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**LIGO Caltech 40-Meter Prototype Procedures Manual**

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## 1. Introduction

This document has three purposes:

- As the 40-meter prototype nears completion, more and more physicists and engineers will be coming to work in the lab for the first time. This manual will help familiarize them with the various subsystems in the lab and their operation.
- All operational procedures (how to lock the PSL reference cavity, how to reboot the digital suspension crates, etc.) will be centralized in this single, easy-to-update document.
- A troubleshooting guide will be included for each subsystem, cataloguing as much as possible of our experience in installing and commissioning the 40-meter interferometer.

The manual is divided into individual chapters for each subsystem, making it easier to update specific sections as the interferometer matures. Users should be sure to list the date and purpose of the most recent revision at the beginning of each chapter.

## 2. General Laboratory procedures

Last updated 9/30/05, AJW

### 2.1. Safety

- Safety is NUMBER ONE in any lab, including the 40m Lab, which has high voltage, at least one powerful laser, many potential trip and fall hazards, etc. 40 Meter lab Safety procedures are documented in LIGO-M040092 and Laser Standard Operating Procedures are documented in LIGO-M010088-02. These documents are posted in key places in the lab, and are available on the web:

- LIGO-M040092: <http://www.ligo.caltech.edu/~cit40m/Docs/40mSafety.doc>
- LIGO-M010088: [http://www.ligo.caltech.edu/~cit40m/Docs/40mPSL\\_SOP.pdf](http://www.ligo.caltech.edu/~cit40m/Docs/40mPSL_SOP.pdf)

All people working at the Caltech LIGO 40 Meter Interferometer Laboratory (including students and visitors) must be familiar with the safety and emergency response procedures put in place by Caltech, LIGO, and the 40 Meter Lab management. Familiarity and understanding of everything in this document is mandatory for all personnel working at the 40 Meter Lab. There are regular safety briefings for all 40 Meter Lab personnel in which the material in this document is reviewed.

- It is the responsibility of all personnel working in the lab to be aware of all safety issues relevant to themselves and *all other people present in the lab*, and keep safety considerations at the highest priority at all times.
- Everyone who works in the lab must be aware of proper procedures in case of emergencies such as fire, earthquakes, floods, etc.
- Anyone who works with lasers in the 40m lab, especially the high-powered Nd:YAG laser, must be trained, must work with the knowledge of the laser operator in charge, and must follow standard operating procedures as described in the PSL SOP document mentioned above.
- Anyone who works on electrical systems must follow the Lockout/Tagout procedure described in the Safety document mentioned above.
- Anyone who works on the vacuum system must be supervised by Steve Vass or Bob Taylor. Vacuum transitions should be performed by at least two people.
- Anyone who works with hazardous materials must be aware of the proper procedures, and obtain prior approval from Steve Vass or Bob Taylor.
- Anyone who works with the laboratory cranes must be aware of the proper procedures, and obtain prior approval from Steve Vass or Bob Taylor.
- If you are working in the interferometer hall or control room, make sure everyone else in these rooms knows what you are doing and where you are working. Do not touch anything that is not directly related to your work. Put everything back in working order.
- All visitors to the 40m interferometer hall, including repairmen and firemen, must be escorted by a trained member of the 40m lab staff. Visitors must wear laser safety goggles and booties at all times. Visitors must always be cautioned to touch nothing, lean on nothing, watch their step carefully and look out for trip hazards, and keep their laser safety glasses on at all times.

### 2.2. Equipment

- Any and all non-trivial activity in the 40m lab, especially any changes to the interferometer (lasers and optics, electronics and cabling, software, etc) must be documented in the 40m electronic log.

- All laser beamlines must be enclosed and shielded from accidental exposure to the eye. All changes to beamlines must be documented. After any and all work on laser beamlines, the entire area must be thoroughly scanned with an IR viewer. Any evidence of beam scattering or clipping must be remedied. All loose cables, cable ties, or other potential beam clipping hazards must be well secured and/or snipped close.
- All electrical wiring and cabling should be well labeled. Ideally, all cables should be labeled on both ends with a unique ID that corresponds to the engineering drawing, and the locations of the connectors on both ends.
- Unused or unplugged cables will not be tolerated. Please remove any/all cables that are not in use. Leaving them dangling invites both confusion and ground loops. Cables that are dangling or unlabeled will be yanked.

### 3. Vacuum System

Last updated on 07/23/03 by D. Ugolini.

#### 3.1. System Overview

The layout of the 40-meter vacuum system is shown in Figure 2-1. Four different types of pumps are used to evacuate the interferometer volume below  $10^{-6}$  torr. A pumpdown begins with three oil-based roughing pumps (RP1-3, shown at left), which are connected to the main volume through valve V3 and manual valve RV1. These pumps reduce the main volume pressure from 760 torr to 0.5 torr in about three hours. If the entire pumpspool has been brought to atmospheric pressure, the roughing pumps can be used to evacuate it through valve V6. If the pressure on the roughing pumps gets too low, pump oil can be sucked into the system; this is prevented in three ways:

- The roughing pumps can only be connected to the main volume through connection of a manual line and the opening of manual valve RV1. We require a qualified person to monitor the vacuum system at all times while the roughing pumps are in use, and disconnect the manual line as soon as they are no longer running.

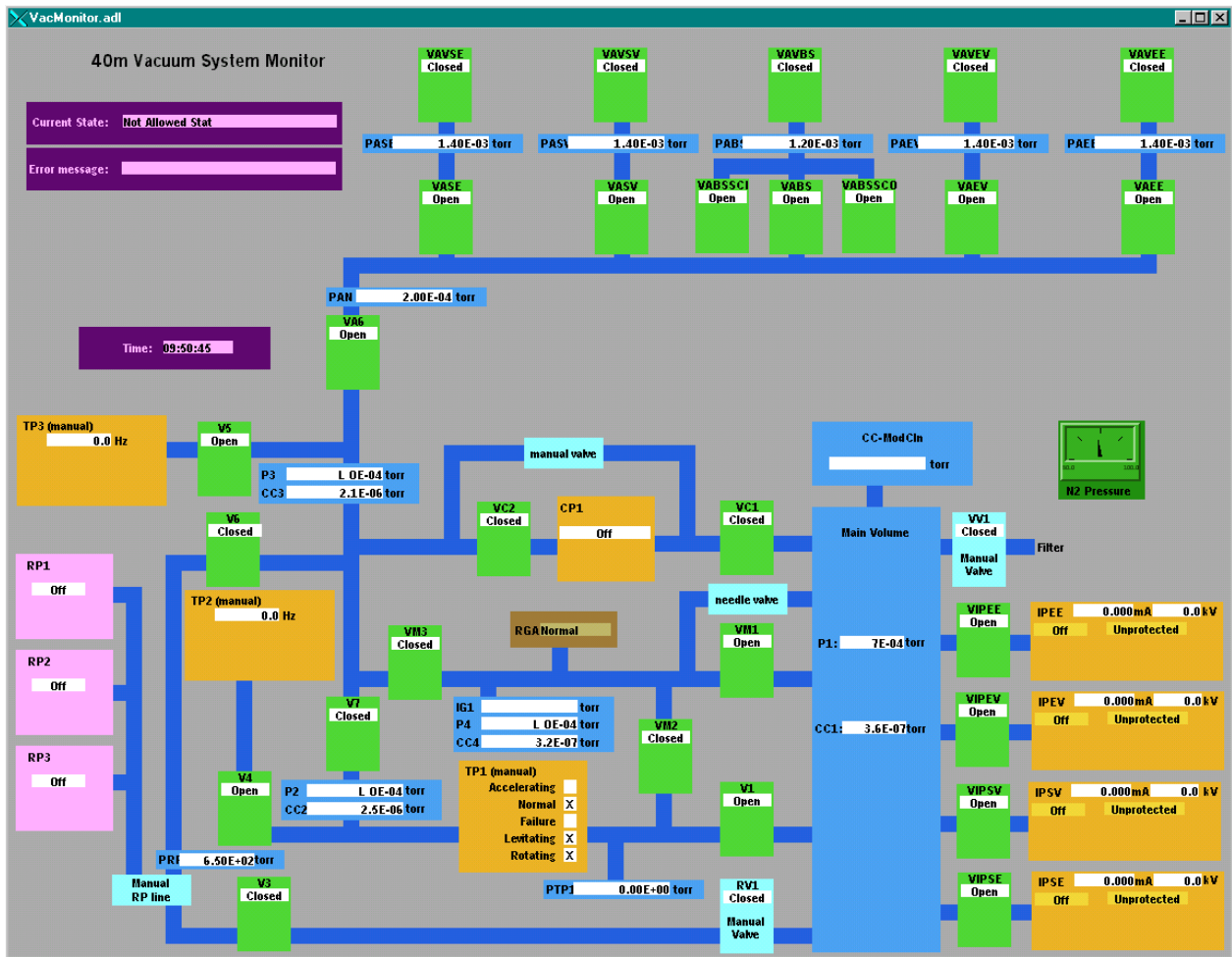


Figure 31: Vacuum system layout, as shown by MEDM screen VacMonitor.adl

- Each roughing pump has a relief valve set to 0.35 torr.

- The EPICS interlock code should shut the roughing pumps off and close V6 if pressure gauge PRP reads less than 0.25 torr.

Once the roughing pumps are disconnected, the system is switched over to three turbopumps: TP1, a magnetically-levitating rotary vane pump under manual control, and TP2/3, two smaller rotary pumps controlled through EPICS. These are connected to the main volume by opening valves V1, V4, V5, and V7. The pumpdown is initially very slow, taking an hour to go from 0.5 torr to 0.05 torr. At that point the pressure begins to fall quickly, and TP3 is reassigned to keeping the annuli (hollow spaces between the chambers and the chamber doors) down to 1 millitorr by closing valve V7 and opening valve VA6. Hardware interlocks prevent the opening of valves V4 and V5 if TP2/3 are not running, while software interlocks prevent the opening of valves V1, V4, and V5 if the pressure differential is too great ( $> 1.0$  torr).

The pressure falls quickly to below  $10^{-4}$  torr, but depending on how long the system has been at atmosphere, it may take as much as a month to reach  $10^{-6}$  torr on turbopumps alone. This is primarily due to water vapor, for which the turbopumps have a low pumping speed. Cryopump CP1 is a cold trap that removes water vapor quickly, helping the system reach  $10^{-6}$  torr in as little as three days. It must be run for two hours with valve CP1 closed to reach operating temperature, and a hardware interlock must be manually overridden before the valve is opened. Software interlocks also prevent the opening of valve VC1 if the main volume pressure is  $> 1.0$  torr. After several days of running, the cryopump should be regenerated by closing valve VC1, opening valve VC2, and letting TP3 pump on the cold trap.

Once the pressure is below  $4 \times 10^{-6}$  torr, vibration-free running may begin by using ion pumps IPSE, IPSV, IPEV, and IPEE. These pumps use high-voltage filaments to ionize the remaining gas molecules, and large magnets to pull the ions into an absorbent material. Software interlocks prevent the gate valves VIPSE, VIPSV, VIPEV, and VIPEE from opening if the main volume pressure is greater than  $4 \times 10^{-6}$  torr.

A residual gas analyzer (RGA) connects to the main volume through valve VM1, and measures the partial pressures of various gasses when the total pressure is below  $10^{-5}$  torr. VM1 is software-interlocked to close if the main volume pressure exceeds this level. In addition, the largest gate valves in the system (V1 and VM1) require a “kick” of nitrogen to open or close. These valves are software-interlocked to close if the nitrogen pressure falls below 55 torr. Two nitrogen bottles are connected to the system through an auto-switching pressure regulator in the main entrance to the lab. A responsible vacuum expert should check each workday to see if an empty nitrogen bottle needs to be replaced.

The system is vented by connecting gas bottles to the main volume through manual valve VV1. Nitrogen is used first until the pressure reaches 25 torr. The rest of the vent is done with dry air bottles. A full vent uses up about five bottles, and takes just under three hours.

### 3.2. Recognized System States

There are seven states recognized by the vacuum system EPICS state code. The system should only be in an unrecognized state when under the supervision of a vacuum expert. The states are defined by which valves are open and which pumps are running, as shown below. Note that a valve or pump in [brackets] may be either open/on or closed/off in the given state.

State: **All Off**

Open: None

On: None

State: **Chamber Open**

Open: V4, V5, VM3, [VABSSCI], [VABSSCO]

On: TP1, TP2, TP3, [IPEE], [IPEV], [IPSV], [IPSE]

State: **Vacuum Normal** (maglev/annulus only)

Open: V1, V4, V5, VA6, VAEE, VAEV, VABS, VASV, VASE, VABSSCI, VABSSCO, [VM1]

On: TP1, TP2, TP3, [IPEE], [IPEV], [IPSV], [IPSE]

**State: Turbopumps + Cryopump**

Open: V1, V4, V5, VC1, VA6, VAAE, VAEV, VABS, VASV, VASE, VABSSCI, VABSSCO, [VM1]  
 On: TP1, TP2, TP3, CP1, [IPEE], [IPEV], [IPSV], [IPSE]

**State: Turbopumps + Ion Pumps**

Open: V1, V4, V5, VC1, VA6, VAAE, VAEV, VABS, VASV, VASE, VABSSCI, VABSSCO, VM1,  
 VIPEE, VIPEV, VIPSV, VIPSE  
 On: TP1, TP2, TP3, IPEE, IPEV, IPSV, IPSE

**State: Maximum Pumping Speed** (all pumps running)

Open: V1, V4, V5, VC1, VA6, VAAE, VAEV, VABS, VASV, VASE, VABSSCI, VABSSCO, VM1,  
 VIPEE, VIPEV, VIPSV, VIPSE  
 On: TP1, TP2, TP3, CP1, IPEE, IPEV, IPSV, IPSE

**State: Vibration-Free** (ion pumps only)

Open: VM1, VIPEE, VIPEV, VIPSV, VIPSE  
 On: IPEE, IPEV, IPSV, IPSE

**3.3. Allowed State Transitions**

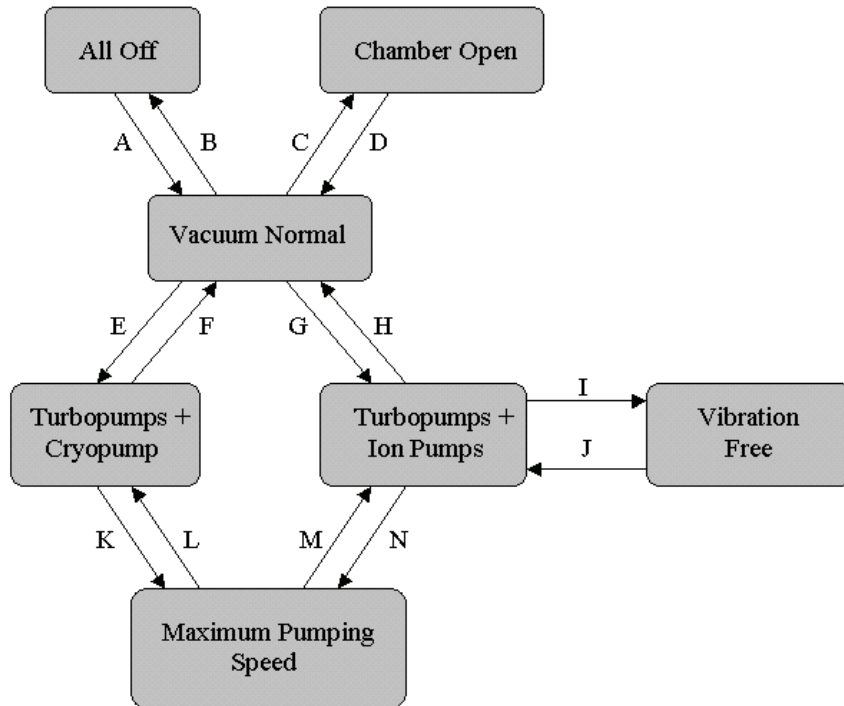


Figure 32: Permitted vacuum system state transitions

Figure 2-2 shows the allowed vacuum system state transitions. Each transition is labeled with a letter corresponding to one of the sequences listed below. During a pumpdown or vent, users should occasionally note interesting numbers (main volume pressure, turbopump rotational speed, etc) in the vacuum logbook along with the sequence instruction they have reached at that time.

**3.3.1. Transition A: All Off → Vacuum Normal**

A001 IPEE ON  
A002 IPEV ON  
A003 IPSV ON  
A004 IPSE ON  
A005 OPERATOR: Connect N2 cylinder to vent line  
A006 VV1 OPEN  
A007 CONDITION: Wait until P1 > 25 torr  
A008 OPERATOR: Close N2 cylinder, replace with dry air cylinder  
A009 CONDITION: Repeat until P1 = atmospheric pressure  
A010 VV1 CLOSE  
A011 V7 OPEN  
A012 CONDITION: RGA filament must be OFF.  
A013 VM3 OPEN  
A014 VA6 OPEN  
A015 TP2 ON  
A016 OPERATOR: Switch TP2 controller to STANDBY  
A017 CONDITION: Wait until TP2 rotation frequency > 950 Hz  
A018 TP3 ON  
A019 OPERATOR: Switch TP3 controller to STANDBY  
A020 CONDITION: Wait until TP3 rotation frequency > 950 Hz  
A021 V7 CLOSE  
A022 VA6 CLOSE  
A023 VM3 CLOSE  
A024 OPERATOR: Connect roughing pump line  
A025 RP1 ON  
A026 RP2 ON  
A027 RP3 ON  
A028 CONDITION: Wait until PRP < 0.35 torr  
A029 VC2 OPEN  
A030 V6 OPEN  
A031 CONDITION: Wait until P3 < 0.5 torr  
A032 V6 CLOSE  
A033 V5 OPEN  
A034 CONDITION: Wait until CC3 < 10<sup>-4</sup> torr  
A035 VC2 CLOSE  
A036 V5 CLOSE  
A037 V7 OPEN  
A038 V6 OPEN  
A039 CONDITION: Wait until P2 < 0.5 torr  
A040 V6 CLOSE  
A041 V7 CLOSE  
A042 V4 OPEN  
A043 TP1 ON  
A044 VM3 OPEN  
A045 V6 OPEN  
A046 CONDITION: Wait until P3 < 0.5 torr  
A047 V6 CLOSE  
A048 VM3 CLOSE  
A049 VA6 OPEN  
A050 V6 OPEN  
A051 CONDITION: Wait until PAN < 0.5 torr  
A052 V6 CLOSE

A053 V5 OPEN  
A054 V3 OPEN  
A055 RV1 OPEN  
A056 CONDITION: Wait until P1 < 0.5 torr (about 3 hours)  
A057 V3 CLOSE  
A058 RV1 CLOSE  
A059 VA6 CLOSE  
A060 V7 OPEN  
A061 V1 OPEN  
A062 VM1 OPEN  
A063 RP1 OFF  
A064 RP2 OFF  
A065 RP3 OFF  
A066 OPERATOR: Disconnect roughing pump line  
A067 CONDITION: Wait until P2 < 0.05 torr (about 1 hour)  
A068 V7 CLOSE  
A069 VA6 OPEN  
A070 VAEV OPEN  
A071 CONDITION: Wait until PAN < 1 torr  
A072 VAEV OPEN  
A073 CONDITION: Wait until PAN < 1 torr  
A074 VABS OPEN  
A075 CONDITION: Wait until PAN < 1 torr  
A076 VABSSCI OPEN  
A077 CONDITION: Wait until PAN < 1 torr  
A078 VABSSCO OPEN  
A079 CONDITION: Wait until PAN < 1 torr  
A080 VASV OPEN  
A081 CONDITION: Wait until PAN < 1 torr  
A082 VASE OPEN  
A083 CONDITION: If CC3 < 10<sup>-5</sup> torr, turn RGA filament ON

### 3.3.2. Transition B: Vacuum Normal → All Off

B001 OPERATOR: Turn RGA filament OFF  
B002 V1 CLOSE  
B003 VM1 CLOSE  
B004 V4 CLOSE  
B005 V5 CLOSE  
B006 TP1 OFF  
B007 OPERATOR: Wait until TP1 indicates “OFF” (about 8 minutes)  
B008 VA6 CLOSE  
B009 VAEV CLOSE  
B010 VAEV CLOSE  
B011 VABSSCO CLOSE  
B012 VABSSCI CLOSE  
B013 VABS CLOSE  
B014 VASV CLOSE  
B015 VASE CLOSE  
B016 TP2 OFF  
B017 TP3 OFF  
B018 OPERATOR: Make sure calibrated leaks are closed  
B019 IPEE OFF  
B020 IPEV OFF

B021 IPSV OFF  
 B022 IPSE OFF

### 3.3.3. Transition C: Vacuum Normal → Chamber Open

C001 VAEV CLOSE  
 C002 VAEV CLOSE  
 C003 VABS CLOSE  
 C004 VASV CLOSE  
 C005 VASE CLOSE  
 C006 VM1 CLOSE  
 C007 VA6 CLOSE  
 C008 VM3 OPEN  
 C009 V1 CLOSE  
 C010 OPERATOR: Connect N2 cylinder to vent line  
 C011 OPERATOR: Set regulator to 30 psi  
 C012 OPERATOR: Make sure interferometer high voltages are off  
 C013 VV1 OPEN  
 C014 CONDITION: Wait until P1 > 25 torr  
 C015 OPERATOR: Replace N2 cylinder with dry air cylinder  
 C016 CONDITION: Add air cylinders until P1 = atmospheric pressure  
 C017 VAV\*\* OPEN (\*\* corresponds to chamber you wish to open)  
 C018 CONDITION: Wait until PA\*\* = atmospheric pressure  
 C019 VAV\*\* CLOSE  
 C020 OPERATOR: Repeat C017-C019 for each chamber to be opened

### 3.3.4. Transition D: Chamber Open → Vacuum Normal

Note: If one or more of the annuli (particularly the BS) are at atmosphere, it may be necessary to deviate from this procedure and use the roughing pumps to evacuate the annulus line. Consult a vacuum expert before proceeding.

D001 OPERATOR: Check jam nuts on compensating bellows  
 D002 OPERATOR: Turn RGA filament OFF  
 D003 VM3 CLOSE  
 D004 VABSSCI CLOSE  
 D005 VABSSCO CLOSE  
 D006 VA6 OPEN  
 D007 OPERATOR: Check that TP2 and TP3 are in standby mode  
 D008 VAEV OPEN  
 D009 CONDITION: Wait until PAN < 1 torr  
 D010 VAEV OPEN  
 D011 CONDITION: Wait until PAN < 1 torr  
 D012 VABS OPEN  
 D013 CONDITION: Wait until PAN < 1 torr  
 D014 VABSSCI OPEN  
 D015 CONDITION: Wait until PAN < 1 torr  
 D016 VABSSCO OPEN  
 D017 CONDITION: Wait until PAN < 1 torr  
 D018 VASV OPEN  
 D019 CONDITION: Wait until PAN < 1 torr  
 D020 VASE OPEN  
 D021 CONDITION: Wait until PAN < 1 torr  
 D022 VV1 CLOSE  
 D023 OPERATOR: Connect roughing pump line

D024 OPERATOR: Operator must be present until D041  
 D025 RP1 ON  
 D026 RP2 ON  
 D027 RP3 ON  
 D028 OPERATOR: Check roughing pump oil levels  
 D029 CONDITION: Wait until PRP < 0.35 torr  
 D030 V3 OPEN  
 D031 RV1 OPEN  
 D032 CONDITION: Wait until P1 < 0.5 torr (about 3 hours)  
 D033 V3 CLOSE  
 D034 RV1 CLOSE  
 D035 VA6 CLOSE  
 D036 V7 OPEN  
 D037 V1 OPEN  
 D038 RP1 OFF  
 D039 RP2 OFF  
 D040 RP3 OFF  
 D041 OPERATOR: Disconnect roughing pump line  
 D042 CONDITION: Wait until P2 < 0.05 torr (about 1 hour)  
 D043 V7 CLOSE  
 D044 VA6 OPEN  
 D045 CONDITION: If CC4 <  $10^{-5}$  torr, turn RGA filament ON  
 D046 CONDITION: If CC1 <  $10^{-5}$  torr, VM1 OPEN

### 3.3.5. Transition E: Vacuum Normal → Turbopumps + Cryopump

E001 OPERATOR: Switch cryopump compressor and controller ON  
 E002 CONDITION: Wait until CP1 reads COLD  
 E003 OPERATOR: Reset CP1 interlock to turn CP1 ON  
 E004 VC1 OPEN

### 3.3.6. Transition F: Turbopumps + Cryopump → Vacuum Normal

F001 VC1 CLOSE  
 F002 VC2 OPEN  
 F003 OPERATOR: Switch cryopump compressor and controller OFF  
 F004 CONDITION: Wait until cryopump fully warms up  
 F005 CONDITION: Wait until CC3 <  $10^{-4}$  torr  
 F006 VC2 CLOSE

### 3.3.7. Transition G: Vacuum Normal → Turbopumps + Ion Pumps

G001 CONDITION: Wait until CC1 <  $4 \times 10^{-6}$  torr  
 G002 VIPEE OPEN  
 G003 VIPEV OPEN  
 G004 VIPSV OPEN  
 G005 VIPSE OPEN

**3.3.8. Transition H: Turbopumps + Ion Pumps → Vacuum Normal**

H001 VIPEE CLOSE  
H002 VIPEV CLOSE  
H003 VIPSV CLOSE  
H004 VIPSE CLOSE

**3.3.9. Transition I: Turbopumps + Ion Pumps → Vibration Free**

I001 V1 CLOSE  
I002 TP1 OFF  
I003 CONDITION: Wait until TP1 indicates OFF (about 8 minutes)  
I004 V4 CLOSE  
I005 TP2 OFF  
I006 V5 CLOSE  
I007 TP3 OFF

**3.3.10. Transition J: Vibration Free → Turbopumps + Ion Pumps**

J001 TP2 OFF  
J002 OPERATOR: Switch TP2 controller to standby  
J003 CONDITION: Wait until TP2 rotation frequency > 950 Hz  
J004 TP3 ON  
J005 OPERATOR: Switch TP3 controller to standby  
J006 CONDITION: Wait until TP3 rotation frequency > 950 Hz  
J007 V4 OPEN  
J008 TP1 ON  
J009 CONDITION: Wait until TP1 indicates ON  
J010 V5 OPEN  
J011 V1 OPEN

**3.3.11. Transition K: Turbopumps + Cryopump → Maximum Pumping Speed**

K001 CONDITION: Wait until CC1 <  $4 \times 10^{-6}$  torr  
K002 VIPEE OPEN  
K003 VIPEV OPEN  
K004 VIPSV OPEN  
K005 VIPSE OPEN

**3.3.12. Transition L: Maximum Pumping Speed → Turbopumps + Cryopump**

L001 VIPEE CLOSE  
L002 VIPEV CLOSE  
L003 VIPSV CLOSE  
L004 VIPSE CLOSE

**3.3.13. Transition M: Maximum Pumping Speed → Turbopumps + Ion Pumps**

M001 VC1 CLOSE  
M002 VC2 OPEN  
M003 OPERATOR: Switch cryopump compressor and controller OFF  
M004 CONDITION: Wait until cryopump fully warms up

M005 CONDITION: Wait until CC3 < 10<sup>-4</sup> torr  
M006 VC2 CLOSE

### 3.3.14. Transition N: Turbopumps + Ion Pumps → Maximum Pumping Speed

N001 OPERATOR: Switch cryopump compressor and controller ON  
N002 CONDITION: Wait until CP1 reads COLD  
N003 OPERATOR: Reset CP1 interlock to turn CP1 ON  
N004 VC1 OPEN

## 3.4. Vacuum Electronics

The vacuum system controls electronics are located in rack 1Y8 next to the pumps pool. The contents of this rack are shown in Figure 2-3. The VME rack contains two MVME 162 processors, three Xycom 212 digital input modules, and two VMIC 2210 relay output modules. Valve status is read by the digital input modules, while pump status and pressure are read serially through the two addressable switchboxes. Opening a valve or turning on a pump causes a relay in the VMIC 2210 modules to close, sending 24V DC to a relay box where another relay is triggered, sending 110V AC to the appropriate device. There are six of these relay boxes; one main box underneath the pumps pool, and five satellite boxes, one for each test mass chamber and one for the BS chamber. The system is designed such that all computer-controlled valves and pumps will close/turn off if a loss of power occurs.

The complete vacuum electronics schematics can be found in LIGO document number D000338, or on the Internet at <http://www.ligo.caltech.edu/~babbott/D000338.PDF>.

## 3.5. Vacuum Software

### 3.5.1. MEDM Screens

There are only two MEDM screens for the vacuum system – one for monitoring the pressures and system state by general users, and one for controlling the system for experts only.

The monitoring screen can be found on any Martian network machine at `/cvs/cds/caltech/medm / VacMonitor.adl`, or opened from the VAC tab on `sitemap.adl`. This is the same screen shown in Figure 2-1. The overall system state, system error messages, the on/off status of pumps, the open/closed status of valves, and all pressures can be read from this screen, but no buttons are provided for system control.

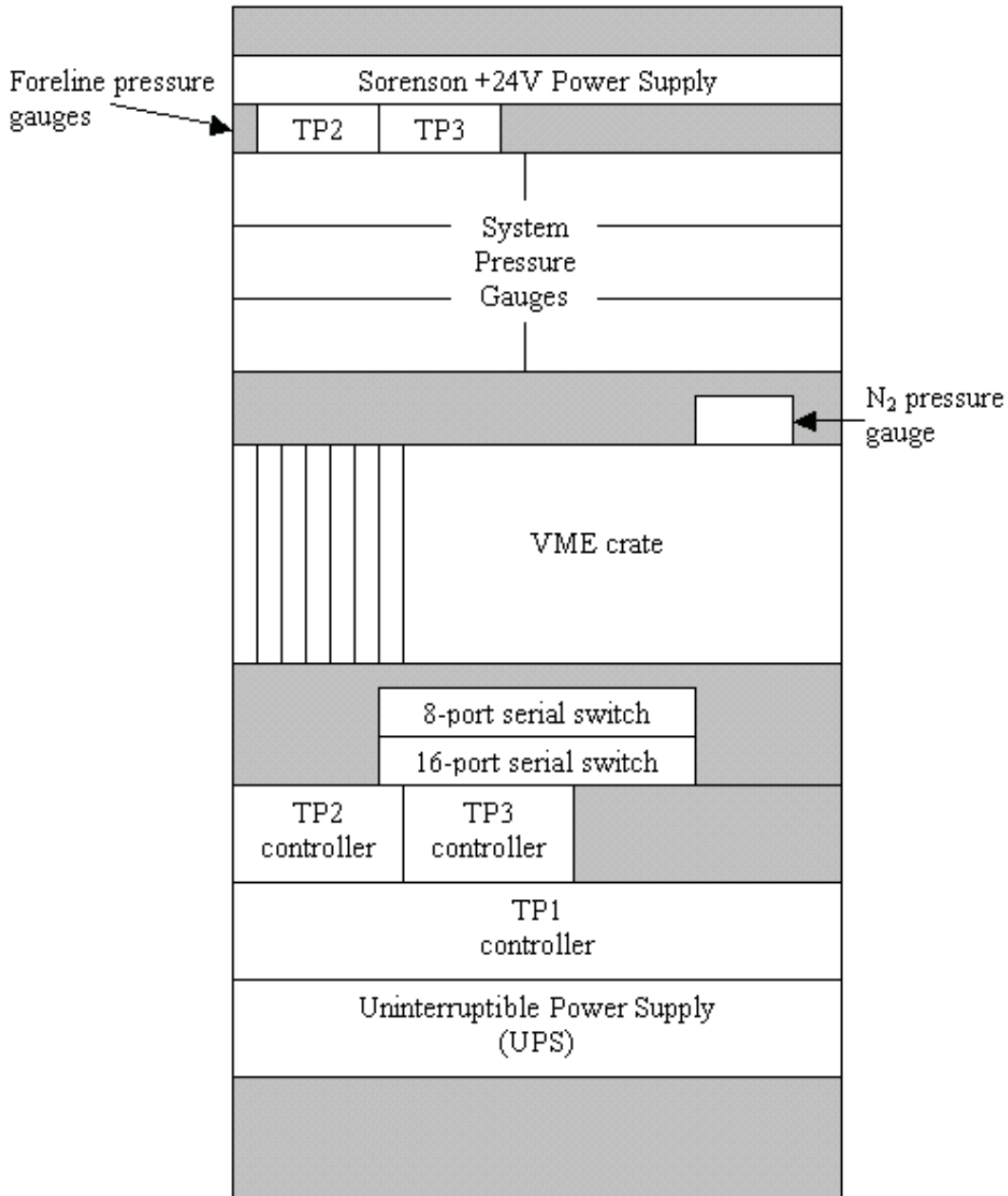


Figure 33: Contents of vacuum controls rack 1Y8

The control screen is located at `/cvs/cds/caltech/target/c1vac1/VacControl.adl`. This screen should only be opened on `cdssol6` when seated at the pumps pool. It is essentially the same as `VacMonitor.adl`, but with control buttons included for all computer-controlled valves and pumps, and an acknowledgement button for clearing system error messages.

These screens are not automatically generated; users making a change should be sure to update both screens separately. For more on modifying screens, refer to the **MEDM** chapter of this procedures manual.

### 3.5.2. EPICS Code

The vacuum system is controlled by two MVME 162 processors designated as c1vac1 (scipe2, IP address 131.215.113.52) and c1vac2 (scipe4, IP address 131.215.113.54). All code loaded and executed by these processor can be found on any Martian network machine at /cvs/cds/caltech/target/\*, where \* is the name of the processor. c1vac1 loads one database (Vac.db) and four object files (VacControl.o, VacSerial.o, VacInterlock.o, VacNitro.o). c1vac2 loads one database (Vac2.db) and two object files (VacIon.o, VacTP.o).

Note that two processors were required in order to support serial communication. Each MVME162 has four serial ports, but only two serial communication chips, each controlling two ports. We have observed that if two ports controlled by the same chip are initialized to two different sets of communication parameters (baud rate, # of data bits, # of stop bits, parity), crashes occur frequently. Thus care must be taken if another serial device is added to the system. If it matches one of the four sets of communications parameters already in use, it may be cabled through an addressable serial port switchbox; if not, a third processor must be installed. In either case, the state code for querying the device and the associated database entries must be assigned to the correct processor.

The source code for the object files can be found at /opt/CDS/d/epics/apple/Caltech/40mVac/40mVacScipe / dev/src. Each routine has the following functions:

- **VacControl.st** is responsible for overall system state recognition.
  - State “init” defines a 24-bit vector for each of the seven recognized states.
  - State “findVector” fills another vector with the on/off status of 24 valves.
  - State “findState” compares the vector from “findVector” to those from “init” to determine the system state, and sends this value to C1:Vac-state\_mon. If the current state does not match any of the defined states, the message “Undefined state” is sent.
- **VacSerial.st** is responsible for serial communication with almost all pressure gauges.
  - State “init” initializes the third serial port on c1vac1 to 9600 baud, 8 data bits, 1 stop bit, and even parity, and defines integer “fd” as the memory location of this port.
  - State “cycle” queries each pressure gauge in turn. Each of the five gauge controllers have 2-4 pressure gauges. The state code first opens a specific port on the 16-port addressable serial port switchbox, and then asks for a pressure reading from each gauge in the controller. Pressures are read as strings and converted to real numbers; the strings are sent to the MEDM screen, so that error messages such as “NO COMM” may be displayed as well.
- **VacInterlock.st** is responsible for all software interlocking.
  - State “init” zeroes some counters for time-delayed interlocks.
  - State “ipGate” closes and prevents the opening of the ion pump gate valves if the main volume pressure is less than  $4 \times 10^{-6}$  torr.
  - State “roughingPumps” closes and prevents the opening of valve V6 if the pressure at the roughing pumps falls below 0.25 torr, thus preventing oil backstreaming.
  - State “RGAalarm” is not yet in use, because the RGA alarm bit is not currently wired into the system. Once it is, however, this code will close valves V1, V4, and V5 if hydrocarbon levels grow too high.
  - State “nitSupply” closes the 8” gate valves V1 and VM1 if the nitrogen pressure falls below 55 torr; if the pressure were to fall much lower, it would not be possible to close the valves.
  - State “TP1alarm” closes valve V1 if a fault is detected on the maglev turbopump TP1.
  - State “difference” prevents the opening of valves V1, VM1, and VC1 if the pressure differential is greater than 1 torr, thus preventing an accidental venting of the main volume.

- State “rising” is intended to seal off the main volume if a leak is detected by way of slowly rising pressures. It is not currently in use.
- State “tpSoft” works in combination with a hardware interlock on the TP2/3 controllers to prevent the opening of valves V4 and V5 if the respective turbopumps are not running.
- State “errReset” clears the error message field if the acknowledgement button is pressed.
- State “protectRGA” closes valve VM1 to prevent saturation of the RGA if the main volume pressure exceeds  $10^{-5}$  torr.
- State “slowDown” is a relic of when the serial communication crashes were thought to be caused by the interlock code, and could be ignored or removed without much effect.
- **VacNitro.st** is responsible for reading out the nitrogen line pressure gauge.
  - State “init” initializes the second serial port of c1vac1 to 9600 baud, 7 data bits, 1 stop bit, and odd parity.
  - State “cycle” queries the nitrogen pressure gauge once a second, and converts the string response to a floating point number.
- **VacIon.st** is responsible for ion pump querying and control.
  - State “init” initializes the second serial port of c1vac2 to 1200 baud, 8 data bits, 1 stop bit, odd parity.
  - State “cycle” checks the voltage and current of each ion pump filament, and sends commands to turn the pump on/off or turn protection (low-voltage) mode on/off.
- **VacTP.st** is responsible for querying and control of turbopumps TP2 and TP3.
  - State “init” initializes the third and fourth serial ports of c1vac2. The default values of 9600 baud, 8 data bits, 1 stop bit, and no parity are used. Both ports can be used because the communication parameters are the same.
  - State “cycle” checks the status and rotation speed of the pump, and sends commands to turn the pump on/off or turn standby (low-speed) mode on/off.

For more on modifying and compiling EPICS state code, see the **EPICS** chapter of this procedures manual.

### 3.6. Ongoing System Improvements

- A cable needs to be run from pressure gauge CCMC to the vacuum control rack, and the state code VacSerial.st must be modified to read out pressures from CCMC.
- TP2 and TP3 are no longer manual; the medm screens should be modified to reflect this.
- The RGA alarm needs to be added to the system.

### 3.7. Rebooting the EPICS cpus c1vac1 and/or c1vac2

See the EPICS section about how to modify code if necessary. Once you’ve copied over the code to /cvs/cds/caltech/target/c1vac1 (or c1vac2), you can reboot *safely*:

- You *should* be able to just press the “reset” button on the c1vacX vme cpu in rack 1Y8-13-1 (or c1vac2 in 1Y8-13-3), while standing there to make sure it all goes ok. BUT, it won’t; due to a timing

problem that we've yet to resolve, when the cpu comes back up, it thinks that the N2 supply is low, so it shuts V1 and VM1. So...

- Before you reboot, shut V1 and VM1 from the EPICS control screen.
- After reboot, the IPs will be disoriented. To get the EPICS control screen to agree with the state of the IPs. If the IP ON/OFF is reversed:
  - Set to OFF, Unprotected on MEDM screen
  - At each of the 4 pump controllers, turn off HV and turn off power
  - Then, turn on power and then HV. Make sure pump is in REMOTE mode.
- If IP Protect/Unprotect is reversed:
  - Set to OFF, Unprotected on MEDM screen
  - At pump controller, press LOC/REM twice.

### 3.8. Troubleshooting Guide

***I press the button to open a valve, but nothing happens, and when I look again, the button is set to "Closed".***

A software interlock has prevented you from opening a valve in an unsafe situation (large pressure differential, turbopump not running, etc). Make sure you understand why the interlock is being tripped before you proceed.

***I press the error acknowledgement button, but the error message is still there.***

You released the button too quickly; the interlock code only checks the acknowledgement button about once every 0.5 seconds. Try holding the button down.

***Several valves open and close intermittently.***

There are two places where the ribbon cable connections may come loose: at the VMIC 2210 relay output modules in the vacuum controls rack, and at the black relay box under the pumps pool. Make sure all of these connectors are tightly in place.

***The control buttons on the MEDM screen for the ion pumps are not behaving properly.***

The ion pump controllers are old and somewhat eccentric; because of how the serial communications work, it is possible to put them in a state where the control buttons on the MEDM screen have the opposite of their intended effect. If the On/Off button is reversed:

- Turn ion pump to Unprotect at MEDM screen; wait until the readback says Unprotect.
- Turn pump to Off at MEDM screen.
- Go to the ion pump, and flip the HV switch in front to Off.
- There is a power switch at the rear of the pump. Switch it off, wait ten seconds, and switch it on.
- Turn the HV switch in front of the pump to On.
- Make sure the pump is in Remote mode. If it is not, press the LOC/REM button once.

If the Protect/Unprotect button is reversed:

- Turn ion pump to Unprotect at MEDM screen; wait until the readback says Unprotect.
- Turn pump to Off at MEDM screen.
- Go to the ion pump, and press the LOC/REM button twice.
- Go back to the MEDM screen and turn the pump On. Wait until the pump readback says On and the voltage reading is at a maximum (usually 7.5V).
- Switch to Protect at the screen.

## 4. Pre-Stabilized Laser (PSL)

Last updated 07/023/03 by D. Ugolini.

### 4.1. System Overview

The 40-meter PSL is based on the same Nd:YAG Lightwave 1064 mm laser used at the main LIGO sites. The 10'x6' PSL table is located in the blue enclosure at the northwest corner of the IFO hall, with the layout shown in Figure 3-1. The 10W beam is brought to a height of three inches above the table by a periscope, and passed through a pair of cylindrical lenses to correct astigmatism. A pickoff mirror then redirects 70mW of beam to the frequency stabilization path. Pairs of mode-matching lenses are used to focus the beam into the major optical elements in each path.

The low-power beam (left half of Figure 3-1) is sent through a Pockels cell where 21.5 MHz sidebands are applied, then makes a double pass through an acousto-optic modulator (AOM) for a 160 MHz frequency shift. The beam then passes through another periscope and is locked to a suspended fixed-length reference cavity. The reflected light is read out by a tuned RF photodiode and sent to a mixer in the Frequency Stabilization Servo. The laser frequency is kept locked to the reference cavity through three actuators: a heater on the master oscillator crystal (slow), a PZT on the crystal (fast), and a phase-correcting Pockels cell downstream of the NPRO (very fast).

The main beam first passes through a half-wave plate/splitting cube combination, which allows us to attenuate the beam power to a desired level. Two steering mirrors then aim the beam into a pre-mode cleaner (PMC). Reflected light from the front of the PMC is read out by a tuned RF photodiode and sent to a mixer in the PMC servo. The transmitted light is directed through three Pockels cells for the mode cleaner and IFO sidebands (currently only two are in place), and then brought to the proper height for the IFO by a periscope at the northeast corner of the table. A second attenuator at the periscope allows us to independently control the power levels in the interferometer.

### 4.2. PSL Procedures

Before performing any procedures that involve turning the laser on/off or working in the PSL enclosure when the laser is running, the user should be familiar with the 40-meter Standard Operating Procedure, LIGO-M010088-00-R, which can be found at [http://www.ligo.caltech.edu/~ajw/40mPSL\\_SOP.pdf](http://www.ligo.caltech.edu/~ajw/40mPSL_SOP.pdf). In particular, note that only a qualified Laser Operator should disable the enclosure interlocks and initiate work on the table; a list of registered laser personnel can be found next to the enclosure sign-in sheet.

#### 4.2.1. Turning on the Laser

1. Announce to everyone in the control room and the IFO hall that you are turning the laser on. Make sure that no one is working in the IFO hall without safety glasses.
2. On the west wall of the IFO hall, next to the PSL enclosure, is a key switch labeled "Laser Control". Turn this key to the ON position.
3. Under the east desk in the control room is the PSL chiller. On the chiller control panel, press the following buttons in this order: **ON/OFF**, then **RS232**, then **RUN/STOP**. When the **ON/OFF** button is pressed, you should hear the chiller begin circulating water. When the last button is pressed, the RS232 light on the chiller control panel should be lit, and the temperature should read on the digital display.
4. In rack 1Y1, look at the Lightwave power supply. At the far left is a keyswitch; turn this to ON. The power supply will perform self-diagnostics for about 15 seconds, after which the laser is ready. If you see the message CHLR FLT on the power supply digital display, there is a problem with the chiller. Go

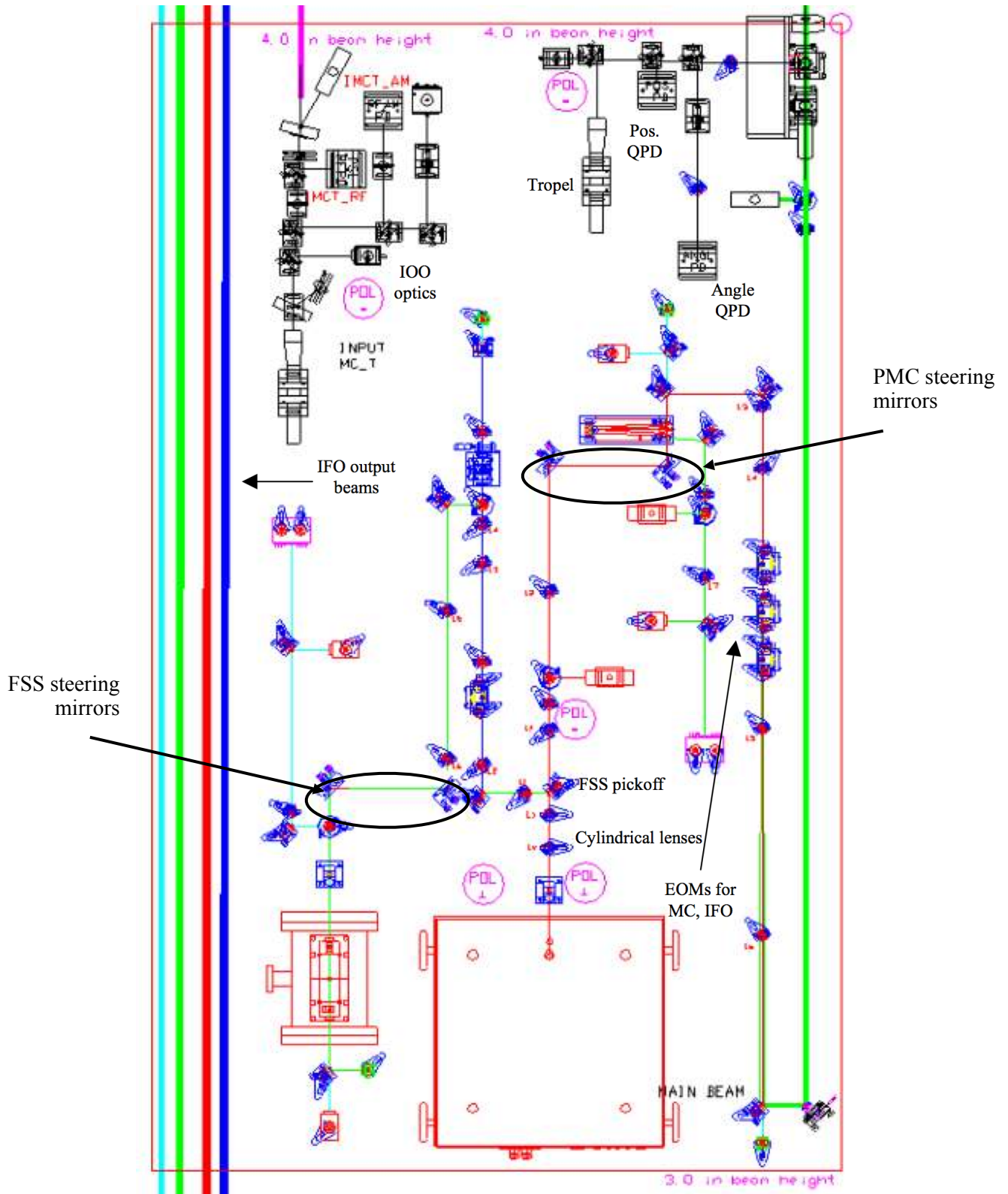


Figure 3-1: Layout of 40-meter PSL table back to Step 2 (starting the chiller), or consult a laser expert.

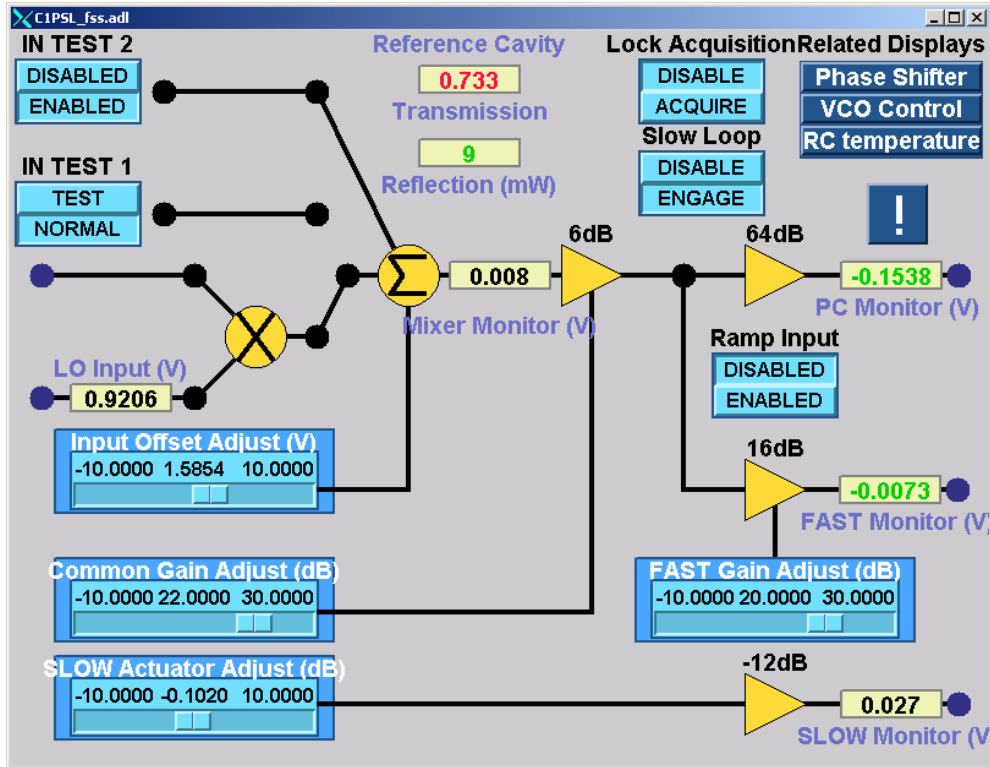
5. To the right of this key is a switch to make the master oscillator begin lasing. Set this switch to **LASE**. The light above the switch should turn on immediately. If it does not, an interlock may be broken; check the enclosure doors, or consult a laser expert.
6. The next switch to the right activates the power amplifier. Set this switch to **ENABLE**. The digital display to the right should say “Ramping Current” for a few seconds, followed by “Lase.”
7. The final switch on the right opens the laser shutter. Set this switch to **OPEN**.
8. Press the **DISPLAY 1** button on the power supply until the laser current is displayed. This should read 20.00A. If it does not, turn the large knob next to the display to set the current to 20 amps.
9. The laser is now running, but you should wait about 15 minutes for it to thermally stabilize before attempting to lock the reference cavity, and several hours before taking important measurements.

#### 4.2.2. Aligning the Reference Cavity

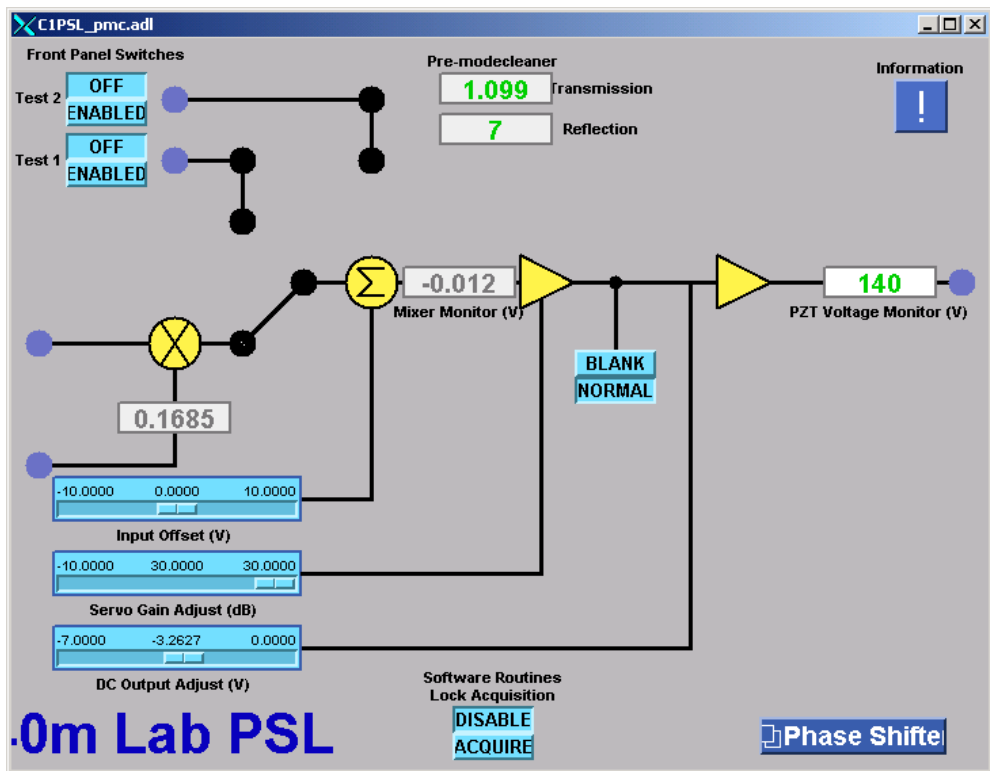
1. Use the FSS steering mirrors (circled in Figure 3-1) to center the low-power beam through the iris in front of the reference cavity.
2. Set a function generator to a 10 Hz sine wave, 10 Vpp, zero offset.
3. Using a BNC to single-pin LEMO adapter, send the function generator output into the connector labeled RAMP INPUT on the front of the FSS servo card in rack 1Y1.
4. Open the MEDM screen C1PSL\_fss.adl (see Figure 3-2a), located in /cvs/cds/caltech/medm/psl. Turn the **Ramp Input** switch to ENABLE.
5. Find the transmitted beam through the reference cavity; it should be flickering rapidly through many different TEM modes. Center a camera on this beam.
6. “Walk the beam” (change one axis on one steering mirror, then the same axis on the other mirror) while watching the transmitted beam on a monitor. You are trying to maximize the brightness of the TEM<sub>00</sub> mode. Work first horizontally, then vertically, then repeat. As you get closer, you may wish to reduce the voltage of your ramp input to reduce the number of other modes you see. Just make sure to use the Slow adjust slider to center your ramp on the TEM<sub>00</sub> mode.
7. Turn the **Ramp Input** switch to DISABLE.
8. Using a BNC to SMA adapter, connect an oscilloscope to the DC output of the reflected beam RF photodiode.
9. Steer the reference cavity reflected beam onto the RFPD, using the oscilloscope to maximize DC output.
10. Turn the **Ramp Input** switch back to ENABLE. Whenever the TEM<sub>00</sub> mode is excited in the reference cavity, the DC voltage at the RFPD should dip down close to zero. Trigger the scope on this dip.
11. Walk the beam again until the dip in DC voltage goes as close to zero as possible.
12. Turn the **Ramp Input** switch to DISABLE and disconnect the function generator. The reference cavity should now be ready for locking.

#### 4.2.3. Aligning the Pre-Mode Cleaner

1. In these instructions, we will call the first steering mirror before the pre-mode cleaner (the farther west of the two steering mirrors) M1 and the other mirror M2.
2. Attenuate the beam down to < 1 watt for safety. Block the beam upstream of M1.



(a)



(b)

Figure 3-2: MEDM screens for (a) the frequency stabilization servo and (b) the pre-mode cleaner.

3. Unbolt the pre-mode cleaner and shift it out of the way of the beam path, and then unblock the beam. Make note of the line of holes on the table that passes from M2 through the center of the two flat mirrors on the PMC.
4. Set an iris to 3" high and place it close to M2, on the line of holes previously noted. Steer M1 until the beam passes through the iris.
5. Move the iris as far from M2 as possible while still keeping it on the noted line of holes. Now steer M2 until the beam passes through the iris.
6. Repeat steps 4 and 5 until the mirrors no longer need to be steered. Then block the beam, reinstall the PMC, and unblock the beam.
7. Set a function generator to a 10 Hz sine wave, 2V<sub>pp</sub>, zero offset. Send this signal into the LEMO connection labeled **EXT DC INPUT** on the PMC servo card.
8. Open the MEDM screen C1PSL\_pmc.adl (see Figure 3-2b), located in /cvs/cds/caltech/medm/psl. Set the **DC Output Adjust** slider to -2V.
9. Find the transmitted beam through the reference cavity; it should be flickering rapidly through many different TEM modes. Center a camera on this beam.
10. "Walk the beam" (change one axis on one steering mirror, then the same axis on the other mirror) while watching the transmitted beam on a monitor. You are trying to maximize the brightness of the TEM<sub>00</sub> mode. Work first horizontally, then vertically, then repeat. As you get closer, you may wish to reduce the voltage of your ramp input to reduce the number of other modes you see. Just make sure to use the DC Output Adjust slider to center your ramp on the TEM<sub>00</sub> mode.
11. Disconnect the function generator. Using a BNC to SMA adapter, connect an oscilloscope to the DC output of the reflected beam RF photodiode.
12. Steer the reference cavity reflected beam onto the RFPD, using the oscilloscope to maximize DC output. Make sure not to saturate the DC output; there is an attenuator upstream to reduce the beam power if necessary.
13. Reconnect the function generator. Whenever the TEM<sub>00</sub> mode is excited in the reference cavity, the DC voltage at the RFPD should dip down close to zero. Trigger the scope on this dip.
14. Walk the beam again until the dip in DC voltage goes as close to zero as possible.
15. Disconnect the function generator. The reference cavity should now be ready for locking.

#### 4.2.4. Locking the Reference Cavity

1. Make sure you can see a monitor showing the reference cavity transmitted camera image. You will also need the MEDM screen C1PSL\_fss.adl (see Figure 3-2a), located in /cvs/cds/caltech/medm/psl.
2. Shut off the slow loop by pressing **ENGAGE** under **Slow Loop** at the top right of the FSS screen.
3. Open the loop by pressing **TEST** under **In Test 1** at the top left of the FSS screen.
4. Right-click on the **SLOW Actuator Adjust** slider at the lower left of the FSS screen. On the menu that appears, set the **VALUE** field to 0.0, and then wait about 15 seconds for the system to equilibrate. If the slider was far from zero, you should see several different spatial modes flash by on the reference cavity transmitted monitor.
5. Right-click again on the **SLOW Actuator Adjust** slider. This time choose the "-2" increment button. This will allow you to move the slider 0.01 volts at a time.
6. Place your cursor over the **SLOW Actuator Adjust** slider. Now start slowly tapping the right arrow key on your keyboard, waiting about three seconds between taps, and watch the camera monitor. You are looking for the TEM<sub>00</sub> mode – a single bright, round spot in the center of the monitor. You will see

many more complicated modes, then eventually a very dim spot (very faint, you may miss it) followed by a brighter one; these are both sidebands. Stop when you get to the next bright round spot.

7. If you skip past the TEM<sub>00</sub> mode, right-click on the **SLOW Actuator Adjust** slider and choose the “-3” increment button. Now tap the left arrow key on your keyboard until the mode comes back on the monitor.
8. Close the loop by pressing NORMAL under **In Test 1**. If the bright mode image instantly disappears, you have accidentally tried to lock on a sideband; press TEST to open the loop and look for the correct mode again. If you fail more than a couple of times, tell a laser expert that some of the settings may have changed (a phase flip in the modulation, for example).
9. Begin the slow loop by pressing ENGAGE under **Slow Loop**. The reference cavity is now locked.

#### 4.2.5. Locking the Pre-Mode Cleaner

1. Make sure you can see a monitor showing the pre-mode cleaner transmitted camera image. You will also need the MEDM screen C1PSL\_pmc.adl (see Figure 3-2b), located in /cvs/cds/caltech/medm/psl.
2. Look at the power incident on the PMC reflected photodiode, shown at the top center of the PMC screen. If this number is greater than about 40, you will have difficulty locking the pre-mode cleaner. Ask a laser expert to reduce the power to this photodiode.
3. Open the loop by pressing BLANK on the blanking switch near the center of the PMC screen.
4. Right-click on the **DC Output Adjust** slider at the lower left of the PMC screen. On the menu that appears, set the VALUE field to -2.0.
5. Right-click again on the **DC Output Adjust** slider. This time choose the “-2” increment button. This will allow you to move the slider 0.01 volts at a time.
6. Place your cursor over the **DC Actuator Adjust** slider. Now start tapping the left arrow key on your keyboard to scan for the TEM<sub>00</sub> mode – a single bright, round spot in the center of the monitor. You can scan fairly quickly, since unlike the FSS slow loop, the pre-mode cleaner responds instantly.
7. Once you have found the TEM<sub>00</sub> mode, use the left and right arrow keys to make the image on the monitor as bright as possible.
8. Close the loop by pressing NORMAL on the blanking switch near the center of the PMC screen. The pre-mode cleaner should now be locked. If the bright mode image disappeared, you were either not well-centered on the mode, or some settings have been changed (a phase flip in the modulation, for example). Try again, but if you don’t succeed in two more tries, find a laser expert to check the settings.

#### 4.2.6. Optimizing FSS Gains

1. Connect the mixer monitor output from the FSS servo card to a spectrum analyzer. Set the analyzer range from 100 Hz to 100 kHz. You will also need the MEDM screen C1PSL\_fss.adl (see Figure 3-2a).
2. Reduce the **Common Gain Adjust** and **Fast Gain Adjust** sliders to zero. Lock the reference cavity.
3. Right-click on the **Common Gain Adjust** slider and choose an increment of “0”. This will move the slider 1 db per click. Do the same for the **Fast Gain Adjust** slider.
4. Position the cursor over the **Common Gain Adjust** slider. Tap the right arrow button on your keyboard, waiting a few seconds between taps, and watch the signal on the spectrum analyzer. You are looking for a peak at 10 kHz, showing that the servo is becoming unstable at the crossover frequency.
5. When the peak appears, press the left arrow button twice to reduce the common gain by 2 db. This should cause the 10 kHz peak to disappear.
6. Position the cursor over the **Fast Gain Adjust** slider and begin tapping the right arrow button. You are again looking for a peak 10 kHz on the spectrum analyzer.

7. When the peak appears, press the left arrow button twice to reduce the fast gain by 2 db. The peak should again disappear. The FSS gains are now optimized.

#### 4.2.7. Optimizing PMC Gain

1. Connect the mixer monitor output from the PMC servo card to both an oscilloscope and a spectrum analyzer. Set the spectrum analyzer range from 100 Hz to 100 kHz. You will also need the MEDM screen C1PSL\_pmc.adl (see Figure 3-2b).
2. Reduce the **Servo Gain Adjust** slider to zero. Lock the pre-mode cleaner.
3. Right-click on the **Servo Gain Adjust** slider and choose an increment of “0”. This will move the slider 1 db per click.
4. Position the cursor over the **Servo Gain Adjust** slider. Tap the right arrow button on your keyboard, waiting a few seconds between taps, and watch the signal on both the oscilloscope and spectrum analyzer. You are looking for a resonance peak at any frequency (but probably around 3-30 kHz) that would represent an oscillation in the servo.
5. If an oscillation occurs, press the left arrow button twice to reduce the gain by 2 db. The oscillation should disappear; if not, continue reducing the gain until it does. The PMC gain is now optimized.

#### 4.2.8. Aligning Electro-Optic Modulators (Pockels Cells)

1. Place a Thorlabs PDA55 just downstream of the EOM to be aligned. Put the PDA55 output into an oscilloscope with a timescale of  $\sim 0.5$  sec/div. This “stripchart” style of setting will make it easier to see the effects of your alignment.
2. There are four adjustment screws in the EOM base. Each pair controls the horizontal and vertical displacement of one end of the EOM; adjust each screw and observe the effect it has by eye. Using these screws (and the steering mirrors upstream, if necessary), make sure the beam is incident on the input aperture of the EOM.
3. Check to see if there is any throughput to the PDA55. If not, there is a large horizontal or vertical tilt in the EOM. You want to shift the downstream end of the EOM until light is transmitted. Try to correct this by eye at first, and then adjust the tilt while watching the oscilloscope. Any little signal is enough; if you can't get any transmission, find a laser expert. Make sure you don't steer the upstream end of the EOM such that the incident light no longer goes through the aperture.
4. Once you have some signal, start with one adjustment screw, and turn it to maximize the signal on the oscilloscope. Repeat this process for the next screws, until you have maximized for all four in turn.
5. Iterate through this process one or two more times, until you no longer need to make changes.
6. Replace the PDA55 with a beam scanner and check the shape of the output. Maximum transmission does not always mean best beam quality; sometimes there can be strange artifacts or distortions. If there are, make small adjustments to the screws to restore good beam quality. Reinsert the PDA55 to make sure you have not lost more than a small percentage of your throughput. The EOM is now aligned.

#### 4.2.9. Aligning the Acousto-Optic Modulator

1. The acousto-optic modulator has a very small aperture, so it is important to make sure the beam is small and collimated. This is best achieved by ensuring there is a waist of 150 microns at the AOM. If used in double pass operation, a ROC = 30cm lens is placed 30 cm after the AOM. The return beam will be sufficiently collimated to pass through the AOM.
2. For initial alignment, make sure no RF power is connected to the AOM. The spot should be roughly aligned using an IR viewer so that it passes straight through the AOM, approximately centered both vertically and horizontally. A power meter should be used to ensure that the transmitted power is within a few percent of the incident power.

3. The RF drive should now be connected. The transmitted beam should now consist of 3-5 spots, one of which is the original spot. An iris should be used to select one of the first order spots (by blocking the other spots) on the transmitted beam – the first order spots are the ones closest to the central (unmoved) spot.
4. A power meter should be used to determine the power in the first order beam. The 4 screws on the AOM base should now be used to maximize the power in this first order spot in an iterative fashion, as detailed in the EOM alignment procedures.
5. Once alignment has been approximately optimized using these screws, the micrometer controlling the x-axis translation of the AOM should be adjusted so that the input beam is as close as possible to the PZT side of the crystal. The acoustic waves in the crystal used to shift the beam frequency are strongest near this side, and the sound wave propagation time is at a minimum, leading to faster response.
6. The 4 screw alignment should now be re-optimized to maximize power in the first order spot. The combination of translation and re-alignment should be repeated until the power is both at a maximum and decreases sharply if the input spot comes closer to the PZT side of the crystal.
7. The power in the first order spot under optimal single pass alignment with maximum RF drive should be approximately 80% of the input power.
8. The return beam is reflected off a ROC = 30cm mirror, 30 cm from the AOM. The return beam is aligned by ensuring it passes through the iris used to select the first order spot.
9. When the return beam passes through the AOM crystal, there should be several output spots (with RF drive connected). To determine which of these spots is the first order spot of the return beam, inject a slow (approximately 1 Hz), high amplitude modulation onto the RF drive. This can be done using the cable connected to the PSL output on the modecleaner servo.
10. With the modulation connected, one of the double pass spots will remain stationary. This is the spot which should be selected. For this spot only, the AOM precisely undoes the angle shift it imparts on the single pass beam. This spot is the first order single pass, first order return pass spot. It is important to use the first order-first order spot rather than the first order-zero order spot, which may initially appear brighter.
11. Once the first order-first order spot has been identified and selected (via use of an iris to block the other return spots), the power should be maximized by adjusting the alignment ROC = 30cm mirror. Once the mirror alignment is at its best, the alignment of the 4 screws in the AOM base can be tweaked (only by a tiny amount) to increase the power in the return spot.
12. Using this method, the power in the return spot should be approximately 60% of the power in the spot initially incident on the AOM (approximately 80% efficient each way).

#### 4.2.10. Turning Off the Laser

1. Look at the Lightwave power supply in rack 1Y1. Set the far right switch to **SHUTTER CLOSE**.
2. Set the next switch to the left to **AMPLIFIER STANDBY**.
3. Set the next switch to the left to **MASTER OSC STANDBY**.
4. Turn the keyswitch on the power supply to **POWER OFF**. All lights should now be off on the power supply.
5. Under the east desk in the control room is the chiller. On the chiller control panel, press the following buttons in this order: **RS232**, then **CLEAR**, then **ON/OFF**. When the last button is pressed, water should stop circulating, all lights should be off, and the digital display should read OFF.
6. On the west wall of the IFO hall, next to the enclosure, is a keyswitch labeled “Laser Control”. Set this switch to **OFF**. The laser is now off and the enclosure interlocks disabled.

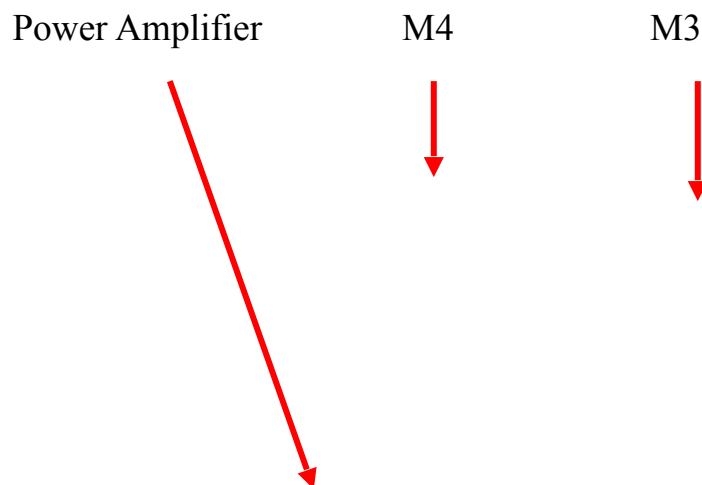
#### 4.2.11. Replacing the NPRO

Note: Replacing the NPRO is a delicate procedure, and once undertaken, the lab will have no laser to work with until it is completed properly. Make sure you thoroughly understand the following instructions before attempting. Refer to <http://www.ligo-wa.caltech.edu/~rick/PSL/4kPSL/Documents/Tune4klaser.PDF> for a more detailed overview of this procedure. Also, always wear face masks when removing the laser cover.

1. Make sure the power to the laser is off; refer to Section 3.2.10.
2. Remove the cover of the laser. A picture of the interior is shown in Figure 3-3. The NPRO is at the bottom of the picture, just left of center. Carefully remove the cable from the back of the NPRO, unbolt it from the table, and remove it.
3. Insert and bolt down the new NPRO, and reattach the rear cable. Don't worry about alignment yet; the bolts allow little room for variance, and the steering will be done downstream.
4. Turn the laser on, but leave the shutter closed.
5. Align the Pockels cell just downstream of the NPRO; refer to Section 3.2.8. There is an added requirement here, however: make sure that the reflected beam spot from the EOM does not go back into the NPRO aperture, or you will induce oscillations in the laser.
6. Open the laser shutter, and set the high-power calorimeter to measure the beam right where it leaves the laser box. Be aware that up to 10W of power will be present between the power amplifier and the laser output. Make sure you know where the high power is and keep your hands clear!
7. Adjust mirrors M1 and M2 (see Figure 3-3) to maximize the power output as read by the calorimeter. Again, you must also make sure that any reflected spots (such as from the lens just after M2) do not reenter the NPRO aperture. Place a block after each element in turn up to the Faraday isolator to identify the source of each reflection.
8. The new NPRO is now installed. For best results, put a BeamScan at the output of the EOM and at the main laser output to check the beam shape, and adjust the EOM or M1/M2 as necessary.

#### 4.2.12. Tuning the Power Amplifier

Note: Tuning the power amplifier is a delicate procedure, and once undertaken, the lab will have no laser to work with until it is completed properly. Make sure you thoroughly understand the following instructions before attempting. Refer to <http://www.ligo-wa.caltech.edu/~rick/PSL/4kPSL/Documents/Tune4klaser.PDF> for a more detailed overview of this procedure. Also, always wear face masks when removing the laser cover.



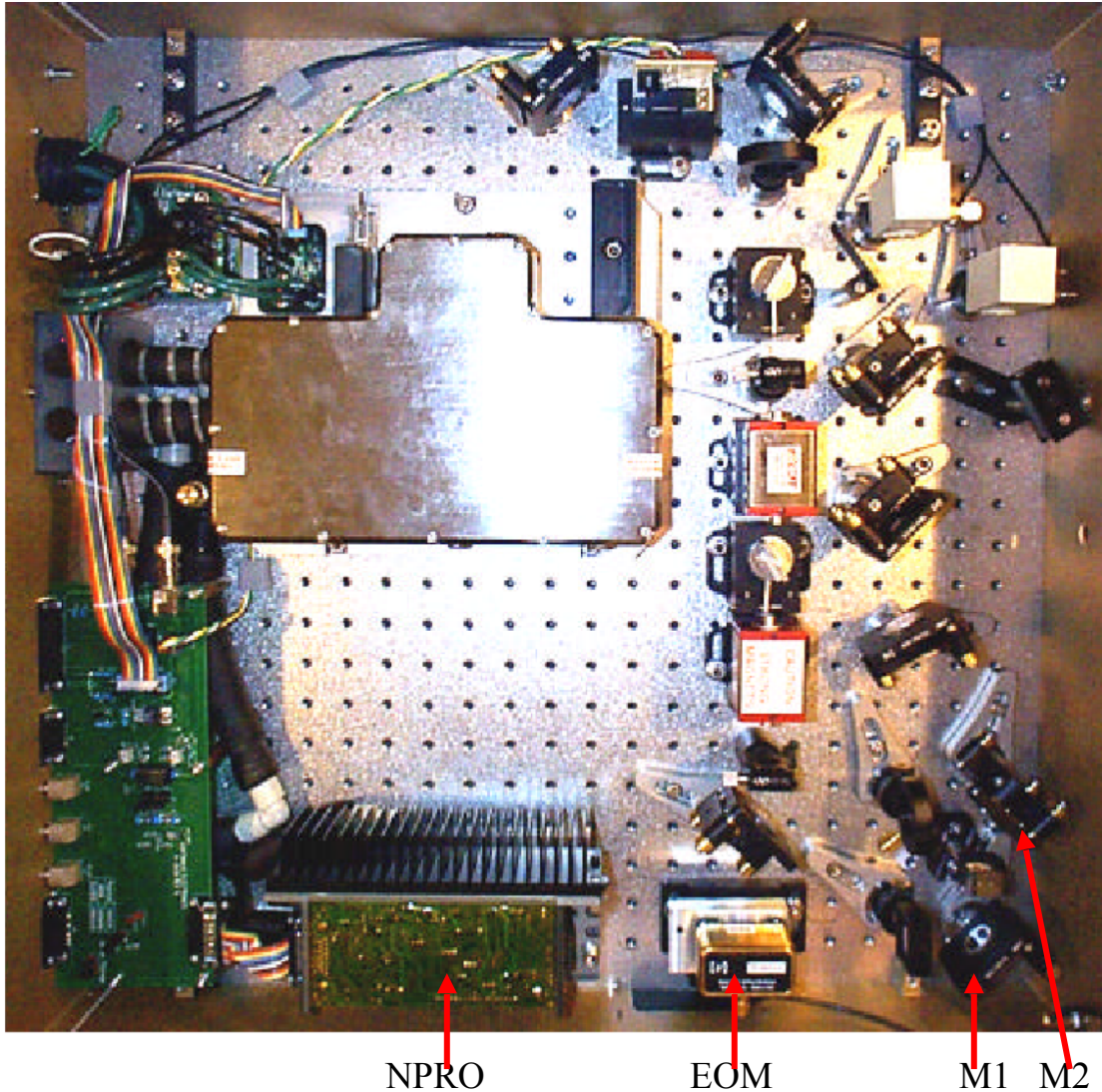


Figure 43: Interior of Lightwave 10W laser

1. Make sure the laser is on and the shutter open. Set the high-power calorimeter at the output of the Lightwave laser box.
2. Remove the cover of the laser. Figure 3-3 shows the interior of the Lightwave box. Be aware that 10W of power is present between the power amplifier and the laser box output, and you will be working close to it. Identify where the high power is, and keep your hands clear!
3. The only optics you need to adjust are mirrors M3 and M4. **Gently** walk these mirrors in first one axis and then the other to maximize the power output at the calorimeter. You may have to iterate from one axis to the other as much as three times. You should be able to get an output of 10-11W. If not, make sure that the output of the NPRO is on the order of 0.5W; if not, the NPRO may be dying. Find a laser expert.
4. With a BeamScan, measure the shape of the output beam. Adjust mirrors M3 and M4 **very slightly** if the beam is not a round TEM<sub>00</sub> mode. You should be able to fix the beam shape without dipping

significantly below 10W. If you cannot, the beam may be misaligned through the Faraday isolator; find a laser expert.

- The power amplifier is now aligned. Replace the cover on the laser.

### 4.3. PSL Electronics

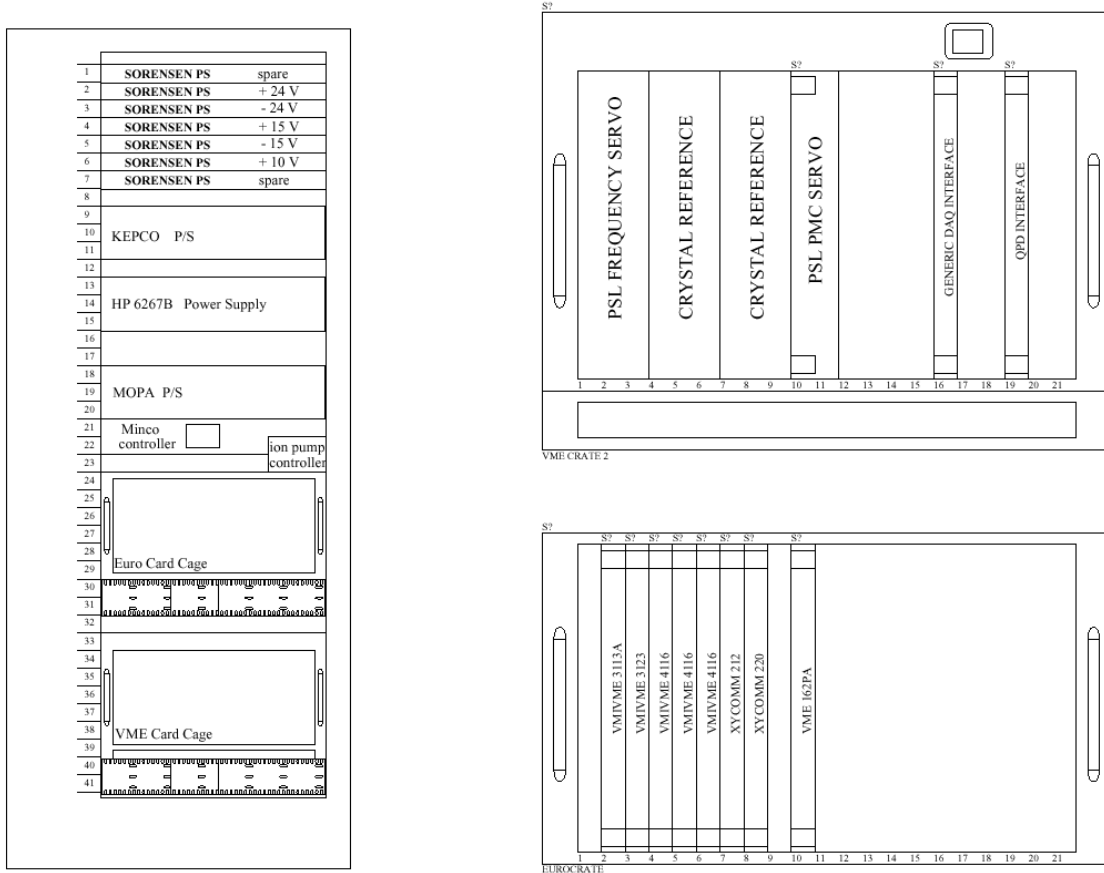


Figure 44: Contents of the PSL rack 1Y1, with details of the VME (top) and Eurocard (bottom) crates

Figure 3-4 shows the contents of the PSL electronics rack, located at the southeast corner of the PSL enclosure. The Kepco power supplies deliver +/- 150V to the EOMs and +300V to the pre-mode cleaner PZT. The HP6267B powers the heating jacket of the reference cavity, while the Minco controller adjusts the power output to maintain a constant temperature. All of the servo electronics are contained in the Eurocard crate, and the interface to EPICS switching and readback is taken care of by the VME crate. The rack wiring schematic can be found in document D980535-B-C.

Figure 3-5 shows the control block diagram for the PSL servos, taken from document D000214-00-C. Other important schematics include the FSS servo (D980536-B), PMC servo (D980352-B), VCO (D980401), and ISS servo (D980399-B, not currently installed at the 40m).

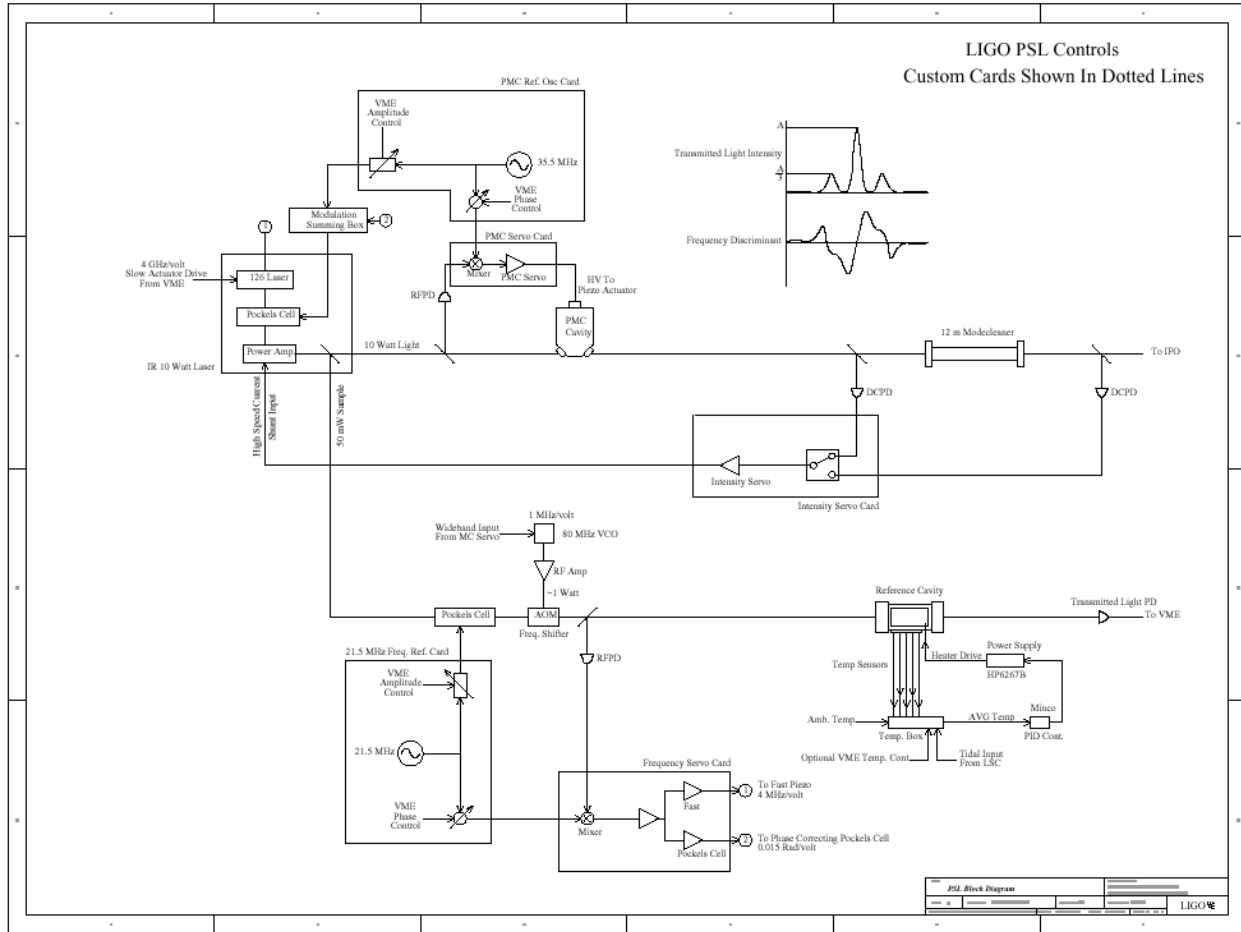


Figure 44: Control block diagram of PSL servos, from document D000214-00-C

## 4.4. PSL Software

### 4.4.1. MEDM Screens

Most of the day-to-day operation of the PSL will be handled from the FSS and PMC servo screens, shown in Figure 3-2a and 3-2b, respectively. These screens can be accessed directly, or can be called up from the main PSL screen at `/cvs/cds/caltech/medm/psl/C1PSL_Main.adl`, shown in Figure 3-5. This screen also provides links to a detailed NPRO overview, the VCO control screen, and the ISS servo screen (which exists despite the servo not currently being installed).

### 4.4.2. EPICS Code

The PSL VME crate is controlled by a single MVME 162 processor designated as `c1psl` (`scipe3`, IP address `131.215.113.53`). All code loaded and executed by this processor can be found on any Martian network machine at `/cvs/cds/caltech/target/c1psl`. The PSL processor loads two databases, one specifically for intensity servo commissioning (`iss.db`) and one for all other PSL fields (`psl.db`). One object file is loaded (`sl.o`) to control FSS slow loop.

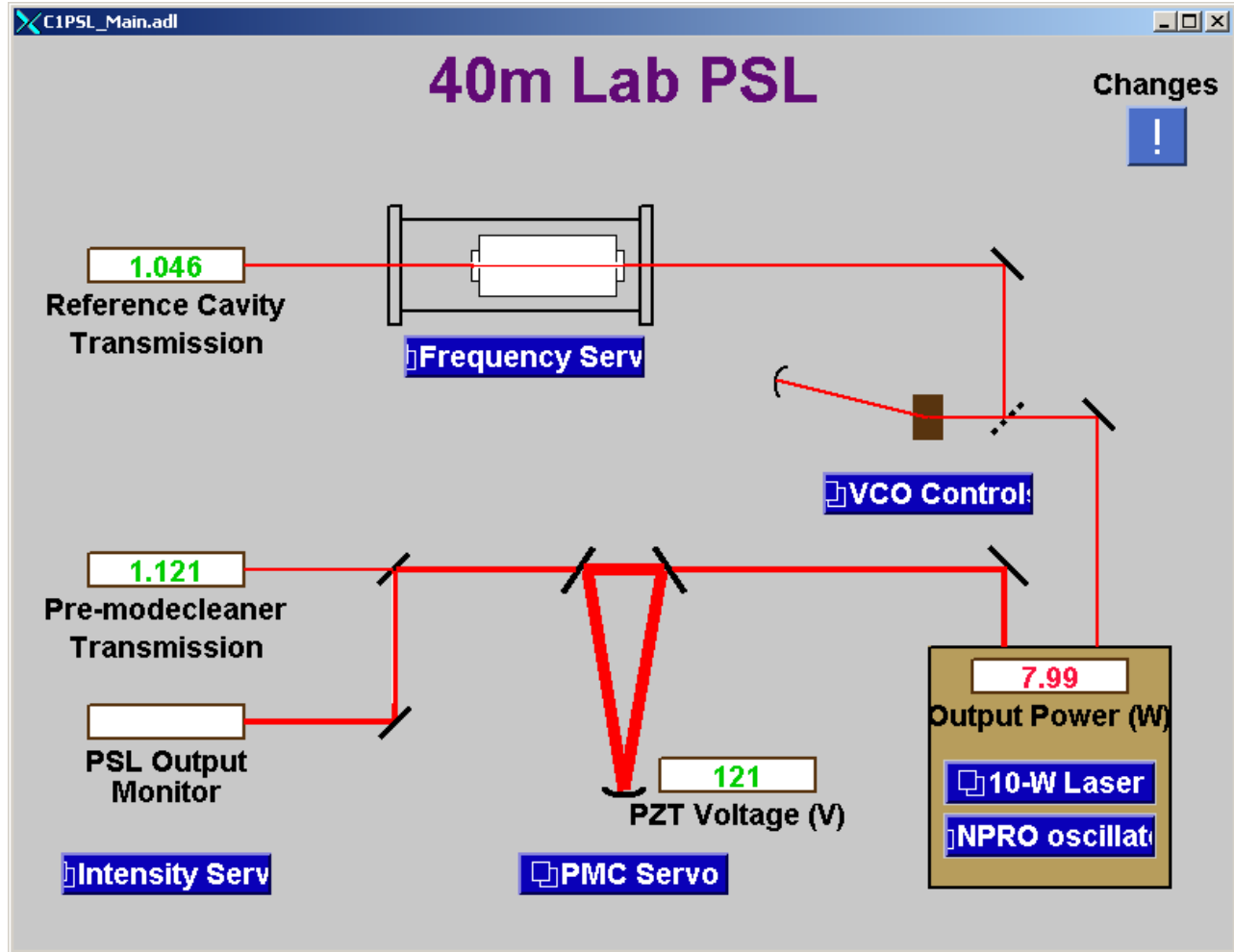


Figure 45: Main PSL MEDM screen

The source code can be found at `/opt/CDS/d/epics/apple/Caltech/40mVac/40mVacScipe/dev/src/sl.st`. Each state has the following functions:

- State “init” checks that all necessary channels are connected to the EPICS database.
- State “check\_sle” makes sure that the slow loop has been enabled on the FSS MEDM screen. The routine will remain in this state until the loop is enabled.
- State “get\_fast” reads in the value of the fast PZT correction signal from the EPICS database.
- State “adjust\_slow” is the heart of the slow loop. It first checks whether the fast PZT signal is more than FASTLIMIT away from zero volts (FASTLIMIT is currently 0.5V; lock is lost when the fast signal is forced to exceed roughly  $\pm 2.5V$ ). If it is, the slow loop slider will be adjusted by an amount SLOWJOG (currently set to 0.02V). If for some reason the slider were being adjusted in the wrong direction, this would be corrected by switching the “<” to “>” in the line “if (fast\_voltage < 0.0) {“.
- State “wait” delays an amount TIMEOUT before repeating the loop (currently 10 seconds). This delay should always be at least three seconds, the relaxation time of the actuator.

#### 4.5. Ongoing System Improvements

- The waist size and position of the output beam from the MOPA wanders over time. This should be checked with a beam scanner every 4-6 months, and the mode-matching adjusted accordingly.
- The LLO PSL picks off the reference cavity beam downstream of the pre-mode cleaner in order to remove frequency noise injected by the PMC (length noise from the PZT, for example). Little improvement has been seen, but with the poorer acoustic and seismic isolation in the 40m PSL, the improvement from such a change may be more noticeable.
- The parameters of the Minco controller need to be adjusted to provide more stable temperature control of the reference cavity.

#### 4.6. Troubleshooting Guide

***I have set the reference cavity to a TEM<sub>00</sub> mode, but when I close the FSS loop the beam spot disappears. Why won't it lock?***

You may be trying to lock to a sideband. Shift the slow adjust slider about 0.03V in either direction and make sure there are no brighter TEM<sub>00</sub> spots. If this is not the problem, then most likely someone has changed the phase or amplitude of the RF modulation; ask a laser expert to check.

***I have set the pre-mode cleaner to a TEM<sub>00</sub> mode, but when I close the PMC loop the beam spot disappears. Why won't it lock?***

Because the PMC servo has such high gain, if there is too much light hitting the reflected RF photodiode than even a small error signal will send the loop shooting well past resonance. Make sure the reflected light reading on the PMC MEDM screen is below 40 and try again. If this is not the problem, then most likely someone has changed the phase or amplitude of the RF modulation; ask a laser expert to check.

***The power output/cavity visibility/mode-matching of the PSL has changed dramatically!***

Shifts in the temperature of the master oscillator can cause a “mode hop” from one resonant longitudinal mode to another, causing significant changes in laser performance. Make sure the slow adjust slider on the FSS servo is within  $\pm 0.5V$  of zero.

## 5. 40m Computer Network

Last updated 7/23/03 by D. Ugolini.

### 5.1. Network Overview

Figure 4-1 shows a block diagram of the 40m computer network. The bulk of the important workstations at the 40m are on a separate “Martian” network for reasons of security. The machines on this network are all on the 113 subnet (i.e., have IP addresses of 131.215.113.xxx), as opposed to the general computing machines, which are on the 115 subnet. Remote access to the Martian network can only be achieved by first logging onto a gateway machine that exists on both the 115 and 113 subnets. This machine is identified as rana on the 115 subnet and rana113 on the 113 subnet.

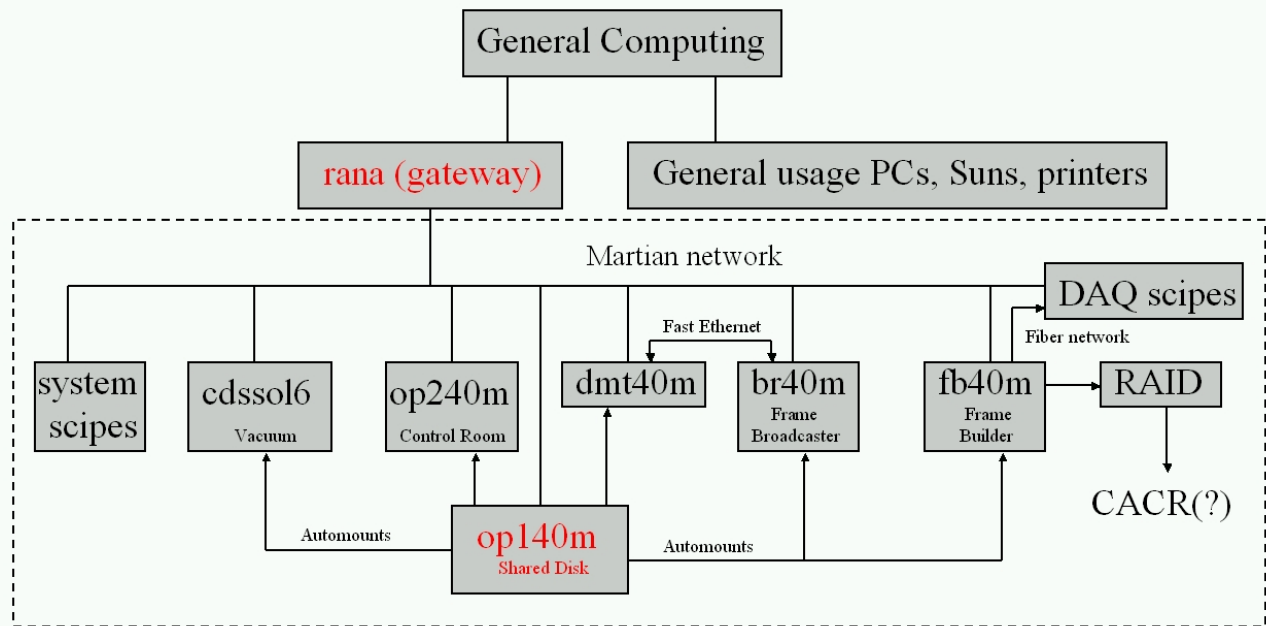


Figure 51: Block diagram of the 40m computer network

There are seven Sun workstations currently on the Martian network:

- op140m and op240m – control room workstation
- dmt140m – control room DMT server
- fb40m – DAQ frame builder
- br40m – DAQ frame broadcaster
- cdssol6 – Vacuum rack workstation

Almost all of the files important to the functioning of the 40m are contained on op140m; the other Martian network machines automount the op140m disk to the directory /cvs/cds. Note that rana also mounts the op140m shared disk but does not have write access, again for security reasons.

Two other types of devices are found on the Martian network: the VME processors and the DAQ RAID array. The VME processors are referred to as “scipes” (EPICS spelled backwards), and are given an IP address of 131.215.113.(50+x), where x is the number of the scipe (i.e., scipe1 is 131.215.113.51). A complete list of the scipes and their identities can be found by listing the file /etc/hosts on any Martian

network machine. When booted, the VME processors remote shell login to op140m to load the operating vxWorks and their startup code; for more information, see the EPICS chapter in this procedures manual.

The RAID (**R**edundant **A**rray of **I**nexpensive **D**isks) is an array of eight 77 GB disks in the DAQ rack (1Y7) that saves all of the frames and trend data twice over, to protect against loss of data in the event of a disk crash. The RAID mounts to the directory /usr1 on any Martian network machine, allowing frames to be copied for analysis.

There are only two usernames in regular use on the Martian network machines. “controls” is used for work relating to EPICS code and databases, MEDM screens, and use of dtt or dataviewer. “cit40m” is used for any modeling or data analysis that should be available to the entire 40m group.

ftp and telnet are disabled on all Martian network machines. All remote logins require ssh, and file transfer may be done through the secure copy command “scp”. Type “man scp” into any Sun workstation for more details.

## 5.2. Index of /cvs/cds Directories

### 5.2.1. /cvs/cds/dvSave – Dataviewer saves

This is the dataviewer save directory. Any postscript files generated from dataviewer will default to this directory, and must be moved to general computing through rana via the “scp” command. Also, if channel assignments are saved in dataviewer, the resulting XML file will go into the /cvs/cds/dvSave/savesets subdirectory.

### 5.2.2. /cvs/cds/caltech/burt – Autoburt snapshots

Every hour snapshot files are automatically generated for each EPICS database, which can be used to restore important settings through the **B**ack-**U**p and **R**estore **T**ool (BURT). The snapshot files can be found at /cvs/cds/caltech/burt/autoburt/snapshots/<year>/<month>/<day>/<time>/\*.snap. The channels saved in each snapshot are determined by the autoBurt.req files located in each EPICS target directory; see Section 4.2.5. The BURT tool is started by typing “burtgoeey” on op140m.

### 5.2.3. /cvs/cds/caltech/chans – DAQ, digital filter settings

Two important types of files are contained in this directory. The first is master.config, which lists every channel saved to frames by the DAQ, their sampling rate, units, gain, and so on. Also included are the test points and excitation channels that are not normally saved to frames. There is a short description of the formatting at the beginning of the file, but only a DAQ expert should modify the contents of master.config.

There are also several files of the form SUS\_<optic>\_COEF or SUS\_<optic>\_INPUT\_COEF. These files list the coefficients for the digital filters applied to each suspension. You will rarely need to text-edit this file. Filters can be modified or added through the Foton tool; look for more detail in the GDS chapter of this procedures manual.

### 5.2.4. /cvs/cds/caltech/medm – MEDM screens

All of the MEDM screens (.adl files) are located in this directory. Eight screens are listed in the main directory:

- C0DAQ\_DETAIL.adl – Main DAQ overview screen
- C1VIDEO.adl – Controls the assignment of camera inputs to control room monitors
- Checklist.adl – Overview of all critical IFO parameters that should be checked daily
- Pcount.adl – Particle counter screen
- PEM.adl – Display for particle counter, weather station (not in use), and other PEM tools

- sitemap.adl – Screen with links to all other 40m MEDM screens, organized by subsystem
- STACIS.adl – STACIS readbacks and fault indicators
- VacMonitor.adl – Vacuum readback screen, with no buttons for system control

There are also six subdirectories for related groups of screens:

- asc – ASC subsystem; currently just QPD screens
- dev – Screens still under development, as well has the LHO versions of imported screens
- ioo – WFS and mode cleaner control screens
- psl – PSL screens; see Chapter 3 for more detail
- sus – All optic suspension screens
- timing – Timing and network readback

The vacuum control screen Vac\_Control.adl is kept in a separate directory for security through obscurity.

### 5.2.5. /cvs/cds/caltech/target – EPICS code

When each VME processor boots, it first loads the vxWorks operating system from op140m, and then looks for its startup code in the directory /cvs/cds/caltech/target/<name of scipe>. The files contained in this directory include:

- startup.cmd – The file that points the VME processor to its databases, driver files, etc. Except for one line (the location of the home directory), this file is identical for all scipes.
- database.load, obj.load, seq.load, seq.exe – Subroutines called by startup.cmd that give the names and locations of all databases and compiled state code to be loaded and executed.
- \*.db – Databases to be used by the scipe.
- \*.o – Compiled state code to be used by the scipe.
- autoBurt.req – This is a list of all database channels to be saved by the Autoburt tool each hour, and is not involved with scipe rebooting.

Note that the source state code is not kept on op140m. All state code is kept on luna, in the directory /opt/CDS/d/epics/apple/Caltech/40mEpics/40mEpics/dev/src. The files can be read or modified by logging into luna as cit40m. In order to compile state code:

- Go to /opt/CDS/d/epics/apple/Caltech/40mEpics/40mEpics/dev/target/mv162/obj.
- Remove any .c, .i, or .o files for the code you wish to compile. Make sure you have a backup!
- Type “source ~barker/epics” to set all of the proper definitions.
- Type “setup epics/release/r3.12.2” to start EPICS.
- Type “make”. All files listed in /opt/CDS/d/epics/apple/Caltech/40mEpics/40mEpics/dev/makefile will be compiled

For more detail, talk to an EPICS expert, or reference the EPICS chapter in this procedures manual.

## 5.3. Ongoing System Improvements

- The Checklist.adl and sitemap.adl MEDM overview screens require updating on a regular basis.

## 5.4. Rebooting the DAQ

When the DAQ controller is rebooted, it disturbs the front end reflective memory loop, kicking the suspensions. To avoid this duringf reboot, the connection of the DAQ controller to the front end reflective memory loop should be temporarily bypassed, then re-instated after reboot.

Bypass the DAQ controller in the RFM loop:

- from a web browser on the martian network, go to <http://131.215.113.90> (this talks to the RFM bypass switch on the top of rack 1Y6).
- Log in as admin , password = password (all lower case).
- c0daqctrl is port 4. Switch the Bypass control from Auto to On.
- Hit Update.

Reboot c0daqctrl:

- Either push the little recessed button on the VME cpu in 1Y7-11-1, or
- telnet c0daqctrl  
vmeBusReset (case sensitive!)  
ctrl-]
- Watch the medm screen /cvs/cds/caltech/medm/timing/C1RFM\_NETWORK\_NEW.adl as the lights turn red, and then, one by one, back to green (hopefully); it takes 2-3 minutes. **Also watch the suspension watchdogs** to make sure there's no unintended disturbance of the suspension controllers.
- The light for fb40m is usually the last to turn green, 16 seconds into the new run. Or... the GDS AWG lights might stay red until you re-enable the c0daqctrl RFM bypass, next.

Undo the daqs controller bypass in the RFM loop:

- from a web browser on the martian network, go to <http://131.215.113.90> (this talks to the RFM bypass switch on the top of rack 1Y6).
- Log in as admin , password = password (all lower case).
- c0daqctrl is port 4. Switch the Bypass control from On to Auto.
- Hit Update.

## 5.5. Troubleshooting Guide

***The DAQ Controller is showing FAULT.***

See “Rebooting the DAQ”, above.

***The DAQ Controller is running fine, but the Framebuilder is showing FAULT.***

Type “ps -ef | grep daqd”. Find the process number for daqd. Type “kill <process number>”. The process will automatically respawn and the framebuilder will restart. If there is no daqd process running, go to the subdirectory /export/home/controls/core3.d and execute “start\_daqd” to begin the process.

***My Sun workstation is hung, and nothing I do has any effect. Should I shut off the power?***

No! To safely reboot a Sun:

- If the system is ok, log in as root (su), and type “init 6”. This is the way to power down gracefully.
- If the system is hung, but you can get in somehow (eg, by telneting in as root), type “sync” and then “reboot”.

- If it's really hung, hold down the Stop key (upper left of keyboard) and press "a" (this will mess up the computer, so it is not recommended under normal circumstances). This will produce an "ok" prompt; type "boot" to restart the machine.

## 5.6. Computer rebooting procedures (DRAFT)

When rebooting a computer on the Reflective Memory Network, it is possible that the Reflective Memory loop will be disturbed in an uncontrolled manner, possibly kicking the suspensions. To ensure that this does not happen, the suspension watchdogs for all suspensions should be placed in the Shutdown mode. On some machines (e.g., the DAQ, see section 4.4) it may be possible to bypass the machine being shutdown, or bypass the DSC in the RFM (see section 4.4 for an example of this procedure). There are several subtleties to bypassing machines, however:

- The DSC RFM bypass (port 5) switches out the vertex controllers, as well as `clsuslinuxpce`—if you want to reboot the end stations, you must be aware of this.
- Several of the machines (including all suspension controllers and `cllsc`) actually load their epics settings upon initialization, and they get these settings via the RFM—thus they must be connected to the RFM to reboot successfully. Also necessary for these machines:
- `clepics` must be running, and happy (that is, its `losepics` task must actually be running). If all epics screens look good, then this task is working—if some buttons that you normally see are missing or blank, check to see that this machine is working before attempting any reboots.
- Bypassing the DSC in the RFM has the same effect, generally, as placing all the optics watchdogs in shutdown mode. Since the latter leaves all RFM connections intact, it should be the preferred method.

Suspension controllers: (Vertex = `clsusvme`; Ends = `cliscec,cliscey`)

Ensure that the optics will not be kicked by shutting down the damping by engaging the Watchdogs (e.g., press the Shutdown button), on **ALL** optics.

Reboot `clsusvme`:

- Turn off power key on crate containing `clsusvme` (1Y4-33-1).
- Count to 30, slooowly. Switch power back on.
- Then instruct `clsusvme` to run its code:
- From any martian computer,  

```
telnet clsusvme
</cvs/cds/caltech/target/clsusvme/startup.cmd
```
- The `vme` cpu will now be too busy to talk to you. Ctrl-] to get out of telnet.
- After a bit, all the lights on the crate should turn green, and the light for `clsusvme` on the C1RFM\_NETWORK epics screen should turn green.

This should also automatically restart the linux cpus which filter the data: `clsuslinuxpc1` (1Y6-XX) and `clsuslinuxpc2` (1Y6-XY) and they should start their work automatically. If not,

```
ssh clsuslinuxpc1
su (password is r..t....)
reboot
```

and it should automatically (via `/etc/rc.local` ??) start up  
`clsuslinuxpc1/startup.cmd`  
`caltech/target/clsuslinuxpc1/los2.o`

`/cvs/cds/caltech/target/`  
which should start `/cvs/cds/`

and the cpu will be very busy.

Restart the end suspension controllers, cliscex (1X4-30-1) and cliscey (1Y9-30-1) the same way, by cycling the power (counting to 30 in between) and then

```
telnet cliscex
</cvs/cds/caltech/target/cliscex/startup.cmd
telnet cliscey
</cvs/cds/caltech/target/cliscey/startup.cmd
```

which should also restart the linux cpu clsuslinuxpce (1Y6-XX). If not, you will have to reboot it manually, as above.

It may also be necessary to restart the EPICS (auxiliary) crate for the suspensions, clsusaux (1Y5-25-1) by cycling the power.

It should come up without the need to telnet in.

#### LSC/ASC

- c1lsc (1X3-2-1) does not startup automatically. If it is rebooted, you must telnet in, then
 

```
</cvs/cds/caltech/target/c1lsc/startup.cmd
sp lsc_start
```
- clasc (1X3-13-1)
- cliovme (1Y2-34-11) must be started manually, via the
 

```
</cvs/cds/caltech/target/ciovme/startup.cmd
```
- claslinux (1Y6-XX) is very touchy. May have a disk problem—with some finesse, it can be coaxed into starting. Sometimes the reset button on the EPICS screen actually works.

#### DAQS/AWG:

- c0daqctrl (1Y7-?-?)
- c0dcu1 (1Y7-?-?)
- c0daqawg (1Y6-?-?)
- c0daqepics (1Y7-?-?)
- c0daqepicss0 ????

#### EPICS cpus:

- clepics (linux PC in 1Y6-XX)
- clauxex (1X4-30-11, which gets rebooted when cycling power on 1X4-30)
- clauxey (1Y9-30-11, which gets rebooted when cycling power on 1Y9-30)
- cliscaux (1X3-24-1)
- claux (1X1-9-1)
- cliool0 (1Y2-34-1)
- clpem1 (1Y6-?-?)
- clpsl (1Y1-?-1)
- clvac1 (1Y8-?-?)
- clvac2 (1Y8-?-?)

Restart using DAQ\_NETWORK screen:

Correct order for cold start (very DRAFT status):

- clepics --make sure this is running
- epics auxiliary crate
- DAQ

At this point (before rebooting the suspension controllers but after epics is running well), you should use the AUTOBURT tool to restore settings.

- Suspension controllers
- Everything else
- Once everything is actually running well, only then engage the suspension damping by switching the watchdogs to **Normal**. If you didn't do the BURT restore before rebooting the suspension controllers, be aware that the BURT restore will switch on the damping immediately—thus you must check the epics screen for each suspension to make sure that **all** the data/monitor values are being read out normally **before** doing the BURT restore.

## 5.7. Shutting Down “Everything”

To shut down all the electronics in a rack (in case, e.g., an electrician needs to work on one):

1. Ensure that the optics will not be kicked. This can be accomplished by either:
  - a) bypassing whatever machines you are shutting down in the Reflective Memory Network (see section 4.6 Rebooting Computer Procedures).
  - b) shutting off the damping on all the suspensions, by clicking the Shutdown button on the watchdogs. This is what you must do if you are going to shut down a rack that contains a Reflective Memory hub.
2. Begin by shutting down the VME crates. Simply turn the key to the “Off” position.
3. Log in to any UNIX or linux boxes in the racks. As root, type “poweroff” to shut them down. Do NOT just press the power button on the front. On the linux PC's you may have to turn off the power switch on the front afterwards, but make sure the machine has been shut down from the command line first.
4. Turn off any DC power supplies. If two supplies are providing power of equal but opposite polarity, they should be switched off at the same time.
5. If shutting down 1Y7, turn off the RAID.
6. Switch off the Reflective Memory hub.

To turn everything back on, reverse the procedure for shutting everything down. The linux and UNIX machines should come back on their own. You will have to telnet into the suspension controllers and other front end machines to get them restarted (read section 4.6 Rebooting Computer Procedures for details).

**Computing at the Caltech LIGO 40 Meter Interferometer Laboratory**

8/20/2002 Lisa Goggin [goggin\\_l@ligo.caltech.edu](mailto:goggin_l@ligo.caltech.edu)

**General Computing**

Fiber link to West Bridge 131.215.115.x

hub 1

hub2

hub3

m16.ligo.caltech.edu	Dell Dim 8200	Win2K	131.215.115.116	contr ol room north	GC	Miyaka wa
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m17.ligo.caltech.edu	Dell Dim 8200	Win2K	131.215.115.117	control room north	GC	
m3.ligo.caltech.edu	Dell Dim 8200	Win2K	131.215.115.103	control room north	GC	Mow-Lowry
m53.ligo.caltech.edu	Dell Dim 8200	Win2K	131.215.115.153	control room north	GC	Goggin
m93.ligo.caltech.edu	Dell Dim 8200	Win2K	131.215.115.193	control room north	GC	Vass
m24.ligo.caltech.edu	Dell Dim 8200	Win2K	131.215.115.124	control room north	GC	Taylor
m18.ligo.caltech.edu	Dell Dim 8200	WinXP	131.215.115.118	control room north	GC	Bhatt
m25.ligo.caltech.edu	Dell Dim 8200	WinXP	131.215.115.125	control room north	GC	Eichenfield
zuben.ligo.caltech.edu	Ultra10	SunOS5.8	131.215.115.77	North annex north	GC	
rana.ligo.caltech.edu	Ultra30	SunOS5.8	131.215.115.56	North annex comp rack	GC	Gateway to 113 net

**Martian Network**

Fiber link to West Bridge			131.215.113.x			
Wireless Access Point Orinoco						
?	Dell Ins 2500 laptop	Win2K	131.215.113.wireless	IFO Hall	EPICS display	
?	Dell Ins 2500 laptop	Win2K	131.215.113.wireless	IFO Hall	EPICS display	
rana113	Ultra30	SunOS5.8	131.215.113.201	North annex comp rack	Control s	Gateway to 115 net

op140m		blade 100	SunOS5.8	131.215.113.211		control room south	Control s	
dmt140m		blade 100	SunOS5.8	131.215.113.204		control room south	Control s	
op240m		blade 100	SunOS5.8	131.215.113.212		control room south	Control s	
cdssl6		sparc10	SunOS5.8	131.215.113.7		IFO 1Y9	EPICS Vac control	
hp140		HP printer		131.215.113.220		control room south	printer	
c1psl scipe3		MVME1 62	VxWorks/ EPICS	131.215.113.53		IFO 1Y1- 32-1 0	op140m:/cvs/cds/ caltech/target	EPICS PSL control
c1iool0	scipe7	MVME1 62	VxWorks/ EPICS	131.215.113.57		IFO 1Y2- 34-1	op140m:/cvs/cds/ caltech/target	EPICS control
c1iovmc	scipe17	VME P3	VxWorks	131.215.113.67		IFO 1Y2- 34-1 1	op140m:/cvs/cds/ caltech/target	IO WFS
c1susvmc	scipe18	VME P3	VxWorks	131.215.113.68		IFO 1Y4- 33-1	op140m:/cvs/cds/ caltech/target	SUS VME
c1susaux	scipe5	MVME1 62	VxWorks/ EPICS	131.215.113.55		IFO 1Y5- 27-1	op140m:/cvs/cds/ caltech/target	EPICS SUS control
c1pem1	scipe1	MVME1 62	VxWorks/ EPICS	131.215.113.51		IFO 1Y6- 13-4	op140m:/cvs/cds/ caltech/target	EPICS PEM control
c0daqawg	scipe28	VME P3	VxWorks	131.215.113.78		IFO 1Y6- 13-1 1	op140m:/cvs/cds/ caltech/target	AWG
c1suslinuxpc1	scipe20	Intel	Linux	131.215.113.70		IFO 1Y6	op140m:/cvs/cds/ caltech/target	SUS PC1
c1suslinuxpc2	scipe23	Intel	Linux	131.215.113.73		IFO 1Y6	op140m:/cvs/cds/ caltech/target	SUS PC2
c1asclinux	scipe25	Intel	Linux	131.215.113.75		IFO 1Y6	op140m:/cvs/cds/ caltech/target	ASC PC
c1suslinuxpce	scipe27	Intel	Linux	131.215.113.77		IFO 1Y6	op140m:/cvs/cds/ caltech/target	ETM PC

c1epics	scipe19	Intel	Linux	131.215.113.69	IFO 1Y6	op140m:/cvs/cds/ caltech/target	LOS EPICS
c0daqctrl	scipe21	VME P3	VxWorks	131.215.113.71	IFO 1Y7- 10-1	op140m:/cvs/cds/ caltech/target	DAQ Control ler
c0daqepics	scipe26	MVME1 62	VxWorks/ EPICS	131.215.113.76	IFO 1Y7- 10-9	op140m:/cvs/cds/ caltech/target	DAQS EDCU
c0dcu1	scipe24	VME P3	VxWorks	131.215.113.74	IFO 1Y7- 10-1 1	op140m:/cvs/cds/ caltech/target	PEM ADCU
br40m		sparc10	SunOS5.8	131.215.113.203	IFO 1Y7- 1		DAQ Frame broadcaster
fb40m		sparc10	SunOS5.8	131.215.113.202	IFO 1Y7- 2		DAQ Frame builder, SCSI RAID array
c1vac1	scipe2	MVME1 62	VxWorks/ EPICS	131.215.113.52	IFO 1Y8- 13-1	op140m:/cvs/cds/ caltech/target	EPICS VAC control
c1vac2	scipe4	MVME1 62	VxWorks/ EPICS	131.215.113.54	IFO 1Y8- 13-3	op140m:/cvs/cds/ caltech/target	EPICS VAC control
cdssol6		sparc10	SunOS5.8	131.215.113.7	IFO 1Y8		VAC workstation
c1iscey	scipe29	VME P3	VxWorks	131.215.113.79	IFO 1Y9- 25-1	op140m:/cvs/cds/ caltech/target	ETMY VME
c1auxey	scipe10	MVME1 62	VxWorks/ EPICS	131.215.113.60	IFO 1Y9- 25-1 1	op140m:/cvs/cds/ caltech/target	EPICS ETMY control
c1aux	scipe11	MVME1 62	VxWorks/ EPICS	131.215.113.61	IFO 1X1- 9-1	op140m:/cvs/cds/ caltech/target	EPICS video, illuminators, EOS
c1lsc	scipe22	MVME1 62	VxWorks/ EPICS	131.215.113.72	IFO 1X3- 24-1	op140m:/cvs/cds/ caltech/target	LSC
c1iscex	scipe30	VME P3	VxWorks	131.215.113.80	IFO 1X4- 25-1	op140m:/cvs/cds/ caltech/target	ETMX VME

c1auxex	scipe9	MVME1 62	VxWorks/ EPICS	131.215.113.59	IFO 1X4- 25-1 1	op140m:/cvs/cds/ caltech/target	EPICS ETMX control
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## **6. Digital Suspension Controls (DSC)**

## **7. Mode Cleaner Controls (IOO)**

## 8. Data Acquisition (DAQ)

### 8.1. Frame Builder

The frame builder is fb40m, a Sun Sparc 10 workstation located in the DAQ rack, 1Y7 (next to br40m, the frame broadcaster, which broadcasts frames to the GDS DMT (Data Monitoring Tool) system. At present (April 2004) we don't run DMT, but that's what dmt240m, a Sun Enterprise 450, is for.

Through some magic that I don't know about, whenever fb40m is rebooted, it automatically starts the frame builder, `/export/home/controls/core3.d/daqd`. This program reads a configuration file `/export/home/controls/core3.d/daqdrc.full` to find out where to store frames and with what frequency, and keeps logs of every time it is restarted.

The file `daqdrc.full` instructs `daqd` to put frames in `/export/home/controls/core3.d/data/frames` which is soft-linked to `/usr1/frames`. It also keeps (second) trend frames and minute trend frames. To summarize:

- `/usr1/frames` contains 48 directories (`/usr1/frames/DataNN`), each containing one hour of full frame files, for a total of 2 days of full frame files. Each frame file is 16 seconds of data, so there are  $60*60/16 = 225$  files per directory. Each frame file contains all of the data channels specified in `master.config` (see below).
- `/usr1/trend-frames` contains 30 directories (`/usr1/trend-frames/Data0` through `Data 29`), each containing one day of second-trend frame files, for a total of 30 days of second trends. Each file contains exactly one minute (60 seconds) of data, so there are  $24*60 = 1440$  files per directory. Each trend file contains second trends (mean, min, max over one second) for all of the data channels specified in `master.config` (see below).
- `/usr1/minute-trend-frames` contains 11 directories (`/usr1/minute-trend-frames/Data0` through `Data9`), each containing one year (actually, 360 days) of minute-trend frame files, for a total of 11 years of minute trends. Each file contains exactly one hour of data, so there are  $360*24 = 8640$  files per directory. Each minute trend file contains minute trends (mean, min, max over one minute) for all of the data channels specified in `master.config` (see below).
- Also in `/usr1/minute-trend-frames` is the directory `conv1` which contains files, one for each data channels specified in `master.config`, with minute trend data for that channel (ie, it is the other "striping" of the data).

The frame builder reads `/cvs/cds/caltech/chans/master.config` to determine which front-end and/or EPICS channels it will log to frames. Field #8 of that list is equal to 1 if that channel is to be logged to full and trend frames. If that field is 4, the corresponding channel will be available in `dataviewer` and `dtc`, but is not written to frames for storage.

## **9. Physics Environment Monitoring (PEM)**

## 10. EPICS State Code

How to compile and load EPICS state code:

For example, c1vac1 and c1vac2:

Login into **luna**

The source code for the object files can be found at

```
cd /opt/CDS/d/epics/apple/Caltech/40mVac/40mVacScipe /dev/src.
```

Modify code.

To compile:

```
cd ../target
```

```
cd mv162/obj
```

```
source ~barker/.cshrc
```

```
setup epics/release/r3.12.2
```

```
make
```

if successful, copy it to /cvs/cds/caltech/target/c1vac1 (or whatever)

(log on to rana, scp from luna to rana:export/home/controls ; eg,

```
cd /export/home/controls
```

```
scp cit40m@luna: /opt/CDS/d/epics/apple/Caltech/40mVac/40mVacScipe /dev/  
target/mv162/obj/VacInterlock.o .
```

then on op140m:

```
scp cit40m@rana113:/export/home/controls/ VacInterlock.o .
```

Reboot c1vac1 by pushing reset button on vme module (but see section 4 for cautions before doing that!)

## **11. MEDM**

## 12. Dataviewer

Close dataviewer when you are done using it; otherwise, it takes up resources that can slow down that computer.

To close dataviewer, choose “Exit” from the File menu of the main screen. Then, hit Return in the yellow message screen.

If you kill dataviewer in anything but the approved way (eg, with “kill -9 <pid>”), it will leave behind connections that will make it difficult or impossible to start dataviewer again on that computer.

To see what connections exist, and kill them so that dataviewer can be restarted, say: “ipcs -q” to list the connections; note the number, and then say “ipcrm -q <number>”

## 13. DTT

## 14. Autoburt

BURT = Backup and Restore facility built into EPICS. Can save any/all EPICS database values, on a regular basis. We endeavor to save ALL values, read-backs as well as settings.

Snapshots: sub-directories of /cvs/cds/caltech/burt/autoburt/snapshots have hourly snapshot files

Each target in /cvs/cds/caltech/target has an autoBurt.req file (generated automatically from the \*.db files by a script that Rolf has).

/cvs/cds/caltech/burt/autoburt/burt.cron appears to do the job of running autoburt on a timer, but I don't know how or where this is run at the 40m. It will search through /cvs/cds/caltech/target/\*/autoBurt.req files, build a .requestlist file, and burt all of it.

Many target directories have a saverestore.req file, and you can see in the startup.cmd that they load saverestore object files. I think this means they will load the latest saverestore.sav file upon reboot; but I don't know how those saverestore.sav files get created; does it have anything to do with autoburt?