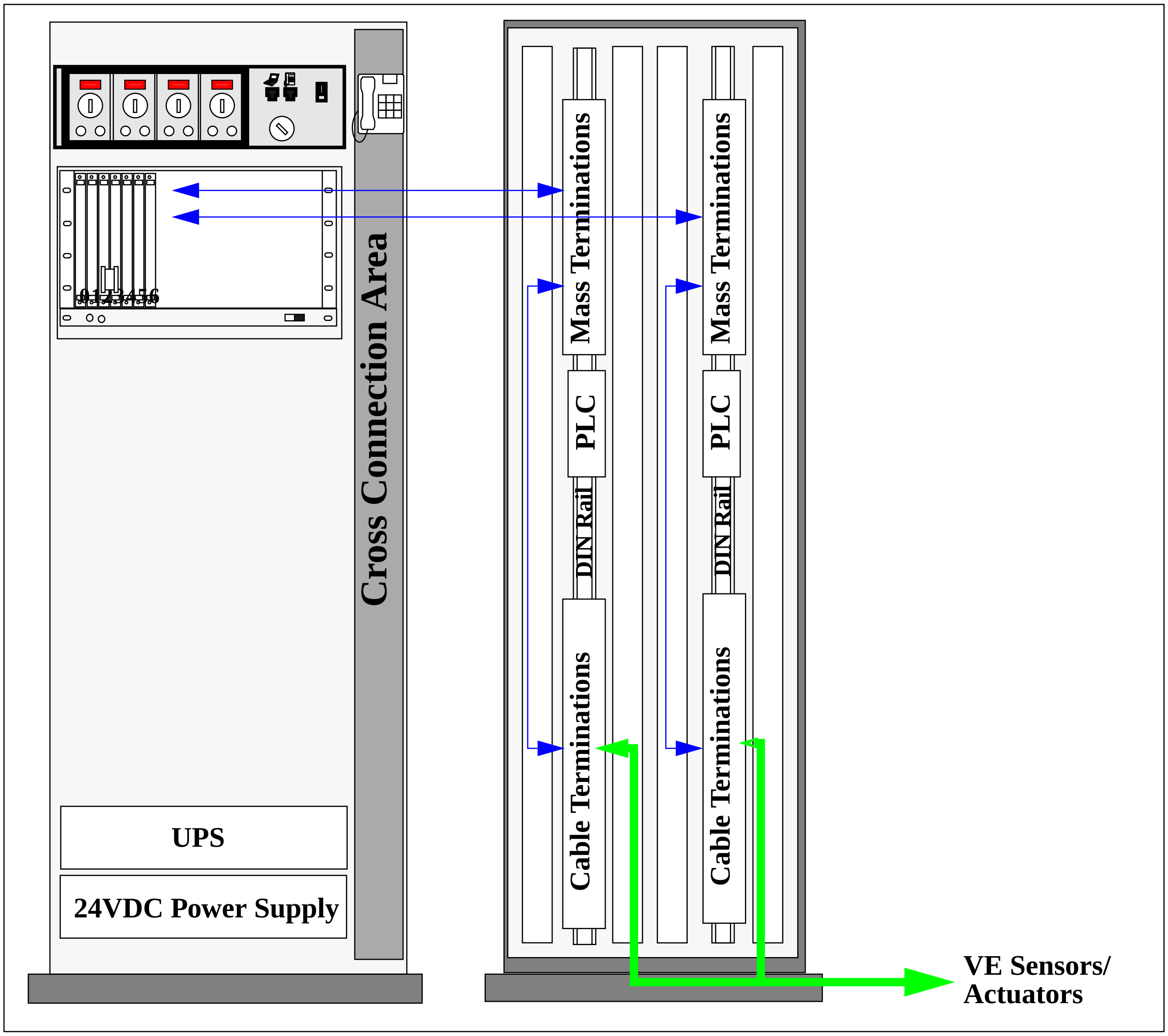

Figure 2: VCMS Standard Rack Configuration

3.2. Service Panel

Figure 3: VCMS Service Panel shows a detail of the units to be installed at each VCMS rack (except the Corner Station Mechanical Room, which has no key locks). This panel contains:

- Two 15A breakers, one which directly feeds one rack plug strip, the other the UPS
- Phone jack, for connection of LIGO phones
- Network jack, for connection of computers for local operations
- Local/Computer operation key switch
- Up to four isolation valve bypass modules

The latter is used to bypass isolation valve interlocks during designated maintenance/commissioning periods, and to operate the valves locally. Each module contains:

- Bypass indicator light, which glows red whenever the interlocks are bypassed.
- Bypass key switch, which is used to bypass the interlocks
- An open and close push-button, used to locally operate the valve whenever the Local/Computer switch is in local. These push-button have indicator lights which indicate the present position of the valve. The open push-button indicator will light green whenever the valve is open, the closed push-button will light red if the valve is closed, and neither will be illuminated when the valve is not at an open or closed switch.

The Local/Computer operation key switch selects the isolation valve open/close control location. In Local, the valves may only be operated via the open/close push-button. In Computer, valves may only be operated via the VCMS computer system.

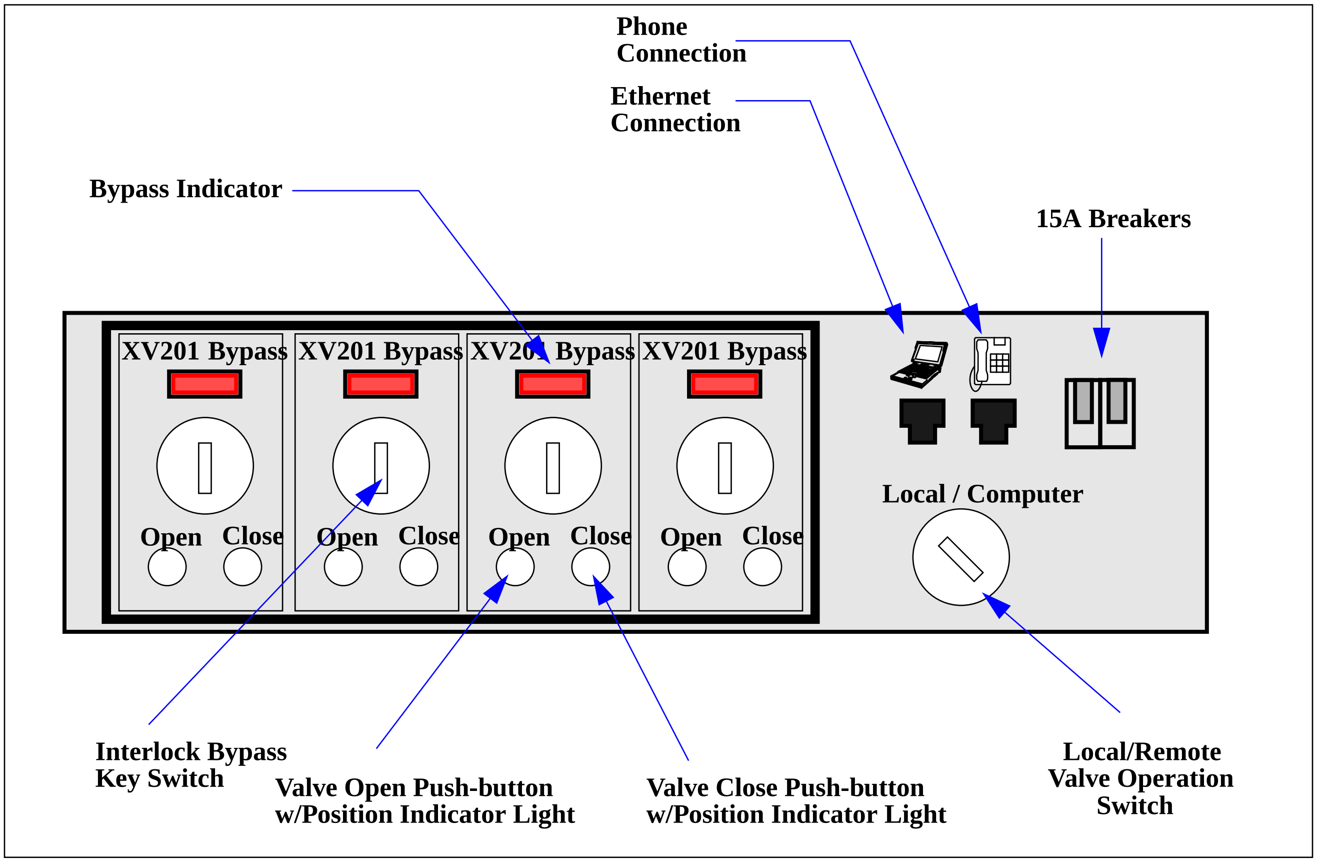

Figure 3: VCMS Service Panel

3.3. Standard VME layout

Each subsystem is to be stand-alone in as much as it contains its own VME crate and processor. Each VME subsystem will be identical in its hardware contents, as shown in Figure 4: Standard VCMS VME Crate, except for the Mechanical Room Subsystem (MRS). While all subsystems will contain the modules shown in slots 0 through 6, the MRS and mid stations will contain the additional modules in slots 7, 8 and 9 due to the higher I/O count in those areas.

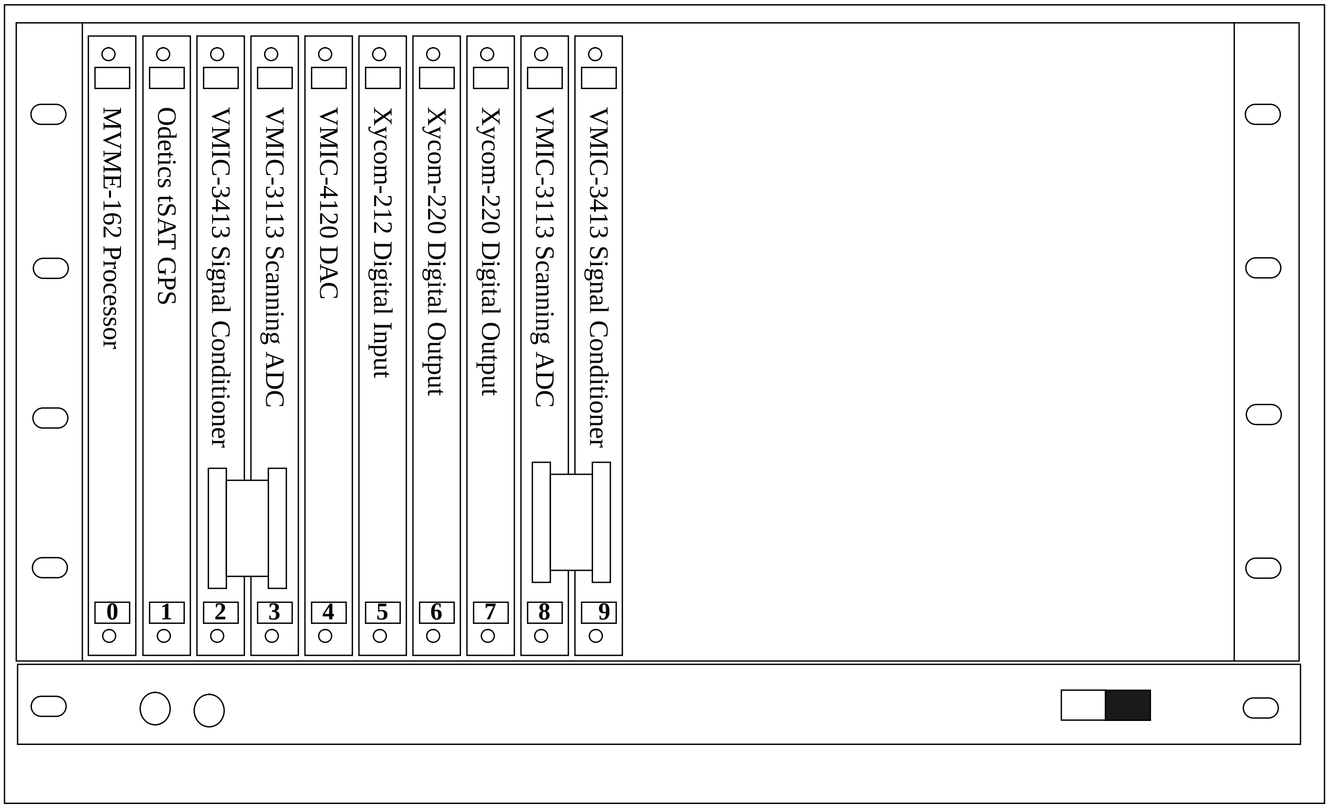

Figure 4: Standard VCMS VME Crate

3.3.1. Processor

The primary processor for the VCMS will be a Motorola MVME-162, which is a 68040 based unit. Connection to the CDS networks is via an ethernet connection to an MVME-712 transition module installed in a slot at the rear of the VME crate.

3.3.2. Timing

The TSAT Global Positioning System (GPS) module in slot 1 is the LIGO standard for time synchronization of all LIGO systems. Since the VCMS is to be the first installed LIGO CDS, the VCMS VME crates will contain the master receiver units in each building. In the corner station, one VME crate will contain a receiver and the other two slave units connected to the receiver unit via coax cable. Time synchronization will be via IRIG-B. All VCMS data will be timestamped using this system.

3.3.3. Analog Signal Conditioning and ADC

Analog signal conditioning will be done using a VMIC-3413 module. This unit will accept -10 to 10VDC, 4-20mA and thermocouple inputs. It has 32 channels, with each channel individually configurable for the various input types. The output of this unit is directly compatible with and connector compatible to the VMIC-3113 Scanning ADC module. This unit provides 32 ADC channels with 12 bit resolution.

3.3.4. Analog Output

Various control loops to be provided by the VCMS require 4-20mA outputs to actuators. To provide this, the VMIC-4120 will be used. Each module contains eight, 12 bit resolution, DAC channels.

3.3.5. Binary Input/Output

All VCMS binary I/O will be using 24VDC. Xycom 212 and 220 modules will provide this I/O, each module capable of connecting 32 channels.

3.4. I/O Channel Counts

The following tables provide channel count information for each VME subsystem as derived from PSI signal tables and P&ID, as referenced by Table 1: PSI P&ID Listing and the LIGO ICD: LIGO System and Detector - Vacuum Equipment. These I/O tables refer to the Hanford site only.

Table 2: Corner Station - Right Arm VME I/O Counts

VME Module	*Module Type*	*Chan*	*Used*	*Notes*
VMIC-3413	Signal Conditioner	32	29	22 - 0/10VDC 3 - 4/20ma 4 - TE Total -> 22
VMIC-3113	Scanning ADC	32	29	Direct connect from 3413
VMIC-4120	D/A	8	4	All 4-20 ma outputs
XYCOM-212	Binary Input	32	24	
XYCOM-220	Binary Output	32	4	
Total I/O			46	

Table 3: Corner Station - Mechanical Room VME I/O Counts

VME Module	*Module Type*	*Chan*	*Used*	*Notes*
VMIC-3413	Signal Conditioner	32 x 2	45	45 - 0/10VDC
VMIC-3113	Scanning ADC	32 x 2	45	Direct connect from 3413
VMIC-4120	D/A	8	1	All 4-20 ma outputs
XYCOM-212	Binary Input	32	26	
XYCOM-220	Binary Output	32 x 2	34	
Total I/O			106	

Table 4: Corner Station - Left Arm VME I/O Counts

VME Module	*Module Type*	*Chan*	*Used*	*Notes*
VMIC-3413	Signal Conditioner	32	26	19 - 0/10VDC 3 - 4/20ma 4 - TE
VMIC-3113	Scanning ADC	32	26	Direct connect from 3413
VMIC-4120	D/A	8	3	All 4-20 ma outputs
XYCOM-212	Binary Input	32	24	
XYCOM-220	Binary Output	32	4	
Total I/O			42	

Table 5: Mid Station VME I/O Counts

VME Module	*Module Type*	*Chan*	*Used*	*Notes*
VMIC-3413	Signal Conditioner	32 x 2	36	22 - 0/10VDC 6 - 4/20ma 8 - TE
VMIC-3113	Scanning ADC	32 x 2	36	Direct connect from 3413
VMIC-4120	D/A	8	5	All 4-20 ma outputs
XYCOM-212	Binary Input	32	22	

Table 5: Mid Station VME I/O Counts

VME Module	*Module Type*	*Chan*	*Used*	*Notes*
XYCOM-220	Binary Output	32	10	
Total I/O			59	

Table 6: End Station VME I/O Counts

VME Module	*Module Type*	*Chan*	*Used*	*Notes*
VMIC-3413	Signal Conditioner	32	21	14 - 0/10VDC 3 - 4/20ma 4 - TE
VMIC-3113	Scanning ADC	32	14	Direct connect from 3413
VMIC-4120	D/A	8	3	All 4-20 ma outputs
XYCOM-212	Binary Input	32	21	
XYCOM-220	Binary Output	32	7	
Total I/O			37	

3.5. Signal Naming Convention

The computer software representation of all VCMS signals will follow a standard naming convention. Since there will be signals which directly couple from PSI inputs, signals which only appear in the VCMS software (virtual signals), such as various calculations involving multiple PSI signals, and VCMS internal diagnostic signals, there will be variations on this standard. These standards are described in the following subparagraphs.

3.5.1. Vacuum Equipment Signals

The convention for the naming of all signal representations within the VCMS software which directly interface to the PSI equipment will be as follows:

1. Site designator, followed by a colon
   - H: Hanford
   - L: Livingston
2. System designator, followed by a dash
   - VAC-
3. Subsystem designator, followed by a dash (Note: For designator purposes, subsystem is defined as in

the VCMS DRD for VE, not by the VCMS subsystems)
- RES- Right End Station
- RMS- Right Mid Station
- CLM- Corner station, Left Manifold
- CRM- Corner station, Right Manifold
- CSV- Corner Station, Vertex
- CSD- Corner Station, Diagonal
- LMS- Left Mid Station
- LES- Left End Station

4. PSI device designator as shown on PSI P&IDs and data tables

Examples:

H:VAC-CLM-PT114A would be the Pirani gauge transmitter reading in the Hanford corner station left manifold area.

L:VAC-LES-PT723B would be an ion gauge reading in the Livingston left end station area.

3.5.2. Virtual Channels

Virtual channels are those which do not have a direct interface via VME I/O to VE. These are anticipated to be of two types:

1. Various calculations, such as rate of rise, LN2 time to depletion, etc. For these, a unique two letter combination will be developed for the device part of the designator. This two letter convention will not conflict with PSI device designators. As an example, a rate of rise calculation for a section of the Hanford right end station might be designated as H:VAC-RES-RR001.
2. Channels which bear a direct correlation to a VE input or output signal, but do not directly connect to the VME I/O. In this case, the signal designator is the same as the VME I/O name, with the addition of a dash and number at the end. Figure 5: 2500 l/s Ion Pump Start shows as example of this. In all cases where a setpoint is accessible from a VCMS control panel, the input from the operator is actually sent to an intermediate channel, not directly to the channel which connects to the VME I/O. Therefore, when the Start Icon is selected by the operator in the example, H:VAC-CSV-HS162A-01 is set. Other software then verifies that the vacuum system is in a proper state to allow the pump to be turned on. If it is, that software will then set H:VAC-CSV-HS162A to the proper value to start the pump. That channel is directly connected via the VME I/O to the pump start actuator.

3.5.3. VCMS Internal Data Channels

The VCMS will also contain internal data channels, such as VCMS self diagnostics and performance information. These channels will have as a subsystem designator CDS, followed by a dash and four numbers, such as H:VAC-CDS-0001.

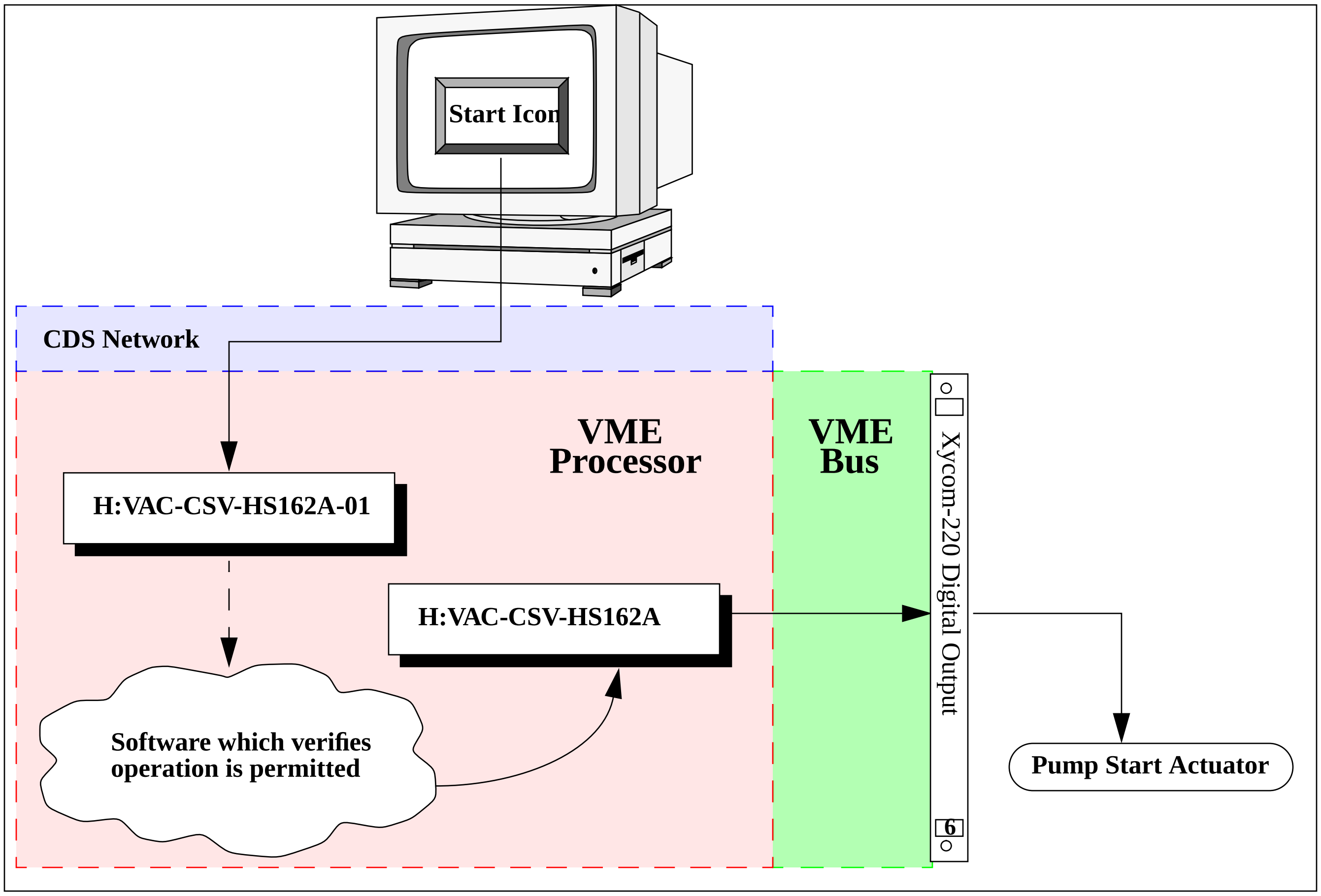

Figure 5: 2500 l/s Ion Pump Start

4 SYSTEM LEVEL CONTROL AND MONITORING

4.1. Operator Interfaces

Operator interfaces for the VCMS will be developed and run under the LIGO CDS standard Sammi software. Displays will be developed in a hierarchical structure, with icon and menu driven selections to rapidly move between displays. The minimum set of displays are to be:

- Top level Navigator, which allows access to all displays through icon selection
- System overview(s)
- Overview for each subsystem
- Cryopump overview
- Individual cryopump displays
- Individual subsystem displays
- VCDS diagnostics page

4.2. Alarm Management

Alarm enunciation and logging is to be done with the EPICS alarm manager. The vacuum system will be a branch of the site alarm tree, with vacuum subsystems as additional lower level branches. The alarm manager will log all alarms and warnings when setpoints are exceeded and when the values drop back within the normal ranges.

4.3. Data Archival

Data archival will be accomplished with the EPICS data archival tools. In general, logging of various signal types will occur as follows:

- All digital (binary) signals will be logged on change.
- All analog signals will be logged when they change by more than their defined archive deadbands.
- All operator settings will be logged whenever they are changed. These will be logged to a separate file.

4.4. VCMS Self Diagnostics

The VCMS will monitor its own hardware and software status. This status will be reported on a separate operator display page, as well as enunciating faults via the VCMS alarm manager.

Figure 6: VCMS Self Diagnostics Tree shows the structure of the VCMS self diagnostics. For each VCMS VME processor, diagnostics will be run every 10 seconds. The hardware will be checked by one code module, the specific checking to be performed dependent on the I/O module type. This code will present a byte encrypted word to the VCMS VME master diagnostic program which indicates the status of all modules in the VME crate.

Each software module developed for the VCMS will also run diagnostics on demand from the VME master diagnostic program every 10 seconds. Status returned will be the present state of the program. The master diagnostic program will also initiate an alarm on non-response of software to diagnostic requests.

One of the VCMS VME processors will be assigned as a master for overall system diagnostics. It will collect the various status information from each individual processor and ensure that they are all operating properly. One other processor will be assigned as a backup to this function to monitor the health of the master unit itself.

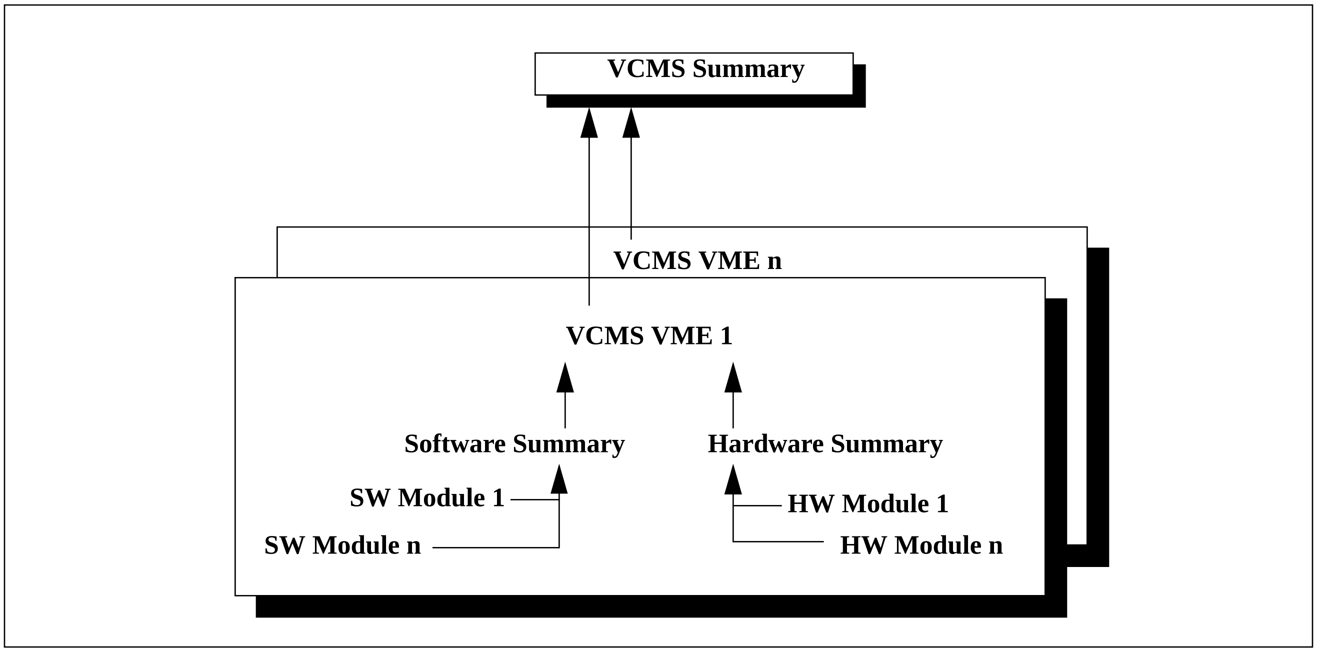

Figure 6: VCMS Self Diagnostics Tree

5 SUBSYSTEM AND ASSEMBLY CONTROL AND MONITORING

5.1. 80K Cryopumps

There are to be a total of eight cryopumps at the Hanford site and four at the Livingston site. The signals associated with these assemblies and their connection to the VCMS is shown in Figure 7: Cryopump Signal Connections.

5.1.1. Interlocks

Whenever the 80K cryopump ion gauge readings is > 1×10^{-4} Torr or its Pirani gauge reading is > 1×10^{-3} Torr, the VCMS will close the level control valve and not allow it to be opened until these conditions are met. This will be accomplished in software on the VME processor which monitors the section in which the cryopump resides. Once per second, the software will compare the gauge readings with the trip points. If the trip points are exceeded and the level control valve is open, it will be closed. If the closed loop level control is operating (5.1.2.1 LN2 Level Control), it will also be turned off.

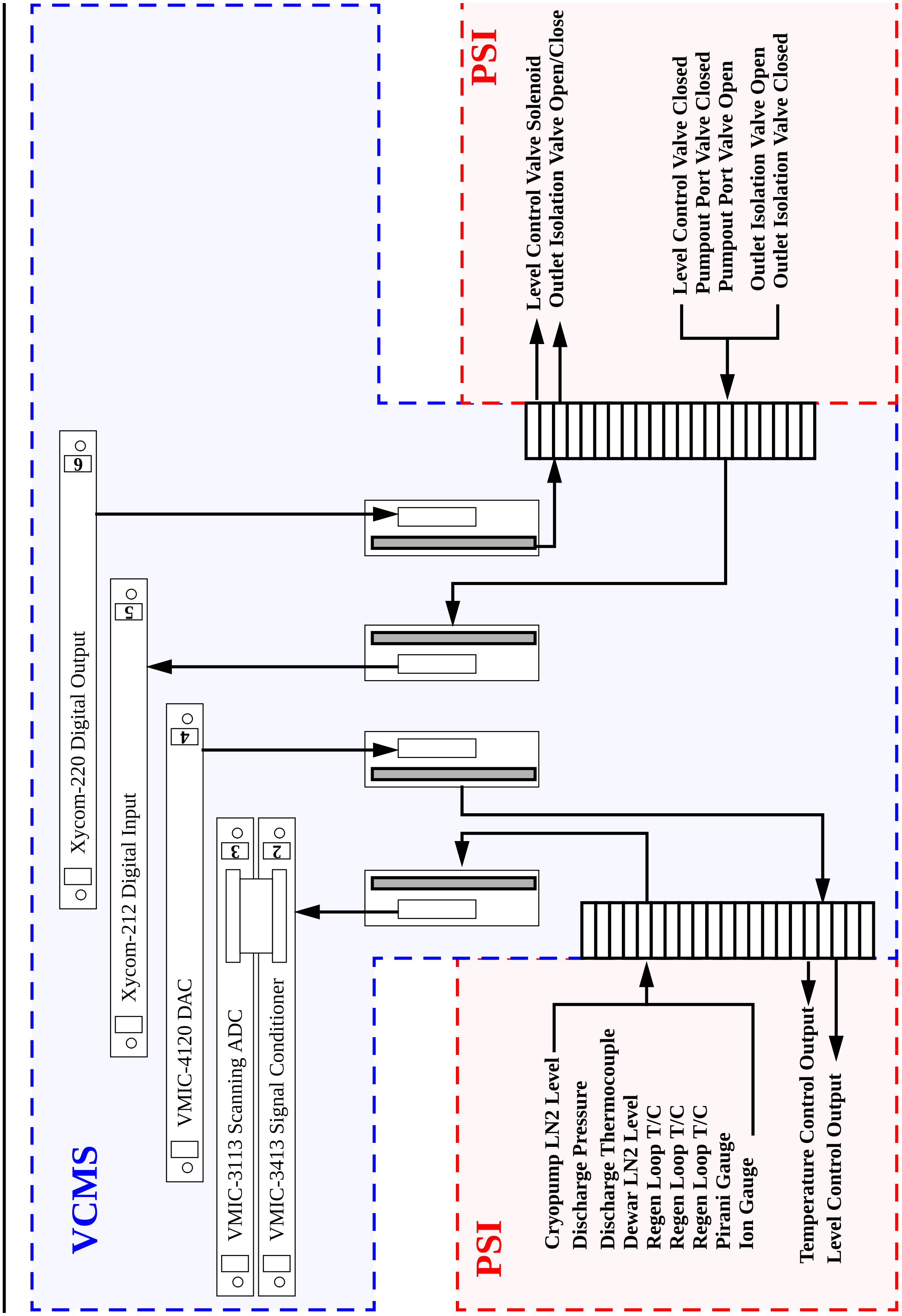

Figure 7: Cryopump Signal Connections

5.1.2. Closed Loop Control

The VCMS is to provide closed loop control for LN2 level and regeneration temperature. The design is TBD, pending information from PSI.

5.1.2.1 LN2 Level Control

TBD.

5.1.2.2 Regeneration Temperature Control

TBD.

5.1.3. Automatic Sequences

The VCMS will automatically calculate Dewar LN2 consumption rate and estimated time to Dewar empty. This will be done with EPICS calculation records, with Dewar level and capacity as inputs. The latter, capacity, will be built into EPICS as a static analog input record. These calculations will be performed once every 10 seconds.

5.2. HAM Chambers

The only VE device associated with a HAM chamber is a 75 l/s ion pump, from which the VCMS will monitor pump current. This signal will be connected, via the termination blocks and the VMIC-3413 signal conditioner, to the VMIC-3113 ADC. A single EPICS analog input record will read this signal from the ADC module, updating information at a 1Hz rate.

5.3. BSC

The BSC have the following associated devices:

- Pirani Gauge
- Ion Gauge
- 75 l/s annulus ion pump
- Purge air valve

For the BSC, the VCMS primarily provides monitoring functions for the gauge readings and the ion pump current reading. The VCMS must also control the purge air supply, the design for which is TBD pending more information to be provided by PSI.

Figure 8: BSC Signal Connections shows the interface wiring. The analog input channels will be handled in software as single EPICS analog input records, updated at 1Hz.

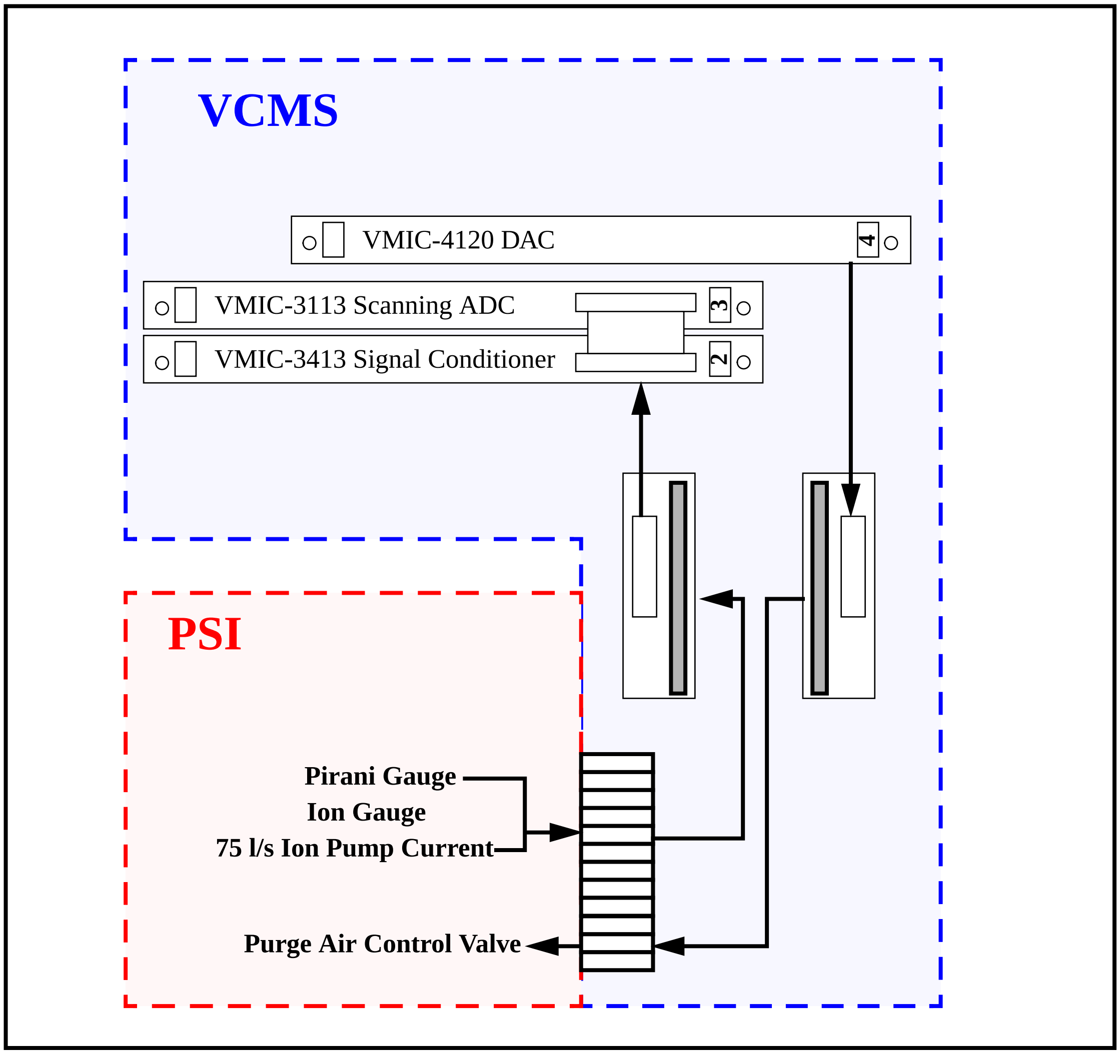

Figure 8: BSC Signal Connections

5.4. Isolation Valves

There are to be a total of 20 isolation valves at the Hanford site and 12 at the Livingston site. Each valve assembly consists of a 44” or 48” pneumatically or electrically operated gate valve, along with a 25 l/s annulus ion pump. For each valve, the VCMS provides monitoring of associated signals, the ability to operate (open/close) the valves either locally or through the computer system and critical interlock functions to prevent the opening of these valves when unsafe conditions exist.

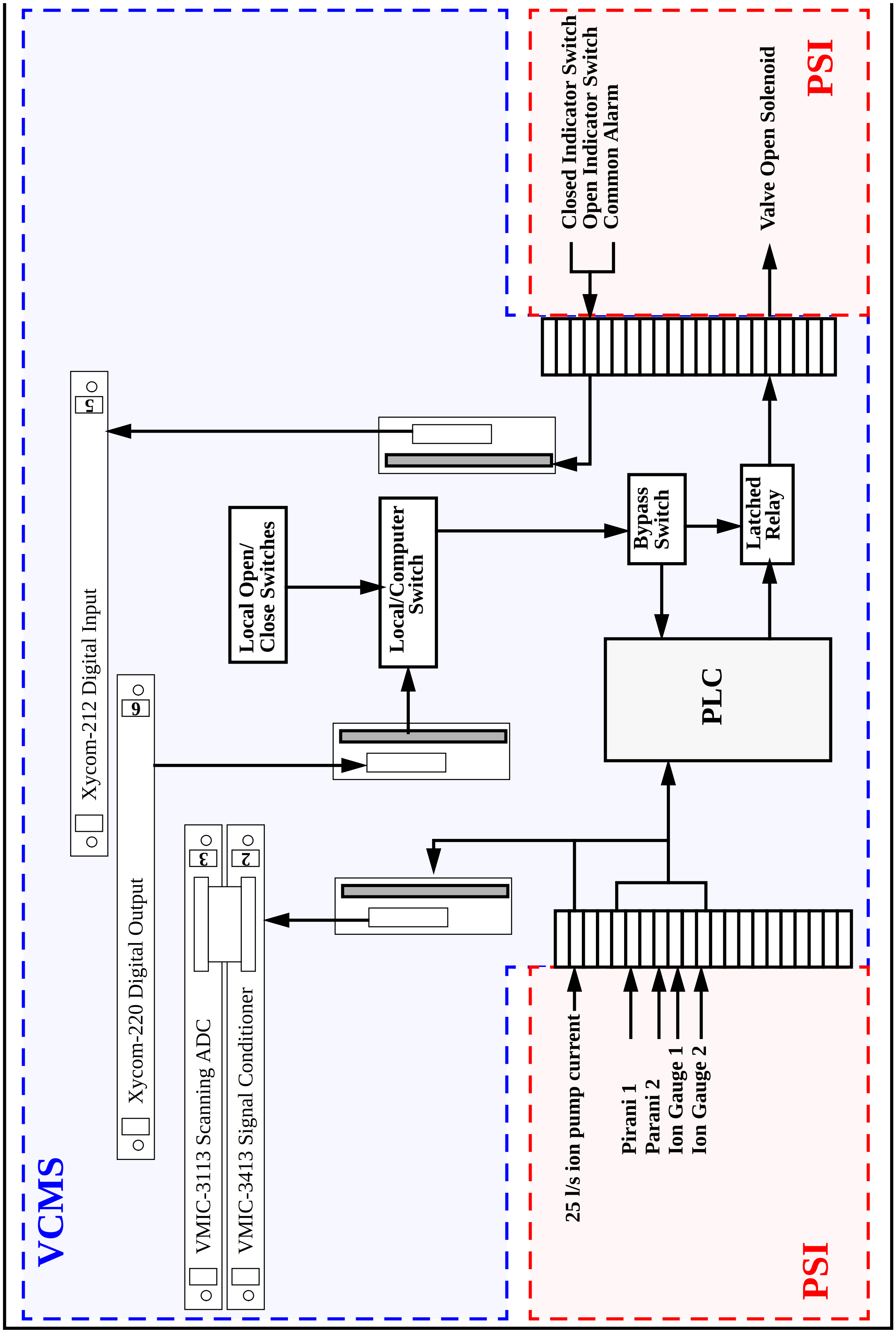

Figure 9: Isolation Valve Connections

5.4.1. Interlocks and Permits

As defined in the VCMS Requirements Document and shown in Figure 10: Isolation Valve Interlock Chain, the VCMS must provide a hierarchy of interlocks to prevent the opening of vacuum section isolation valves until it is safe to do so. In the VCMS, the upper two layers will be provided by software in the VME processors. The lowest level, and most critical, will be accomplished with software in an embedded PLC. The physical implementation of this interlock chain is shown in Figure 11: Isolation Valve Interlock Chain.

For specific maintenance periods, the VCMS must also provide a means to bypass these interlocks. To accomplish this, the VCMS will provide a key lock system and submit a formal interlock bypass procedure for LIGO management approval.

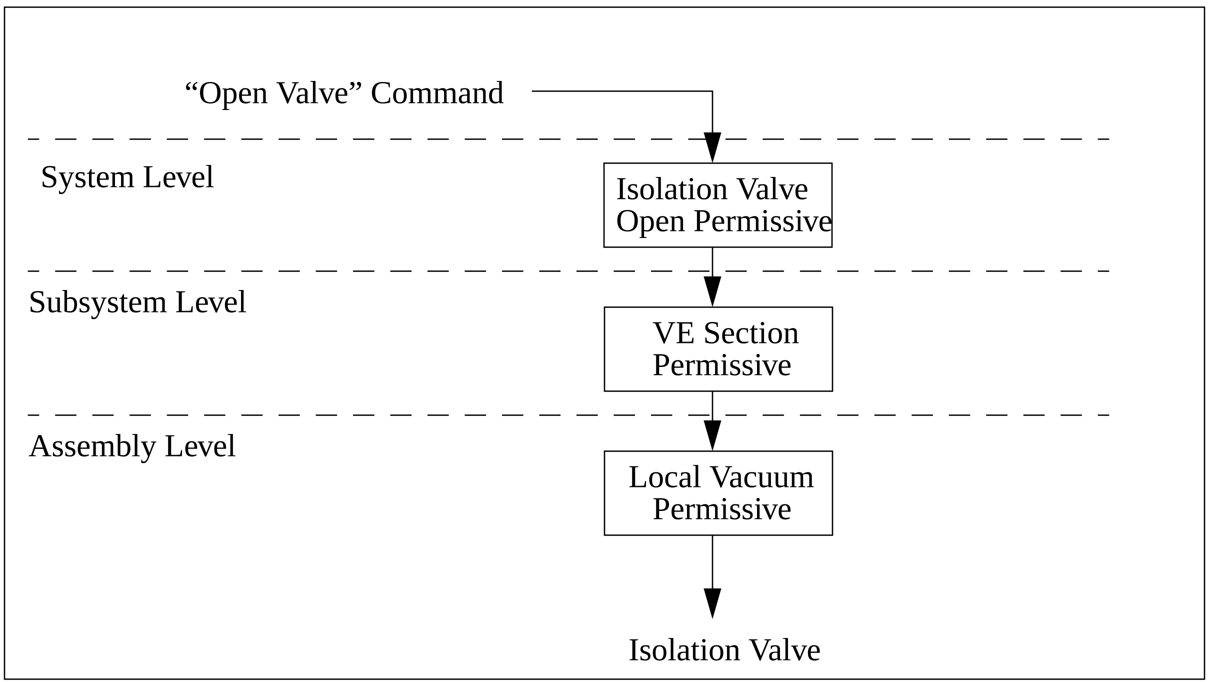

Figure 10: Isolation Valve Interlock Chain

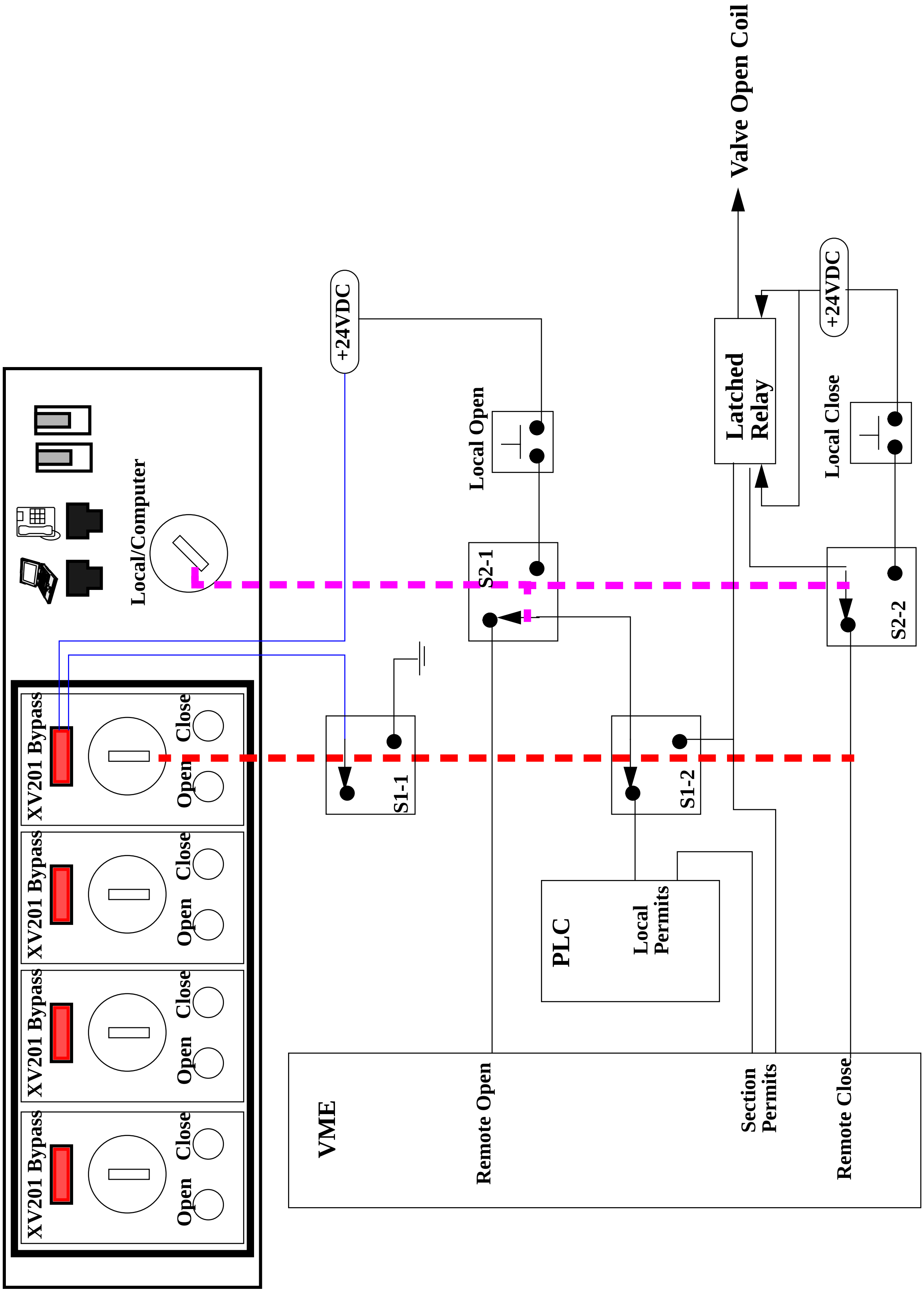

Figure 11: Isolation Valve Interlock Chain

5.4.1.1 Normal Operation

Figure 11: Isolation Valve Interlock Chain depicts the interlock chain for one isolation valve. In normal operation, the key switches are as shown, with the Local/Remote switch set to Remote and the Bypass key removed.

The interlock chain is designed to prevent opening of the isolation valve unless all of the following conditions are met:

1. Local Vacuum Permit is True:
   - The nearest up and down stream Parani gauges both provide a reading of $< 1\times10^{-3}$ Torr
   - The nearest up and down stream Ion gauges both provide a reading of $< 1\times10^{-4}$ Torr
2. VE section Permit is True:
   - Local Vacuum Permit is True
   - All ion pumps are on and operational within the isolatable section.
   - All pumpout port valves in that section are closed.
3. Isolation Valve Permit is True:
   - Vacuum section Permit is true for both sections either side of the isolation valve.

5.4.1.1.1 Remote Valve Operation

With the Local/Computer switch in the Computer position (as shown), operation of the valve is from the VCMS computer system, either a local laptop plugged into the Net jack on the service panel, or any other computer connected to the VCMS network. The opening sequence is as follows:

1. Operator selects a “Valve Open” icon on a VCMS operator display.
2. The operator is prompted by another icon to confirm that this is the desired operation, if the interlock chain is complete. If the VCMS detects that the interlock chain is not complete, the operator will be notified by a display message and the Valve Open request will be cancelled.
3. The open request will be transmitted via the CDS networks to the VME processor which controls that valve. That processor will then issue a “Remote Open” via a VME digital (binary) output module. This signal is in the form of a 24VDC pulse of one second duration.
4. This output is wired through S2-1 and S1-3 to one side of a relay within the PLC.
5. The PLC has as inputs the ion and Pirani gauge readings necessary to evaluate the Local Vacuum Permit. If this is calculated to be True, the relay is closed and the signal passes on to one side of a relay controlled by the VME processor.
6. The VME processor also has access to the previous vacuum readings, and will independently calculate a Local Vacuum Permit. Either directly through its VME I/O or via another VCMS VME processor on the network, it will also have the information necessary to calculate the VE section permit and the Isolation Valve Permit. If all permits are True, it will close the relay, and the signal will pass to the “Close” side of the latched relay.
7. The latched relay will move to the “Closed” position, providing 24VDC to the PSI provided Valve Open Coil, thereby causing the isolation valve to move to the open position.

No interlocks are involved in the closing of isolation valve. As shown in Figure 11: Isolation Valve Interlock Chain, on operator request, a Remote Close signal is issued by the VME processor. This 24VDC, one second pulse passes through S1-3 and S2-2 to the "Open" side of the latched relay. This will then cause the relay to open and 24VDC will be removed from the Valve Open Coil.

5.4.1.1.2 Local Valve Operation

The interlocking scheme for local operation of the valves is identical as above. The difference is that the Local/Computer switch will now be in the Local position, causing S2-1 and S2-2 to disconnect the computer signals and connect the manual push-button located on the service panel. One push-button allows opening of the valve via S2-1, and the other closes the valve via S2-2.

5.4.1.2 Maintenance Operations

It will be necessary during acceptance testing and certain maintenance periods to open and close the isolation valves while the system is at air. When the system is not at high vacuum, the interlocks described previously would prevent such operation. Therefore an interlock bypass mechanism is designed into the system for these special operations.

5.4.1.2.1 Key Lock System

A key lock system, similar to that used in personnel safety systems, is designed into the VCMS to allow bypassing of the isolation valve interlocks.

As shown in Figure 12: Isolation Valve Master Key Panel, a key panel will be located at the FCR. This is a capture key system, with one key for each isolation valve. These keys are normally inserted into their respective locks, turned and captured by the panel. These keys may only be removed by first inserting a master key into the Master lock and turning it to the Release position.

The isolation valve keys fit into locks located on the service panels at VCMS control racks in VE areas. Once a key is inserted and turned, the interlocks for that valve are bypassed.

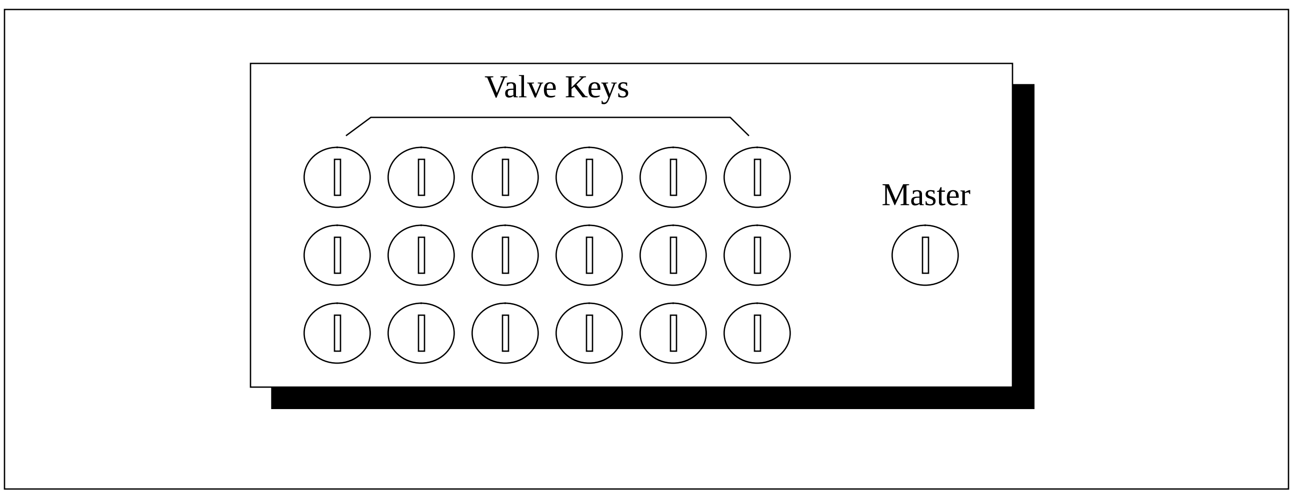

Figure 12: Isolation Valve Master Key Panel

5.4.1.2.2 Interlock Bypass Procedure

The bypassing of the interlock system will require a formal procedure to be followed. An overview of such a procedure is as follows:

1. A Temporary Operational Safety Procedure (TOSP) is submitted for approval. A checklist within the TOSP is followed to verify the VE is in a proper and safe state for opening of valves.
2. Once the TOSP is approved and signed, the Master key is inserted into the FCR capture key lock and the appropriate isolation valve key released to those who are to perform the test activity.
3. When ready to operate the valve, the valve key is inserted into the key lock at the VCMS control rack service panel and turned to the bypass position. The local/remote switch at that panel must also be turned to the Local position.

The valve interlocks are now bypassed and the valve may be opened and closed locally at the VCMS control rack using the open/close push-button on the service panel. Referring again to Figure 11: Isolation Valve Interlock Chain, once the valve key is turned to the bypass position:

- S1-1 switches ground to the bypass indicator light, causing it to illuminate.
- S1-2 performs the actual bypassing of the interlocks by providing a feed around past the PLC and VME interlock relays.

5.4.2. Automatic Sequences

Software within one of the VCMS process controllers will monitor the rate of rise calculations being performed on all of the isolatable VE sections as well as the average pressure in these sections. If the rate of rise or absolute pressure exceed a settable threshold, an alarm will be sent to the alarm manager. If not overridden by an operator within a settable time period, this software will issue a “Close” command to all isolation valves.

5.5. Beam Tubes/Manifolds

5.5.1. Hardware Configuration

There are a number of VE devices which directly connect to the beam tubes and manifolds which the VCMS must control and/or monitor. These devices are:

- 2500 l/s ion pumps
- Pirani Gauges
- Ion Gauges
- 10” Pumpout Port Valves
- 6” Pumpout Port Valves (LVEA only)

As listed in the VCMS DRD, various quantities of these devices connect to any given VE section. Figure 13: BT/Manifold Signal Connections shows the various devices and their interface to VCMS.

5.5.2. Software

For the latter four devices listed above, the VCMS will provide EPICS records to monitor the readings since no control is required. Signals from the two gauge types, however, will be used in the isolation valve interlock calculations described in section 5.4.1. Interlocks and Permits.

The VCMS must provide the capability to start and stop the 2500 l/s ion pumps. Each pump unit actually has two separate pumps, each with a start/stop actuator. Therefore, the VCMS must simultaneously operate both. Prior to allowing a pump to turn on, the software will also verify that the vacuum in the isolatable section that the pump resides in is at a proper level for pump operation.

5.5.3. Rate of Rise Calculations

Two rate of rise calculations will be performed for each isolatable section of the VE system, one based on the Pirani gauge readings and the other on the ion gauge readings. The VCMS will calculate an average value in Torr of all Pirani/ion gauges in a section and calculate the difference in averages over an operator selectable time period.

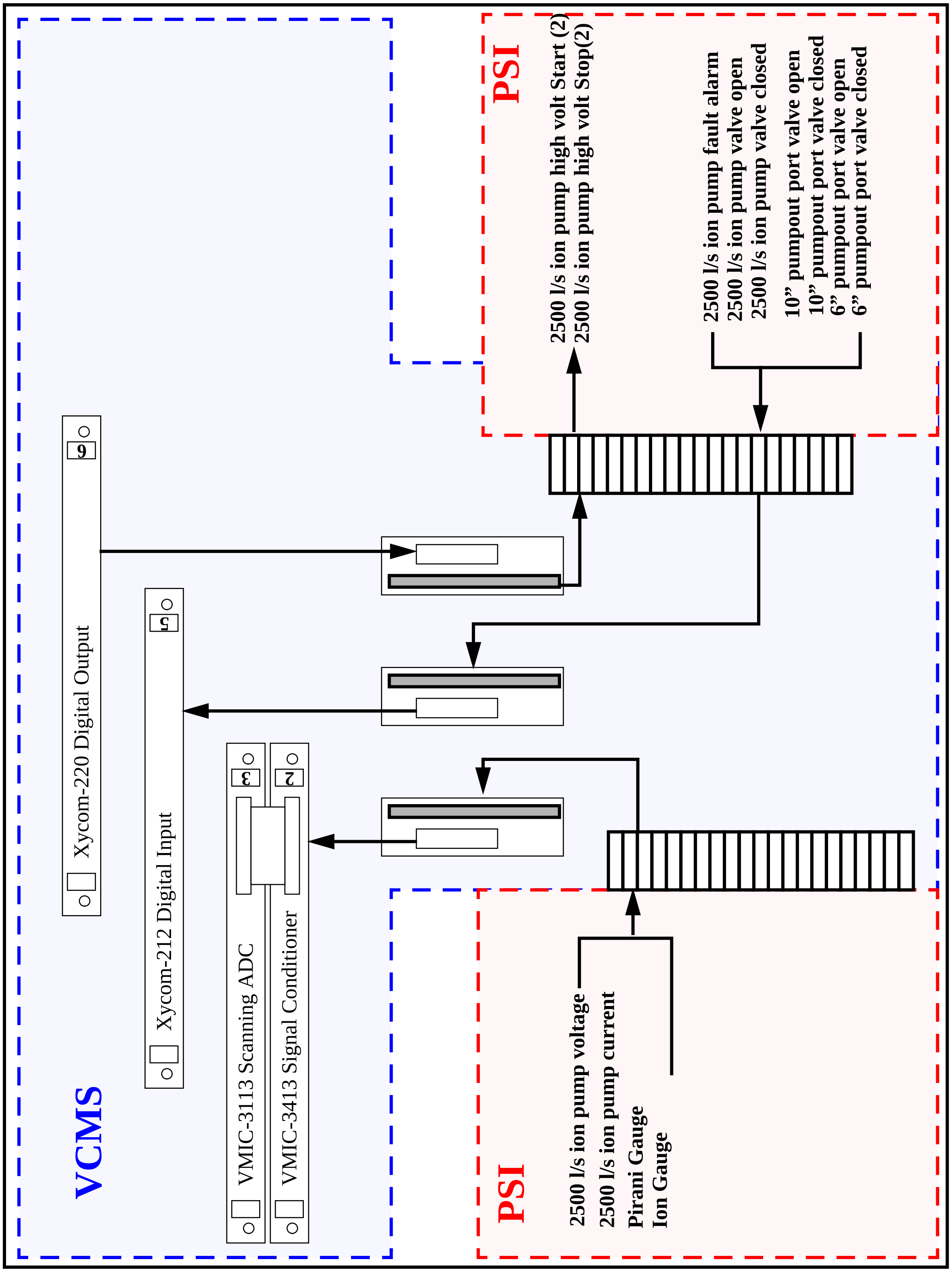

Figure 13: BT/Manifold Signal Connections

5.6. Pumpdown Carts

Portable pumpdown carts will be employed to initially evacuate the VE to the point where ion and cryogenic pumps can be started. These will be multiple units of two types: Turbopump carts and roughing carts. Backing pump systems for these carts will be located in the mechanical room in each VE building, with associated signals run to the pump carts by PSI. A junction box on these carts will then provide signals for monitoring by the VCMS. The interfaces and signals associated with these assemblies are shown in Figure 14: Turbo and Roughing Pump Connections.

5.6.1. Cabling

For all previous assemblies, the wiring was provided by PSI up to the VCMS rack enclosure and terminal blocks. In the case of pumpdown carts, the VCMS must provide cabling up to these assemblies. To accommodate this, and the fact that pump carts move, the VCMS will provide:

1. Two cables, one for each cart type, pulled to each pumpout port location from the nearest VCMS control rack, terminated in a TBD connector. Turbo pump cart cables will be run to the 10” pumpdown ports and roughing pump cart cables to the 6” ports, the latter located only in the LVEA.
2. An umbilical cable from the pumpdown cart termination panel, terminated in a compatible mating connector to the cable of 1 above.

As a pumpdown cart is moved into position for operation at a pumpdown port, its umbilical is plugged into the nearby VCMS connector, which links it into the nearest VCMS VME subsystem for monitoring. The connectors for the two cart types are different, such that a turbo cart umbilical cannot be plugged into a roughing cart monitor cable and vice versa.

Since these carts are portable and the VCMS is required to both monitor and archive data from them, it is necessary that the carts be identifiable when they are connected at the ports. To accomplish this, each pumpdown cart umbilical connector will be keyed, as shown in Figure 15: Pumpdown Cart Identification, by a connection of jumpers at the umbilical cable connector. These jumpers return the VCMS provided 24VDC signal on up to three lines, thereby providing a number of 1-7, as detected by software monitoring the 3 bits on the Xycom-212 module.

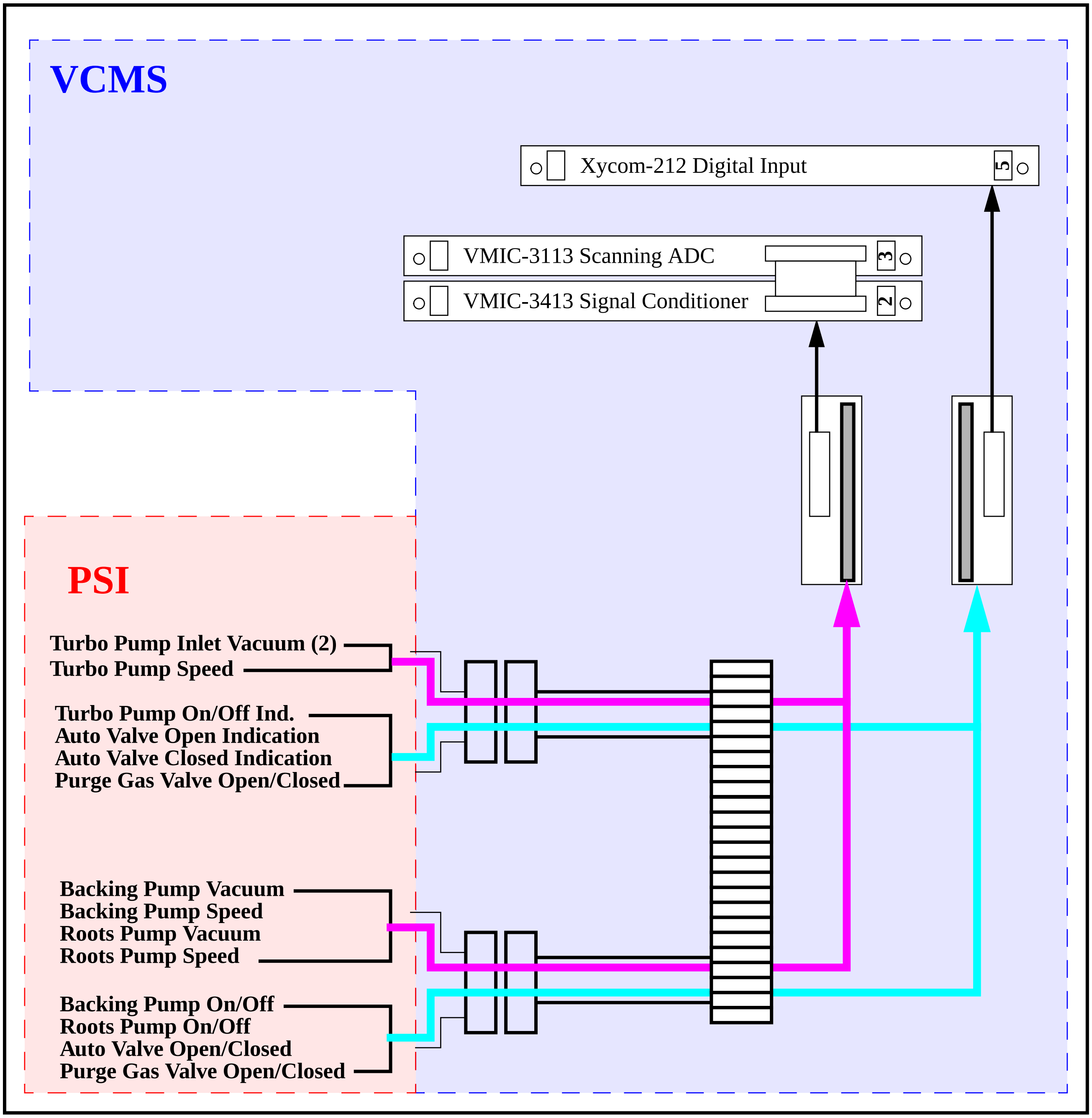

Figure 14: Turbo and Roughing Pump Connections

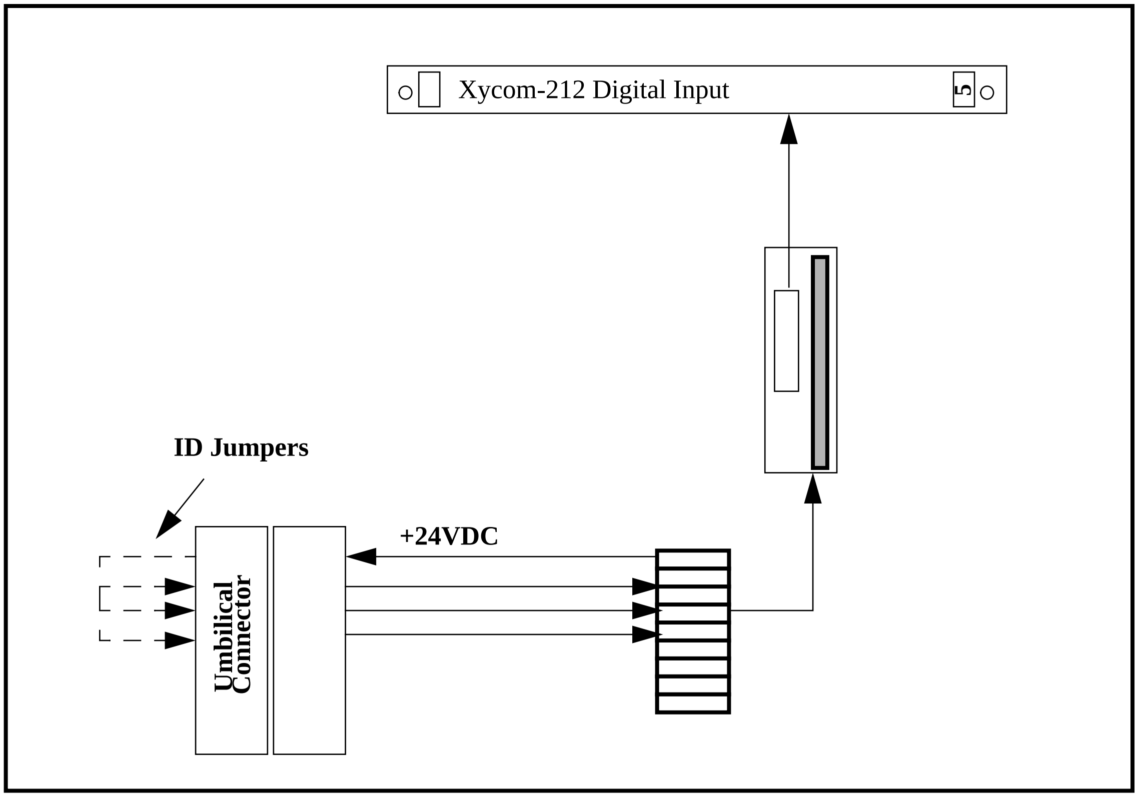

Figure 15: Pumpdown Cart Identification

5.6.2. Monitoring Software

Since the pumpdown carts are portable and can be connected to different VME crates, but still must maintain there data channels, the software must be somewhat different than for other, stationary assemblies. An example of how this would be done is shown in Figure 16: Pumpcart Software.

One of the VCMS processors will contain the EPICS records for all pump carts. In the example, this is depicted as “Remote EPICS Records”, which contains a set of information for each turbo pump cart. The individual VME processors will keep a local EPICS record set for each cart cable connection to its VCMS rack. When a pumpdown cart is connected, the Cable Key will change to a non-zero value, an event monitored by the local SNL software. This software in turn uses the key to identify which remote record set corresponds to this key and makes a data connection via the CDS network. It then continuously takes pumpcart data at a TBD rate and transfers that data to the appropriate pumpcart data records. When the pumpdown cart umbilical is unplugged, the key will go to zero, and the SNL software will stop the data monitoring process.

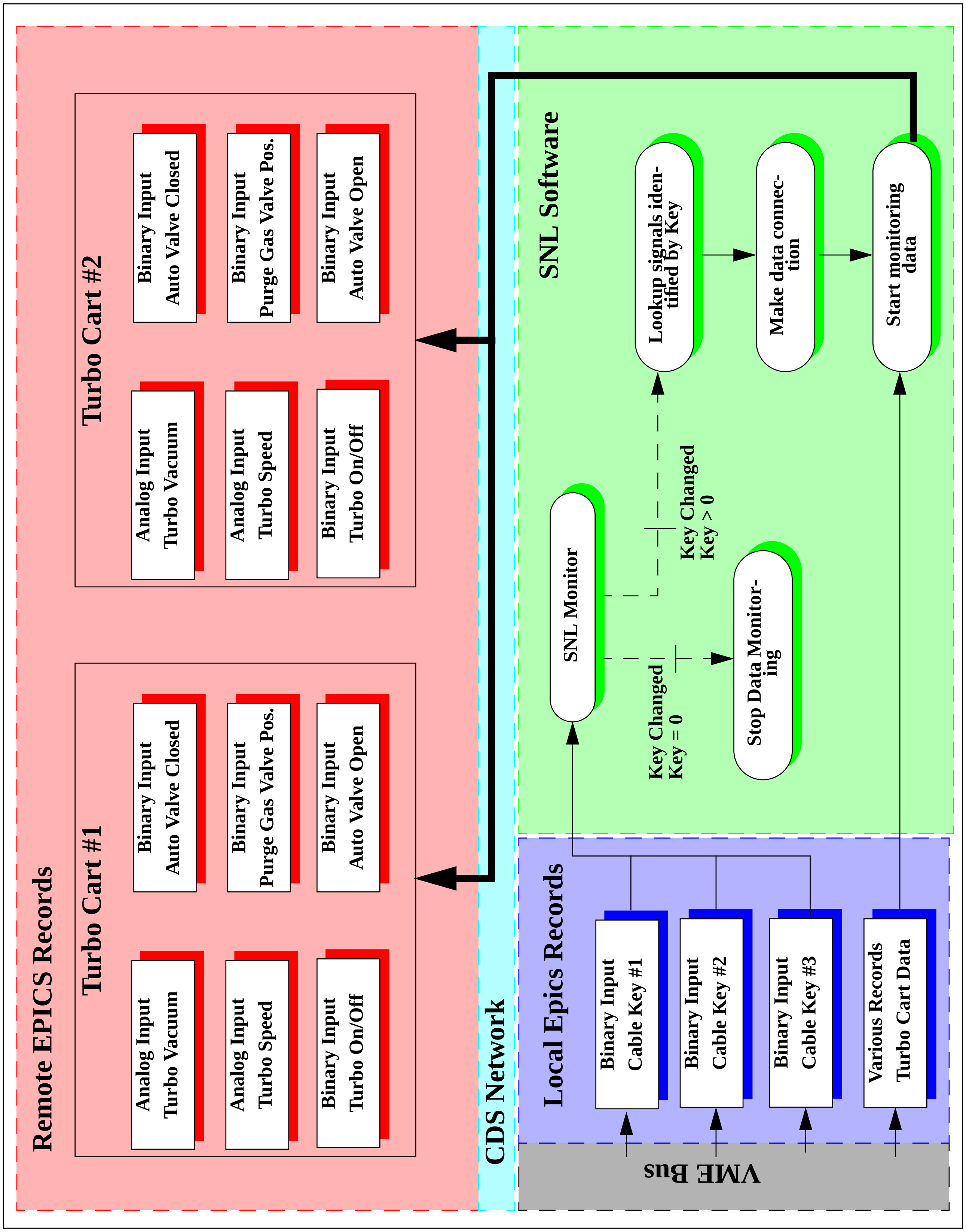

Figure 16: Pumpcart Software