NICI
Adaptive Optics System
User Manual

Revision 0.38 beta
September 2004

This version of the User Manual is still a working, pre-release version.
Expect changes and additions, especially during commissioning.

ABSTRACT: This document provides a system level overview of the NICI Adaptive Optics system. It aims to provide usage procedures, a functional description of the system and its major components, and indicate service and calibration procedures.

Revision History

Revision #:	Author	Description	Date
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1 Introduction

This is the User Manual for the adaptive optics system for the NICI instrument. This manual provides an overview of the instrument, optical layout, descriptions of the major components, instructions for setting up the NICI AO components for observing, a list of software commands, and basic troubleshooting. Section 3 is intended for observers while sections 4-8 are directed toward the technical staff.

Section 1.2 provides a general overview of the system, the AO Electronics, and of the NICI AO software.

Section 2 discusses how to setup NICI’s AOS for observations. Observers should read this section.

Section 3 provides detailed functional descriptions of NICI's AO subsystems. This section is relevant for engineers, operators, and technicians wishing to understand the low-level implementation details of NICI's AO optics, electronics, software, mechanisms, and system cabling.

Section 4 describes maintenance, service, and basic troubleshooting of the instrument.

Section 5 discusses safety issues with NICI. Everybody working with NICI should read this section.

Section 6 provides a list of definitions and acronyms for terms used throughout this document.

Section 7 provides a summary of the list of AO commands available through the NICIui socket.

1.1 Basic definitions and terms

NICI is a based on a wavefront sensing technique called curvature sensing (Roddier reference). The basic approach is that the normalized difference in intensities between two extra-focal images is related to the second spatial derivative of the wavefront. We define as our wavefront sensor signal the normalized difference of these extra focal images:

$$\text{WFS Signal} = (I_A - I_B) / (I_A + I_B) = AC / DC$$

The two intensities (**I_A,I_B**) refer to the intensities in the corresponding subapertures of the wavefront sensor in each extra-focal image, the **AC** term is the difference, and the **DC** term is the sum of the intensities. Each subaperture generates a single WFS Signal at a rate set by the frequency of the system’s Membrane mirror (MM).

An adaptive mirror that introduces curvature to the surface of the mirror makes the system’s corrections. The control signals for the deformable mirror (DM) are generated from the WFS signals via a **control matrix** and a **control servo**. The difference between where the deformable mirror currently is and where the WFS wants it is the DM error signal. The DM error signal is derived directly from the WFS signals via a matrix multiplication by the control matrix. Given that the system is often working in the faint guide star limit, NICI allows the option of averaging intensities over several wavefront samples before generating a DM error signal. The signals that drive the deformable mirror are the integration of all past DM error signals. Specifically, a control servo takes into account the current position of all the mirror’s actuators as well as a term consisting of a gain (0-1) multiplied by the calculated DM error signal. This algorithm is referred to as the primary control loop. There are control loops for the deformable mirror (primary loop), for off-loading tip/tilt to two tip/tilt actuators (TT loop), and for off-loading the tip/tilt actuators to the telescope pointing. The DM updates are made at a rate equal to the MM frequency divided by the number of averaged samples.

1.2 NICI AO component overview

NICI is an 85-element curvature adaptive optics system. The major functional components of NICI are an 85-element curvature wavefront sensor (WFS), a curvature deformable mirror (DM), Real-Time (RT) Linux server, User Interface (UI) server, and custom electronics. All of the control and status of NICI is graphically available to the user through the X-Windows User Interface (XUI).

NICI's AOS components consist of 6 components. These assemblies are the deformable mirror (DM), the lenslet array (LLA), the membrane mirror (MM), and the thermal electronics enclosure (Ebox), the Avalanche photo-diode (APD) Enclosure, and the control software. The Thermal Electronics Enclosure contains the electronics for NICI's AO components. The APD Enclosure houses the 85 Avalanche Photodiodes (APDs) and 5 spare APDs. The system's wavefront sensor's lenslet array is also an integral part of the APD enclosure. Its fiber optic cables are routed through the APD Enclosure.

1.2.1 Electronics Overview

The major electronics parts of the system are the RT Server, a High-Voltage Amplifier (HVA) Chassis, a Counter Chassis, a tip/tilt platform actuator controller, a terminal server (DIGI Portserver), and a pair of remote power control devices. All of these subsystems reside in the electronics thermal enclosure. The components that interface directly with the electronics are the WFS's APDs, the Membrane Mirror (MM), Deformable Mirror (DM), the DM tip/tilt platform, and Field Steering Mirror (FSM).

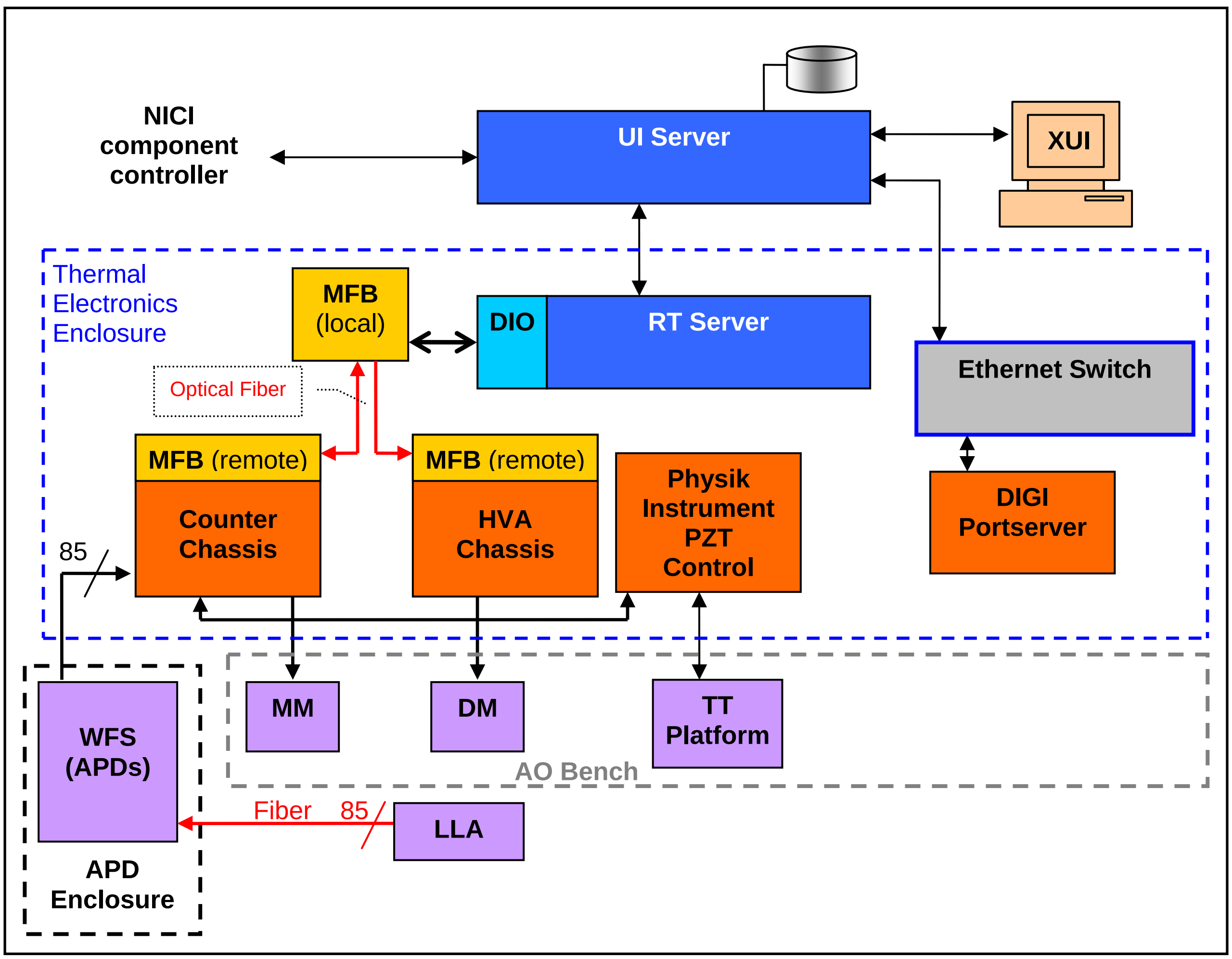


Figure 1 NICI System Block Diagram

The basic flow through the electrical system is as follows. First, photons passed by the LLA are converted into TTL pulses by the APD modules. These pulses flow through 85 BNC cables from the APD enclosure to the Counter Chassis. Here the pulses are integrated and sent to the RT Server via a fiber optic cable. The RT computer calculates the wavefront errors and the DM and TT platform control signals. These signals are sent to the High-Voltage Amplifier Chassis (HVA) via another fiber optic cable. The HVA chassis converts the signals into high-voltage signals to drive the DM and TT platform. Auxiliary controls (such as mechanism controls) are done via the User Interface and a terminal server.

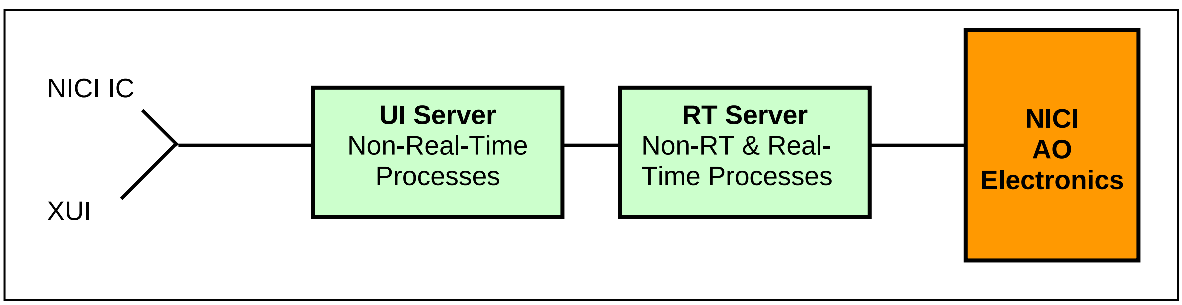
1.2.2 Software Overview

All NICI software runs on either the real-time server (NICIrt) or the user interface server (NICIui). The real-time processes (servo loop and the digital I/O) run on an RTLinux dual-Athlon computer (NICIrt). All other tasks are considered non-real time. The non-RT processes include the User Interface, mechanism control, target acquisition, data telemetry, and communicating to the telescope control system. These non real-time processes run under the Linux user-space on the RT Server or on a separate Linux OS computer (UI Server).

Communication between servers is via sockets and RPC. Processes running in the same server communicate via shared memory. In general the user will only interact with the system via non-RT processes running on the UI Server machine. Specifically, an X-Windows User Interface (XUI) provides control for all AO system parameters, real-time (correction) functions, system setup, system control, mechanisms, diagnostics, and feedback of system status. The XUI is described in detail in Section 2.

For more information on the RT and UI servers, and their operating systems, see Section 3.1.1 Servers Description.

Communication with the NICI instrument controller is done via a socket interface to the NICIui machine.



2 Setting up the NICI AO components for observing

This section describes how to interact with the AO components of the NICI AO system. This information is meant to convey what observers need to know and do for observations.

2.1 Overview

The basic observing startup procedure includes bringing up the NICI, loading the default parameters, then acquiring the guide star. These steps are summarized below:

- Startup processes on NICIrt and NICIui using startup scripts
- Initialize the system (if starting from reboot or power off)
  - Initialize mechanisms
  - Send default parameters to system
- Acquire guide star

- Position WFS filter wheel, position FSM to on-axis point, point telescope at guide star
- Set extra-focal distance and DM update frequency
- Offset with dithering tool
- Observe

During observations, the only parameters that are changed are the control servo gains (pr.gain, tt.gain), the membrane mirror stroke/extra-focal distance and frequency, and the DM loop update rate. These are all controlled graphically through the NICI XUI or through the NICI command line. System diagnostics are displayed graphically on the XUI.

The normal shutdown procedure for the end of a night of observing is as follows:

- Open all loops (put loop into Idle state
- Move the WFS Filter wheel to Opaque
- Shutdown the APD, then HVA power supplies
- Run the shutdown.m macro
- If the entire system is being powered down, then you also run the shutdown scripts from NICIrt and NICIui.

2.2 AO Software and User Interface (XUI)

This section describes the basic interface to the AO software. Greater detail on the User Interface (and especially on engineering and calibration functions of the user interface) can be found in Section **Error! Reference source not found.**. The XUI provides a graphical interface to NICI AOS and permits control over all AO functions, configuration parameters, and AO correction.

The XUI has 5 sub-windows, or tabs. They are the Operator (Opr), View, Macro, Imat, and Engineering (Eng) Tabs. The Operator, View, and Macro tabs are commonly used by observers and are briefly described in this section. Further detail on these screens and on the calibration and engineering uses of the XUI are described in Sections 0 and 3.3.6. A particular tab selected as the current XUI display by clicking on the corresponding tab near the bottom of the XUI window.

Note that there are known bugs in the XUI software. These are discussed in section 3.3.7 below.

2.2.1 XUI Operator Tab

The XUI's Operator Tab is the primary window for control and monitoring of the AO servo loop and mechanisms. It also provides APD Enclosure temperature monitoring and power control over the components of NICI. The Operator Tab is divided into 3 parts:

- System Status
- Loop and Servo Control
- Mechanism Status and Control

These 3 parts are explained in the sections below. The Messages window and Command Prompt are displayed with all tabs and are described in the introduction of Section 2.2 above.

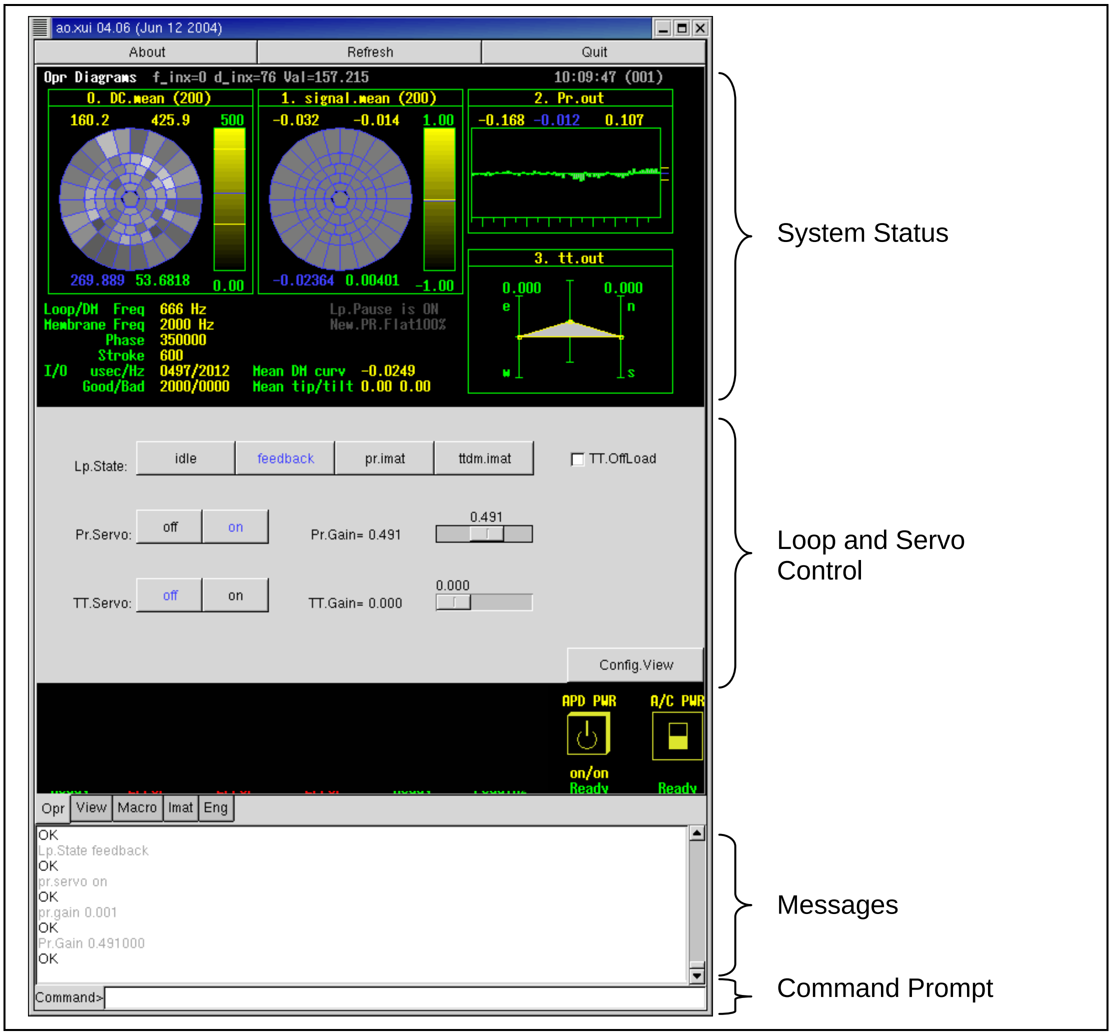


Figure 2 XUI Operator Tab

2.2.1.1 XUI Operator Tab: Command Prompt

The XUI command prompt interface provides a simple and fast interface to the NICI system. Any legal system command can be typed into the command prompt. The usual syntax is ‘command_name parameter’. Command names usual follow a ‘X.Y’ naming convention. For example, the primary loop gain command name is (pr.gain). Command names are not case sensitive. As a convention, the XUI parameter displays are labeled with their command name. For example, in the XUI operator tab window, the primary loop gain is labeled ‘pr.gain’.

2.2.1.2 XUI Operator Tab: System Status and basic controls

The System Status portion of the XUI's Operator Tab provides a summary of system status.

Above the DC.mean and signal.mean displays there are three helpful displays that react to mouse placement over the DC.mean and signal.mean diagrams. First is **f_inx**, which indicates which of the diagrams is being displayed, 0 for DC.mean and 1 for signal mean. **d_inx** indicates which actuator or sensor the mouse is hovering over. **val** indicates the value at the actuator or sensor which the mouse is hovering over. Note that the values are displayed when the mouse enters a region but the value is not updated continuously if the mouse is left in the region.

2.2.1.3 XUI Operator Tab: Loop and Servo Control
This part of the XUI Operator Tab controls the loop state, primary servo and flats, and tip/tilt servo. Note that there are several conditions for corrections to be calculated and sent to the DM, Lp.State must be set to feedback, the Pr.Servo must be set to pr, and Pr.Gain must be set to a non-zero value. The equation that represents voltage corrections sent to the DM is like this:

$$V_{actuator}(t) = V_{actuator}(t - 1) + Pr.Gain * Error_{actuator}$$

Pr.Gain is the gain set in the Pr.Gain slide in the Operator Tab and Error is the correction to the DM calculated by the software. Alternatively the user can type the ‘pr.gain value’ command into the XUI command prompt line.

The Lp.State buttons control the state of the loop thread. When loop state is **idle** the AOS does not calculate corrections for the DM. Only WFS counts are read and displayed. When the loop state is in **feedback** calculation of the error signal (corrections to the DM) is enabled. This button must be selected for AO correction to take place.

The **Pr.Servo** button enables the DM control servo. The control servo (loop) is **off** then new corrections to the DM are not being calculated.

If the DM loop in enabled, then the control servo gain is taken from the **Pr.Gain** system parameter. This parameter can be changed using the slider or by typing “pr.gain value” into the AO command line. Nominal values are 0.3 - 0.5. Pr.Gain must be set to a non-zero value for correction voltages to be sent to the DM. Similarly, the Tip/tilt actuator control servo is controlled by the **TT.Servo** button and the **TT.Gain** parameter.

2.2.1.4 XUI Operator Tab: Mechanism Status and Control
This part of the XUI Operator Tab provides the status and control of power and APD temperature status. In most cases, clicking an icon will open a popup menu to change the state of the mechanism or control the power to NICI's hardware components.

2.2.2 XUI Macro Tab
A number of macros are provided for setting up the system. These can be accessed through the XUI Macro Tab. Macros are stored in text files that contain NICI commands with comment lines beginning with the '#' character. The Macro List window contains a list of the macro files found in the directory specified by the Path. To set the path, click the **(set) Path** button and navigate to the desired directory in the popup. The selected macro's contents are display in the window on the right. Selecting a macro and clicking the Execute button execute the macro.

The instrument is delivered with a basic set of macros listed below.

- **init.m**: An initialization macro to be run when starting the AO system.
- **shutdown.m**: A shutdown macro to be run when stopping the AO system.
- **zeroflat.m**: All flats are set to 0.

2.2.3 Known XUI Issues and Resolutions
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- There are known bugs in the software. Please refer to section 3.3.7.

2.3 AO Setup Procedure
This section defines NICI startup procedures for a warm startup and cold startup procedures for bringing up the system electronics and software. These procedures are defined below.

2.3.1 AO System Warm Startup Procedure

The Warm Startup Procedure is used to startup the instrument after a nightly shutdown. That means the High Voltage Power Supplies and APD Power Supplies have been powered down. The XUI may or may not have been shut down.

1. If the XUI has been shut down and the ui stop and rt stop commands were executed for the nightly shutdown, follow the XUI Startup procedure in Section 2.3.3. If only the GUI for the XUI was closed, just launch the XUI.
2. In the XUI Operator Tab click the A/C PWR icon.
3. In the A/C Power popup window verify that the Digiport, NICIrt, PI Box, HVA Chassis, CNTR Chassis, Newport Controller, and Animatics PS are powered on. Power on any of these units that are not powered on.
4. The following steps may be delayed until just prior to observation. The APD Temperature must be monitored at all times when the APDs are powered on.
5. In the A/C Power popup window turn on the HV Power Supplies.
6. Close the A/C Power popup by clicking the Hide button.
7. In the XUI Operator Tab click the APD PWR icon. In the popup window turn on the APD Power.
8. Close the APD Power popup window by clicking the Hide button.
9. Select the Macro Tab in the XUI window.
10. Highlight the init.m macro and click the Execute button.

2.3.2 AO System Cold Startup Procedure

The cold startup procedure should be followed after the instrument has been completely shut down and powered off, or any time the RT Server is reset or powered off. Most of the point here is to execute the rt cold procedure before powering on the HVA and Counter Chassis in order to set the handshaking protocol on the Adlink DIO board for proper communication to the rest of the system.

1. Ensure that all cables are properly connected. (See Section 3.1.6.)
2. On the thermal enclosure access panel, switch the MAINS and UPS power switches on.
3. Power on the UI Server.
4. Log in to the UI Server.
5. Telnet to NICIbaytech Remote Power Control and power on port 2 (RT Server). See Section 3.1.4.3 for user name and password. Type "Help" for a list of Baytech commands.
6. Wait for the RT server to come up. You may monitor the RT Server by pinging from the UI Server or another remote computer until responses are detected.
7. Log in to the RT Server.
8. Change directory to the /home/NICI/ao/scripts directory. Execute the "./rt cold" command.
9. On NICIbaytech power on ports 1 (Digiport), 4 (PI Box), 5 (HVA Chassis), and 7 (Counter Chassis). See Section 3.1.4.3 for user name and passwords. It is recommended to power on the Counter Chassis before the HVA Chassis.
10. Logout of NICIbaytech and telnet to NICIbaytech2. Power on ports 2 (APD Temp Sensor), See Section 3.1.4.3 for user name and passwords. DO NOT POWER ON PORTS 5 OR 6!!
11. Follow the XUI Startup procedure in Section 2.3.3.
12. The following steps may be delayed until just prior to observation as the APD temperature must be monitored at all times when the APDs are powered on.
13. Click the A/C PWR icon in the XUI Operator Tab.
14. In the A/C Power popup window turn on the HV Power Supplies.
15. Close the A/C Power popup by clicking the Hide button.
16. In the XUI Operator Tab click the APD PWR icon. In the popup window turn on the APD Power.
17. Close the APD Power popup window by clicking the Hide button.
18. Select the Macro Tab in the XUI window.
19. Highlight the init.m macro and click the Execute button.
20. Monitor the APD Temperature in the XUI Operator Tab as long as the APDs are powered on.

2.3.3 AO S/W Startup

To start the AO software, first open two separate windows (x-terms) and log on to the UI (NICIui) and RT (NICIrt) servers (login: NICI, passwd: ao_NICI). Typing xterm_ao on NICIui pulls up two xterm windows appropriately sized with one logging into NICIrt. These are useful for issuing the initialization scripts. If the RT server has been shut down or rebooted, the cold start command must first be issued. From the RT window run the RT initialization script with the start option. Then from the UI window run the UI initialization script with the start option. The paths and script execution for both scripts are shown below. The order is important.

nicirt: /home/nici/nici/ao/scripts/rt cold (Only for cold starts.)
nicirt: /home/ nici/nici/ao/scripts/rt start
niciui: /home/ nici/nici/ao/scripts/ui start

The UI script will start the socket threads, periodic task threads, and launch the XUI. Once these scripts have been run it is possible to launch additional instances of the XUI by executing the XUI script on the UI server as shown below.

niciui: /home/ nici/nici/ao/xui &

If you are the first to bring up the XUI window (e.g. you ran the ui start command), then you must run the initialization macro (init.m) at this point. Switch to the XUI Macro Tab, select the initialization script, *init.m*, and click execute. The XUI is now ready to control and monitor the AO system.

To close any instance of the XUI the user just clicks the Quit button in the top right corner of the XUI window. This will simply close the current XUI window (there can be multiple instances) but does not stop the AO system. Note that running the ui stop command kills all running XUI processes.

2.4 Starting the AO observations

CAUTION: The WFS Filter Wheel must be set to an appropriate filter for the brightness of the guide star to be used for an observation. It is critical that the WFS Filter Wheel be set to opaque when beginning this procedure.

When you are ready to expose the LLA to photons, proceed by moving from the strongest attenuating filter to weaker. Monitor the maximum APD photon count in the XUI Operator or View Tab. If more photon counts are necessary to reach the optimal count level, proceed to the next filter. Monitor the maximum APD photon count in the XUI Operator or View Tab. **Do not exceed 1000 photon counts/cycle**. Continue stepping one filter at a time until an appropriate photon count is achieved. The optimal photon count is approximately 500 photon counts/cycle.

Table of Guide Star Brightness vs. WFS Filters

WFS Filter Slot	Filter	Filter Throughput	Δm	m_{gs}
0				
1				
2				
3				
4				

Generally the observing procedure simply involves following the setup procedure defined in Section 2.3 and then assuring that the system setup parameters are set to their default values. The default system setup parameters are defined in the table below. Once the electronics and software are running, the following procedure should be done (nightly).

1. Turn on the DM high-voltage amplifiers
2. Put the WFS filter wheel into Opaque and turn on the APDs.
3. Put the internal source into the IN position.
4. Move the WFS filter wheel to the position for the internal source.
5. Close the DM loop.
6. Set the pr.imat.cycles to 5
7. Run a pr.imat calibration, save the imat, and analysis the imat using IDL/imatalign.pro
8. If the imat has changed appreciably, run a set of imats
9. Close the loop (possibly on new imat inverse if its changed significantly) and take a new system flat.

   You are now ready to slew to the first target.

10. Open the loop, put the WFS filter wheel to opaque, and move the internal source to the OUT position.
11. On the target, start P2/P1 guiding at 10Hz (not 200Hz) and put the guide star at the hot spot in Abu.
12. Offset the telescope/NICI to target (if off-axis) and beginning observing sequence.

During the observations there are very few parameters to adjust. As mentioned above, the photon flux on the LLA should not exceed its maximum threshold. For very faint stars, the wavefront sensor signals can be averaged over several samples. This improves the SNR for the measurement. The number of cycles to average over is set by the command lp.dm_coadds. The loop gain is automated so it does not need to be changed. The membrane mirror frequency and phase are fixed parameters and should normally not be changed from the default values. The MM stroke can be changed but in general this parameter can be set conservatively with no appreciable loss in delivered performance.

Commands to change the above parameters can be issued in the command prompt of the XUI. Generally the label on the parameters that are displayed in the XUI correspond to a command that can be used to set the parameter. The following commands will cover most of the needs for an observer.

- **freq N**: Sets the frequency of the MM in Hz where N = [0, 2000]. In use the nominal range is N = [1000, 2000].
- **stroke N**: Sets the stroke of the MM where N = [0, 5000].
- **lp.dm_coadds N**: Sets the number of co-adds to accumulate before updating the DM where N = [1, 10].
- **pr**.gain: Manually sets the loop gain of the DM control servo.

Occasionally new IMATs may be generated prior to an observation run. Generally this won't be necessary. If new IMATs are desired, allow at least 3 to 4 hours of daytime work for this task and follow the procedure defined in Section 4.1.1.

Very rarely an allignment may be necessary prior to startup. In this case please refer to the NICI Optical Allignment Document and follow the procedure defined therein. Otherwise it is assumed that the instrument has been properly been installed on the telescope.

Default System Setup Parameters	
Membrane Mirror	
Frequency	2000 Hz
Stroke	2000 DN
Extra-focal distance	~0.35 meters
Control Servo Loop	
WFS co-adds	3

DM Update rate	666 Hz
DM gain	0.6
TT gain	0.001

Figure 3 Table of Default System Setup Parameters

2.5 AO Shutdown Procedure

This section defines NICI shutdown procedures for end of night and end of run shutdown.

2.5.1 End of Night Shutdown Procedure

The end of night shutdown procedure is intended to be used in the middle of an observation run at the end of the night. Most equipment is left powered on. It is, however, crucial to power down the APDs and the High Voltage Power Supplies for the DM.

1. Put the WFS filter wheel into the opaque position.
2. In the XUI Operator Tab click the APD PWR icon. In the popup window power down the APD Power Supplies.
3. Close the APD Power popup window by clicking the Hide button.
4. In the XUI Operator Tab click the A/C PWR icon. In the popup window power down the HV Power Supplies by clicking the off button.
5. The preceding steps are all that is really necessary for end of night shutdown. Users may like to continue with the following steps to close the XUI and stop the UI and RT processes. If so, follow the procedure defined in Section 2.3.3 for XUI Shutdown.

2.5.2 End of Run Shutdown Procedure

At the end of an observing run, telescope personnel may like to completely shut down the instrument. This section defines the procedure for shutting down and powering down all of NICI.

1. Follow the end of night shutdown procedure defined in Section 2.5.1.
2. Follow the XUI shutdown procedure defined in Section 2.5.3.
3. Telnet to NICIbaytech. See Section 3.1.4.3 for user name and passwords. Type "Help" for a list of Baytech commands.
4. Power off ports 4 (PI Box), 5 (HVA Chassis), and 7 (Counter Chassis).
5. Login to the RT Server as root. The root password should be labeled on the RT Server in the thermal enclosure.
6. As root execute the "shutdown -h now" command on the RT Server.
7. Wait for the RT Server to complete the shutdown sequence. Usually this takes about 60 seconds. You may monitor the state by pinging the RT Server and waiting for the responses to stop.
8. The next step is to power down the RT Server. This can be done by the power switch on the server in the thermal enclosure of in the telnet session to NICIbaytech. The RT Server is on NICIbaytech port 2.
9. Verify that ports 2, 4, 5, and 7 on NICIbaytech are off.
10. Exit the telnet session on NICIbaytech.
11. On the access panel of the thermal enclosure switch the MAINS and UPS power switches to off.

2.5.3 AO Software Shutdown

To stop the AO system first run the *shutdown.m* macro from the XUI's Macro Tab then click the XUI's Quit button. Next the ui script must be run on the UI server with the stop option. Before running the ui stop and rt stop scripts, you must execute the shutdown.m macro from within the XUI program. Do this if you are the **last** XUI running. The order is important.

NICIui: /home/nici/nici/ao/scripts/ui stop
NICIrt: /home/nici/nici/ao/scripts/rt stop

3 Subsystem Detailed Descriptions

This section provides low-level details on NICI AO's subsystems. This information may be useful to technicians, telescope operators, and support staff when configuring, calibrating, or troubleshooting NICI.

3.1 Electronics Functional Description

There are 3 major subsystems in NICI's electronics, the Servers, Counter Electronics, and High Voltage Electronics. There are also several other components, the Steering Mirror Controller, the Ethernet Switch, the Portserver, and the Remote Power Control modules. See Figure 4 for a graphical depiction of the electronics components.

The Server subsystem encompasses both the RT and UI servers.

The HVA Electronics consists of several components. There is the HVA Chassis populated with a Remote HVA MFB board and HVA Boards. Another component is the High Voltage Power Supply (HVPS) which feeds power to the HVA chassis for driving the DM's actuators.

The Counter Electronics also consist of several components. There is the Counter Chassis populated with a Remote Counter MFB, Counter Boards, and an amplifier for driving the FSM. The APD Power Supply (APD PS) provides power to the APDs in the WFS.

The RT server, HVA, and Counter electronics work in concert at the core of NICI's processing and correcting functions. Figure 4 provides a block diagram of the RT Server, HVA Electronics, and Counter Electronics. The User Interface (UI) Server provides the interface to the NICI user and controls the mechanisms.

The following sections provide functional descriptions of the subsystems and other components in NICI's electronics.

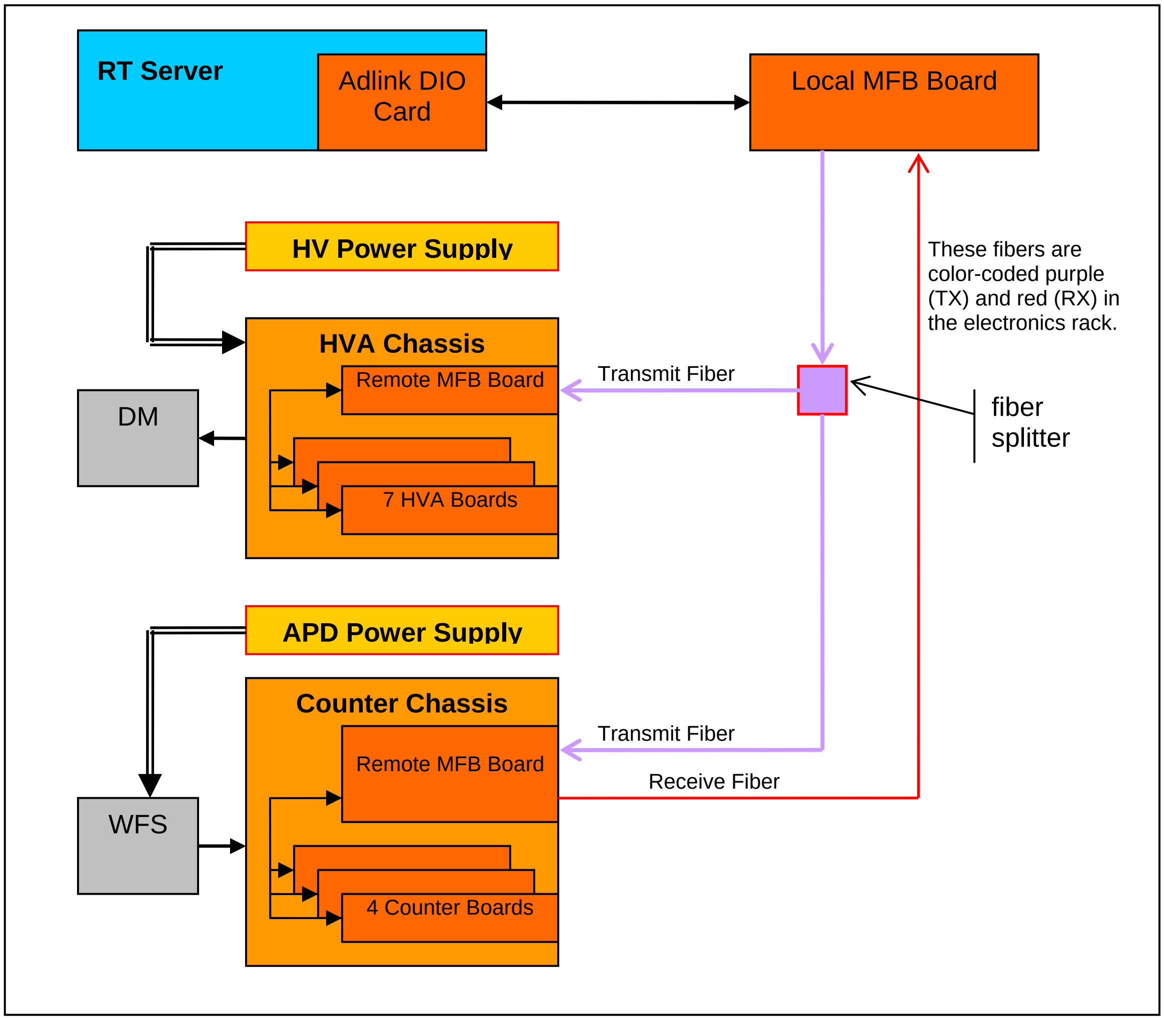

Figure 4 Block Diagram of NICI High Voltage and Counter Electronics Components

3.1.1 Servers Description

There are two Linux servers in NICI, the Real Time (RT) and User Interface (UI) servers. NICI software runs on both of these machines. The RT server is dedicated to real-time tasks and the UI server is dedicated to user interfaces and non-real-time tasks.

- **NICIui:** The User Interface server host name.
- **NICIrt:** The Real-Time server host name.
- **login**: NICI
- **passwd:** ao_NICI

3.1.1.1 RT Server

The RT Server is the workhorse of the system and is responsible for driving much of the electronics. Running RT Linux release 2.4-16rtl, this server is dedicated to real-time tasks such as reading photon counts from the Counter Electronics, calculating corrections, and sending correcting voltages to the amplifiers in the HVA Electronics that drive the DM's actuators.

The RT Server communicates with the HVA and Counter Electronics through an internal Adlink DIO Card. A Local MFB board is associated with the RT server for DIO communication with the HV and Counter subsystems. The Adlink DIO card is connected to the Local MFB board by electrical cable. The Local MFB provides electrical isolation between the servers and electronics by providing a fiber optic communication link to the HVA and Counter Electronics.

The RT Server also has a network connection to the Ethernet Switch. This connection allows the RT Server to mount the hard drive of the UI Server, receive configuration and run time commands from the UI Server, and to provide status of operation.

The fiber network that the Local MFB drives consists of one receive fiber from the Counter Electronics and a transmit fiber split to provide write access to both the Counter and HVA Electronics.

Technical specifications:

- Motherboard: Tyan S2468AN dual AMD Athlon
- Dual Athlon 2.8 GHz
- 1 GB RAM
- 2 80 GB HDD mirrored software RAID array, dual channel Ultra 160 SCSI
- Enclosed in SWT 2U case for accommodating DIO card
- DIO Card: Adlink PCI-7300A. 33MHz, 32-bit, 5V PCI.

3.1.1.2 UI Server

The UI Server's major task is to provide user interfaces for working with NICI. This server runs Redhat Linux release 2.4.18-3smp. The UI Server is dedicated to non-real-time tasks such as serving the XUI for instrument control, driving NICI's mechanisms, and providing configuration and control commands to the RT Server.

The UI Server has a connection to NICI's Ethernet Switch. This connection serves the GUIs to external workstations and is the channel for sockets connecting to NICI.

Technical specifications:

- Compaq Proliant DL360 G2
- Dual Pentium III 1.4 GHz
- 1 GB RAM
- 2 34 GB HDD mirrored RAID array
- Enclosed in standard DL360 G2 1U case

3.1.2 Counter Electronics Functional Description

The Counter Electronics are designed to measure the amount of light received by each of the Wavefront Sensor's 85 APDs. Boards in the Counter Chassis accumulate photon counts that are periodically read and cleared by software. The APD Power Supply provides power to the APDs. Details of these components are in the following sections.

3.1.2.1 Counter Chassis

The Counter Chassis encompasses several components. There is one Remote Counter MFB board, four Counter boards, and one Audio Amplifier. The chassis is a Eurocard style chassis which may appear to accommodate VME cards. The backplane, however, is not designed to support the VME standard. **Inserting standard VME cards into this chassis could have catastrophic consequences.** Don't do it.

The Remote Counter MFB provides a transmit and receive fiber interface to the RT Server. The Counter MFB is very similar to the HVA MFB. In fact the boards are identical but are implemented with different DIP Switch settings. The Counter MFB's DIP Switch should have position 8 set to OFF and all other bits set to OFF. The Counter MFB receives write and read requests via the fiber connection from software running on the RT Server. If the writes are to the Counter Boards, the MFB masters the write and read operations across the backplane. For details on the fiber connection see Section 3.1.1.

The Counter Chassis also houses 4 Counter Boards. An interface to the APDs of 85 coaxial cables provides digital, level sensitive signals indicating the amount of light sensed by the WFS's

APDs. Each Counter board accumulates photon counts from a set of APDs. Periodically RT software requests to read and clear the counts. Each HVA Board has an 8 position dip switch which must have bits 6 - 8 set to particular combinations to indicate what range of APDs for which a board is accumulating counts. All other bits must be set to ON.

The Audio Amplifier (Radio Shack XL-50) is housed in and powered through the Counter Chassis. The Counter MFB provides stepped digital input sine waves to the Audio Amp which the amp drives to the Membrane Mirror.

Slot	Card	APD #s	Counter Board DIP Switch		
			6	7	8
0 - 3	-	-	-	-	-
4	-	-	-	-	-
5	Remote MFB	-	-	-	-
6	-	-	-	-	-
7	-	-	-	-	-
8	-	-	-	-	-
9	Counter 1	0 - 23	ON	ON	ON
10	-	-	-	-	-
11	-	-	-	-	-
12	Counter 2	24 - 47	OFF	ON	ON
13	-	-	-	-	-
14	-	-	-	-	-
15	Counter 3	48 - 71	ON	OFF	ON
16	-	-	-	-	-
17	-	-	-	-	-
18	Counter 4	72 - 95	OFF	OFF	ON
19	-	-	-	-	-
20	-	-	-	-	-

Figure 5 Counter Chassis Slot Assignments, Corresponding APDs, and Counter Board Settings

3.1.2.2 APDs

The Avalanche Photodiodes are used to count photons incident on the DM for AO corrections. The APDs are Silicon Avalanche Photodiode based Single Photon Counting Modules, SPCM-AQR-14-FC modules by PerkinElmer, and previously manufactured by EG&G. The APD enclosure contains APDs from both manufacturers. The APDs are sensitive to overexposure and operation above 35 degrees Celsius. User should closely monitor the APD Temperature Sensor and photon counts to ensure the APD operating environment is within acceptable range.

3.1.2.3 APD Power Supply

The APDs in the WFS are powered by the APD Power Supply, two Sorensen DCS 8-125E power supplies. This Sorensen supply is rated at 0-8V, 0-125 A for low voltage, high current operation. This power is carried over what are effectively welding cables. Note that some documentation refers to these power supplies as "Sorensen #1" and Sorensen #2."

3.1.3 High Voltage Electronics Functional Description

The High Voltage Electronics are designed to drive high voltage signals to the DM's actuators. There are two major components in the HV Electronics, the HVA Chassis and the High Voltage Power Supply (HVPS). The HVPS provides power to the HVA Chassis for driving the DM's actuators. Details of these components are in the following sections.

3.1.3.1 HVA Chassis

The HVA Chassis houses two kinds of boards, a Remote HVA MFB board and seven HVA boards. The chassis is a Eurocard style chassis which may appear to accommodate VME cards. The backplane, however, is not designed to support the VME standard. **Inserting VME cards into this chassis could have catastrophic consequences.** Don't do it.

The Remote HVA MFB provides an Rx fiber interface to the RT Server. The transmit fiber interface is not used. This MFB is very similar to the Counter MFB. The boards are identical but their software functionalities are implemented with different DIP Switch settings. The HVA MFB's DIP Switch should have position 8 set to ON and all other bits set to OFF. The HVA MFB receives write requests from software via the fiber connection. If the writes are to the HVA Boards, the MFB masters the write operation across the backplane. For details on the fiber connection see Section 3.1.1.

Software writes digital values for corrections to the seven HVA Boards. The HVA Boards implement DACs for driving amplifiers which drive the DM's actuators at high voltage. The HVA boards are slave devices to software via the HVA MFB.

The HVA chassis has 21 card slots numbered 0 through 20 starting from the left side of the front of the chassis. The following table indicates board slot assignments and corresponding DM actuators. HVA cards plug in to one slot, but their amplifier circuits are tall enough to effectively occupy the adjacent slot. Each HVA card has an 8 position dip switch which must have bits 5-7 set to a particular combination corresponding to an address range (DM actuator). The other positions of the dip switch, 1 - 4 and 8, should all be set to the ON position.

Slot	Card	DM Actuators	HVA DIP Switch		
			5	6	7
0	Remote MFB	-	-	-	-
1	HVA	0 - 11	ON	ON	ON
2	-	-	-	-	-
3	HVA	12 - 23	OFF	ON	ON
4	-	-	-	-	-
5	HVA	24 - 35	ON	OFF	ON
6	-	-	-	-	-
7	HVA	36 - 47	OFF	OFF	ON
8	-	-	-	-	-
9	HVA	48 - 59	ON	ON	OFF
10	-	-	-	-	-
11	HVA	60 - 71	OFF	ON	OFF
12	-	-	-	-	-
13	HVA	72 - 83	ON	OFF	OFF
14	-	-	-	-	-
15	HVA	84 -95	OFF	OFF	OFF
16 - 20	-	-	-	-	-

Figure 6 HVA Chassis Slot Assignments, DM Actuators channels, and HVA Board DIP switch settings

3.1.3.2 High Voltage Power Supply (HVPS)

The power to drive the DM's actuators is supplied by the HVPS. The power is distributed to the HVA Boards in the HVA Chassis. The supply is from two Sorensen DCS 600-1.7 power supplies rated at 0 – 600 V, 1.7 A. These power supplies are tuned to high voltage, low current operation.

3.1.3.3 High Voltage Safety Interlock
As a safety feature the High Voltage electronics are designed to disable high voltage power to the DM over the HVA cables when either or both of the cables are disconnected. There is a loopback signal through both HVA cables to the HVA chassis that detects whether both HVA cables are connected on each end. If this loop is broken, high voltage to the HVA Cables is disabled.

On the back side of the HVA chassis there is a receptacle labeled "Safety Interlock" below which a plug is mounted. This plug should not be plugged into the Safety Interlock receptacle under normal operation. If the plug is inserted, the safety feature that disables high voltage to disconnected HVA cables is disabled. That can create a hazardous exposed high voltage condition on disconnected HVA cables. This safety override is a feature used for development and high voltage signal monitoring.

3.1.4 Miscellaneous Components
There are several other components of NICI's electronics. Besides the subsystems already discussed there are the Tip/Tilt Steering Mirror, the DIGI Port Portserver, an Ethernet Switch, and a Remote Power Control module.

3.1.4.1 Ethernet Switch
The Ethernet Switch provides the ability for various electronics components in the electronics to communicate. It also acts as a fiber uplink to the facility LAN. The switch has RJ-45 connections to both Baytech Remote Power Control modules, the Digi Portserver, and the RT Server.

3.1.4.2 Digi Portserver
The DIGI Port Portserver provides the ability to permit serial communication connections to the mechanisms and controllers from NICI's Ethernet network (by the UI Server). The following table indicates the Portserver's port assignments.

Port	Connected to
4	
5	
6	
7	
8	
9	APD (Omega) Temperature Sensor
10	reserved
15	NICIbaytech
16	NICIbaytech2

3.1.4.3 Remote Power Control
The Remote Power Control modules, two Baytech RPC3-15 units, provide the capability to remotely control and monitor power to NICI's electronics components via telnet. Each module has an Ethernet connection to NICI's local network (for users), a serial connection to the Digi Portserver (for software), and eight 120VAC outlets. The host names of the modules are NICIbaytech and NICIbaytech2. A command list can be obtained in a telnet session with the 'help' command. Users may turn outlets on and off, query the status of the outlets, and monitor current consumption and internal RPC temperature.

User: NICI
Passwd: ao_NICI

The table below indicates which electronics components are assigned to which Remote Power Supply outlets.

Outlet	NICIbaytech	NICIbaytech2

1	DIGI Portserver	Unused
2	RT Server	APD (Omega) Temp. Sensor
3	Unused	Unused
4	Physik Instrumente	Unused
5	HVA Chassis	APD PS
6	Unused	APD PS
7	Counter Chassis	Spare
8	Fiber optic source	HVA PS (both)

Figure 7 Table of Remote Power Control Port Assignments

3.1.5 APD Temperature Sensor

The APDs are sensitive and expensive equipment. The APD Temperature Sensor monitors the temperature inside the APD Enclosure in an attempt to avoid operating the APDs at too high of a temperature. The electronics for the sensor are in the thermal enclosure. An icon in the XUI Operator Tab indicates the APD enclosure temperature. The icon for the APD temperature is color coded in stages from green to yellow to orange to red. Operators and observers should carefully monitor the APD temperature. If the APD temperature is observed to be rising towards the red zone, the APDs should be shut down and allowed to cool before further use. Operation in the red zone, or above 35 degrees Celsius, may result in catastrophic failure of the APDs.

If the APD Temperature sensor detects temperatures above 35 degrees Celsius, an audible alarm in the thermal enclosure will sound.

Some references to the APD Temperature Sensor may be as the Omega Temperature Sensor, as Omega is the manufacturer of the sensor electronics.

3.1.6 Cabling

This section describes the system level cabling of NICI. Connections between assemblies are pictured and defined below. The following cables are NICI's system cables.

- 2 HVA Cables
- 4 APD Power Cables
- Utility Cable
- 85 APD Coax
- 85 WFS Fiber

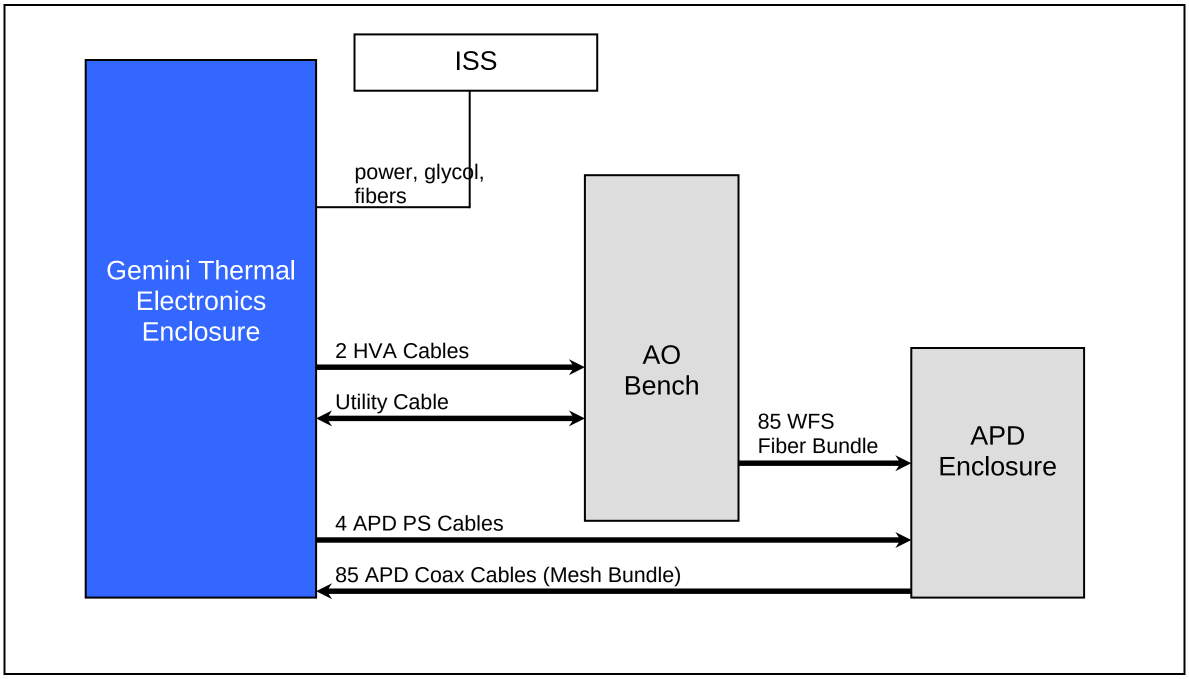

Figure 8 System Level Cabling Diagram

3.1.6.1 HVA Cables
The HVA Cables provide a connection from the HVA Chassis to the Optical Enclosure for routing the high voltage signals to the DM. The connectors are cylindrical 66-pin Mil-spec connectors. There is a rather particular shielding scheme used on this cable. Consult the High Voltage Connections spreadsheet for more details.

3.1.6.2 APD Power Cables
The APD Power cables route power from the Sorensen APD Power Supplies in the thermal enclosure to the APDs in the APD Enclosure. They are designed for high current capacity.

3.1.6.3 Utility Cable
The Utility Cable carries the following power and control signals:

- Membrane Mirror Power, Control

3.1.6.4 APD Coax Cables
The APD Coax Cable routes 95 APD BNC coax cables and connections for the APD Temperature Sensors from the thermal enclosure to the APD enclosure. The APD coax cables carry photon count pulses from the APDs to the Counter Chassis in the thermal enclosure. There are 10 spare coax cables routed in this collection of cables, labeled Spare 1 - Spare 10. Spare 1 - Spare 5 are delivered connected to the 5 spare APD modules in order (with the same labeling). The collection of coax and temperature monitor cables is bundled in a mesh jacket.

3.1.6.5 WFS Fiber Cables
The WFS Fiber Cable consists of 85 fiber optic cables. These pass from the end of the LLA on the AO Bench to the APDs in the APD Enclosure. These cables carry photons captured by the lenslet array to the APDs to be counted. The 85 cables are bundled in a mesh jacket.

3.2 NICI Software Functional Description

This section describes the NICI AOS's Software. The primary roles of software are to control and manage the AO control servo and to provide interfaces to the system. The real time processes run on the RT server.

3.2.1 Software Features and Design Notes

This section provides a list of the features of NICI's software. This list was derived from the software requirements.

- Code is written in standard C.
- Real-Time and Non-Real Time Processes:
    - RT code runs under RT-Linux release 2.4-16rtl.
    - Non-RT code runs under RedHat Linux release 7.3, kernel 2.4.18-3smp.
    - Non-RT processes do not interfere with RT processes.
    - RT and Non-RT processes communicate via sockets and RPC. Communication between processes running in the same server is via shared memory.
    - Both the RT and UI servers have dual processors.
- Control Servo:
    - The control servo consists of a wavefront measurement and the calculation of a correction to be applied to the DM.
    - The control servo operates at up to 2000 Hz. Nominal operational frequencies are 1000 – 2000 Hz.
    - Latency is minimized. Latency is the time from the measurement of the wavefront to the correction being applied to the Deformable Mirror.
- User Interface:
    - Provides graphical feedback of system status.
    - Provides control of system configuration and operational parameters.
    - Controls WFS data recording.
    - Provides control over all mechanisms.
- Instrument Interface Requirements:
    - Socket to access and change system parameters and data

3.2.2 Compiling the software

This must be done as root on the NICItrt machine. Type 'make' in the nici/nici/ao directory to remake the binaries. Note that you must not change the directory structure since paths to binaries are hardcoded into the software.

3.2.3 Code Modules

The AO software is separated into a number of threads. On the real-time machine, the only real-time threads are the loop and the dio board driver. All other threads are run within user space in the Linux OS. The figure below shows the major software components of the AOS along with their interactions. The main components are the real-time processes (loop/driver), the shared memory on the real-time machine, a set of socket server/clients between the realtime machine and the user intereface machine, a copy of the NICIrt machine shared memory on the NICIui machine, an instruction/command parser, and the user interface.

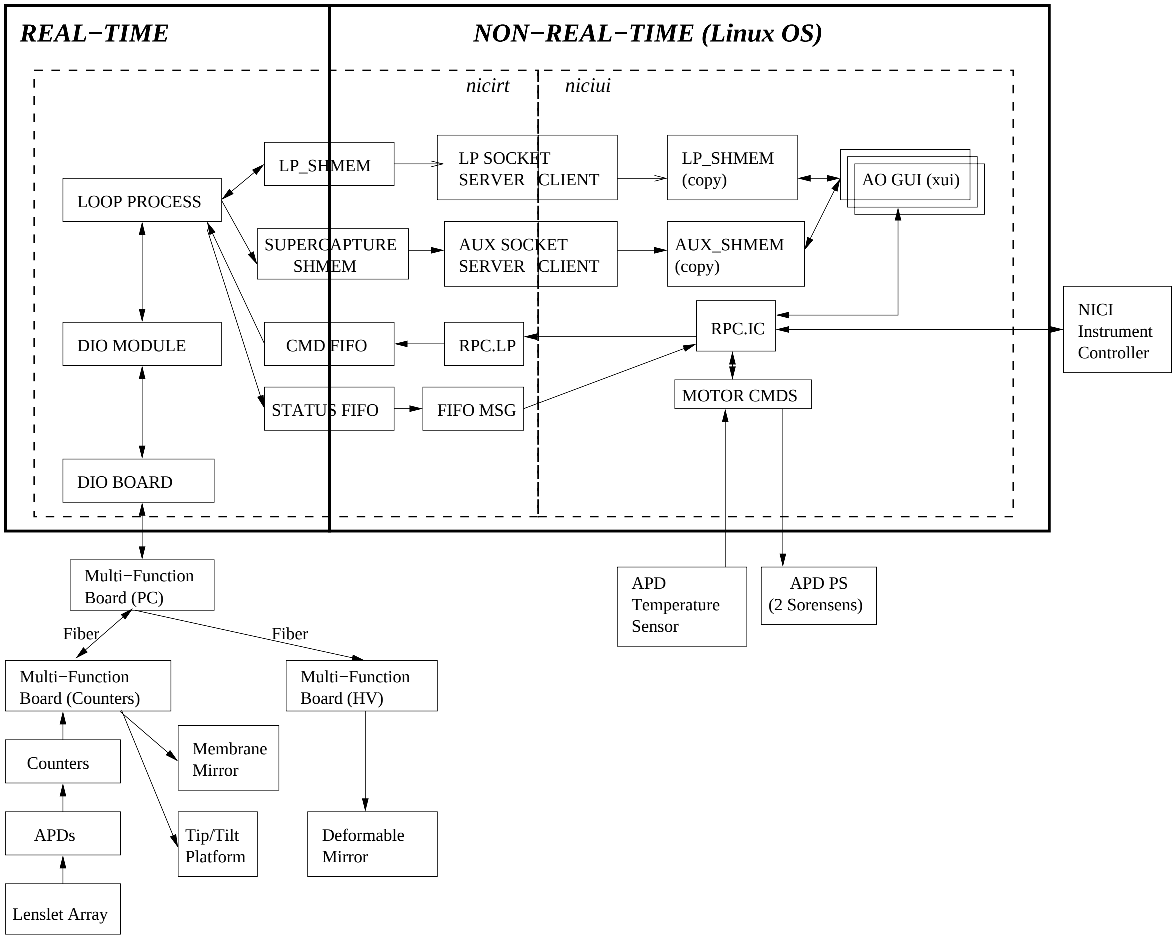

Figure 9 Software modules and their interactions

3.2.3.1 Loop Thread

The Loop is at its most basic level simply the calculation of the error signals, and the control servo for the DM. It handles this basic task with the highest priority. In addition to the basic control servo, the loop thread handles a number of minor tasks after the completion of the control servo.

Once hardware and software are initialized, the loop thread performs the basic loop procedure. What is included in this 'loop' depends on the loop state (lp.state). The algorithm is illustrated below.

As long as loop is not paused the loop thread proceeds through the following steps.

1. Accept data from AO Counter Chassis, Calculation of the WFS signal

2. Depending on state of loop:

Feedback:	Calculate DM error signals, control servo, tip/tilt control servo
PR.imat:	Book keeping and performance of DM interaction matrix.
TT.imat:	Performance and book keeping of TT interaction matrix.
Idle:	Nothing done.

3. Process any new commands sent to system

4. Calculate mean parameters

5. Handle periodic tasks (e.g. Telescope offloading (tip/tilt/focus))

3.2.3.2 IC

The IC thread runs on the NICIui machine. All commands to the AOS are parsed by this process. In particular, any command from the XUI or from the external socket are handled by the IC thread. It parses the command and directs it to the appropriate process on the real-time machine or to a mechanism (e.g. the APD power supplies).

3.3 NICI AO User Interface (XUI)

This section describes the User Interface. The XUI provides a graphical interface to NICI AOS and permits control over all AO functions, configuration parameters, and AO correction.

The XUI has 5 sub-windows, or tabs. They are the Operator (Opr), View, Macro, Imat, and Engineering (Eng) Tabs. The Operator, View, and Macro tabs are commonly used by observers and are briefly described in this section. A particular tab selected as the current XUI display by clicking on the corresponding tab near the bottom of the XUI window.

Outside of the tab sub-window are the About, Refresh, and Quit buttons, a Messages window, and a Command Prompt.

Clicking the **About** button displays information about the version of software.

Clicking the **Refresh** button will force the XUI window to be refreshed.

Clicking the **Quit** button closes the current XUI window (but does not stop the AO system).

The **Messages** window displays command echo and output. It also displays error messages.

The **Command Prompt** provides a means for command line user input for sending commands directly to NICI.

Note that there are known bugs in the XUI software. These are discussed in the section below.

3.3.1 XUI Operator Tab

The XUI's Operator Tab is the primary window for control and monitoring of the AO servo loop and mechanisms. It also provides APD Enclosure temperature monitoring and power control over the components of NICI. The Operator Tab is divided into 3 parts:

- System Status
- Loop and Servo Control
- Mechanism Status and Control

These 3 parts are explained in the sections below. The Messages window and Command Prompt are displayed with all tabs and are described in the introduction of Section 2.2 above.

The Config. View button opens a popup window that permits selection of the diagrams displayed in the Operator Tab. The Configure View popup window is shown and described in Section 3.3.2.

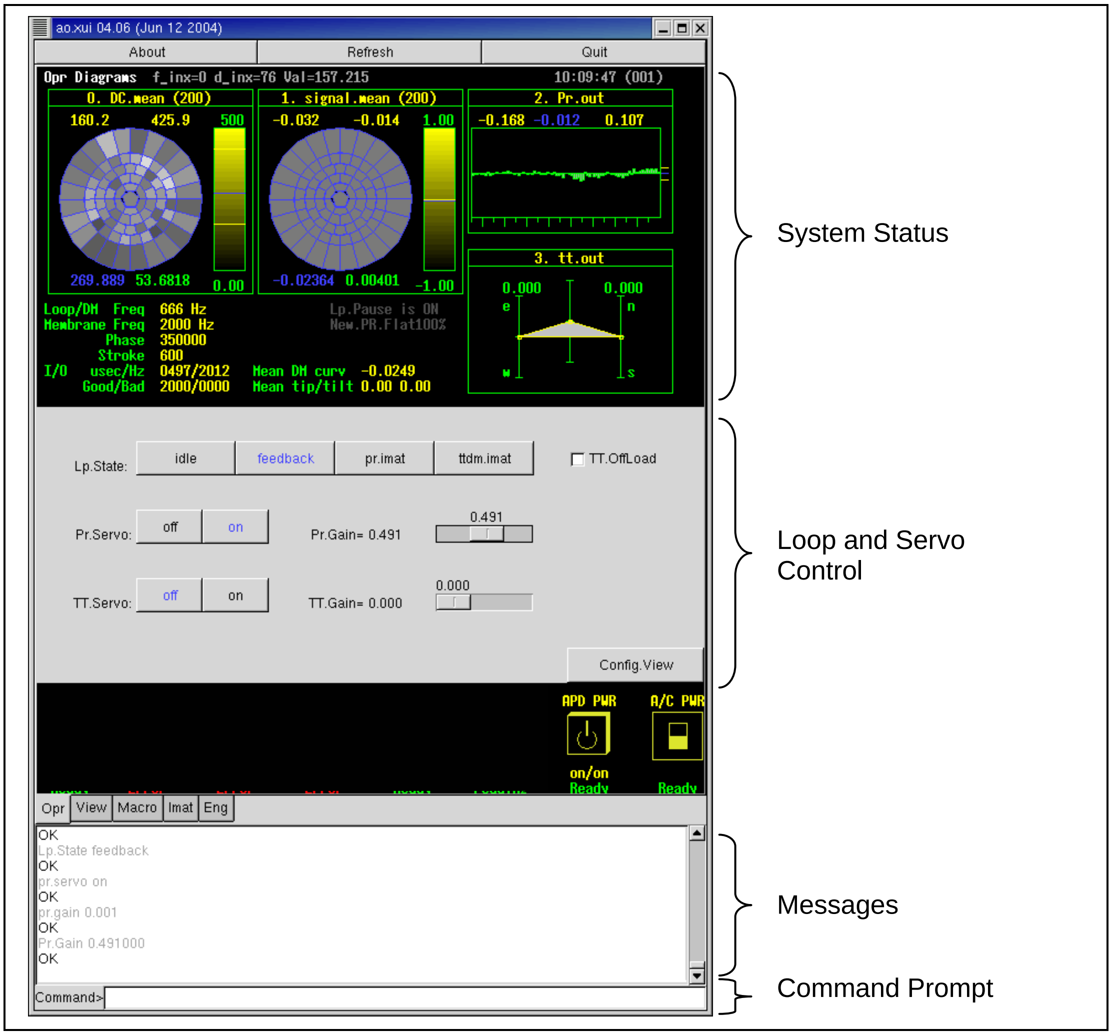

Figure 10 XUI Operator Tab

3.3.1.1 XUI Operator Tab: Command Prompt

The XUI command prompt interface provides a simple and fast interface to the NICI system. Any legal system command can be typed into the command prompt. The usual syntax is 'command_name parameter'. Command names usual follow a 'X.Y' naming convention. For example, the primary loop gain command name is (pr.gain). Command names are not case sensitive. As a convention, the XUI parameter displays are labeled with their command name. For example, in the XUI operator tab window, the primary loop gain is labeled 'pr.gain'.

3.3.1.2 XUI Operator Tab: System Status

The System Status portion of the XUI's Operator Tab provides a summary of system status.

Above the DC.mean and signal.mean displays there are three helpful displays that react to mouse placement over the DC.mean and signal.mean diagrams. First is **f_inx**, which indicates which of the diagrams is being displayed, 0 for DC.mean and 1 for signal mean. **d_inx** indicates which actuator or sensor the mouse is hovering over. **val** indicates the value at the actuator or sensor which the mouse is hovering over. Note that the values are displayed when the mouse enters a region but the value is not updated continuously if the mouse is left in the region.

- **DC.mean**: The DC.mean diagram graphically shows the mean WFS count rate in counts/sample/sub-aperture. The number displayed in parentheses indicates the number of samples used to calculate the mean. The numbers surrounding the sensors in the circular diagram indicate the minimum (top left), maximum (top right), average (bottom left) and standard deviation (bottom right) of the counts across all 85 sub-apertures. The vertical bar to the right shows the count color-coding that is displayed in the sensors in the diagram. Below and above this bar are the minimum and maximum display values of the DC.mean respectively. Three horizontal bars in the vertical bar graphically depict the minimum, maximum, and average (blue) DC.mean across all 85 sensors.

- **signal.mean**: The signal.mean diagram shows the error signal mean (full range +/- 1). The number displayed in parentheses indicates the number of samples used to calculate the mean. The numbers surrounding the sensors in the circular diagram indicate the minimum (top left), maximum (top right), average (bottom left) and standard deviation (bottom right) of the error signal mean across all 85 elements. The vertical bar to the right shows the signal color-coding that is displayed in the sensors in the diagram, minimum, maximum, and average error signal bars. Below and above this bar are the minimum and maximum range values of the signal.mean respectively. Three horizontal bars in the vertical bar graphically depict the minimum, maximum, and average (blue) signal.mean across all 85 sensors.
- **Pr.out**: The primary out diagram shows the output voltages to the DM normalized to +/- 1 from +/- 400V.
- **tt.out**: The tip/tilt output diagram shows the orientation of the tip/tilt actuators along the two axes. There is also a numerical display of the tilt for each axis normalized to +/- 1.
- **Loop/DM Freq**: The Loop/DM Frequency display indicates the frequency at which corrections are sent to the DM. This number is an integer fraction of the Membrane Mirror frequency.
- **Membrane Mirror Status**
  - **Freq**: The Membrane Frequency display indicates the frequency at which WFS measurements are taken and the frequency of the Membrane Mirror. Nominal frequency is 2000 Hz. The minimum and maximum frequencies are 1000Hz and 3500 Hz respectively.
  - **Phase**: The Phase display indicates the phase of the MM. This is the time between a voltage being applied to the MM and sampling photons in the WFS. This phase is a parameter that is set during commissioning and should not generally be changed by the user.
  - **Stroke**: The Stroke display indicates the stroke of the MM. See the section 4.1 for information on the conversion between the MM stroke and extra-focal distance.
- **I/O Status**
  - **usec/Hz**: Diagnostic information for I/O from the RT server. It displays the rate at which the WFS measurements are being sent to the NICIrt computer (usec/Hz).
  - **Good/Bad**: Diagnostic information for I/O from the RT server. The number of ‘Bad’ transmissions is the number of transmission errors per second.
- **Lp.pause**: Indicates if the loop state is paused or not paused. Note that the loop state can be ‘feedback’ but still be paused. This is the case when dithering offsets are made.
- **New.PR.Flat**: Indicates the percentage of completeness of a primary (DM) Flat voltage calculation. Under normal operation PR flats will not be calculated.
- **Mean DM curv**: This status parameter indicates the average voltage applied to the inner 61 actuators of the DM normalized to +/- 1. The Mean DM Curve helps to indicate to the user when focus offload to the telescope may be needed.
- **Mean tip/tilt**: This status parameter indicates the average voltage applied to the Tip/Tilt platform's X and Y-axes normalized to +/- 1. The Mean Tip/Tilt number helps to indicate to the user when pointing offload to the telescope may be needed.

3.3.1.3 XUI Operator Tab: Loop and Servo Control

This part of the XUI Operator Tab controls the loop state, primary servo and flats, and tip/tilt servo. Note that there are several conditions for corrections to be calculated and sent to the DM, Lp.State must be set to feedback, the Pr.Servo must be set to pr, and Pr.Gain must be set to a non-zero value. The equation that represents voltage corrections sent to the DM is like this:

$$V_{actuator}(t) = V_{actuator}(t - 1) + Pr.Gain * Error_{actuator}$$

Pr.Gain is the gain set in the Pr.Gain slide in the Operator Tab and Error is the correction to the DM calculated by the software. Alternatively the user can type the ‘pr.gain value’ command into the XUI command prompt line.

- **Lp.State**: Controls the state of the loop thread.
  - **idle**: When this button is selected NICI does not calculate corrections for the DM. Only WFS counts are read and displayed.
  - **feedback**: When this button is selected, calculation of the error signal (corrections to the DM) is enabled. This button must be selected for AO correction to take place.
  - **pr.imat**: This button puts the AO loop into a mode for calculating an IMAT for the DM. Observers should not click this button. Generally this function is better executed in the Imat Tab.
  - **ttdm.imat**: This button puts the AO loop into a mode for calculating an IMAT for the Tip/Tilt Mirror. Observers should not click this button. Generally this function is better executed in the IMAT Tab.
- **TT.Offload**: When this box is checked, enables loop software to automatically perform Tip/Tilt offloading to the telescope based on offloading parameters set at commissioning to correct telescope drift. When unchecked, Tip/Tilt offloading is disabled.
- **Pr.Servo**: Enables and controls updates and corrections being sent to the DM.
  - **off**: When this button is selected, no corrections are sent to the DM.
  - **pr**: When this button is selected enables corrections to be sent to the DM. Note that the Lp.State must be set to feedback and the Pr.Gain set to a non-zero number for meaningful corrections to be sent to the DM.
- **Pr.Gain**: This slide sets the gain on the error correction to be applied to the DM as shown in v(t) calculation above. Nominal values are 0.3 - 0.5. Pr.Gain must be set to a non-zero value for correction voltages to be sent to the DM.
- **TT.Servo**:
  - **off**: Clicking this button disables the Tip/Tilt servo.
  - **dm**: Clicking this button enables the Tip/Tilt Mirror to correct for telescope guiding and pointing errors (drift).
- **TT.Gain**: Gain applied to the tip/tilt error correction calculation. Nominal value is 0 - 0.001.

3.3.1.4 XUI Operator Tab: Mechanism Status and Control

This part of the XUI Operator Tab provides the status and control of power and APD temperature status. In most cases, clicking an icon will open a popup menu to change the state of the mechanism or control the power to NICI's hardware components.

- **APD Temp**: This icon displays the temperature inside the APD Enclosure according to the APD Temperature Sensor. The popup menu's omega.init selection initializes software communication with the APD Temperature Sensor. This should be done after boot-up and to troubleshoot communication errors with the sensor. If any condition other than green occurs, the coolant flow should be checked. The icon is color coded as follows
  - **Green**: For acceptable temperature < 30 degrees Celsius
  - **Yellow**: For warm temperature > 30 degrees Celsius. Caution should be exercised when the Yellow range has been reached. The APDs may reach this level if the light level incident on the APD modules is too large. Consider using a stronger filter in the WFS filter wheel. Do not let the temperature reach 35 degrees Celsius.
  - **Red**: For **critical** temperature range > 35 degrees Celsius. The APDs should not be operated at or above 35 degrees Celsius, as they can be destroyed. If the APD temperature reaches 35 degrees Celsius, move the WFS filter wheel to opaque and shutdown the APD modules. Check that coolant is still flowing through the APD enclosure.

- **APD PWR**: This icon displays the power status of the 2 APD Power Supplies. Clicking this icon opens a popup window to control the power to the APDs. Note that software will move the WFS Filter Wheel to opaque before the APDs are powered on or off. Never attempt to change the APD power state if the loop.pause is enabled or if the MMstroke is zero. Software will also prohibit powering off the APDs if the photon counts on the APDs in not below a threashold. The threshold is set by the system parameter apd.off.ceil (displayed in the View-Setup window). The APD.Power.Init button initializes software communication with the APD Power Supply power controller. This should be done at boot-up and to troubleshoot communication problems with APD Power Supplies. When powering the APD Power Supplies on or off, users should **always** check the power status in the Operator Tab. If the expected power state does not match the expected state, click the APD.Power.Init button in the APD Power popup and set the desired power state again. The popup window is shown in **Error! Reference source not found.**.

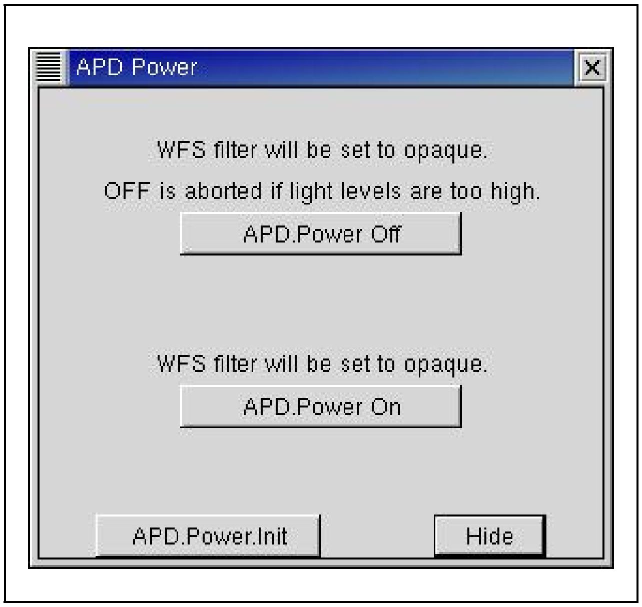

Figure 11 XUI Operator Tab APD PWR Popup Window

- **A/C PWR**: Clicking this icon opens a popup window that provides control over the two Baytech Remote Power Control modules. This permits power control over the various electronics components in NICI. Electronics components can be powered on or off by clicking the corresponding on or off button in the popup window. The Baytech.Init button initializes software communication with the Remote Power Control modules. This should be done after boot-up and to troubleshoot communication problems with the RPCs. Occasionally the RPCs won't respond to a power state change. In this case the displayed power state will not change to the desired state and a communications error will be displayed in the xterm from which the "ui start" command was run. The user should then click the Baytech.Init button and set the power state again.
-

3.3.2 Config. View Popup Window for the XUI Operator and View Tabs

The diagrams displayed in the Operator Tab and the Diagram and Text window of the View Tab can be selected with the Configure View popup window. This window is opened by clicking the Config. View button in either the Operator or View Tab. This popup window is shown in **Error! Reference source not found.**.

Each of the diagrams displayed has an index number in its label. To change the diagram displayed for a particular index, select the number in the Index box in the Configuration View popup window.

Then select the diagram to display in the Source box. Select a diagram type in the Type box. Autoscale for the diagrams can be turned on or off in the Autoscale box. The Range figures are for designating the maximum and minimum values for autoscaling. Click Apply to apply changes to displayed diagrams.

Similarly columns displayed in the APD Sensor Text Display window of the View Tab can be specified. Select the column to change next to the Text.View.Source button and specify what is to be displayed in the box on the right. To apply changes to columns, click the Text.View.Source button.

Note that the first time the Configure View window is opened after a system shutdown (that is, after a "ui stop" "rt stop" as in the Section 2.3.3) the index number does not match the source until the index has been scrolled. That means the first time an instrument user opens a Configure View popup, the index should be scrolled.

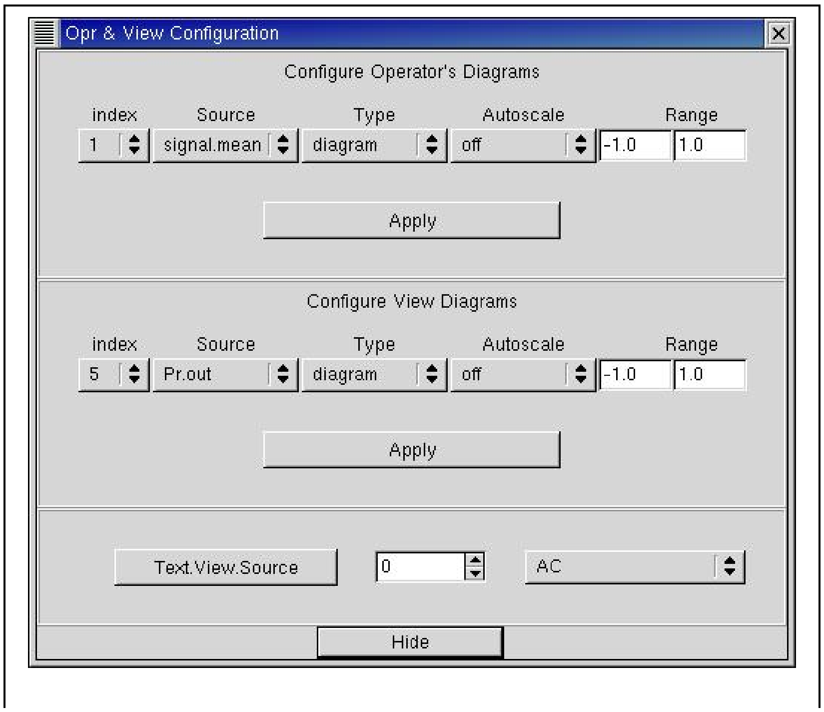

Figure 12 XUI Operator and View Tabs Configure View Popup Window

3.3.3 XUI Macro Tab

The XUI Macro Tab provides a means for creating and executing command macros. Macros are stored in text files that contain NICI commands with comment lines beginning with the '#' character. The Macro List window contains a list of the macro files found in the directory specified by the Path. To set the path, click the **(set) Path** button and navigate to the desired directory in the popup. The selected macro's contents are display in the window on the right. The Mask field filters the macro files displayed in the Macro List window.

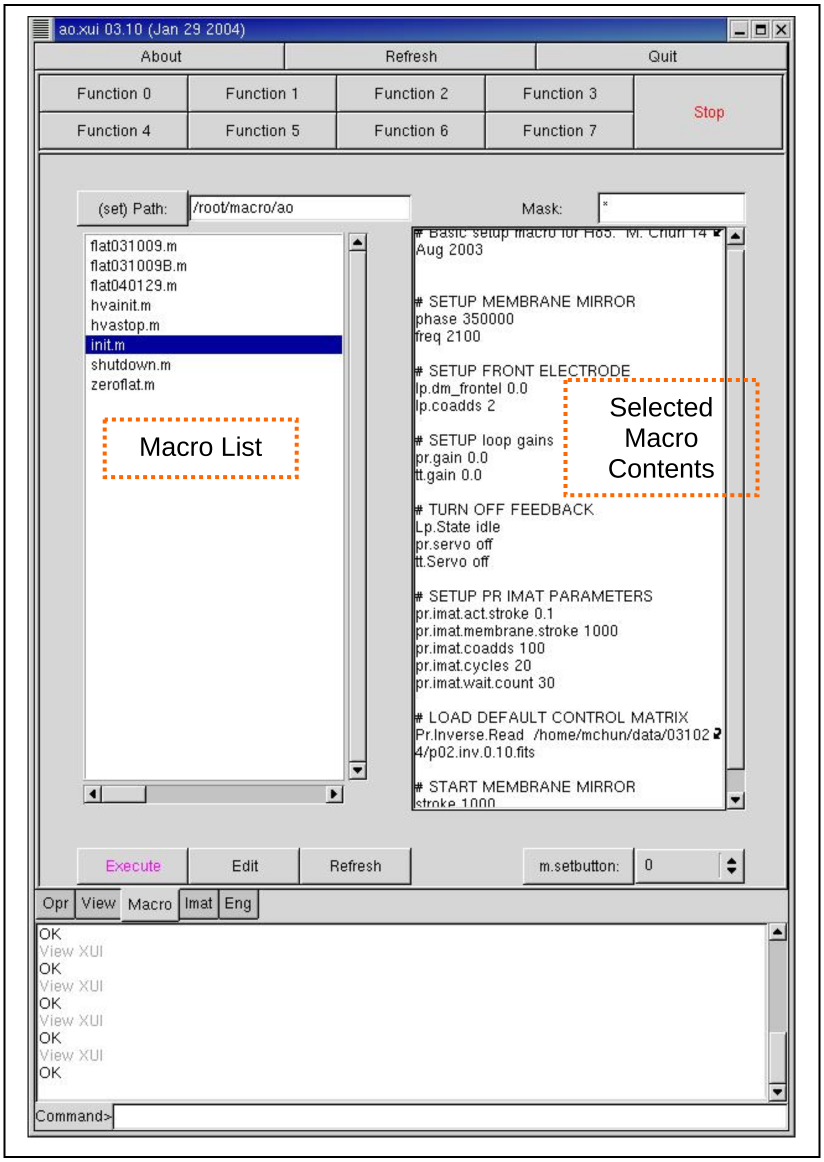

Figure 13 XUI Macro Tab

Macros are executed by selecting a macro and clicking the **Execute** button. The commands in the Macro will be executed sequentially. Command echo, command output, and any errors will be displayed in the Messages window. The **Edit** button opens the currently selected macro file in the gedit text editor. They are simple ascii files and can be editing with any editor. Note that the displayed contents of a macro edited by using the popup gedit window or in an external editor do not refresh automatically. The **Refresh** button will scan the directory specified by the path to refresh the list of macros in the Macro List and update the display of the Selected Macro Contents. Macro execution can be terminated by clicking the **Stop** button.

Macros can be assigned to one of the 8 Function buttons. First select a macro from the Macro List. Next select the number of the Function button which should be assigned by scrolling to the number next to the **m.setbutton** button. Finally click the m.setbutton.

The instrument is delivered with a basic set of macros listed below.

- **init.m**: An initialization macro to be run when starting the AO system.
- **shutdown.m**: A shutdown macro to be run when stopping the AO system.
- **zeroflat.m**: All flats are set to 0.

3.3.4 XUI View Tab

The XUI View Tab is a configurable display of system data. Which data is displayed is controlled by a set of radio buttons on the bottom of the display panel and by a configuration dialog accessible via the Config.View button next to the radio buttons. The radio buttons change between a preprogrammed set of displays. These show data as diagrams, data as text, system parameters, mechanism status, and configuration parameters for the XUI.

The XUI View Tab is used to display a variety of low level AO system information. There are 5 displays selectable in the View Tab. They are diagrams (Dia), a text display of APD sensor data (Text), loop setup parameters (Setup), motor status (Motor), and XUI configuration parameters (XUI). These selectable displays are pictured and described in this section.

The About, Refresh, and Quit buttons, and the Messages window, and Command Prompt are common to all XUI tabs and are described in the introduction of Section 2.2.

3.3.4.1 XUI View Tab Diagram (Dia) Display

The Diagram Display of the View Tab shows a set of 9 configurable diagrams that present a variety of information about AO system operation. This display is selected by clicking the "Dia" radio button in the View Tab. This display is shown in Figure 14. In the diagram display mode, system data can be displayed as grayscale images or as histograms. In the gray scale image mode, the minimum value(upper left), maximum value (upper right), average (lower left), and standard deviation (lower right) of the data are displayed along with the grayscale image. For histograms, the min/max/average values are displayed above the histogram.

The Config.View button opens a popup window which permits selection of the diagrams displayed in the View Tab Diagram Display. The Configure View popup window is shown and described in Section **Error! Reference source not found.**

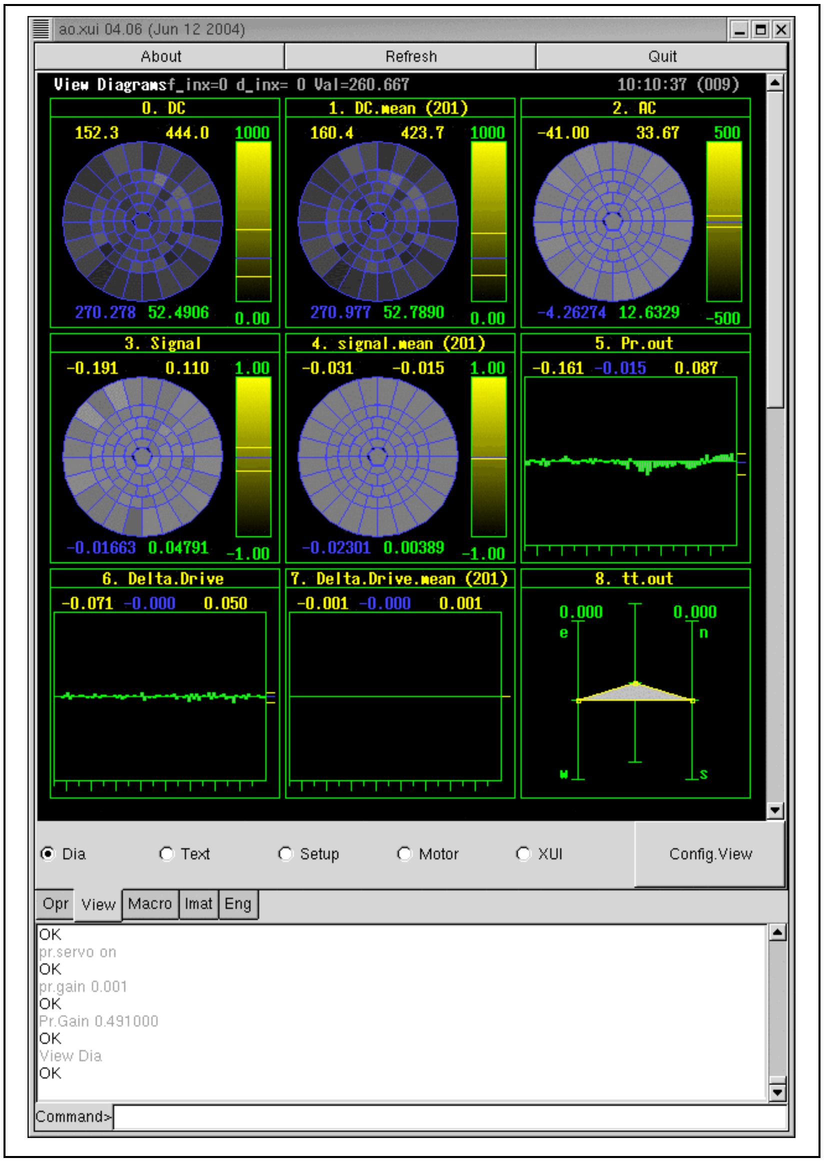

Figure 14 XUI View Tab Diagram (Dia) Display

The following list describes each of the diagrams in View Tab Diagram Display.

Above the DC and DC.mean displays there are three helpful displays that react to mouse placement over the diagrams. First is **f_inx**, which indicates which of the diagrams is being displayed, 0 for DC, 1 for DC.mean, etc. Then there is **d_inx** which indicates which actuator or sensor the mouse is hovering over. Then there is the **val** display which indicates the value at the actuator or sensor which the mouse is hovering over.

- **DC**: The DC diagram graphically shows the WFS count rate in each sub-aperture. The numbers surrounding the sensors in the circular diagram indicate the minimum (top left), maximum (top right), average (bottom left) and standard deviation (bottom right) of the counts across all 85 sub-apertures. The vertical bar to the right shows the count color coding that is displayed in the sensors in the diagram. Below and above the vertical bar are the minimum and maximum range values of the count rate respectively. Three horizontal bars in the vertical bar graphically depict the minimum, maximum, and average (blue) DC value across all 85 sensors.

- **DC.mean**: The DC.mean diagram graphically shows the mean WFS count rate in counts/sample/sub-aperture. The number displayed in parentheses indicates the number of samples used to calculate the mean. The numbers surrounding the sensors in the circular diagram indicate the minimum (top left), maximum (top right), average (bottom left) and standard deviation (bottom right) of the counts across all 85 sub-apertures. The vertical bar to the right shows the count color coding that is displayed in the sensors in the diagram. Below and above this bar are the minimum and maximum range values of the DC.mean respectively. Three horizontal bars in the vertical bar graphically depict the minimum, maximum, and average (blue) DC.mean across all 85 sensors.
- **AC**: The AC diagram graphically shows the difference in sampled intensities between phase A and phase B samples for each sub-aperture. The numbers surrounding the sensors in the circular diagram indicate the minimum (top left), maximum (top right), average (bottom left) and standard deviation (bottom right) of the intensity differences across all 85 sub-apertures. The vertical bar to the right shows the AC color coding that is displayed in the sensors in the diagram. Below and above this bar are the minimum and maximum range values of the AC values respectively. Three horizontal bars in the vertical bar graphically depict the minimum, maximum, and average (blue) AC values across all 85 sensors.
- **Signal**: The Signal diagram shows the error signal normalized to +/- 1. The numbers surrounding the sensors in the diagram indicate the minimum (top left), maximum (top right), average (bottom left) and standard deviation (bottom right) of the signal across all 85 elements. The vertical bar to the right shows the signal color coding that is displayed in the sensors in the diagram, and minimum, maximum, and average (blue) horizontal signal bars.
- **signal.mean**: The signal.mean diagram shows the error signal mean normalized to +/- 1. The number displayed in parentheses indicates the number of samples used to calculate the mean. The numbers surrounding the sensors in the circular diagram indicate the minimum (top left), maximum (top right), average (bottom left) and standard deviation (bottom right) of the error signal mean across all 85 elements. The vertical bar to the right shows the signal color coding that is displayed in the sensors in the diagram, minimum, maximum, and average (blue) error signal horizontal bars.
- **Pr.out**: The primary out diagram shows the output voltages to the DM normalized to +/- 1 from +/- 400V. Above the diagram are shown, from left to right, the minimum, average, and maximum output voltages.
- **Delta.Drive**: This diagram shows the change in voltage to be applied to the DM, that is, v(t) - v(t - 1). Above the diagram are shown, from left to right, the minimum, average, and maximum change in voltage.
- **Delta.Drive.Mean**: This diagram shows the mean change in voltage to be applied to the DM, that is, v(t) - v(t - 1). Above the diagram are shown, from left to right, the minimum, average, and maximum mean change in voltage. The number of samples used to calculate the mean is shown in parentheses.
- **tt.out**: The tip/tilt output diagram shows the orientation of the tip/tilt mirror along the east-west and north-south axes. There is also a numerical display of the tilt for each axis normalized to +/- 1.

3.3.4.2 XUI View Tab APD Sensor Text Display (Text)

The APD Sensor Text Display shows a variety of information on each of the 85 APDs. This display is selected by clicking the "Text" radio button in the View Tab and is shown in Figure 15.

There are 7 columns of data for the APDs. Each row is a collection of the 7 data points for one sensor, numbered in the left-most column (00 - 84). The column headings are in green. The following list defines the column headings.

The Config. View button opens a popup window which permits configuration of the columns displayed in the View Tab APD Sensor Text Display. The Configure View popup window is shown and described in Section **Error! Reference source not found.**

- **PhaseA**: This is a real-time display of the photon count of an APD in the phase A portion of the loop.
- **PhaseB**: This is a real-time display of the photon count of an APD in the phase B portion of the loop.
- **AC**: The AC column shows the difference in sampled intensities between phase A and phase B samples.
- **DC**: The DC column shows the WFS count rate in each sub-aperture.
- **DC.mean**: This is mean of the WFS count rate in counts/sample/sub-aperture. The number of samples used to calculate the mean is displayed below the bottom row of the display.
- **Signal**: Displays the error signal.
- **signal.mean**: This column shows the normalized error signal mean. The value to which this column is normalized is configurable in the Configure View screen described in Section **Error! Reference source not found.**. The number of samples used to calculate the mean is displayed below the bottom row of the display.

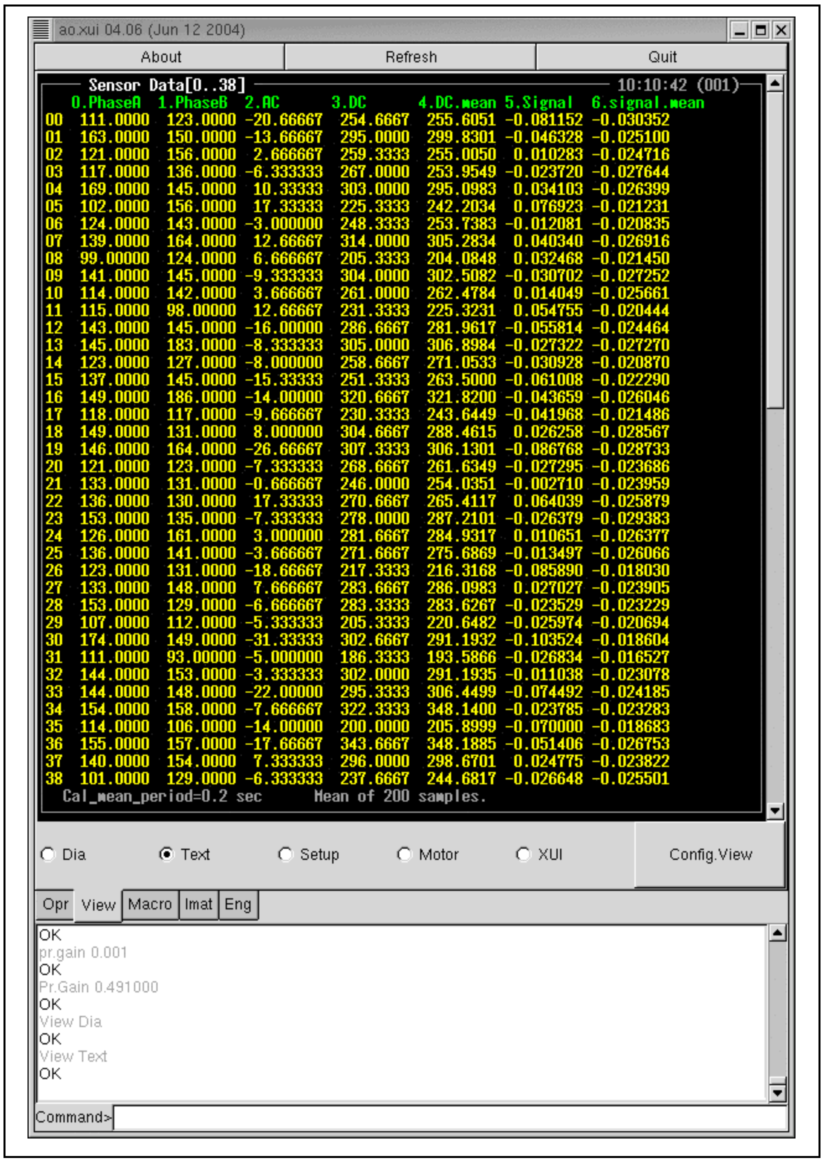

Figure 15 XUI View Tab APD Sensor Text Display (Text)

3.3.4.3 XUI View Tab Loop Setup Display (Setup)

The Loop Setup Display shows text representations of loop setup parameters (lp->parameters), loop status (lp->status), loop data (lp->data), and some miscellaneous data points. Many of the items in this display are not intended to be used by observers and are displayed for instrument configuration during commissioning. The Loop Setup Display is shown in Figure 16.

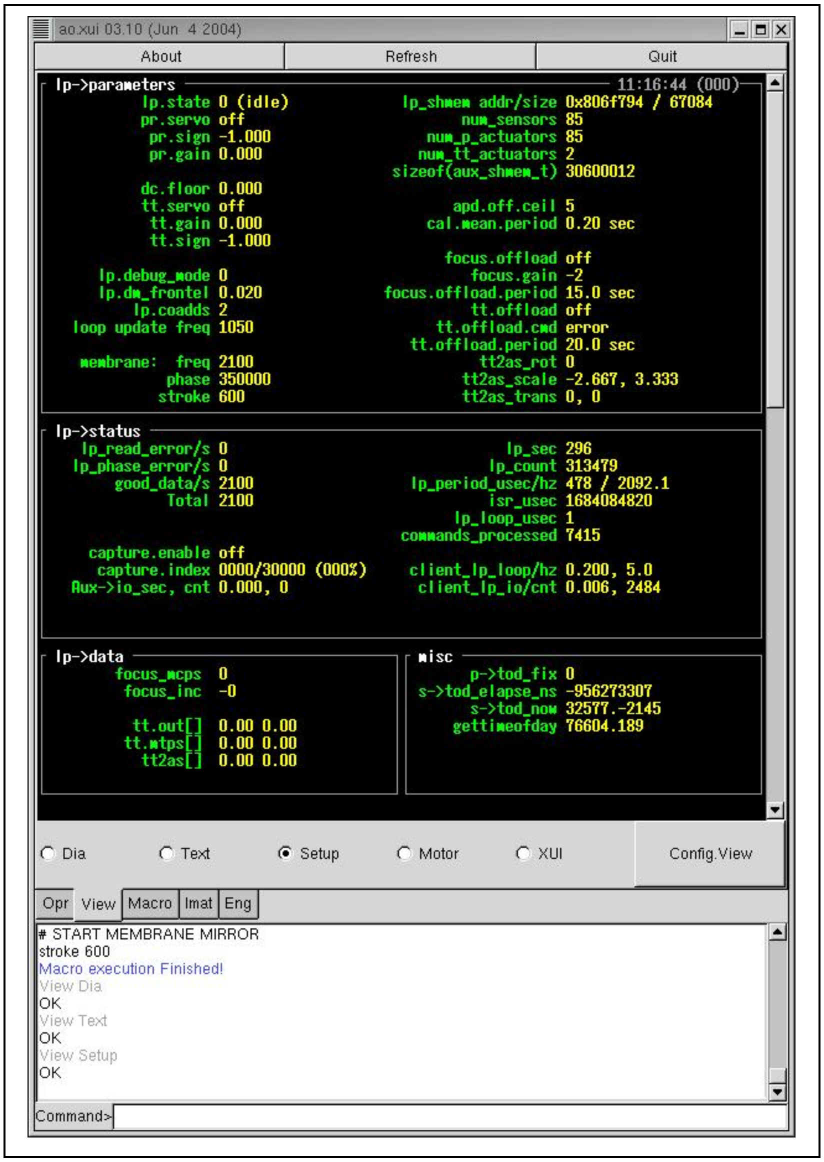

Figure 16 XUI View Tab Loop Setup Display (Setup)

There are four sections to the Loop Setup Display. They are parameters, status, data, and misc. The contents of these sections are described in the following lists.

Parameters

The parameters section (lp->parameters) displays servo loop parameters. Additional information on these parameters may be found in Section 2.2.1.3. Some of the parameters are used only for development or commissioning and can be ignored (and not changed) by the instrument user.

- **lp.state**: Displays the state of the loop thread. The states are
  - **(0) idle**: The AO system is not calculating corrections.

  - **(1) feedback**: Indicates that calculations of the error signals (corrections to the DM) are enabled. Having corrections actually being sent to the DM also requires pr.servo state to be pr and pr.gain to be set to a non-zero number.
  - **(2) pr.imat**: Indicates that an IMAT for the primary (DM) is being calculated.
  - **(3) ttdm.imat**: Indicates that an IMAT for the Tip/Tilt Mirror is being calculated.
- **pr.servo**: Indicates whether updates and corrections are being sent to the DM. The states are
  - **off**: No corrections are being sent to the DM.
  - **pr**: Indicates that corrections and updates are enabled to be sent to the DM. Having corrections actually being sent to the DM also requires the lp.state to be feedback and pr.gain being set to a non-zero number.
- **pr.sign**: Indicates the sign to be applied to pr.gain.
- **pr.gain**: Indicates the gain on the error correction to be applied to the DM.
- **dc.floor**: Indicates the minimum valid photon count rate per subaperture intensity measurement. Values less than this are set to zero.
- **tt.servo**: Indicates whether the Tip/Tilt servo is enabled (dm) or disabled (off).
- **tt.gain**: Gain applied to the tip/tilt error correction calculation.
- **tt.sign**: Indicates the sign applied to the tt.gain for TT servo correction calculations.
- **lp.debug.mode**: This is a development parameter. Do not change this value.
- **lp.dm_frontel**: Provides control over an 86th electrode on the DM. Do not modify this parameter.
- **lp.coadds**: Indicates the number of cycles of WFS sampling before updating the corrections sent to the DM. Each WFS cycle consists of one phase A and one phase B intensity measurement. There can be between 1 and 10 WFS measurements per DM correction signal update. When lp.coadd > 1, the average A and B intensities are used in the calculation of the DM update signals. Valid range is 1 to 10.
- **loop update freq**: This is the frequency of updates of the correction signal to the DM. It is the MM frequency divided by the number of co-adds in lp.coadds.
- **membrane**: Several parameters for the Membrane Mirror.
  - **freq**: Indicates the frequency at which WFS measurements are taken and the frequency of the Membrane Mirror
  - **phase**: The Phase display indicates the phase of the MM. This is the time between a voltage being applied to the MM and sampling photons in the WFS.
  - **stroke**: The Stroke display indicates the stroke of the MM which corresponds to extra-focal distance.
- **lp_shmem addr/size**: This is a software system memory parameter and can be ignored by users. Do not change these values.
- **num_sensors**: This is a software system memory parameter and can be ignored by users. Do not change these values.
- **num_p_actuators**: This is a software system memory parameter and can be ignored by users. Do not change these values.
- **num_tt_actuators**: This is a software system memory parameter and can be ignored by users. Do not change these values.
- **sizeof(aux_shmem_t)**: This is a software system memory parameter and can be ignored by users. Do not change these values.
- **apd.off.ceil**: Indicates the APD photon count threshold above which software prevents powering down the APDs.
- **cal.mean.period**: Indicates the period, or number of loop cycles, over which means are calculated for loop monitoring parameters such as DC.mean and signal.mean.
- **focus.offload**: Indicates whether focus offloading to the telescope is enabled (on) or disabled (off).
- **focus.gain**: A focus offloading parameter that is set at commissioning. Do not change this value.
- **focus.offload.period**: Indicates the period for focus offloading checks. This parameter is set at commissioning and should not be changed by the instrument user.

- **tt.offload**: Indicates whether Tip/Tilt offloading to the telescope is enabled (on) or disabled (off) for correcting telescope drift.
- **tt.offload.cmd**: This is a development and commissioning parameter and should be ignored by the user.
- **tt.offload.period**: Indicates the period for Tip/Tilt offloading checks. This parameter is set at commissioning and should not be changed by the instrument user.
- **tt2as_rot**: This is a development and commissioning parameter and should be ignored by the user. Do not change this parameter.
- **ttas_scale**: This is a development and commissioning parameter and should be ignored by the user. Do not change this parameter.
- **tt2as_trans**: This is a development and commissioning parameter and should be ignored by the user. Do not change this parameter.

Status
The status section (lp->parameters) of the View Tab's Setup Display displays status information regarding WFS data capture and loop status. Generally this section can be ignored by the instrument user.

- **lp_read_error/s**: This is a loop debug development parameter and should be ignored by the user.
- **lp_phase_error/s**: This is a loop debug development parameter and should be ignored by the user.
- **good_data/s**: This is a loop debug development parameter and should be ignored by the user.
- **Total**: This is a loop debug development parameter and should be ignored by the user.
- **capture.enable**: This is a development parameter regarding WFS data acquisition and should be ignored by the user. Do not change this parameter.
- **capture.index**: This is a development parameter regarding WFS data acquisition and should be ignored by the user.
- **Aux->io_sec, cnt**: This is a development parameter regarding WFS data acquisition and should be ignored by the user.
- **lp_sec**: Status regarding the rate of AO system to RT server communication. Users ignore.
- **lp_count**: Status regarding the rate of AO system to RT server communication. Users ignore.
- **lp_period_usec/hz**: Status regarding the rate of AO system to RT server communication. Users ignore.
- **isr_usec**: Status regarding the rate of AO system to RT server communication. Users ignore.
- **lp_loop_usec**: Status regarding the rate of AO system to RT server communication. Users ignore.
- **commands_processed**: Status regarding the rate of AO system to RT server communication. Users ignore.
- **client_lp_loop/hz**: Status regarding loop processing which can be ignored by the user.
- **client_lp_io/cnt**: Status regarding loop processing which can be ignored by the user.

Data
The data section (lp->data) of the View Tab's Setup Display displays status information regarding internal servo loop data. The information here can be ignored by instrument users and should not be changed.

Misc
The miscellaneous section (lp->misc) of the View Tab's Setup Display displays unused, historical information. The information here should be ignored by instrument users and should not be changed.

3.3.4.4 XUI View Tab Motor Status Display (Motor)

The Motor Status window (Status) displays status information for all of the NICI mechanisms. Each mechanism has several data points. The data points for each mechanism are defined in the following list. Each motor has a state or ready, busy, or error. The busy state generally implies that the mechanism is in motion. This display is shown in **Error! Reference source not found.**.

APD:

- **state**: Indicates the status of the communication channel to the power controller for the APD, ready, busy, or error. The error state can usually be corrected by initializing the software communication channel (see Section 2.2.1.4).
- **function**: This is an internal software bookkeeping parameter and should be ignored by instrument users.
- **percent**: When in the busy state, provides an approximation of the percentage of completeness of the previously commanded movement.
- **sim**: Indicates whether commands to the FSM mechanism are simulated (1) or actually issued to the mechanism (0).
- **rc**: On mechanism errors, indicates a software error code.
- **Sorensen1**: Indicates whether APD Power Supply #1 is on or off.
- **Sorensen2**: Indicates whether APD Power Supply #2 is on or off.
- **Temperature**: Indicates the temperature sensed by the APD Temperature Sensor in degrees Celsius.

3.3.4.5 XUI View Tab XUI Configuration Display

The XUI Configuration Display provides some configuration information on the XUI. Most of this information is not useful to observers. The useful observer information is the display that shows the assignment of the Function Buttons in the Macro Tab. This display is shown in Figure 17.

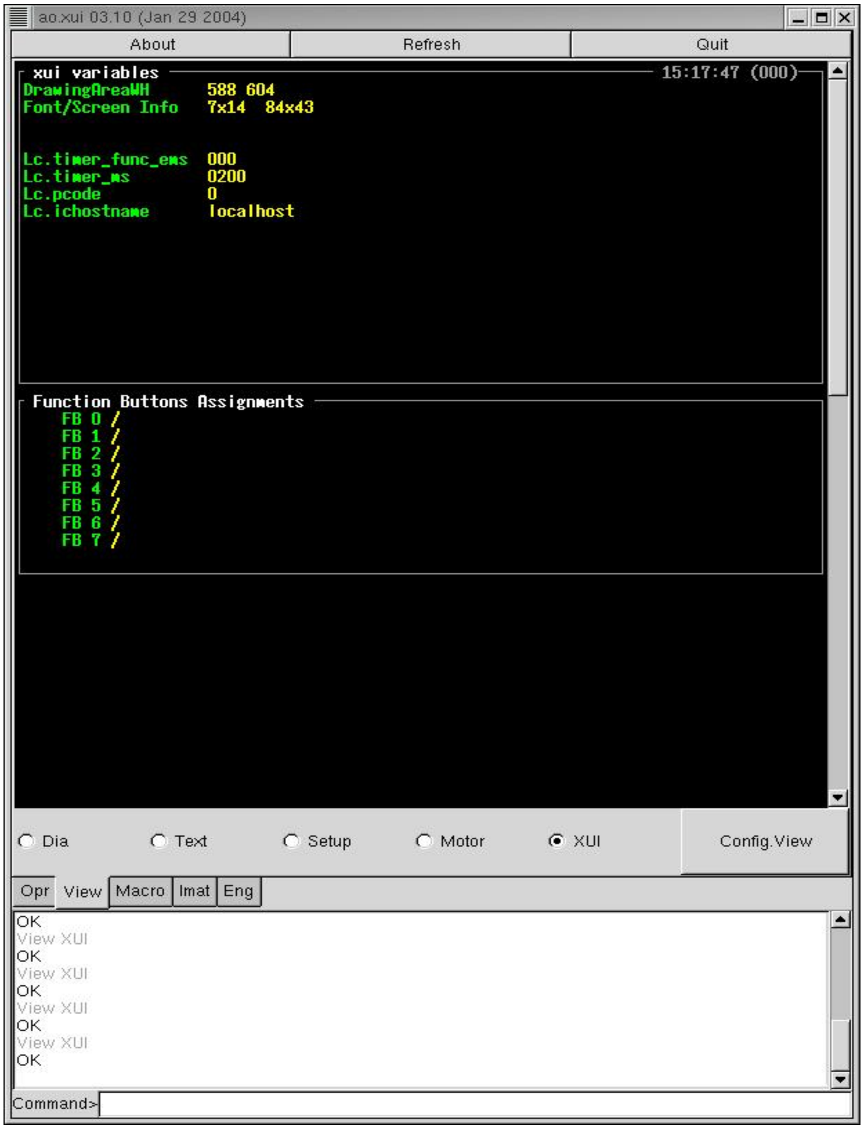

Figure 17 XUI View Tab XUI Display (Status)

3.3.5 XUI Engineering Interface Tab

The Engineering Interface Tab (Eng) of the XUI is provided for engineering use of NICI and for troubleshooting. Observers should not use the functions provided in this tab. The Engineering Tab is selected by clicking the "Eng" tab in the XUI window. An image of the Engineering Tab is provided in Figure 18.

The About, Refresh, and Quit buttons, and the Messages window, and Command Prompt are common to all XUI tabs and are described in the introduction of Section 2.2.

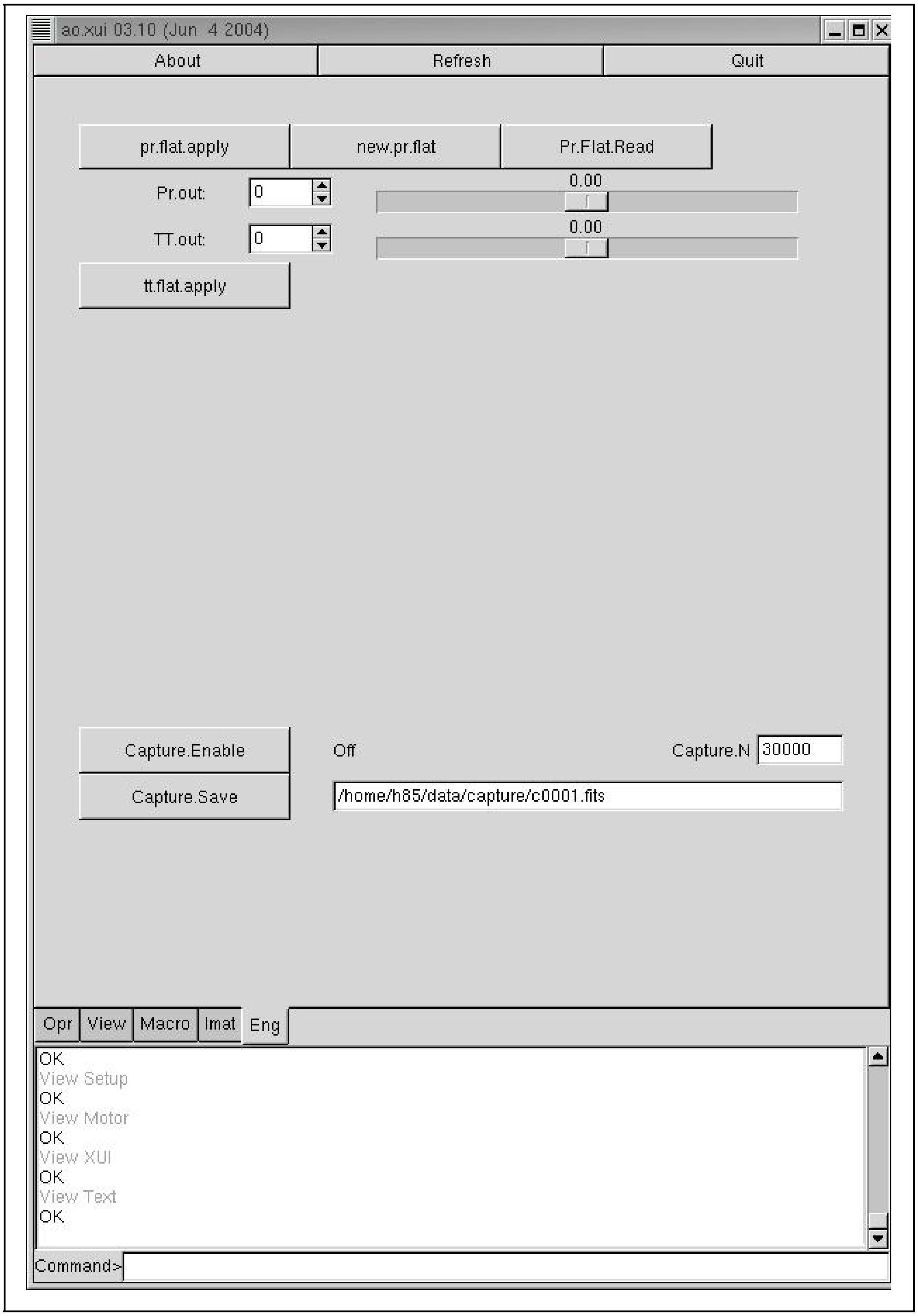

Figure 18 XUI Engineering Tab (Eng)

The following list describes the functions provided by the Engineering Tab.

- **pr.flat.apply**: Clicking this button sends the current values of the system variable pr.flat to the DM. Pr.flat is an average of the error signal over 30 seconds calculated by the loop.
- **new.pr.flat**: Clicking this button causes a new set of flat voltages to be calculated for the primary (DM) and stores the values in the pr.flat system variable.
- **Pr.Flat.Read**: Reads a FITS file for the primary (DM) flat voltages. This flat is set at commissioning and should not be altered by users or operators. **Pr.out**: Here engineers

apply a voltage to a specific DM actuator. The box on the left selects the actuator and the slide sets the voltage.

- **Pr.out**: Here engineers apply a voltage to a specific DM actuator. The box on the left selects the actuator and the slide sets the voltage.
- **TT.out**: This slide controls the output to the Tip/Tilt Mirror. The X axis is selected by scrolling to 0; the Y axis is selected by scrolling to 1. The slide controls the output to the selected axis.
- **tt.flat.apply**: Applies flat voltages to the TT actuators.
- **Capture.Enable**: Enables corrections applied to the DM to be captured in a FITS file. Phase A counts, phase B counts, voltages to the DM, and voltages to the TT Mount are captured for every cycle.
- **Capture.N**: Specifies the number of samples to be captured when capture is enabled.
- **Capture.Save**: Specifies the name of the file to which data will be captured.

3.3.6 XUI Interaction Matrix Tab

The IMAT Tab provides an interface for generating interaction matrices for the DM (primary) and Tip/Tilt Mount. This window is selected by clicking the IMAT Tab in the XUI window. Generally this tab is only needed if the optical alignment has changed. A screen capture of the IMAT Tab is provided in Figure 19.

The first part of the IMAT tab is a display of the parameters and status of generation of the DM and Tip/Tilt IMATs. The second part of the IMAT Tab provides control over IMAT generation.

The About, Refresh, and Quit buttons, and the Messages window, and Command Prompt are common to all XUI tabs and are described in the introduction of Section 2.2.

3.3.6.1 IMAT Status and Parameters

The top portion of the IMAT Tab provides a display of the parameters used to calculate the IMAT and the status of the generation of the IMAT for the Primary (DM) and the Tip/Tilt mirror. This section defines the status and parameter elements.

Primary IMAT

- **Parameters**
  - **pr.imat.act.stroke**: This is the stroke of the DM normalized to +/- 1 (from +/- 400 volts).
  - **pr.imat.membrane.stroke**: This is the stroke (related to the WFS extra-focal distance) of the MM used during IMAT measurement. See section 4.1 for information on the conversion of membrane mirror stroke to extra-focal distance.
  - **pr.imat.coadds**: Sets the number of samples at each position of an actuator during IMAT generation.
  - **pr.imat.cycles**: Sets the number of times each actuator is exercised during primary (DM) IMAT generation
  - **pr.imat.wait.count**: Sets the number of AO loop cycles to wait after applying voltage to an actuator before taking a measurement during IMAT generation
- **Status**
  - **lp.state**: This line indicates the state of the AO loop during IMAT generation. See Section 2.2.1 for more details.
    - **0**: Idle
    - **1**: Feedback
    - **2**: Pr.imat
    - **3**: ttdm.imat
  - **fun_id**: Indicates an internal ID# of what stage of the IMAT calculation is being executed. This can be ignored by the user.
  - **current actuator**: Indicates the DM actuator currently being exercised in the IMAT generation process.
  - **current i coadd**: Indicates how many co-adds have completed for the current actuator in the IMAT generation process.

    - **current i cycle**: Indicates how many cycles through the actuators have completed during the IMAT generation process.
    - **mean_photon_rate**: Indicates the mean number of photon counts / sub-aperture / sample.

TipTilt IMAT

- **Parameters**
    - **tt.imat.act.stroke**: This is the stroke of the TT Mirror. A typical value is 0.1 which is 5% of the full range.
    - **tt.imat.membrane.stroke**: This is the stroke of the MM which corresponds to extra-focal distance. See section 4.1 for information for converting MM stroke to extra-focal distance.
    - **tt.imat.coadds**: Sets the number of samples at each position of an actuator during IMAT generation.
    - **tt.imat.cycles**: Sets the number of times each actuator is exercised during TT IMAT generation.
    - **tt.imat.wait.count**: Sets the number of AO loop cycles to wait after applying voltage to a TT actuator before taking a measurement during IMAT generation.
- **Status**
    - **lp.state**: This line indicates the state of the AO loop.
        - **0**: Idle
        - **1**: Feedback
        - **2**: Pr.imat
        - **3**: ttdm.imat
    - **fun_id**: Indicates an internal ID# of what stage of the IMAT calculation is being executed.
    - **current actuator**: Indicates the TT Mirror actuator currently being exercised.
    - **current i coadd**: Indicates how many co-adds have completed for the current actuator during TT IMAT generation.
    - **current i cycle**: Indicates how many cycles through the TT actuators have completed during TT IMAT generation.
    - **mean_photon_rate**: Indicates the mean number of photon counts / sub-aperture / sample during TT IMAT generation.

3.3.6.2 IMAT Control

This section of the Imat Tab provides control over IMAT generation. The IMAT Control buttons are described in the following list.

- **Lp.State**: Controls the state of the loop thread.
    - **idle**: When this button is selected NICI does not calculate corrections for the DM. Only WFS counts are read and displayed.
    - **feedback**: When this button is selected, calculation of the error signal (corrections to the DM) is enabled. This button must be selected for AO correction to take place.
    - **pr.imat**: This button puts the AO loop into a mode for calculating an IMAT for the DM.
    - **ttdm.imat**: This button puts the AO loop into a mode for calculating an IMAT for the Tip/Tilt Platform.
- **Pr.Imat.Save**: Clicking this button saves the IMAT for the primary (DM) to a file specified by a popup window. Primary IMATs are not automatically saved. This button must be clicked to save a Primary IMAT.
- **Pr.Inverse.Read**: This button is used to load a control matrix (inverse of an IMAT) for the Primary (DM). Clicking this button opens a popup window to prompt for the location of the control matrix.
- **ttDM.Imat.Save**: Clicking this button saves the IMAT for the Tip/Tilt platform to a file specified in a popup window. Tip/Tilt IMATs are not automatically saved. This button must be clicked to save a TT IMAT.

- **ttDM.Inverse.Read**: This button is used to load a control matrix (inverse of an IMAT) for the Tip/Tilt platform. Clicking this button opens a popup window to prompt for the location of the control matrix.

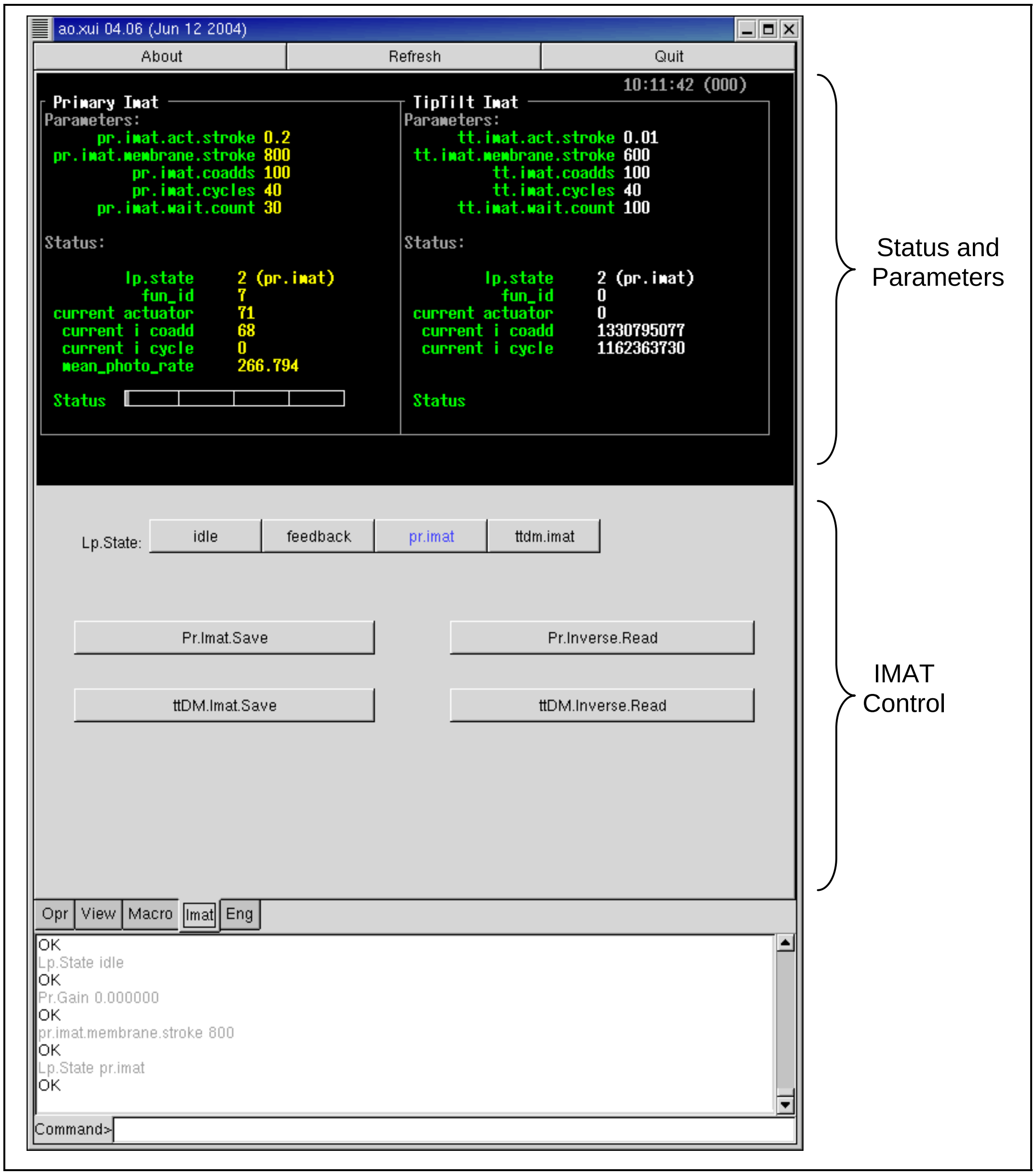

Figure 19 XUI IMAT Tab

3.3.7 Known XUI Issues and Resolutions

- There is a known issue with the manner of closing pop-up windows in the XUI. In the top right corner of all pop-up windows is the standard "X" button that closes the current window. If windows are closed with this "X" button, subsequent pop-ups can have incorrect and unusable contents, they can be garbled. The XUI in general may also become unstable and may crash. The proper method for closing popup windows is to use the "Hide" button instead.

If "X" button is used to close a popup window and the XUI becomes unstable, users should close the XUI by clicking the "Quit" button and then restart the XUI with the following command. If the XUI crashes, the same command can be used to restore the XUI.

NICIui: /home/NICI/NICI/ao/xui

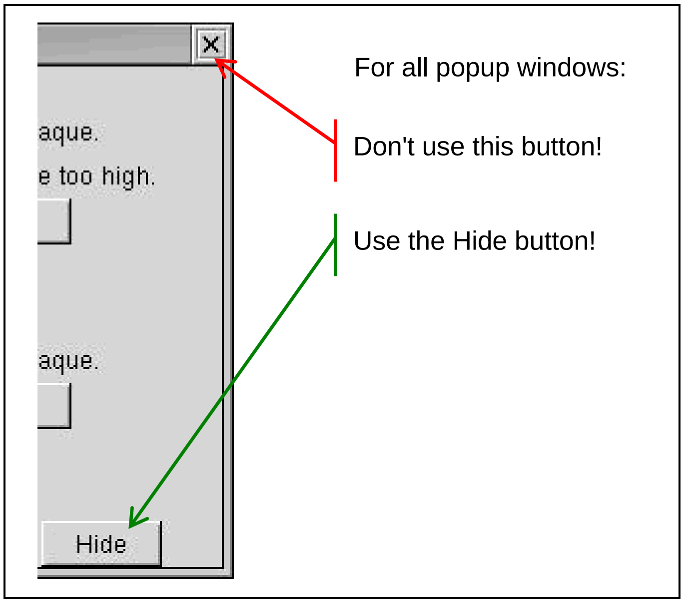

Figure 20 How to Close Popup Windows

- APD power on/off sometimes does not work. Check the power status after attempting a change to confirm the action completed.

- The first time the Configure View window is opened after a system shutdown (that is, after a "ui stop" "rt stop" as in the Section 2.3.3) the index number does not match the source until the index has been scrolled (by choosing the index number in the popup menu). That means the first time an instrument user opens a Configure View popup, the index should be scrolled.

4 Service & Calibration

This section defines the service procedures for NICI.

4.1 System Calibration

4.1.1 Generating System Interaction Matrices

Most observations should be able to use the suite of IMATs generated during commissioning. If a new extra-focal distance (MM stroke) is to be used or if the optical allignment has changed, new IMATs must be generated for the DM (primary) and TT platform.

4.1.1.1 Primary (DM) IMAT Generation with the XUI

This section defines the procedure for generating an IMAT and its inverse (control matrix) with the XUI's IMAT Tab for the DM. This procedure assumes the instrument has already gone thru the startup procedure defined in Section 2.3. Readers may like to refer to the IMAT Tab description in Section 3.3.6. This procedure must be repeated for each MM stroke/extra-focal distance setting.

1. In the XUI Operator Tab click the FCS icon and set the Fiber Calibration Source to "In" from the popup menu.
2. Select the IMAT Tab in the XUI window.
3. In the command prompt execute the command "pr.imat.membrane.stroke N" where N is the MM stroke for the chosen extra-focal distance.
4. Use the default values for other system setup parameters. These should not have to be set unless they've been changed. The default values are defined in Section 2.3.3.
5. In the XUI IMAT Tab click the pr.imat button. The IMAT generation should take approximately 30 minutes.
6. Wait for the Lp.State to return to idle. If you would like to abort the IMAT generation, click the Lp.State idle button.
7. Save the IMAT by clicking the Pr.Imat.Save button. It's helpful to specify a file name that indicates the MM stroke and that the IMAT is for the DM.
8. Generate the inverse of the IMAT with IDL using the IDL script genimats.pro. The genimats script runs through a series of MM strokes and generates the imat and inverse control matrix. The script should be found edited to set the MM strokes used. It can be found in the ~NICI/idl/pro/NICI/ directory on NICIui. Note also that there is a flag for calculating the TT interaction matrix. Since the TT actuator signals are generated from the DM signals they do not depend on the MM stroke. It is easier to generate a TTimat manually.
9. If necessary, proceed to Tip/Tilt Platform IMAT Generation.
10. Once IMAT generation is complete in the XUI Operator Tab click the FCS icon and set the Fiber Calibration Source to "Parked."

4.1.1.2 Tip/Tilt Platform IMAT Generation with the XUI

This section defines the procedure for generating an IMAT and its inverse (control matrix) with the XUI's IMAT Tab for the Tip/Tilt Platform. This procedure assumes the instrument has already gone thru the startup procedure defined in Section 2.3. Readers may like to refer to the IMAT Tab description in Section 3.3.6. This procedure must be repeated for each MM stroke/extra-focal distance setting.

1. In the XUI Operator Tab click the FCS icon and select "in" from the popup menu.
2. Select the IMAT Tab in the XUI window.
3. In the command prompt execute the command "tt.imat.membrane.stroke N" where N is the MM stroke for the chosen extra-focal distance.
4. Load the DM control matrix for the same MM stroke by clicking the Pr.Inverse.Read button and selecting the appropriate control matrix.
5. Select the Operator Tab in the XUI window.
6. Make sure that the Lp.State is set to idle in the Operator Tab.
7. In the Operator Tab set Pr.Servo to on.
8. In the Operator Tab set Pr.Gain to approximately 0.2.
9. Select the IMAT Tab in the XUI window.
10. In the IMAT Tab click the Lp.State ttdm.imat button.
11. In the command prompt execute the "stroke N" command where N is the same MM stroke.
12. Wait until the Lp.State returns to idle. This should take about 10 minutes.
13. Save the TT IMAT by clicking the ttDM.Imat.Save button. It's helpful to specify a file name that indicates the MM stroke and that the IMAT is for the TT platform.
14. Generate the inverse of the IMAT with IDL.

```
IDL> imat = readfits('p76.imat.fits')
IDL> inv  = svdinv(imat,0.05)
IDL> writefits, 'p76.inv.0.05.fits', ROUND(inv*10000)/10000.
```

The svdinv routine is in the ~/NICI/idl/pro directory and uses the IDL SVDC routine.

15. Once IMAT generation is complete in the XUI Operator Tab click the FCS icon and set the Fiber Calibration Source to "Parked."

4.1.2 Lenslet Array Orientation with respect to telescope

4.1.3 Membrane mirror stroke and extra-focal distance in the WFS

4.2 Servicing the system

4.2.1 Recovery from a power outage

4.2.1.1 Power loss while system was not running

4.2.1.2 Power loss while system was running

4.2.2 Servicing Electronics Boards

In the event of electronics board failures in the HVA or Counter Chassis, boards are to be replaced with a spare. It is strongly recommended that all of NICI's electronics be first properly powered down. It is critical to turn off the HV Power Supply before servicing the HVA Chassis.

To remove a board, open the thermal enclosure. Unscrew the two captive screws on the faceplate of the failed board. Then use the ejector tabs to unseat the board. Remove the board. The MFB Boards for both the HVA and Counter Chassis must have bit 8 of the boards dip switch set to indicate which chassis the board is to be installed in. Refer to Sections 3.1.2.1 and 3.1.3.1 for MFB dip switch settings.

A replacement Counter Board must have its dip switch set to indicate its board address and which APDs it is counting. Refer to Sections 3.1.2.1 for Counter Board dip switch settings.

A replacement HVA Board must have its dip switch set to indicate its board address and which DM actuators it is controlling. Refer to Sections 3.1.3.1 for the HVA Board dip switch setting.

Once the dip switch is set, the card can be re-inserted into the chassis. Be sure to insert the card upright (not upside down). Attaining proper seating of the boards in the backplane connectors is crucial. Be sure the boards snap into the backplane connectors. Then press firmly at the top and bottom and then in the center of the faceplate. Tighten the two captive screws to lock the card in its slot.

4.2.3 APD Module Replacement

Occasionally APD modules in the APD enclosure may have to be replaced. This section provides instructions for replacing an APD module completely and also swapping one of the spare APD modules already installed in the APD enclosure. Generally replacing a module would be done during the day and swapping to a spare module may be done during night-time observation.

Telescope personnel involved in the replacement or spare swapping of APDs should be very cautious about this procedure. There is exposed high voltage inside the APD enclosure. The door of the APD enclosure is quite heavy. It is strongly recommended that the APD enclosure (door hinges) be in a vertical, level position before opening the door as the door could swing open or closed under its own weight. In addition the APDs are very sensitive devices.

4.2.3.1 Swapping to a Spare APD Module

The quickest method of replacing a dead APD module is by swapping the fiber and coax connections of the defective module to one of the 5 spare APD modules already installed in the APD Enclosure. It is critical that the APDs be properly powered down before attempting any maintenance.

Materials and Tools Needed:
It may be helpful to bring some small zip ties and a tool for clipping zip ties to the APD enclosure. Also needed is material for insulating BNC and connectors, like shrink wrap and a heat gun. This procedure is estimated to take 20 minutes.

1. Level the APD Enclosure. It is strongly recommended that the APD enclosure (door hinges) be in a vertical, level position before opening the door as the door could swing open or closed under its own weight. When NICI is installed on a side-looking port, this is the case when the telescope is in the zenith position.
2. Identify the number of the defective APD.
3. Pause the AO loop through the XUI Operator Tab.
4. Power down the APD Power Supplies through the XUI Operator Tab's APD Power popup window (see Section 2.2.1.4).
5. Power down the High Voltage Power Supplies through the XUI Operator Tab's AC Power popup window (see Section 2.2.1.4).
6. Verify that the APD Power Supplies are powered down. You may like to open the thermal enclosure's front door to do a visual check. The APD Power Supplies are labeled "Sorensen #1" and Sorensen #2." There should be no illuminated lights on the front panel displays.
7. Open the front panel of the APD Enclosure.
8. Detach the coax cable from the defective APD. APDs are numbered on the side facing the front panel of the APD Enclosure.
9. Remove the power connector from the defective APD.
10. Insulate the power connector from the defective APD to avoid shorts to the power bus bars. Shrink wrap will do nicely. Secure the connector (with a zip tie).
11. Remove the coax cable from the Spare APD.
12. Insulate the spare BNC connector to avoid shorts to the power bus bars. Shrink wrap will do nicely. Secure the spare BNC connector (with a zip tie).
13. Attach the coax cable for the defective channel to the closest spare APD. The APD spares are labeled Spare 1 - Spare 5. Enabling this cable to reach the spare may involve cutting zip ties that secure the cable's routing.
14. Remove the shrink wrap protective covering from the spare power plug near the chosen spare APD.
15. Attach the spare APD power cable to the spare APD.
16. Replace any zip ties that were removed for cable routing to the spare APD.
17. Check that no cables are dangling.
18. Close the APD Enclosure front cover.
19. Open the door of the APD Enclosure. The door is heavy. Be sure to take caution against the door swinging open or closed under its own weight.
20. Detach the fiber cable from the defective APD. APDs are numbered on their back sides.
21. Remove the protective fiber connection cover from the nearest spare APD and install it on the defective APD module's fiber connector.
22. Attach the fiber cable for the defective channel to the closest spare APD.
23. Check that no cables or hoses are dangling.
24. Close the APD door and firmly secure the latches.
25. Power on the High Voltage Power Supplies through the XUI Operator Tab's AC Power popup window (see Section 2.2.1.4).
26. Power on the APD Power Supplies through the XUI Operator Tab's APD Power popup window (see Section 2.2.1.4).

4.2.3.2 Replacing an APD Module

Replacing an APD module is generally a daytime procedure. It is critical that the APDs be properly powered down before attempting any maintenance. This procedure assumes that the instrument has been totally shut down. This procedure is estimated to take 45 minutes. The APDs are mounted with M3 hex screws and will require a 2.5 mm hex wrench to remove and re-install.

1. Level the APD Enclosure. It is strongly recommended that the APD enclosure (door hinges) be in a vertical, level position before opening the door as the door could swing open or closed under its own weight. When NICI is installed on a side-looking port, this is the case when the telescope is in the zenith position.
2. Identify the number of the defective APD.
3. If the AO system is running, pause the AO loop through the XUI Operator Tab.
4. Power down the APD Power Supplies through the XUI Operator Tab's APD Power popup window (see Section 2.2.1.4).
5. Power down the High Voltage Power Supplies through the XUI Operator Tab's AC Power popup window (see Section 2.2.1.4).
6. Verify that the APD Power Supplies are powered down. You may like to open the thermal enclosure's front door to do a visual check. The APD Power Supplies are labeled "Sorensen #1" and Sorensen #2." There should be no illuminated lights on the front panel displays.
7. Verify that the High Voltage Power Supplies are powered down. You may like to open the thermal enclosure's front door to do a visual check. The two HV Power Supplies are labeled "HVDC Sorensen." There should be no illuminated lights on the front panel displays.
8. Open the front panel of the APD Enclosure.
9. Detach the coax cable from the defective APD. APDs are numbered on the side facing the front panel of the APD Enclosure.
10. Detach the power cable from the defective APD. The power cable is connected between the two BNC (coax) connectors.
11. Open the door of the APD Enclosure. The door is heavy. Be sure to take caution against the door swinging open or closed under its own weight.
12. Detach the fiber cable from the defective APD. APDs are numbered on their back sides.
13. From the front panel side of the APD Enclosure, push on the shelf to which the defective APD module is mounted to release the shelf from its locked position. Be careful not to let the shelf swing out quickly.
14. Swing the shelf out being careful not to snag any cables or lines on the front, back, or side of the shelf. Be careful not to crush any lines or cables behind the shelf's hinges.
15. Remove and secure all 8 hex mounting screws from the defective APD with a 2.5 mm hex wrench. These screws are not captive. Don't drop them.
16. Remove the defective APD module.
17. Mount a replacement APD module in place of the defective module. Re-install all 8 hex mounting screws with a 2.5 mm hex wrench.
18. Swing the APD shelf back into its locked position.
19. Attach the fiber cable to the new APD.
20. Close and secure the door of the APD Enclosure.
21. Attach the coax BNC connector to the TTL Output of the new APD module.
22. Insert the power connector for the replaced APD into the new APD module. The power connector is between the two BNC connectors on the APD.
23. Close the APD Enclosure's front cover.

4.3 System Installation

4.3.1 Configuring the Baytech Remote Power Control Modules

This section describes the administrative procedure necessary to configure the Baytech Remote Power Control Modules for network operation. These steps were necessary for initial setup of the modules and will be repeated if the network environment changes. The static IP address, subnet mask, gateway, and unit ID must be set for proper network operation. The connection to the modules can be through a direct serial connection from a PC. The connection can also be made via telnet if the modules are already configured to operate in the network.

At any point during configuration to navigate backwards from a menu simply hit return with no text entered on the command line. For details on the pinout of the administrative cable consult the Baytech manual.

1. Determine the static IP address, subnet mask, gateway, and unit ID (hostname). The unit ID should match the hostname in the network.
2. If connecting to the Baytechs through the administrative serial port, disconnect the serial connection from the Digi Portserver. Connect the administrative cable to the DB-9 serial port of a PC and connect the RJ-45 end to the EIA-232 port on the front panel of the Baytech unit. If connecting via telnet, skip to the login step 4.
3. Start serial communications software on the PC. In Windows you can use Hyperterminal. Set the serial communication parameters to 9600 bps, 8 data bits, 1 stop bit, and no parity.
4. Open the serial connection.
5. If prompted for user name and password, use the administrative login, admin.
6. The RPC-3 menu should appear. Select option 3 for configuration (type '3' and hit return).
7. Select option 1 for IP address. Enter the new IP address in decimal form and hit return. Verify that the correct address is displayed.
8. Select option 2 for subnet mask. Enter the new subnet mask in decimal form and hit return. Verify that the correct subnet mask is displayed.
9. Select option 3 for gateway. Enter the new gateway in decimal form and hit return. Verify that the correct gateway is displayed.
10. Select option 4 for unit ID. Enter the new alphanumeric unit ID (hostname) for the unit and hit return. Verify that the correct unit ID is displayed.
11. Now all necessary parameters have been entered. To save the changes hit return on a blank command line.
12. You will be prompted to accept changes and reset the unit. Enter 'Y' to accept the changes and reset.
13. To verify that the unit has been properly configured for the network ping the hostnames for the units from a remote computer. This step assumes that the network has already been configured to permit the Baytech units to operate on the network.
14. At the RPC-3 menu select option 6 to Logout.
15. Disconnect the administrative cable and reconnect the serial cable from the Digi Portserver to the Baytech.

4.3.2 Configuring the Digi Portserver

The section describes the administrative procedure for configuring the Digi Portserver for operation on a network. These steps were necessary for the initial setup of the unit and will be repeated if the network environment changes. The static IP address, subnet mask, gateway, and hostname must be set for proper network operation. The connection to the Portserver is through a direct serial connection through an administrative cable connected a PC's DB-9 serial port and to port 1 of the Portserver. The connection can also be made via telnet if the unit is already configured to operate in the network.

For a list of Portserver configuration commands type '?'. For help with command options, type a '?' in place of an option.

1. Determine the static IP address, subnet mask, gateway, and unit ID (hostname). The unit ID should match the hostname in the network.
2. If connecting to the Portserver through the administrative serial port, power OFF the Portserver via the Remote Power Control module, NICIbaytech, or via the rear panel power switch.
3. If connecting to the Portserver through the administrative serial port disconnect any cable connected to port 1 of the Portserver. Connect the administrative cable to the DB-9 serial

port of a PC and connect the RJ-45 end to port 1 of the Portserver. (XXXXXXXXXXXX if telnet skip to step XXXXXXXXXXX)

4. Start serial communications software on the PC. In Windows you can use Hyperterminal. Set the serial communication parameters to VT-100 emulation, 9600 bps, 8 data bits, 1 stop bit, and no parity.
5. If connecting to the Portserver through the administrative serial port, power ON the Portserver via the Remote Power Control module, NICIbaytech, or via the rear panel power switch.
6. When prompted for user name and password user the root account.
7. Type the command "set config myname=<hostname>" and hit return.
8. Type the command "set config ip=<decimal IP address>" and hit return.
9. Type the command "set config submask=<decimal subnet mask>" and hit return.
10. Type the command "set config gateway=<decimal gateway address>" and hit return.
11. Verify that all parameters were entered correctly by typing "set config" and hit return.
12. To save the changes the unit must be rebooted. Type the command "boot action=reset" and hit return.
13. To verify the parameters again, wait about one minute for the reboot. Hitting return will bring the login prompt up again. Login again as root and use the "set config" command to display and verify the settings.
14. Type "exit" and hit return to logout.
15. Ping the unit from a remote computer to verify it is working on the network correctly.
16. Disconnect the administrative cable from the PC and Portserver. Replace any cables in port 1 that were removed for the administrative cable.

5 Safety Issues

This section specifies some specific safety issues for NICI. These safety issues cover protection of equipment and personnel. Of course only qualified and trained personnel should handle the equipment.

5.1 APD Overexposure

The Avalanche Photo Diodes are expensive and sensitive equipment. They are particularly vulnerable to overexposure. Extreme caution should be taken to avoid exposing the APDs to more than 1000 photon counts per APD per cycle at a Membrane Mirror Frequency of 2000 Hz, or the equivalent count/frequency ratio at other MM frequencies. The WFS filter wheel should be adjusted to filter the light incident on the APDs.

5.2 APD Temperature

The Avalanche Photo Diodes are expensive and sensitive equipment. The XUI's Operator Screen should be monitored to ensure that the APD temperature reading does not enter the red zone, or exceed the manufacturer's maximum case temperature of 40 degrees Celsius. If the APD Enclosure temperature appears to be reaching the red zone, or above 35 degrees Celsius, the APD power should be switched off and the APDs allowed to cool before resuming use.

When the instrument is to be unattended for an extended amount of time, such as during the day time, the APD Power Supplies should be powered down. If the APDs are not powered down and the XUI is not being monitored, the APD Temperature could rise to exceed their specifications. Any time the APDs are powered on, the APD Temperature should be monitored in the XUI Operator Tab.

5.3 High Voltage and High Current Areas

There are several high current and high voltage areas of NICI. In general all power should be switched off to all parts of the instrument before any enclosures are opened or cables are connected or disconnected for the duration of maintenance or handling. The instrument should never have power applied with any doors open or panels removed on any of the structures.

Some specific areas of high voltage and high current are:

- High Voltage Power Supply (Sorensen)
- HVA Chassis
- High Voltage Cables to the DM and connectors
- The Deformable Mirror
- APD Power Supply (Sorensen)
- APD Power Cables and connectors
- Inside the APD Enclosure.
- The Animatics Power Supply

In normal operation the Safety Interlock connection on the back of the HVA Chassis should remain disconnected. This prevents high voltage signals being exposed on disconnected HVA cables.

5.4 Non-standard VME cards

While the HVA and Counter Chassis may appear to be standard VME chassis, they are not. The backplane does not adhere to the VME standard. Standard VME cards should never be inserted into the HVA or Counter Chassis. Doing so would create an electrical hazard and would likely result in catastrophic damage to the instrument.

6 Acronyms and Definitions

APD	Avalanche Photo Diode.
Control Servo	The process of managing and executing a wavefront measurement through the calculation of a correction which is applied to the DM.
DAC	Digital to Analog Converter. Usually referring to the 2 DACs on the HVA board. May also refer to the DAC on the remote MFB boards in the HVA and Counter Chassis.
DIO	Digital Input/Output. May refer to the DIO CPLD on the Local (PC) MFB, the Adlink or NI DIO cards.
DM	Deformable Mirror.
NICI	In this document this refers to the NICI 85-element Adaptive Optics system developed by the IfA.
HVA	High Voltage Amplifier. May refer to a board or the chassis.
IMAT	Interaction Matrix
LLA	Lenslet Array
MFB	Multifunction Board, an NICI fiber interface board.
MM	Membrane Mirror.
Latency	The time from the measurement of the wavefront to the correction being applied to the Deformable Mirror.
MM	Membrane Mirror.
RPC	Remote Procedure Call.
RT	Real Time, refers to the RT server or a real time process.
Rx	Receive.
SM	Steering Mirror.
TT	Tip/Tilt.
Tx	Transmit.
UI	User Interface.
WFS	Wavefront Sensor.
XUI	NICI's X-Windows User Interface.

Figure 21 Table of Acronyms and Definitions

7 NICI AO S/W Command Set

The following table contains a list of all the NICI commands accepted by the system. The syntax is given with the following abbreviations: ('d' means an integer value, 'f' means a float value)

Command	Syntax	Description
`apd.off.ceil`	`apd.off.ceil d`	Set the maximum value of counts in the APDs to complete the APD 'off' command
`cal.mean.period`	`cal.mean.period f`	Set the period in seconds to calculate the average values displayed in the XUI
`capture.enable`	`capture.enable on/off`	Start a capture
`capture.n`	`capture.n d`	Set the number of frames in the captured WFS buffer. Range is < 30000.
`capture.save`	`capture.save filename`	Save data stored in the capture buffer.
`dc.floor`	`dc.floor d`	Set the minimum value of counts for a valid extrafocal image
`freq`	`freq d`	Sets the frequency of membrane mirror
`get.lp.state`		
`lp.pause`	`lp.pause on/off`	Pauses the AO loops (on) or unpauses it (off)
`lp.state`	`lp.state idle/feedback/pr.imat/tt.imat`	Sets the loop state
`membrane`	`membrane stroke phase freq`	
`new.pr.flat`	`new.pr.flat`	Starts sequence to record a new set of average DM voltages
`peek.data`		Used to access system data via ic
`peek.var`		Used to access system variables via ic
`phase`	`phase d`	Sets the system phase lag between the sampling of the APDs and the membrane mirror commands
`pr.flat.ele`	`pr.flat.ele act value`	
`pr.flat.apply`	`pr.flat.apply`	sends the system 'flat' voltages to the DM
`pr.gain`	`pr.gain gain`	Sets the primary loop gain. This is the loop used in the DM control servo. Normally the gain is between 0.0 and 0.7
`pr.imat.act.stroke`	`pr.imat.act.stroke value`	Sets the actuator poke

		voltage used in the imat
pr.imat.coadds	pr.imat.coadds value	Sets the number of samples at each poke of the actuator used in the imat
pr.imat.cycles	pr.imat.cycles cycles	Sets the number of times to cycle thru the DM actuators in the imat
pr.imat.membrane.stroke	pr.imat.membrane.stroke stroke	Sets the membrane mirror stroke used in the imat
pr.imat.wait.count	pr.imat.wait.count value	Sets the number of samples to skip after poking an actuator before starting to record samples in the imat
pr.imat.save	pr.imat.save filepath	Save imat buffer in memory to disk (FITs file)
pr.inverse.ele	pr.inverse.ele I j value	Send a control matrix element to system memory
pr.out	pr.out act_I value	Set DM voltages
pr.servo	pr.servo [idle,feedback,imat]	Set DM servo state
pr.sign	pr.sign [-1,+1]	Set sign of gain on DM servo
stroke	stroke value	Set stroke of MM
lp.dm_frontel	lp.dm_frontel value	Set voltage of DM front electrode
lp.coadds	lp.coadds value	Set the number of wavefront samples (A and B) to average before sending a update to DM
tt.flat	tt.flat I value	Set the value of the TT flat voltages
tt.flat.apply	tt.flat.apply	Sets the TT actuator values to their respective 'flat' voltages
tt.gain	tt.gain value	Sets the gain of the TT servo loop
tt.imat.act.stroke	tt.imat.act.stroke value	Sets the TT actuator poke voltage used in the TT imat
tt.imat.coadds	tt.imat.coadds value	Sets the number of samples at each poke of the actuator used in the TT imat
tt.imat.cycles	tt.imat.cycles value	Sets the number of times to cycle thru the DM actuators in the TT imat

`tt.imat.membrane.stroke`	`tt.imat.membrane.stroke stroke`	Sets the membrane mirror stroke used in the TT imat
`tt.imat.wait.count`	`tt.imat.wait.count value`	Sets the number of samples to skip after poking an actuator before starting to record samples in the TT imat
`tt.out`	`tt.out [0,1] value`	Set the TT actuators value
`tt.servo`	`tt.servo [idle,feedback,imat]`	Set the state of the TT servo
`tt.sign`	`tt.sign [-1,+1]`	Set the sign on the TT servo gain
`ttdm.imat.save`	`ttdm.imat.save  filepath`	Save TT imat buffer in memory to disk (FITs file)
`ttdm.inverse.ele`	`ttdm.inverse.ele I j value`	Send a TT control matrix element to system memory
`omega.read`	`omega.read`	Starts the thread to read the temperature sensor in the APD box
`apd.init`	`apd.init`	Initializes the s/w for controlling the APD power
`bay.init`	`bay.init`	Initialize the software that controls the Baytech units

8 WFS Data

Some of the internal WFS data can be buffered and saved into a FITS file. The data is sequential and continuous. The WFS extra-focal images (A & B), deformable mirror outputs, and tip/tilt actuator outputs are by default saved.

8.1 Saving WFS Data

A WFS Data capture is initiated by issuing a ‘capture enable’ command. This can done by clicking the Capture.data button in the Engineering Tab of the XUI. During a WFS Data capture, memory in the NICIrt is filled with WFS data. Once the memory is full, its contents is transferred to NICIui’s memory. To save the data buffer you must then issue a Capture.save command. This can be accomplished from the Engr Tab of the XUI as well. Note that the file name must be manually set by the user.

8.2 WFS Data Format

The WFS data is saved into a Simple FITS file with dimensions equal to 85 x 4 x $N_{samples}$.

AXIS1: Sensor or Actuator channel
AXIS2: Intensity A, Intensity B, DM output signal (+-1.0), TT actuator output signal (+-1.0)
AXIS3: time sample

***IMPORTANT NOTE**: Currently the structure's 'TT' element contains the actual WFS signal (A-B)/(A+B) derived by the real-time computer. It is important to note that the loop averages the A and B intensity signals over a set of samples (variable lp.coadds=1-10) so the actual signal in the real-time computer and the signal derived by the getao routine are different (see below)!*

8.3 WFS Data IDL Routines

There is a set of IDL routines for reading the data files. These are contained in the file aoana.pro which by default is loaded and compiled when the NICI user starts IDL on NICIui. The procedure for reading the data files is called 'getao'. getao reads in the data file and then parses the data into an IDL structure. In addition to the saved quantities (intensities from each phase of the sampling (pA, pB) & output voltages (pout and tt)), getao also derives the dc = a+b, ac = a-b, the curvature signal = ac/dc, and the change in voltages (ddrive)).

The syntax is as follows:

```
IDL> c = getao(0)   ;; Looks for file c0000.fits in the current dir
IDL> c = getao("/home/mchun/NICI/data/040624/c0007.fits")
```

The routine getao parses the data into a structure. The structure has the form as follows:

```
   NEL              INT             85
   NSAMP            LONG              30000
   MFREQ            FLOAT           2000.00
   MPHASE           LONG            290000
   MSTROKE          LONG               800
   PA               FLOAT     Array[85, 30000]
   PB               FLOAT     Array[85, 30000]
   DC               FLOAT     Array[85, 30000]
   AC               FLOAT     Array[85, 30000]
   SIG              FLOAT     Array[85, 30000]
   POUT             FLOAT     Array[85, 30000]
   DDRIVE           FLOAT     Array[85, 30000]
   TT               FLOAT     Array[85, 30000]
```

The number of actuators is held in the element 'nel', the number of time samples is held in 'nsamp', and the membrane mirror parameters are held in 'Mfreq', 'mphase', and 'mstroke'. The frequency is in Hz and the sampling is sequential with no missing samples.

Note that the getao routine derives the DC, AC, SIG, and Ddrive values. The WFS signal for each WFS sample is SIG(sensor,t) = (A(sensor,t)-B(sensor,t))/(A+B). These WFS signals differ from those used in the real-time computer since it uses the average A and B values. Namely, the real-time computer uses SIG(sensor,t) = (<A(sensor,t-n:t)> - <B(sensor,t-n:t)>)/(A+B). The averaging of the intensity signals is a fixed boxcar (e.g. not a running average).

There are also a set of misc routines for plotting various parameters of the data structure. calcpsd is useful in that it calculates PSD of an given quantity. Syntax for it can be found by typing calcpsd without any parameters.

```
IDL> calcpsd
```

```
%calcpsd: Usage
  IDL> calcpsd, data, samplingfreq, psd, f, [idx0, idx1]
  IDL> calcpsd, sc.sig(0,*), sc.mfreq, psd, fpsd
```

```
IDL> calcpsd, c.tt, c.mfreq, p, f, 0, 60
```

This calculates the average PSD of the actual WFS signal (c.tt) for the inner 61 sensors. Returns the PSD in the variable p and the corresponding frequency (Hz) in the variable f.