University of Hawaii Hokupa'a-85 Adaptive Optics System User Manual

Revision 0.35 beta
July 1, 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 H85 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
0.35	Mike Thompson	Fixed order of chassis power and rt cold commands in cold start procedure.	7/1/04
0.34	Mike Thompson	Added Digi and Baytech configuration procedure.	7/1/04
0.33	Mike Thompson	Added XUI popup bug workaround. Added Startup and Shutdown Procedures. Cleaned up some XUI parameters, removed some of the no-need-to-answer issues. Removed Vaisala references. Changed default system parameter values.	6/23/04
0.32	Mike Thompson	Added Safety Interlock description and warning. Updated Operator, View Text, View Dia, and Imat Tabs to be running. Other minor clarifications.	6/16/04
0.31	Mike Thompson	More changes per review on 6/1 on rev 0.27. Added APD replacement section to Service and Calibration section. Finished updates to IMAT tab description. Added APD Power Down for idle time to APD Temperature warning. Updated XUI screen captures for IMAT, Eng, and Operator tabs and their descriptions.	6/8/04
0.30	Mike Thompson	Changes per review on 6/1 on rev 0.27. Added many descriptions to XUI View Tab Motor Status section and clarifications to XUI descriptions generally. Added bug descriptions for APD Power popup, Config. View popup. Reversed bit order of Counter Board dip switch settings.	6/2/04
0.27	Mike Thompson	Added XUI Imat Tab details. Verified Macro Tab Function buttons with Tony.	6/1/04
0.26	Mike Thompson	Added many screen captures of XUI to Observing and Engineering/IMAT sections. Added descriptions of Operator Tab popups.	5/26/2004
0.25	Mike Thompson	Changes per review of v0.24 w/ MC. Many clarifications of XUI Operator and Macro tab descriptions and details added. Explicitly marked some issues for MC with "TODO: MC". Added LLA and AO Bench to System Block Diagram. Labeled optical mount features.	5/25/2004
0.24	Mike Thompson	Added cabling diagram and descriptions. Added electronics enclosure to electronics diagram. Added board servicing procedure.	5/24/2004
0.23	Mike Thompson	Changed Ethernet Power Control name to Remote Power Control. Reviewed and updated mechanism functional descriptions. Expanded safety issues. Documented XUI Operator and Macro Tabs. Added FSM and TT electronics descriptions. Expanded introduction. Cleaned up software description.	5/19/2004
0.22	Mike Thompson	Corrections/changes per MC comments in v0.21. Labeled system CAD drawing. Corrected system block diagram connections. Added	5/12/2004

		Mechanism Functional Descriptions. Filled in cabling section.	
0.21	Mark Chun	Added words to sections 1 and 2.	5/11/2004
0.2	Mike Thompson	Removed performance section. Minor clarifications. Expanded mechanisms' functional description. Clarified some electronics functional descriptions, removed some low level details. Added high-level software diagram.	5/5/04
0.1	Mike Thompson	Initial revision aimed at capturing the structure of the document.	5/4/04

Table of Contents

1 Introduction 6
1.1 About Curvature AO Systems 6
2 H85 Instrument Overview 6
2.1 Optics Overview....7
2.2 Electronics Overview 10
2.3 Software Overview....11
3 Observing with H85 13
3.1 Procedural Overview....13
3.2 User Interface (XUI)....13
3.2.1 XUI Startup and Shutdown....13
3.2.2 XUI Operator Tab 14
3.2.2.1 XUI Operator Tab: System Status....15
3.2.2.2 XUI Operator Tab: Loop and Servo Control 16
3.2.2.3 XUI Operator Tab: Mechanism Status and Control 17
3.2.3 XUI View Tab 21
3.2.3.1 XUI View Tab Diagram (Dia) Display 21
3.2.3.2 XUI View Tab APD Sensor Text Display (Text)....23
3.2.3.3 XUI View Tab Loop Setup Display (Setup)....25
3.2.3.4 XUI View Tab Motor Status Display (Motor)....28
3.2.3.5 XUI View Tab XUI Configuration Display 31
3.2.4 Config. View Popup Window for the XUI Operator and View Tabs....32
3.2.5 XUI Macro Tab 33
3.2.6 Known XUI Issues and Resolutions 35
3.3 Observatory Interface 35
3.4 Startup Procedure....35
3.4.1 Warm Startup Procedure 36
3.4.2 Cold Startup Procedure 36
3.5 Setup Procedure....37
3.6 Instrument Configuration....37
3.7 Starting AO Correction....38
3.8 Dithering Procedure....38
3.9 Shutdown Procedure 38
3.9.1 End of Night Shutdown Procedure 38
3.9.2 End of Run Shutdown Procedure....38
3.10 Selected Commands....39
3.11 Mechanism Controls 39
3.12 WFS Data....39
3.13 IDL Commands / Data Reduction....39
4 Subsystem Descriptions 40
4.1 Optics 40
4.1.1 Optics Design Notes 40
4.1.2 Optics Functional Description 40

4.1.3 Additional Optics Documentation 41
4.2 Electronics Functional Description 41
4.2.1 Servers Description 42
4.2.1.1 RT Server 42
4.2.1.2 UI Server 43
4.2.2 Counter Electronics Functional Description 43
4.2.2.1 Counter Chassis 43
4.2.2.2 APDs 44
4.2.2.3 APD Power Supply 44
4.2.3 High Voltage Electronics Functional Description 45
4.2.3.1 HVA Chassis 45
4.2.3.2 High Voltage Power Supply (HVPS) 46
4.2.3.3 High Voltage Safety Interlock 46
4.2.4 Miscellaneous Components 46
4.2.4.1 Field Steering Mirror and Controller 46
4.2.4.2 Tip/Tilt Platform and Controller 46
4.2.4.3 Ethernet Switch 46
4.2.4.4 Digi Portserver 46
4.2.4.5 Remote Power Control 47
4.2.5 APD Temperature Sensor 47
4.2.6 Electronics Design Notes and History 47
4.3 H85 Software Functional Description 48
4.3.1 Software Features and Design Notes 48
4.3.2 Loop Description 48
4.3.2.1 Module Loading 49
4.3.2.2 Common Tasks 49
4.3.2.3 Loop FSM 49
4.3.3 XUI Engineering Interface Tab 49
4.3.4 XUI Interaction Matrix Tab 51
4.3.4.1 IMAT Status and Parameters 51
4.3.4.2 IMAT Control 52
4.4 Mechanisms Functional Description 54
4.4.1 Fiber Calibration Source Mechanism Description 54
4.4.2 Field Steering Mirror Mechanism Description 54
4.4.3 WFS Filter Wheel Mechanism Description 54
4.4.4 SCI Filter Wheel Mechanism Description 55
4.4.5 Camera Focus Stage Mechanism Description 55
4.5 Cabling 55
4.5.1 HVA Cables 56
4.5.2 APD Power Cables 56
4.5.3 Utility Cable 56
4.5.4 APD Coax Cables 56
4.5.5 WFS Fiber Cables 57
4.5.6 Newport FSM Cables 57
4.5.7 Fiber Calibration Source Power/Control 57
5 Basic Troubleshooting 57
6 Service & Calibration 57
6.1 Calibration: Generating IMATs 57
6.1.1 Primary (DM) IMAT Generation with the XUI 57
6.1.2 Tip/Tilt Platform IMAT Generation with the XUI 58
6.2 Servicing Electronics Boards 58
6.3 APD Module Replacement 59
6.3.1 Swapping to a Spare APD Module 59
6.3.2 Replacing an APD Module 60
6.4 Configuring the Baytech Remote Power Control Modules 61
6.5 Configuring the Digi Portserver 62

7 Safety Issues 63
7.1 APD Overexposure 63
7.2 APD Temperature 63
7.3 High Voltage and High Current Areas 63
7.4 Non-standard VME cards 64
8 Acronyms and Definitions 65

List of Figures and Tables

Figure 1 CAD rendering of H85 attached to the Gemini ISS Port 4 (AO Port). 7
Figure 2 Science Path Optics 8
Figure 3 Wavefront Sensor Path Optics from Beamsplitter to Steering Mirror 9
Figure 4 Wavefront Sensor Path Optics from Steering Mirror to Lenslet Array 9
Figure 5 H85 System Block Diagram 11
Figure 6 XUI Operator Tab 15
Figure 7 XUI Operator Tab FSM Popup Window 18
Figure 8 XUI Operator Tab APD PWR Popup Window 20
Figure 9 XUI Operator Tab A/C PWR Popup Window 21
Figure 10 XUI View Tab Diagram (Dia) Display 22
Figure 11 XUI View Tab APD Sensor Text Display (Text) 25
Figure 12 XUI View Tab Loop Setup Display (Setup) 26
Figure 13 XUI View Tab Motor Status Display (Motor) 31
Figure 14 XUI View Tab XUI Display (Status) 32
Figure 15 XUI Operator and View Tabs Configure View Popup Window 33
Figure 16 XUI Macro Tab 34
Figure 17 How to Close Popup Windows 35
Figure 18 Table of Default System Setup Parameters 37
Figure 19 Table of Guide Star Brightness vs. WFS Filters 38
Figure 20 CAD drawing of an optical mount 40
Figure 21 Block Diagram of H85 High Voltage and Counter Electronics Components 42
Figure 22 Counter Chassis Slot Assignments, Corresponding APDs, and Counter Board Settings 44
Figure 23 HVA Chassis Slot Assignments, Corresponding DM Actuators, and HVA Board Settings 45
Figure 24 Table of Remote Power Control Port Assignments 47
Figure 25 High Level Loop Diagram 49
Figure 26 XUI Engineering Tab (Eng) 50
Figure 27 XUI IMAT Tab 53
Figure 28 System Level Cabling Diagram 56
Figure 29 Table of Acronyms and Definitions 65

1 Introduction

This is the User Manual for Gemini's Hokupa'a 85 Element curvature-based Adaptive Optics system (H85). This manual provides an overview of the instrument, optical layout, descriptions of the major components, instructions for observing with H85, setup procedures, a list of software commands, and basic troubleshooting.

Section 2 provides a general overview of the system, a CAD rendering of the instrument, an overview of H85's optics, an Electronics overview, and an overview of H85's software.

Section 3 discusses how to observe with H85. This section should be read by observers.

Section 4 provides detailed functional description of H85's subsystems. This section is relevant for engineers, operators, and technicians wishing to understand the low level implementation details of H85's optics, electronics, software, mechanisms, system cabling, and mechanics.

Section 5 describes basic troubleshooting of the instrument. This section should be read if problems with the instrument are suspected.

Section 6 describes service and calibration procedures.

Section 7 discusses safety issues with H85. This section should be read by everybody working with H85.

Section 8 provides a list of definitions and acronyms for terms used throughout this document.

1.1 About Curvature AO Systems

(TODO: MC - An overview of curvature AO systems. Terms that should be defined: DC, AC, I_1, I_2, MM phase, stroke, phase A/B, pr.flat, tt.flat, IMAT, control matrix.)

2 H85 Instrument Overview

H85 consists of various subsystems: optics, electronics, software, mechanisms, cabling, and mechanics. Users wishing to get an overview of the instrument and its subsystems may find this section useful. An overview is provided for each of these subsystems in the immediately following sections. Users wishing to understand more intricate details of the subsystems should refer to Section 4 Subsystem Descriptions.

H85 is an 85 element curvature adaptive optics system. The instrument consists of 4 major assemblies and a standalone User Interface server. These assemblies are the APD Enclosure, Optical Bench and Enclosure, Thermal Electronics Enclosure, and instrument support frame. 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. The Optical Bench and Enclosure contains all of the optics, notably the deformable mirror. The Thermal Electronics Enclosure contains H85's electronics. The instrument support frame is the structure to which the other major assemblies are mounted and provides a means for attaching the instrument to the telescope.

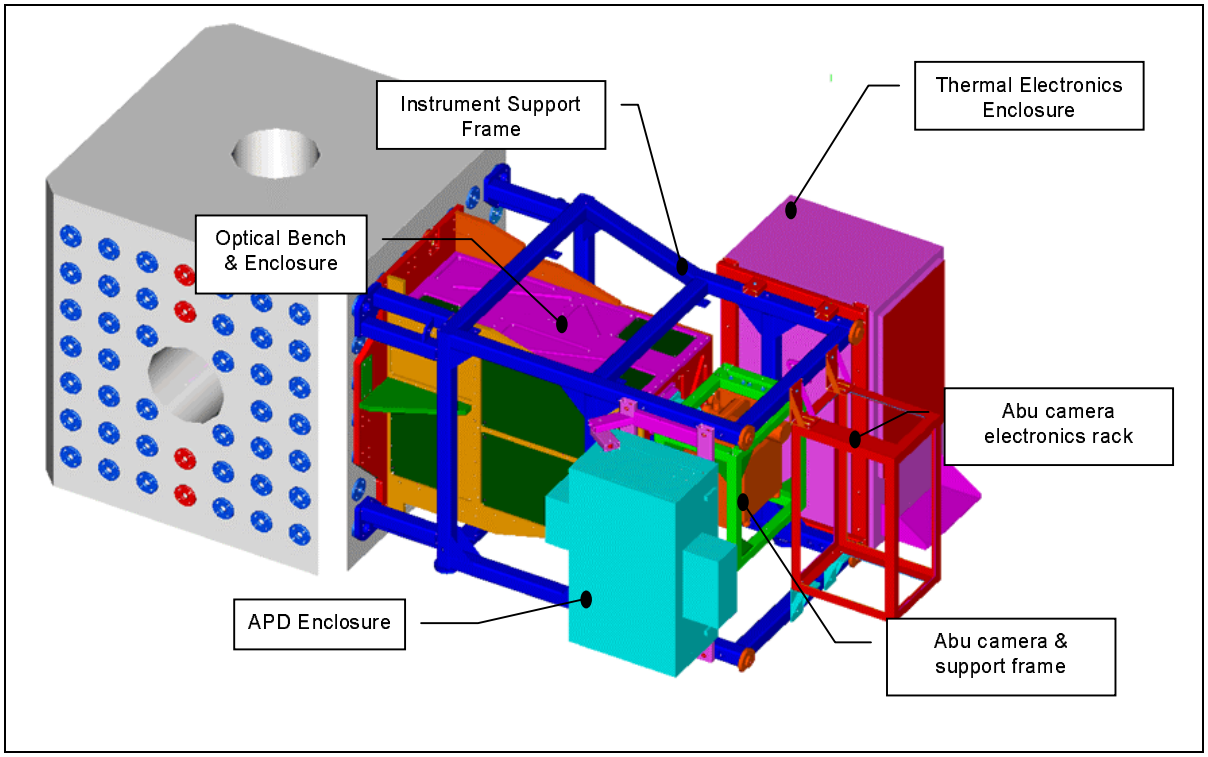


Figure 1 CAD rendering of H85 attached to the Gemini ISS Port 4 (AO Port).

The multicolor enclosure is the optical bench and enclosure. The Cyan box is the APD enclosure. The Pink box is the thermal electronics enclosure. The green frame, orange box, and red frame are the Abu camera, support frame, and electronics rack. A support frame (blue) holds the electronics enclosures.

The major functional components of H85 are an 85 element curvature wavefront sensor (WFS), a curvature deformable mirror (DM), Real-Time (RT) Linux server, User Interface (UI) server, custom electronics, and serially controlled mechanisms.

All of the control and status of H85 is graphically available to the user through the X-Windows User Interface (XUI).

2.1 Optics Overview

The H85 optical specifications were derived assuming that the system-wide non-common path errors are approximately half the expected atmospheric residual. This results in a non-common path wavefront error less than 90 nm rms.

The optical components are split into those within the science channel (common path and science path) and those within the wavefront sensor channel (non-common path). All optical surfaces, except the two off-axis parabolas, are spheres or flats.

The optical paths are shown in Figure 2 - Figure 4. The science beam enters H85 and focuses approximately 30cm inside the ISS interface. The f/16 beam is collimated by the OAP1 and the telescope's secondary is imaged to the location of the deformable mirror. The DM consists of a custom 86-element curvature mirror on a tip/tilt platform. All adaptive corrections are made by

the deformable mirror while slow telescope guide errors are compensated by the tip/tilt platform. The second OAP creates an f/32 beam for the science camera. In order to minimize the space envelope of the instrument we have included three fold flats. For mirrors Fold1 and Fold2 pass the optical beam through the optical bench onto the wavefront sensor side of the bench. A calcium-fluoride beam splitter passes light with wavelengths greater than 1μm to the science instrument. A final fold mirror folds the beam downward to accommodate Abu's requirement of being upward looking.

The wavefront sensor path (shown in Figures 2 and 3) consists of acquisition optics and a curvature wavefront sensor. The CaF2 beam splitter reflects light with wavelengths shorter than 1μm. A one arcminute diameter field of view is passed and collimated by the wavefront sensor's collimator. A field steering mirror (FSM) at a pupil position is used to select the guide star field of view. After the steering mirror is a curvature wavefront sensor. An approximately 5 arcsecond field is passed roughly collimated from the FSM to a "Power to f/60" mirror. This mirror creates an f/60 beam for the membrane mirror (MM). From the MM to the LLA there are three weak spherical mirrors that resize and re-image the pupil to the front of the LLA. 85 optical fibers at the rear of the LLA pass light from the LLA to the APDs in the APD enclosure.

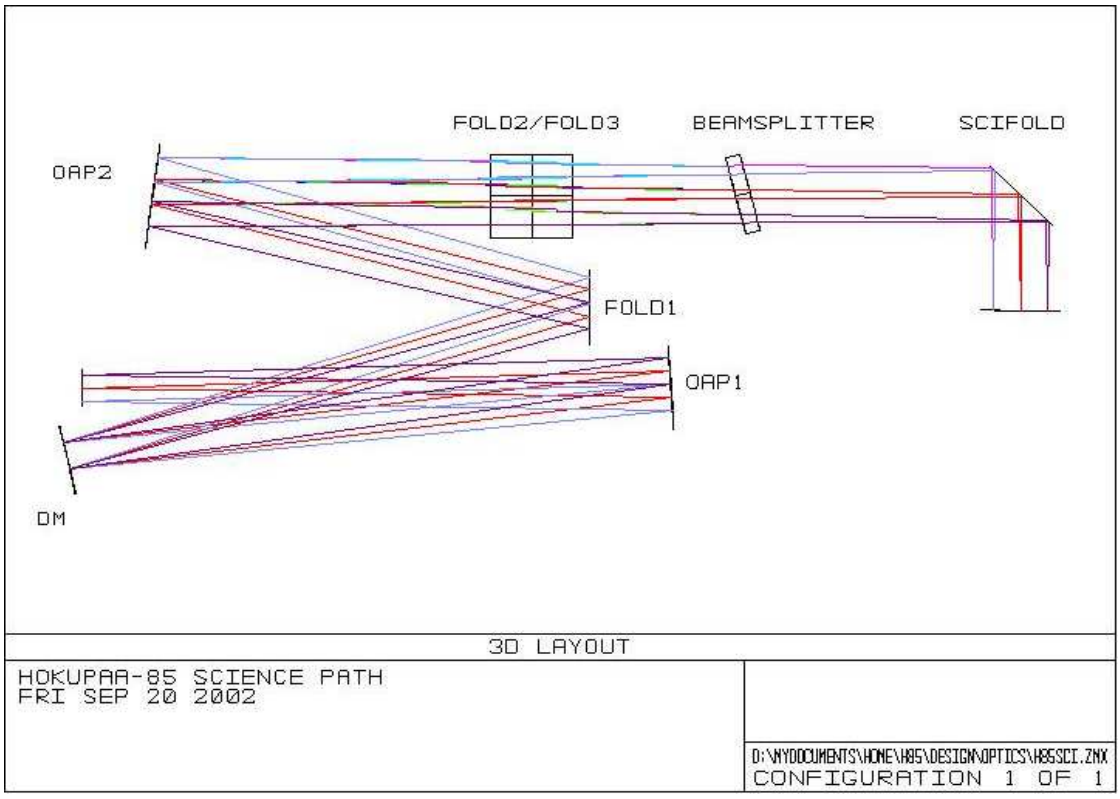


Figure 2 Science Path Optics

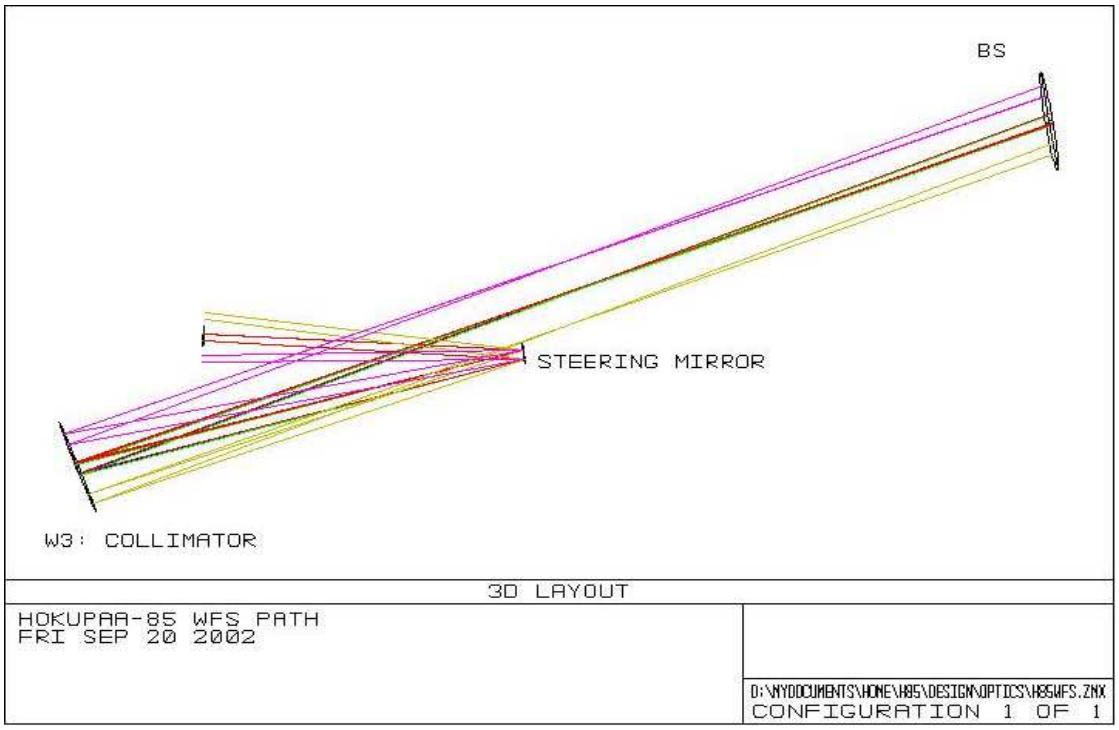


Figure 3 *Wavefront Sensor Path Optics from Beamsplitter to Steering Mirror*

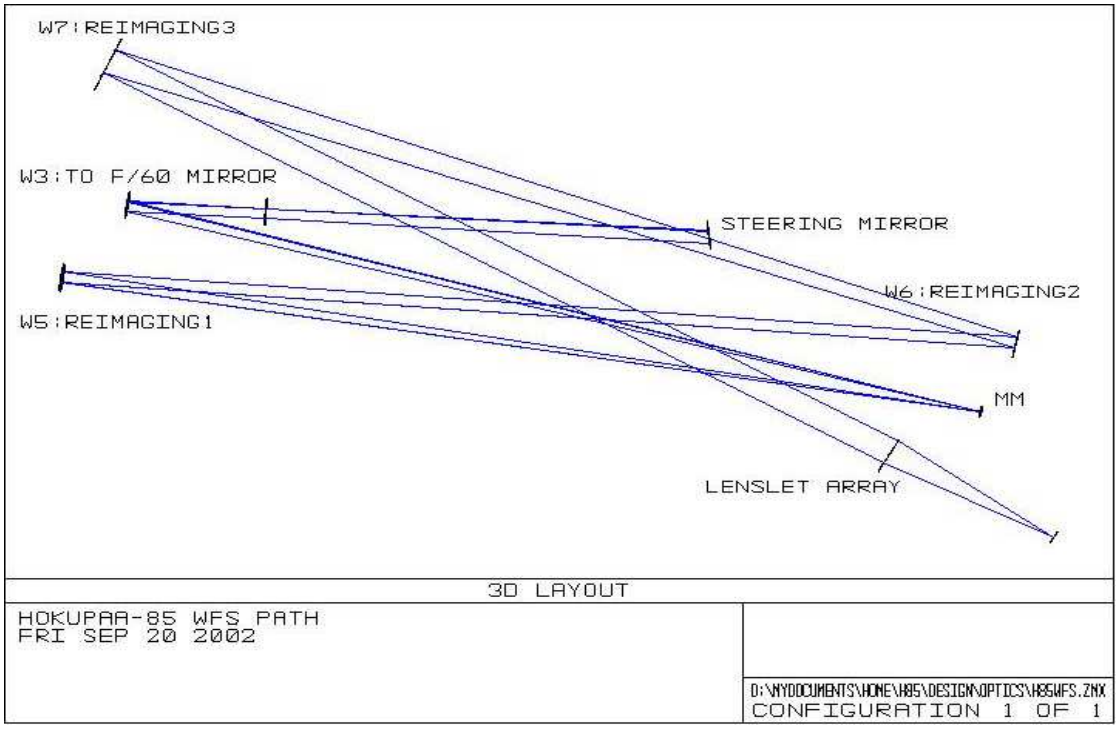


Figure 4 *Wavefront Sensor Path Optics from Steering Mirror to Lenslet Array*

The sizes are driven by the following factors:
(1) A square science FOV (30” x 30”)
(2) WFS acquisition FOV (r=30”)

(3) WFS FOV (r=2" limited by membrane mirror)
(4) By the shear in the beam footprint after the membrane mirror when there is a tilt error

The size of the LLA ultimately limits the maximum allowable residual tip/tilt error. For an extra-focal distance of 0.5 meters (radius of curvature of ±700mm at membrane mirror) the beam footprint on the entrance of the LLA is not vignetted for wavefront tilts less than 0.50 arcseconds (LLA Ø40.0mm).

2.2 Electronics Overview

The system architecture of H85 is briefly described in this section. See the diagram below for a graphical depiction of this description.

The major electronics parts of the system are the RT Server, Local MFB, (Remote) HVA Chassis and (Remote) Counter Chassis, a steering mirror PZT controller, and a terminal server (DIGI Portserver). All of these subsystems reside in the electronics thermal enclosure. The optical components that are directly controlled by the electronics are the Wavefront Sensor (WFS), the Membrane Mirror (MM), Deformable Mirror (DM), a tip/tilt platform, and Field Steering Mirror (FSM).

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 a terminal server. These auxiliary signals are generated by the user via the User Interface.

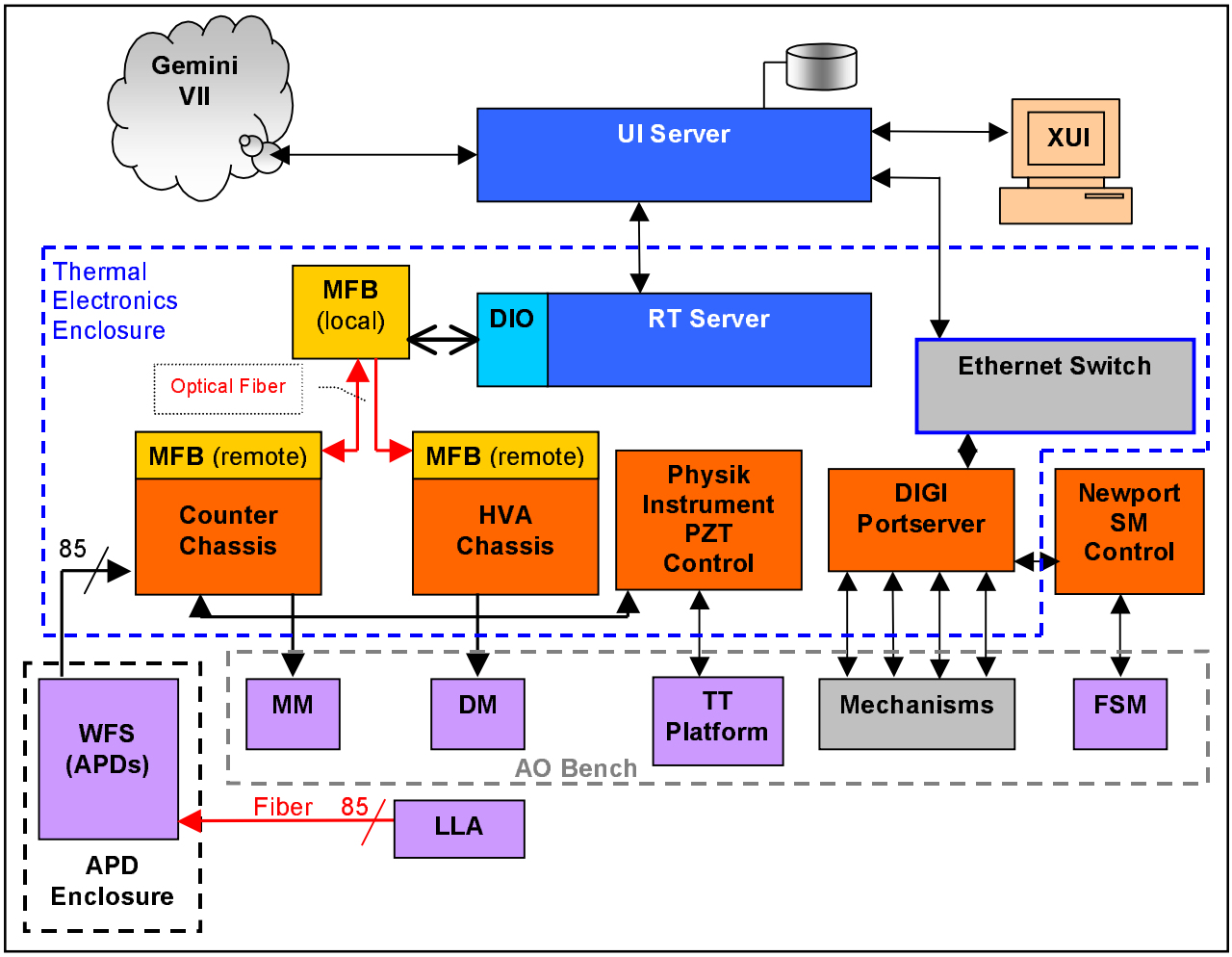


Figure 5 H85 System Block Diagram

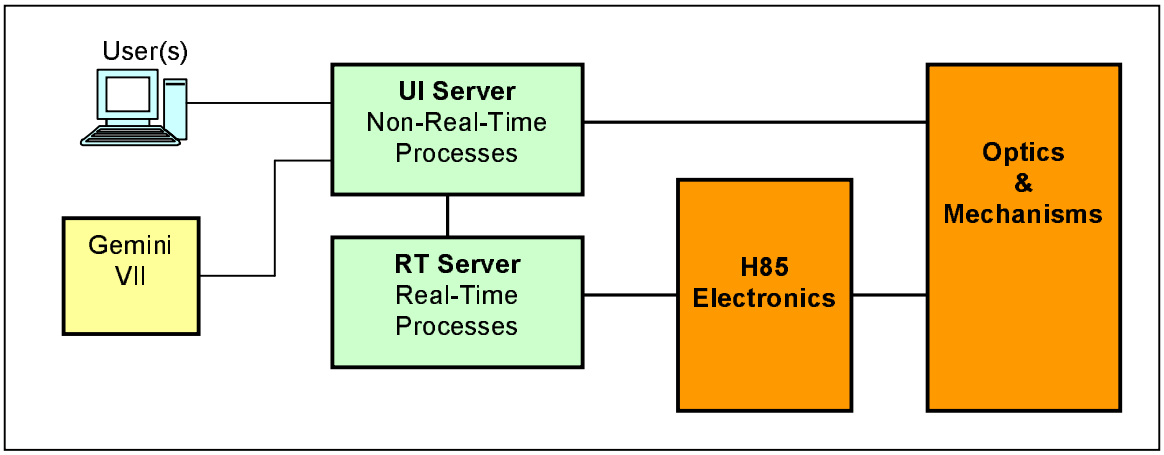
2.3 Software Overview

The H85 software is split into time critical tasks and non-time-critical tasks. The real-time processes run on an RTLinux dual-Athlon computer (RT Server). The only real-time processes are the servo loop and the digital I/O. All other tasks are considered non-real time. The non-RT processes include the User Interface, mechanism control, target acquisition, data telemetry, and off-loading to the telescope pointing. These 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. For more information on the RT and UI servers, and their operating systems, see Section 4.2.1 Servers Description.

An X-Windows User Interface (XUI) provides control for all AO system parameters, real-time (correction) functions, system setup, system control, mechanisms, diagnostics, and provides graphical feedback of system status. The XUI is described in Section 3.

Communication with the Gemini Observatory Control System is handled via the Gemini Visitor Instrument Interface (VII). This interface is used for off-loading of pointing/guide signals and dithering control.



Mechanism control is another non-RT process. There are 5 mechanisms implemented in H85.

- Fiber Calibration Source
- Field Steering Mirror Controller
- WFS Filter Wheel (2" filters)
- SCI Filter Wheel (3" filters)
- Camera Focus Stage

All of the mechanisms except for the Field Steering Mirror are controlled by Animatics Smart Motors. All of the mechanisms have their state displayed graphically in the XUI. The XUI provides a means for users to set the positions of the mechanisms. Each moving mechanism has software limits programmed in.

3 Observing with H85

This section describes how to observe with H85. This information is meant to convey what observers need to know and do for observations.

3.1 Procedural Overview

TODO: a summary of the observational procedures. Maybe include operator preparation summary too. Functionally, what is done? Describe basic startup and shutdown in words.

3.2 User Interface (XUI)

This section describes the X-Windows User Interface (XUI) limited in scope to the direct needs of an observer. Greater detail on the engineering and calibration functions of the user interface can be found in Section 4.3 H85 Software Functional Description. The XUI provides a graphical interface to H85 and permits control over all functions, configuration parameters, and mechanisms and provides feedback on the state of the mechanisms, DM, 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 described in this section. The Imat and Engineering tabs are not used by observers and are described in Sections 4.3.3 and 4.3.4. 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. A list of commands can be found in Section 3.10 Selected Commands.

(TODO: MC TT diagrams label the axes E-W and N-S. Probably these should be changed to X, Y in the diagrams then in the descriptions.)

3.2.1 XUI Startup and Shutdown

To start the XUI first open separate windows (x-terms) and log on to the UI (h85ui) and RT (h85rt) servers (login: h85, passwd: ao_h85). 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.

h85rt: /home/h85/h85/ao/scripts/rt cold (Only for cold starts.)
h85rt: /home/h85/h85/ao/scripts/rt start
h85ui: /home/h85/h85/ao/scripts/ui start

The UI script will 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.

h85ui: /home/h85/h85/ao/xui

Next an initialization macro must be run from the XUI. 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 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. Then the rt script must be run on the RT server with the stop option. The order is important.

h85ui: /home/h85/h85/ao/scripts/ui stop
h85rt: /home/h85/h85/ao/scripts/rt stop

To close 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.

3.2.2 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 H85. 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 3.2 above.

The Config. View button opens a popup window which permits selection of the diagrams displayed in the Operator Tab. The Configure View popup window is shown and described in Section 3.2.4.

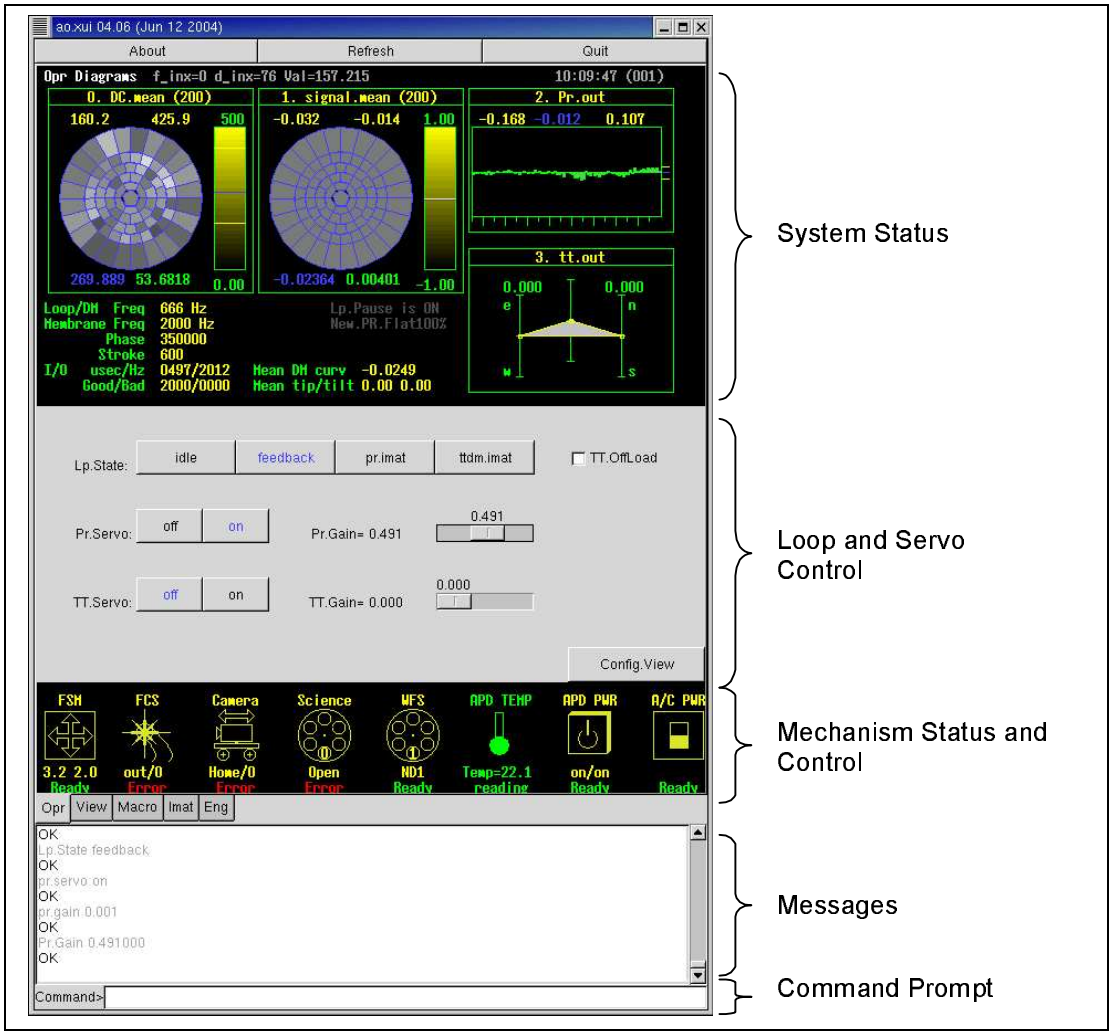


Figure 6 XUI Operator Tab

3.2.2.1 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. 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.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.

- **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 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 mirror along the east-west and north-south 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 1000 - 2000 Hz, maximum is 3500 Hz.
  - **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 which corresponds to extra-focal distance. (TODO: MC - add info on converting stroke to extra-focal distance)
- **I/O Status**
  - **usec/Hz**: Diagnostic information for I/O from the RT server. Generally this is engineering diagnostic information and is not relevant to instrument users.
  - **Good/Bad**: Diagnostic information for I/O from the RT server. Generally this is engineering diagnostic information and is not relevant to instrument users.
- **Lp.pause**: Indicates if the loop state (Lp.State) is paused (on = idle) or not paused (off = feedback).
- **New.PR.Flat**: Indicates the percentage of completeness of a primary (DM) Flat voltage calculation. Under normal operation PR flats should 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. When this number approaches +1 or -1, focus offloading should be initiated. The offloading can be accomplished through the VII.
- **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. When either of these numbers approaches +1 or -1, pointing offload to the telescope should be initiated. The offloading can be accomplished through the VII.

3.2.2.2 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(t) = V(t - 1) + Pr.Gain * Error

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.

- **Lp.State**: Controls the state of the loop thread.
  - **idle**: When this button is selected H85 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. Offloading is communicated to the telescope through the Gemini VII.
- **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.

3.2.2.3 XUI Operator Tab: Mechanism Status and Control

This part of the XUI Operator Tab provides the status and control of mechanisms, component 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 H85's hardware components.

- **FSM**: Clicking this icon opens a popup window to control the Field Steering Mirror for acquiring the guide star. This icon also displays the current values sent to the FSM which are offsets in arcseconds on the sky. The axes, in the instrument coordinate system (X, Y), are displayed below the icon. This popup window is shown in Figure 7. In the popup, users may step the mirror in the 4 directions at a step size specified in arcseconds by clicking the -X, X, -Y and Y buttons. Users may also specify a position of the FSM by entering the coordinates and clicking the SMirror.pos button. (TODO: MC during commissioning map out X, Y.)



Figure 7 XUI Operator Tab FSM Popup Window

- **FCS**: Clicking this icon opens a popup menu to control the Fiber Calibration Source. The source can be turned on and off and the slide mechanism controlled to move the source in and out of the beam. This icon also displays the position of the source (in or out of beam and a number of steps from the parked position), the state of the mechanism, and indicates if the fiber source is on or off. The popup menu options are:
  - **Parked**: Clicking this option parks the FCS.
  - **In**: Clicking this option moves the source to the on-axis position.
  - **fcs.init**: Clicking this button initializes software communication with the FCS. This should be done after boot-up and to troubleshoot mechanism communication errors.
- **Camera**: Clicking this icon opens a popup menu to control the Camera Focus Stage. The icon also displays the position of the stage and an indication of the state of the mechanism. The popup menu provides positions for varying focus locations depending on the target spectrum. **These settings, which may look like filter settings, do not correspond to the filters in the Science Filter Wheel**. The popup menu options are:
  - **Home**: Default position. (TODO: MC define position at commissioning)
  - **J**: (TODO: MC define position at commissioning)
  - **H**: (TODO: MC define position at commissioning)
  - **K'**: (TODO: MC define position at commissioning)
  - **Br-Gamma**: (TODO: MC define position at commissioning)
  - **Br-Alpha:** (TODO: MC define position at commissioning)
  - **L:** (TODO: MC define position at commissioning)
  - **cfs.init:** Clicking this button initializes software communication with the Camera Focus Stage mechanism. This should be done after boot-up and to troubleshoot mechanism communication errors.
- **Science**: Clicking this icon opens a popup menu to control the Science Filter Wheel. Any filter can be selected. This icon also displays the current position of the wheel and the state of the mechanism. The popup menu options are:
  - **Open**: The default position.

  - **User1**: (TODO: define)
  - **User2**: (TODO: define)
  - **User3**: (TODO: define)
  - **User4**: (TODO: define)
  - **User5**: (TODO: define)
  - **sci.init**: Clicking this button initializes software communication with the Science Filter Wheel mechanism. This should be done after boot-up and to troubleshoot mechanism communication errors.
- **WFS**: Clicking this icon opens a popup menu to control the WFS Filter Wheel. Any filter can be selected. This icon also displays the current position of the wheel and the state of the mechanism. The popup menu options are:
  - (**TODO**: **MC -** You specified a label change for ND1 - ND4 to Filter1 - Filter4 to avoid ND density confusion. They're spec'd like this in the Mechanism Description section. These labels in the popup should be changed.)
  - **Opaque**: The default position.
  - **ND1**: (TODO: define filter, change label.)
  - **ND2**: (TODO: define filter, change label.)
  - **ND3**: (TODO: define filter, change label.)
  - **ND4**: (TODO: define filter, change label.)
  - **open**: (TODO: define filter, change label.)
  - **wfs.init**: Clicking this button initializes software communication with the WFS Filter Wheel mechanism. This should be done after boot-up and to troubleshoot mechanism communication errors.
- **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. 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. Consider powering down the APDs in the yellow range and allowing them to cool. 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 the APDs should be powered down immediately and allowed to cool before further operation.
- **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. Software will also prohibit powering off the APDs if the photon counts on the APDs in not near 0. 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 check the power status in the Operator Tab. If the expected power state is not indicated click the APD.Power.Init button in the APD Power popup and set the desired power state again. The popup window is shown in Figure 8.



Figure 8 XUI Operator Tab APD PWR Popup Window

- **A/C PWR**: Clicking this icon opens a popup window that provides control over the two Remote Power Control modules. This permits power control over the various electronics components in H85. 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. The popup window is shown in Figure 9.

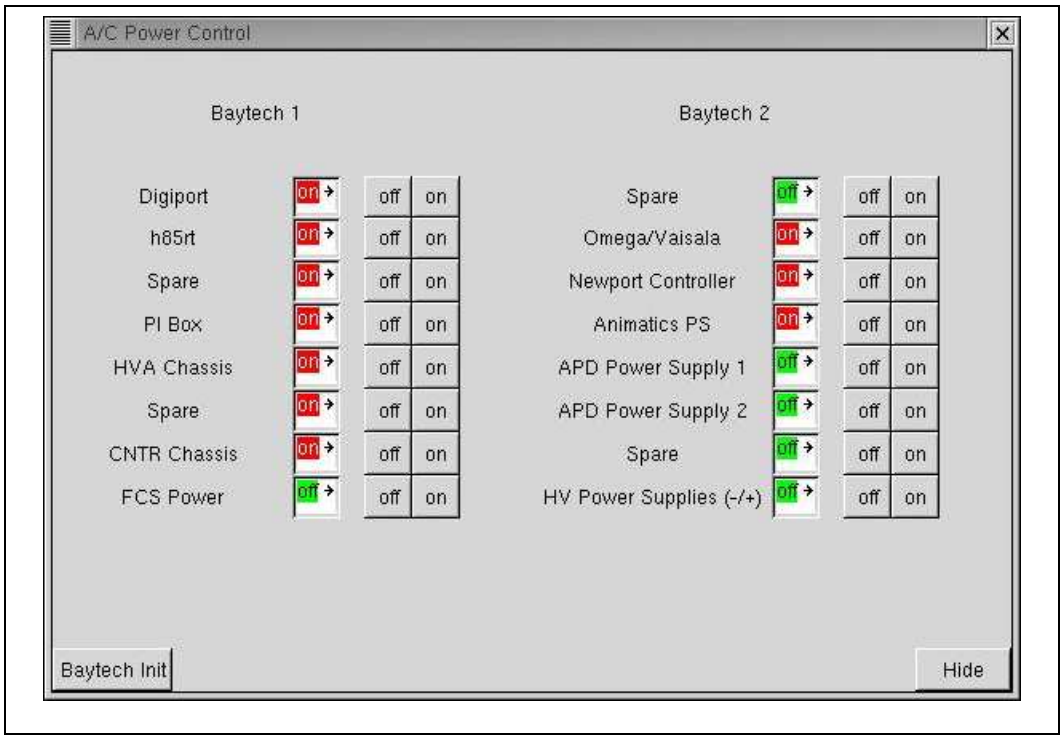


Figure 9 XUI Operator Tab A/C PWR Popup Window

3.2.3 XUI View Tab

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 3.2.

3.2.3.1 XUI View Tab Diagram (Dia) Display

The Diagram Display of the View Tab shows a collection 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 10.

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 3.2.4

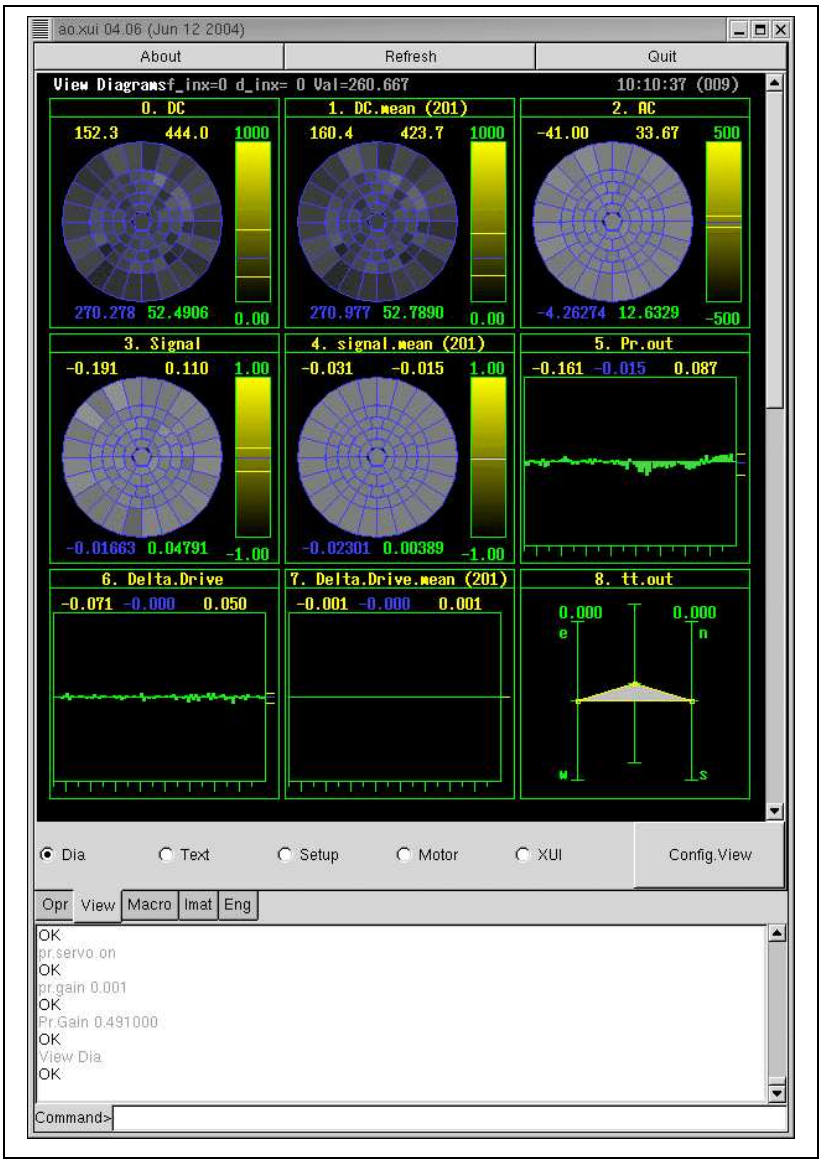


Figure 10 XUI View Tab Diagram (Dia) Display

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.

3.2.3.2 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 11.

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 3.2.4

- **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 3.2.4. The number of samples used to calculate the mean is displayed below the bottom row of the display.

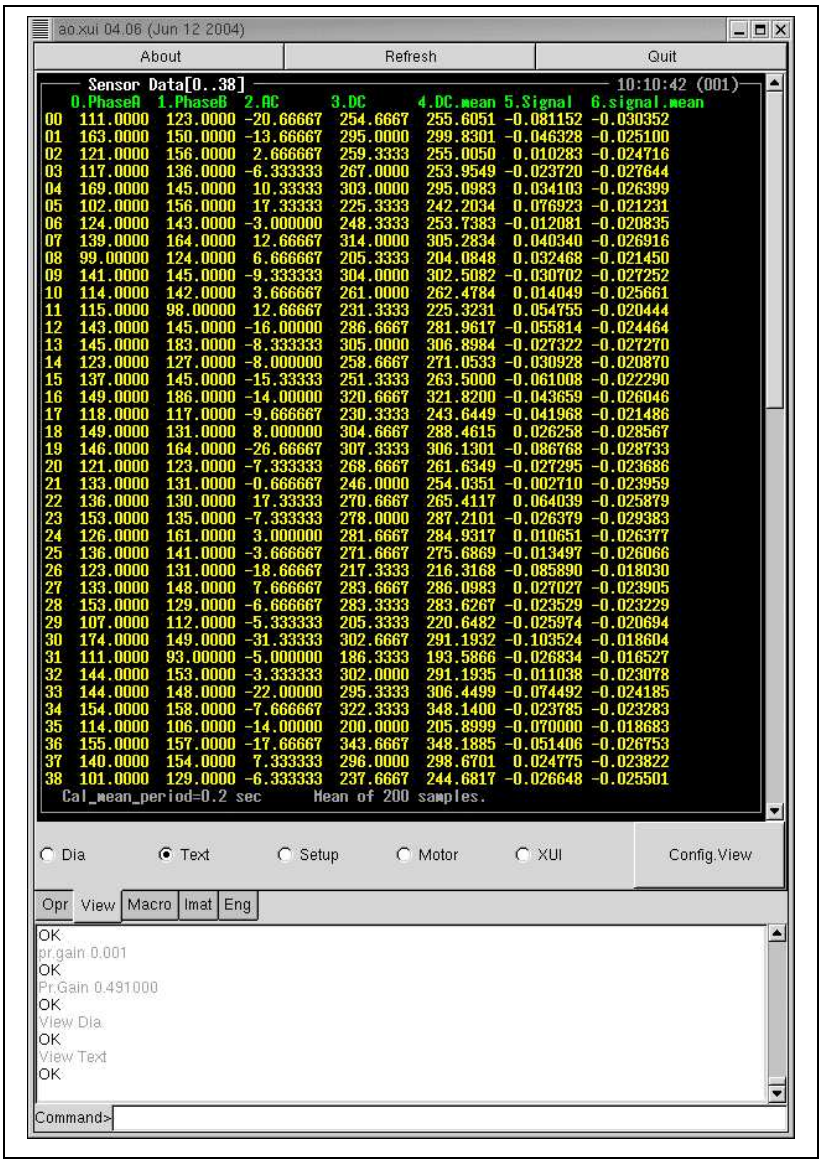


Figure 11 XUI View Tab APD Sensor Text Display (Text)

3.2.3.3 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 12.

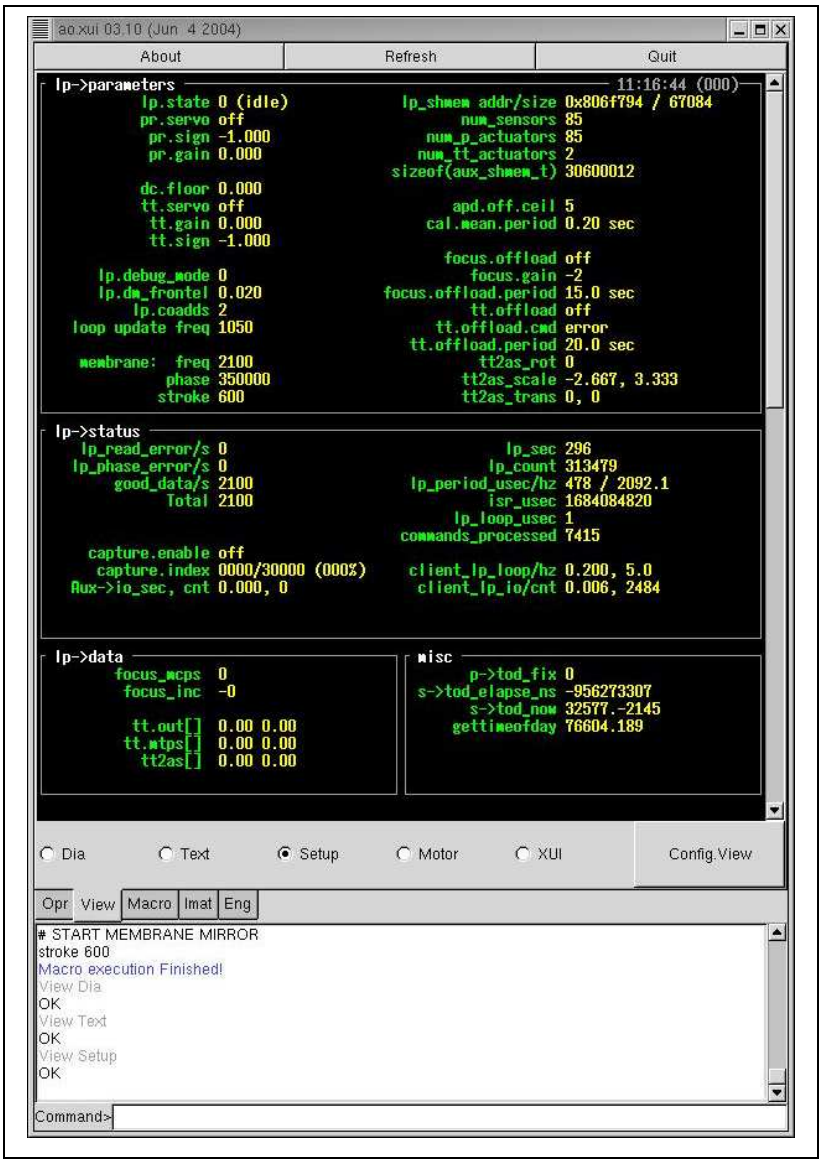


Figure 12 XUI View Tab Loop Setup Display (Setup)

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 3.2.2.2. 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
  - **idle**: The AO system is not calculating corrections.
  - **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.
  - **pr.imat**: Indicates that an IMAT for the primary (DM) is being calculated.
  - **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 APD.
- **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 cycle implies one phase A and one phase B sample per DM correction signal update. 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.

3.2.3.4 XUI View Tab Motor Status Display (Motor)
The Motor Status window (Status) displays status information for all of the H85 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 Figure 13.

WFS Filter Wheel and Science Filter Wheel:

- **state**: Indicates what the motor for the wheel is doing - ready, busy (moving), or error.
- **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 mechanism are simulated (1) or actually issued to the mechanism (0).
- **rc**: On mechanism errors, indicates a software error code.
- **slot**: Indicates which position number in the wheel is currently in the beam.
- **filter**: Indicates which filter position is in the beam.

Fiber Calibration Source:

- **state**: Indicates what the motor for the wheel is doing - ready, busy, or error.
- **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.
- **position**: Indicates the position of the fiber source. The fiber may be at the *Parked* position, *In* the beam at the entrance focus, or at an arbitrary position.
- **laser**: Indicates whether the laser source is off or on.
- **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.
- **acc**: A motor drive parameter that indicates the acceleration of the mechanism.
- **max vel**: A motor drive parameter that indicates the maximum velocity of the slide when moving.
- **bklash**: A motor drive parameter that indicates the backlash of the mechanism.
- **isw**: A low-level diagnostic indicator. Not relevant to instrument users.
- **home**: Indicates the encoder position for home.
- **limits**: Indicates the negative and positive software encoder limits of mechanism movement.
- **Port**: Indicates the port through which the mechanism is connected to the Digi Portserver.

Camera Focus Stage:

- **state**: Indicates what the motor for the wheel is doing - ready, busy, or error.
- **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.
- **pos**: Indicates the encoder position of the CFS.
- **svalue**: A low-level diagnostic indicator. Not relevant to instrument users.
- **sim**: Indicates whether commands to the mechanism are simulated (1) or actually issued to the mechanism (0).
- **rc**: On mechanism errors, indicates a software error code.
- **acc**: Indicates the acceleration of the slide when moved. Don't change this variable.
- **max vel**: Indicates the maximum velocity of the slide when moving. Don't change this variable.
- **size**: A low-level motor parameter. Not relevant to instrument users. Don't change this value.
- **bklash**: Indicates the backlash of the mechanism when stopped.
- **isw**: A low-level diagnostic indicator. Not relevant to instrument users.
- **home**: Indicates the encoder position for the home position.

- **limits**: Indicates the negative and positive limits of mechanism movement.
- **Port**: Indicates the port through which the mechanism is connected to the Digi Portserver.

Field Steering Mirror:

- **state**: Indicates what the mechanism is doing - ready, busy, or error.
- **function**: This is an internal software bookkeeping parameter and should be ignored by instrument users.
- **sim**: Indicates whether commands to the mechanism are simulated (1) or actually issued to the mechanism (0).
- **rc**: On mechanism errors, indicates a software error code.
- **tel_x**: Indicates the position in arcseconds of the FSM's X axis in the telescope coordinate system.
- **tel_y**: Indicates the position in arcseconds of the FSM's Y axis in the telescope coordinate system.

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 3.2.2.3).
- **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.

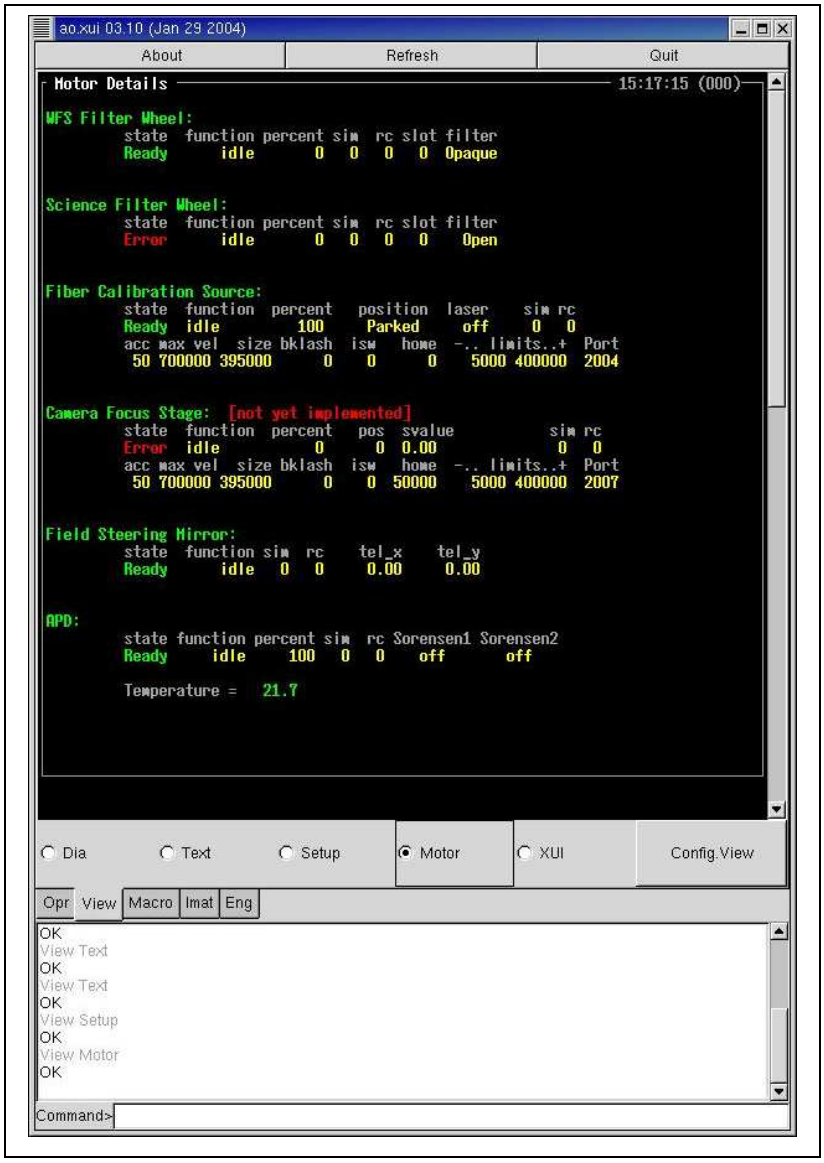


Figure 13 XUI View Tab Motor Status Display (Motor)

3.2.3.5 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 14.



Figure 14 XUI View Tab XUI Display (Status)

3.2.4 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 Figure 15.

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 3.2.1) 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.

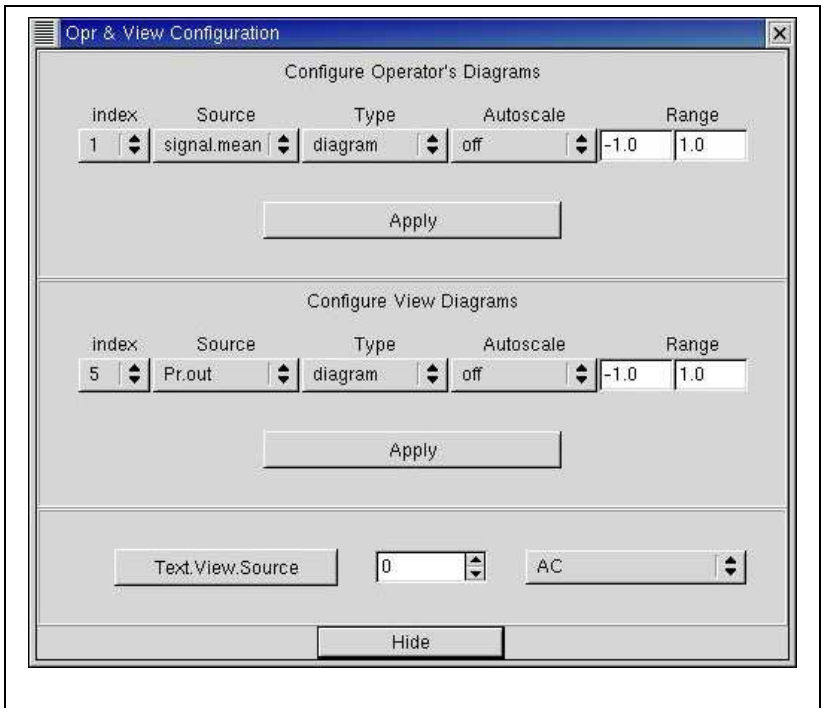


Figure 15 XUI Operator and View Tabs Configure View Popup Window

3.2.5 XUI Macro Tab

The XUI Macro Tab provides a means for creating and executing command macros. Macros are stored in text files that contain H85 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.

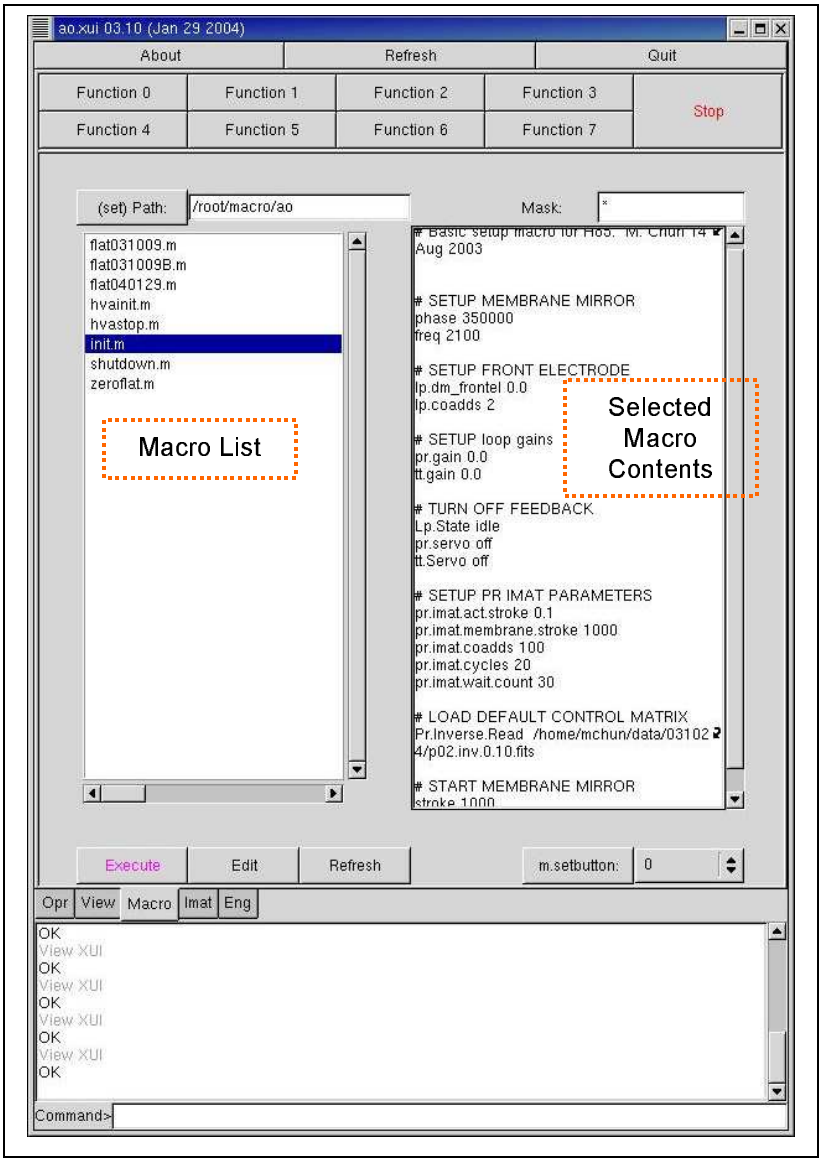


Figure 16 XUI Macro Tab

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. Note that blank lines in macro files generate error messages in the Messages window which can be ignored. The **Edit** button opens the currently selected macro file in the gedit text editor. Of course they can be edited outside of the XUI. 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 minimum set of macros listed below. Other macros, especially for flats, may be included.

- **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.

3.2.6 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 which 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.

h85ui: /home/h85/h85/ao/xui

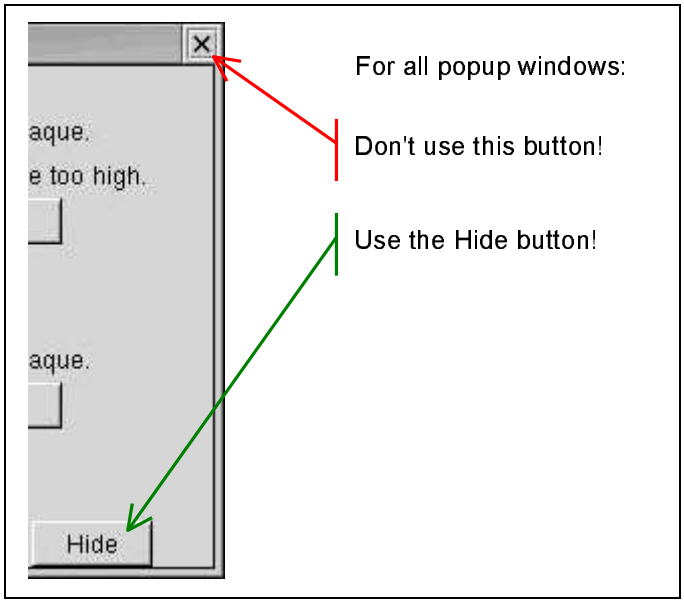


Figure 17 How to Close Popup Windows

3.3 Observatory Interface

The interface of H85 to the Gemini Observatory is the Gemini Visitor Instrument Interface (VII).

TODO. VII description

3.4 Startup Procedure

This section defines H85 startup procedures for a warm startup and cold startup. These procedures are defined below.

3.4.1 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 3.2.1. 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, h85rt, 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.

3.4.2 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 4.5.)
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 h85baytech Remote Power Control and power on port 2 (RT Server). See Section 4.2.4.5 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/h85/ao/scripts directory. Execute the "./rt cold" command.
9. On h85baytech power on ports 1 (Digiport), 4 (PI Box), 5 (HVA Chassis), and 7 (Counter Chassis). See Section 4.2.4.5 for user name and passwords. It is recommended to power on the Counter Chassis before the HVA Chassis.
10. Logout of h85baytech and telnet to h85baytech2. Power on ports 2 (APD Temp Sensor), 3 (Newport FSM Controller), and 4 (Animatics Power Supply). See Section 4.2.4.5 for user name and passwords. DO NOT POWER ON PORTS 5 OR 6!!
11. Follow the XUI Startup procedure in Section 3.2.1.
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.

3.5 Setup Procedure

Generally the setup procedure simply involves following the startup procedure defined in Section 3.4 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.

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 6.1.

Very rarely an allignment may be necessary prior to startup. In this case please refer to the H85 Optical Allignment Document and follow the procedure defined therein. (TODO: MC Create this allignment document.) 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	600 DN
Extra-focal distance	~0.35 meters
Control Servo Loop	
WFS co-adds	2
DM Update rate	666 Hz
DM gain	0.0-0.7
TT gain	0.001

Figure 18 Table of Default System Setup Parameters

3.6 Instrument Configuration

Instrument configuration involves setting the WFS Filter Wheel 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.

Proceed to the first filter, which filters the most light. Monitor the maximum APD photon count in the XUI Operator or View Tab. The optimal photon count is approximately 500 photon counts/cycle. **Do not exceed 1000 photon counts/cycle**.

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 following table provides a guideline for appropriate WFS filters to use with guide stars of particular brightness. Users should still proceed to monitor photon counts while stepping one filter at a time even if an appropriate filter has been determined from this table.

Guide Star Brightness	WFS Filter

Figure 19 Table of Guide Star Brightness vs. WFS Filters

(TODO: MC. Fill in this table at commissioning.)

3.7 Starting AO Correction

(TODO: MC)

- Closing loop
- Running the optimizer

3.8 Dithering Procedure

(TODO: MC)

Telescope off-sets (instrument offsets)
Dithering tool usage

3.9 Shutdown Procedure

This section defines H85 shutdown procedures for end of night and end of run shutdown.

3.9.1 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. In the XUI Operator Tab click the WFS icon. In the popup menu select "Opaque." This moves the WFS Filter Wheel to 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 3.2.1 for XUI Shutdown.

3.9.2 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 H85.

1. Follow the end of night shutdown procedure defined in Section 3.9.1.
2. Follow the XUI shutdown procedure defined in Section 3.2.1.
3. Telnet to h85baytech. See Section 4.2.4.5 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 h85baytech. The RT Server is on h85baytech port 2.
9. Verify that ports 2, 4, 5, and 7 on h85baytech are off.
10. Exit the telnet session on h85baytech.
11. On the access panel of the thermal enclosure switch the MAINS and UPS power switches to off.

3.10 Selected Commands

Commands 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. This section lists some commands that users may need during instrument use.

- **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, 2000]. In use the nominal range is N = [400, 2000].
- **lp.dm_coadds N**: Sets the number of co-adds to accumulate before updating the DM where N = [1, 10].

3.11 Mechanism Controls

Control over all of the mechanisms in H85 is through the XUI Operator Tab described and pictured in Section 3.2.2.

3.12 WFS Data

TODO MC.

3.13 IDL Commands / Data Reduction

TODO MC.

4 Subsystem Descriptions

This section provides low-level details on H85's subsystems. This information may be useful to technicians, telescope operators, and support staff when configuring, calibrating, or troubleshooting H85.

4.1 Optics

This section provides some detail on the Optics subsystem and its components.

4.1.1 Optics Design Notes

The H85 optical specifications were derived assuming that the system-wide non-common path errors are approximately half the expected atmospheric residual. This results in a non-common path wavefront error less than 90 nm rms. Laboratory tests confirm that the residual static errors after correction are small (Strehl ratio at 1.65um ~ 90%).

All optical mounts, except the field steering gimbal mirror, are custom. All the mirrors follow the same principle in design. The optics are registered and held at three points on the front surfaces. The optics are held to the three hard points by three leaf springs at the rear of the optical element. The optical elements are held radially in place by two hard points and one leaf spring which apply a radial force. A schematic drawing of one of the optical mounts is given below.

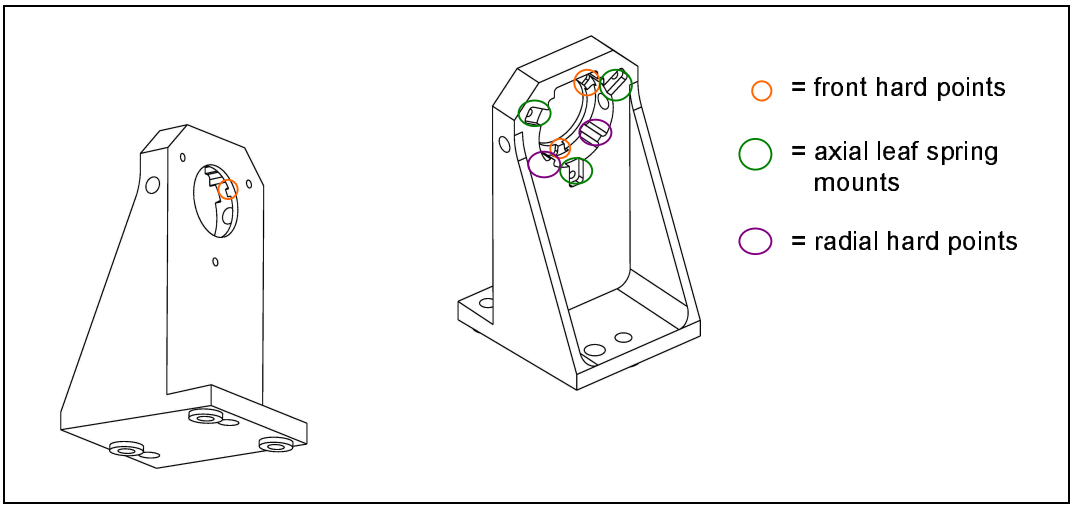


Figure 20 CAD drawing of an optical mount.

This drawing shows the front hard points, radial hard points, and the axial leaf spring locations. The radial leaf spring straddles the optical element at the top of the mount and presses the optic against the two hard-points at the bottom of the optical mount.

4.1.2 Optics Functional Description

The optical components are split into those within the science channel (common path and science path) and those within the wavefront sensor channel (non-common path). All optical surfaces, except the two off-axis parabolas, are spheres or flats.

The **Wavefront Sensor** (WFS) consists of 85 Avalanche Photo Diodes (APDs) for wavefront measurements. The WFS feeds photon counts to the Counter Boards in the Counter Chassis.

As the APDs are quite sensitive, there is a WFS Filter Wheel with opaque, open, and several filters in front of the WFS to protect the APDs from overexposure.

The **Membrane Mirror** (MM) is a flat optical element that generates two out of focus phase images of the wavefront to the WFS. The frequency and stroke of the MM are controlled by software via the Counter Chassis.

The **Deformable Mirror** (DM) is the element that corrects the aberrated image. The DM has 85 piezoelectric correcting elements that are driven by software via the High Voltage Amplifier (HVA) Chassis.

The **Field Steering Mirror** (FSM) is located at a pupil inside the WFS. It selects the position in the field to guide on. The FSM consists of a Newport Gimbal mounted 1-inch flat driven by Newport VP-25AA actuators. The two actuators are high-precision stepper motors.

The **Beam Splitter** (BS) is a calcium-fluoride beam splitter that passes wavelengths longward of 1 micron and reflects wavelengths between 0.5-1 microns. There is a blue leak in the beam splitter for wavelengths shorter than 0.5 microns.

4.1.3 Additional Optics Documentation

More detailed information on H85's optics can be found in the H85 Optics Specifications document at:

//h85ui:/home/h85/documentation/Optics/design/H85OpticsSpecifications.pdf

4.2 Electronics Functional Description

There are 3 major subsystems in H85'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 21 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 H85's processing and correcting functions. Figure 21 provides a block diagram of the RT Server, HVA Electronics, and Counter Electronics. The User Interface (UI) Server provides the interface to the H85 user and controls the mechanisms.

The following sections provide functional descriptions of the subsystems and other components in H85's electronics.

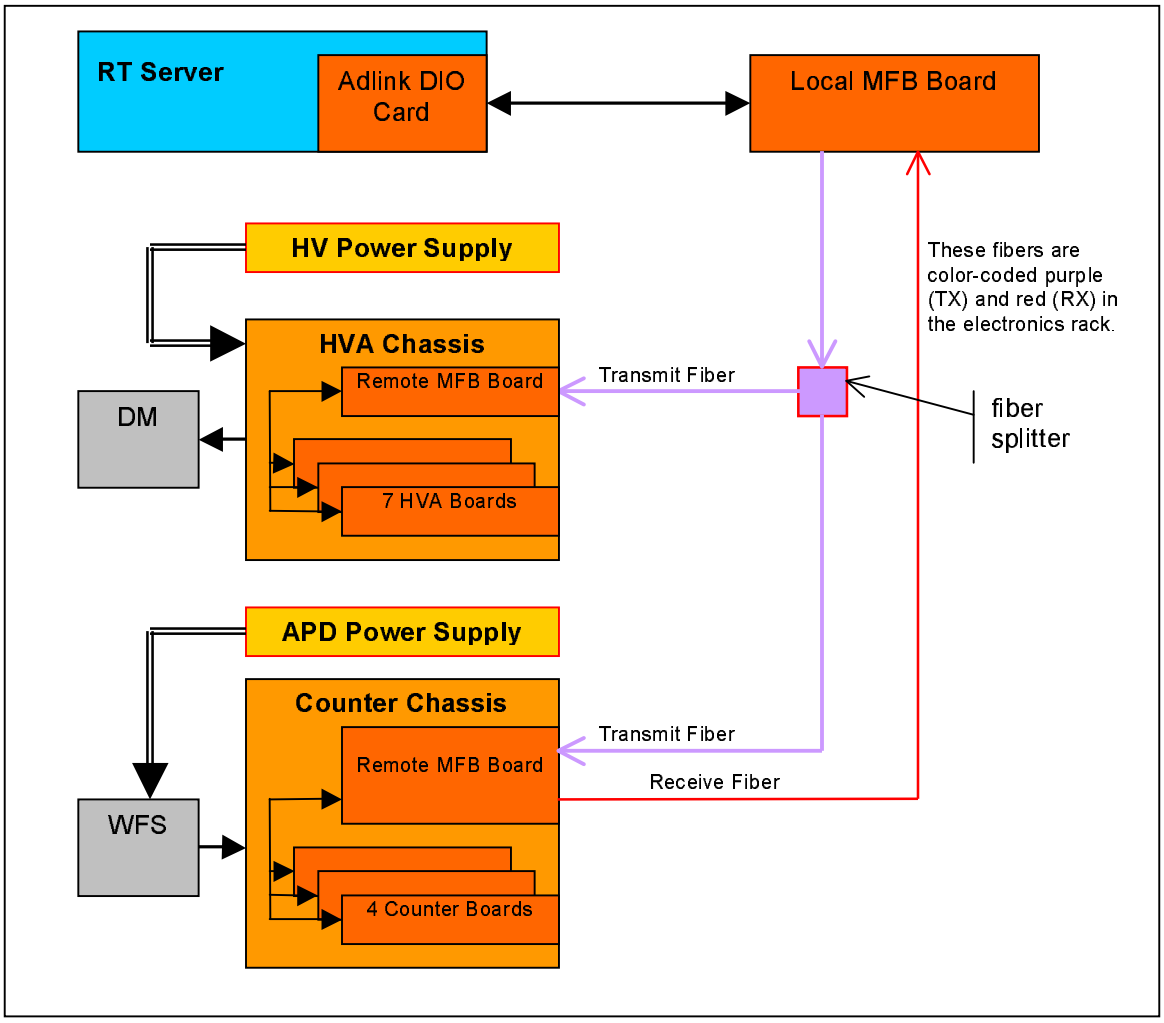


Figure 21 Block Diagram of H85 High Voltage and Counter Electronics Components

4.2.1 Servers Description

There are two Linux servers in H85, the Real Time (RT) and User Interface (UI) servers. H85 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.

- **h85ui:** The User Interface server host name.
- **h85rt:** The Real-Time server host name.
- **login**: h85
- **passwd:** ao_h85

4.2.1.1 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.

4.2.1.2 UI Server

The UI Server's major task is to provide user interfaces for working with H85. 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 H85's mechanisms, and providing configuration and control commands to the RT Server. The UI Server also provides an interface to the Gemini Visitor Instrument Interface (VII) for focus and point offload and dithering.

The UI Server has a connection to H85's Ethernet Switch. This connection serves the GUIs to external workstations and is the channel for sockets connecting to H85.

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

4.2.2 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.

4.2.2.1 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 4.2.1.

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 22 Counter Chassis Slot Assignments, Corresponding APDs, and Counter Board Settings

4.2.2.2 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.

4.2.2.3 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.

Some documentation refers to these power supplies as "Sorensen #1" and Sorensen #2."

4.2.3 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.

4.2.3.1 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 implemented. This MFB is very similar to the Counter MFB. In fact the boards are identical but 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 4.2.1.

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 23 HVA Chassis Slot Assignments, Corresponding DM Actuators, and HVA Board Settings

4.2.3.2 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.

4.2.3.3 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.

4.2.4 Miscellaneous Components

There are several other components of H85's electronics. Besides the subsystems already discussed there are the Field Steering Mirror Controller, the Tip/Tilt Steering Mirror, the DIGI Port Portserver, an Ethernet Switch, and a Remote Power Control module.

4.2.4.1 Field Steering Mirror and Controller

The Field Steering Mirror is used to select a guide star and point it at the WFS. The controller is a Newport ESP 300 Universal Motion Controller and is mounted on the outside of the thermal enclosure. The position of the FSM is set by the user in the XUI. UI Server software drives serial lines from the Digi Portserver to the Newport controller.

4.2.4.2 Tip/Tilt Platform and Controller

The Tip/Tilt (TT) Platform corrects for telescope guiding and pointing errors. It offloads the DM from correcting telescope drift. The dual-axis platform is controlled by a Physik Instrumente PZT Amplifier / Position Servo-Controller 115V. Real-time software calculates the position of the TT Platform and sends them to the MFB Board in the Counter Chassis. Analog inputs to the TT Controller are driven over coaxial cables from the Counter Chassis.

4.2.4.3 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.

4.2.4.4 Digi Portserver

The DIGI Port Portserver provides the ability to permit serial communication connections to the mechanisms and controllers from H85's Ethernet network (by the UI Server). The following table indicates the Portserver's port assignments.

Port	Connected to
4	Animatics Motor - Fiber Calibration Source
5	Animatics Motor - 2" WFS Filter Wheel
6	Animatics Motor - 3" SCI Filter Wheel
7	Animatics Motor - Camera Focus Stage
8	Newport Steering Mirror Controller
9	APD (Omega) Temperature Sensor
10	reserved
15	h85baytech

16	h85baytech2

4.2.4.5 Remote Power Control

The Remote Power Control modules, two Baytech RPC3-15 units, provide the capability to remotely control and monitor power to H85's electronics components via telnet. Each module has an Ethernet connection to H85'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 h85baytech and h85baytech2. 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: h85
Passwd: ao_h85

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

Outlet	h85baytech	h85baytech2
1	DIGI Portserver	Unused
2	RT Server	APD (Omega) Temp. Sensor
3	Unused	Newport
4	Physik Instrumente	Animatics PS
5	HVA Chassis	APD PS
6	Unused	APD PS
7	Counter Chassis	Spare
8	Fiber optic source	HVA PS (both)

Figure 24 Table of Remote Power Control Port Assignments

4.2.5 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.

???Has an automated software procedure for APD shutdown been implemented?

4.2.6 Electronics Design Notes and History

The HVA Chassis houses one Remote MFB board and 7 HVA boards. The Counter Chassis houses a Remote MFB board, four Counter boards, and an Audio Amplifier. This architecture is a slight departure from the 36 element IRTF system in which the Counter and HVA boards were housed in the same chassis. In the H85 system they are housed in separate chassis.

Another change from the previous incarnation is that the NI DIO card was replaced with a more capable Adlink DIO card. For details on the DIO card see Section 4.2.1.1 RT Server.

4.3 H85 Software Functional Description

This section addresses H85's Software subsystem. Software is the driving force of H85 as most of the electronics are passive. The primary roles of Software are to control and manage the AO control servo and to provide interfaces to the system. These tasks are handled by real-time and non-real-time processes. The real time processes run on the RT server and non-real-time processes run on the UI server.

This section provides a general description of the Software subsystem, observatory interface, and details on the engineering uses of the XUI. Generally the engineering use of the XUI is not relevant to instrument users (observers). Observational use of the XUI is covered in Section 3 Observing with H85.

4.3.1 Software Features and Design Notes

This section provides a list of the features of H85'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:
  - Communicates with the telescope control system to allow dithering an off-loading of focus and tilt.
  - Compatible with the Gemini Visitor Instrument Interface (VII).
  - The science instrument can not be sequenced so the dithering tool must rely on human intervention to proceed.

4.3.2 Loop Description

The Loop is a collection of many tasks that are executed in a cyclic manner by H85 for performing AO corrections. The loop tasks can be classed as three phases, module loading, common tasks, and the process specific loop state machine (loop FSM), as illustrated in Figure 25.

During module loading, various software processes and threads are initiated and H85's hardware is configured and set to its initial state. Once hardware and software are initialized, H85 transitions to the Common Tasks. The Common Tasks are tasks common to all observational use of H85 such as gathering WFS data and error diagnostics. Finally the loop FSM is launched in which the AO's interaction matrix (IMAT) is calculated and processed.

Note that generally this discussion on the loop is generally from the software perspective.

(TODO: MC - wants to redraw this diagram... and re-write this section.)

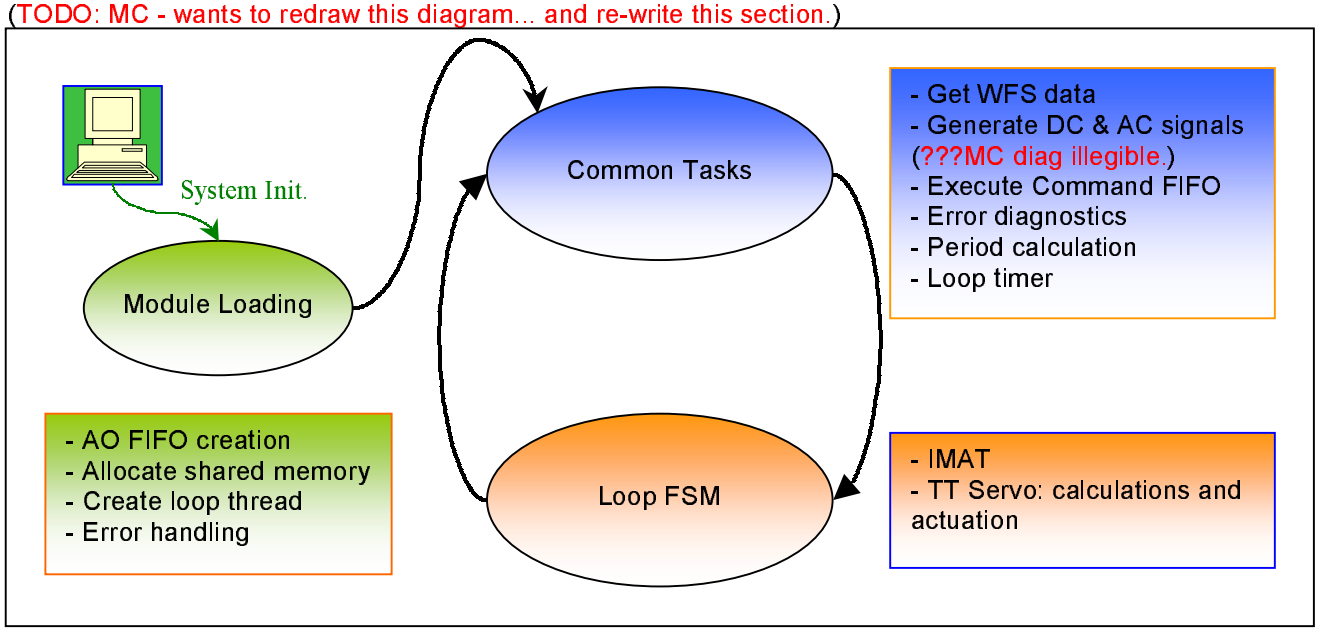


Figure 25 High Level Loop Diagram

The following sections provide some details on the functionality of the module loading, common, and loop FSM tasks.

4.3.2.1 Module Loading

This section discusses some of the details of the collection of the loop tasks that are performed during module loading. Software refers to this process as the initialization module, init_module. Generally in this phase Software is initializing shared memory and AO FIFOs and creates the loop thread.

4.3.2.2 Common Tasks

Once the loop thread is spawned during module loading the AO loop enters the common task phase. The common tasks for any observation are timing, WFS data collection, phase differentiation, generating AC & DC error/curvature signals, and AO FIFO command execution.

4.3.2.3 Loop FSM

(???More details?)

4.3.3 XUI Engineering Interface Tab

The Engineering Interface Tab (Eng) of the XUI is provided for engineering use of H85 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 26.

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 3.2.

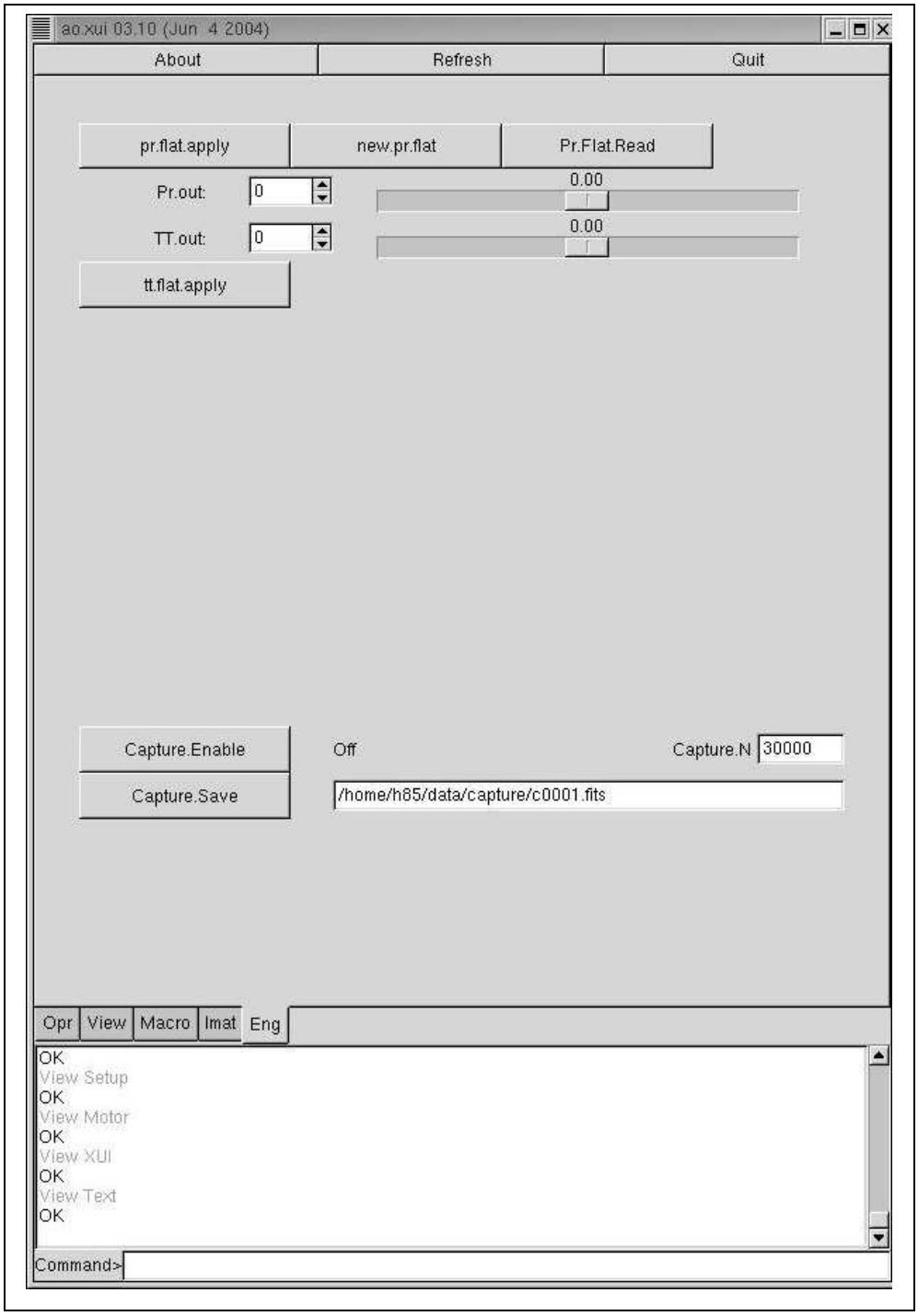


Figure 26 XUI Engineering Tab (Eng)

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.

4.3.4 XUI Interaction Matrix Tab

The Imat Tab provides an engineering 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 should not be used unless the optical allignment has changed. A screen capture of the Imat Tab is provided in Figure 27.

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 3.2.

4.3.4.1 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 (extra-focal distance) of the MM used during IMAT measurement. (TODO: MC - add info on converting 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 3.2.2 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. (Units/range???)
    - **tt.imat.membrane.stroke**: This is the stroke of the MM which corresponds to extra-focal distance. (TODO: MC - add info on converting 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. This value can be ignored by the user.
    - **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.

4.3.4.2 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 H85 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.

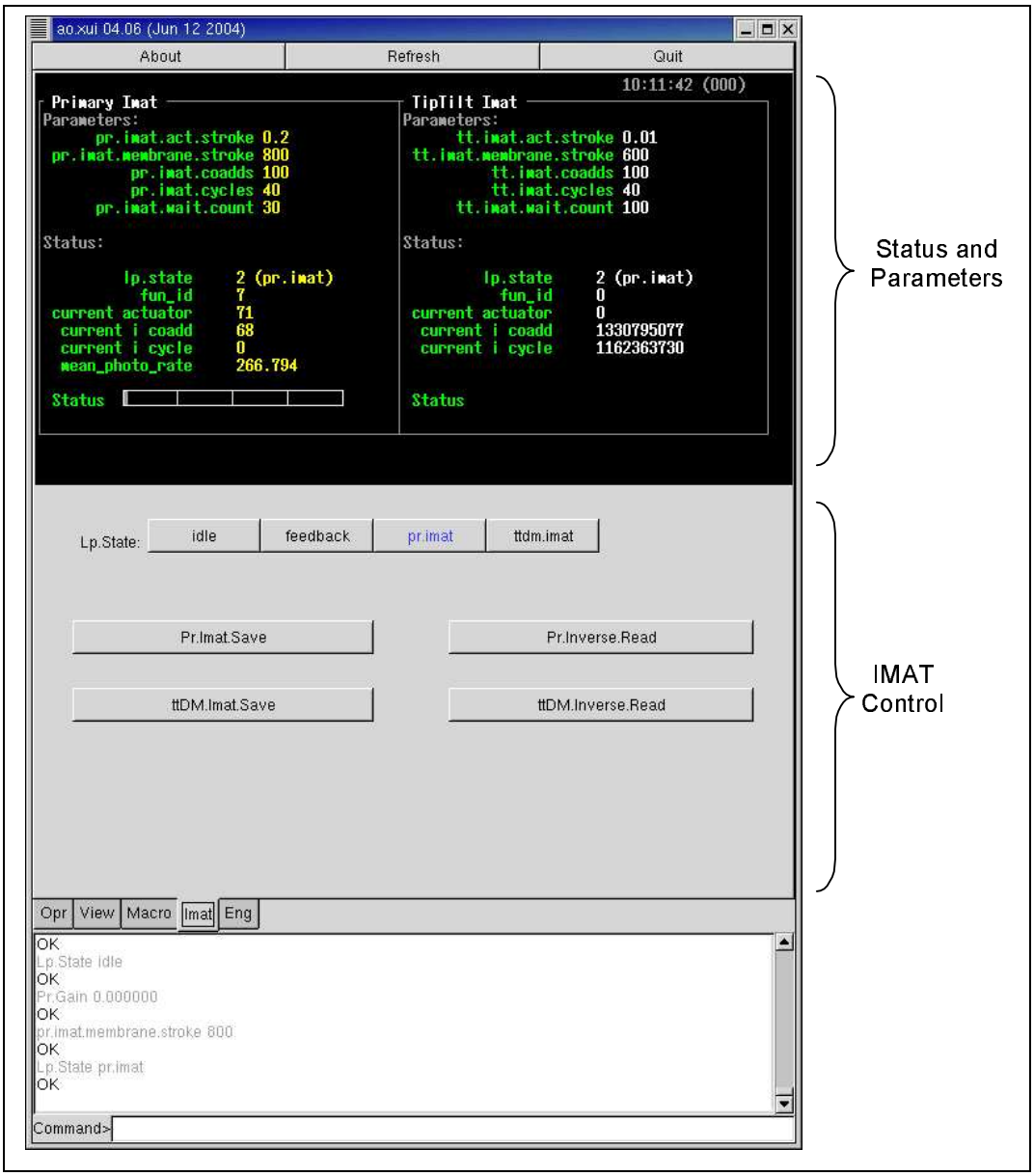


Figure 27 XUI IMAT Tab

4.4 Mechanisms Functional Description

The mechanisms in H85 provide the ability to control filter wheels, camera focus stages, a field steering mirror, and a fiber calibration source.

The mechanisms in H85 are:

- Fiber Calibration Source
- Field Steering Mirror
- WFS Filter Wheel (2" filters)
- SCI Filter Wheel (3" filters)
- Camera Focus Stage

All mechanisms have their states displayed graphically in the XUI and users may set mechanism positions from the XUI. Each moving mechanism has software limits programmed in.

4.4.1 Fiber Calibration Source Mechanism Description

The Fiber Calibration Source (FCS) is an optical fiber that is fed by a laser diode that provides an internal reference source for the system. The output of the fiber resides on a linear translation stage that brings the fiber in and out of the optical path. The FCS can be placed at any number of positions along the FCS stage. Software has 2 defined positions *IN* and *PARKED*. The stage initializes to a *PARKED* position that places the FCS as far out of the beam as possible. The *IN* position places the FCS on-axis. The software interface allows the user to specify an engineering position, based on a number of encoder counts from the parked position, to place the fiber at any arbitrary position along the stage. The parked position is approximately 4 inches out of the beam.

FCS States:

- *Source OFF*: The fiber light source is powered off using the Baytech Remote Power Controller. This is the initialized state.
- *Stage ON*: The fiber light source is powered on using the Baytech Remote Power Controller.
- *Stage PARKED*: The FCS is out of the beam. This is the initialized state.
- *Stage IN*: The fiber calibration stage is placed at the beam entrance focus.
- *Stage at arbitrary position*: The fiber tip is placed N encoder counts from the reference. This is an engineering state and normally is not used.

4.4.2 Field Steering Mirror Mechanism Description

The Field Steering Mirror controls the steering mirror at a pupil inside WFS. Moving this mirror selects the position in the field to guide on. The mechanisms are two Newport VP25AA motorized actuators driven by a Newport Universal Motion Controller/Driver model ESP 300 and an optical mount, a Newport U100G gimbal mount. This mirror initializes to the on-axis state of the mirror. The motorized actuators can move much farther than the optical mount can handle so software has limits set to prevent motion outside a range of +/- 30 arcseconds on the sky.

Field Steering Mirror States:

- *On-axis*: Position "0,0"
- *Arbitrary*: Position x,y (relative to "0,0")

4.4.3 WFS Filter Wheel Mechanism Description

The WFS Filter Wheel places filters in front of the LLA to provide control over the photon count rate incident on the APDs. This provides a measure of safety for the APDs. There are also open and opaque positions on the wheel. The opaque position is the default, initialized stated. The APDs are sensitive and should not be overexposed to light. Software ensures that the filter wheel

does not move through the open position while the wheel is in motion to a new position. Software ensures that the wheel always turns from opaque thru decreasing filter densities of filters. This mechanism implements a detent encoder and three bit address switch to indicate the filter position.

Users should ensure that the APDs are never exposed to more than 1000 counts per APD at a 2000 Hz Membrane Mirror frequency or the equivalent count/frequency ratio at other MM frequencies. Exposure of the APDs to greater flux can cause catastrophic damage to the APDs.

WFS Filter Wheel States:

- *Opaque*: Filter position 0 (default)
- *WFS Filter 1*: Filter position 1 (filter density??? TBD: MC)
- *WFS Filter 2*: Filter position 2 (filter density???)
- *WFS Filter 3*: Filter position 3 (filter density???)
- *WFS Filter 4*: Filter position 4 (filter density???)
- *Open*: Filter position 5 (**caution**: This position easily risks APD overexposure.)

4.4.4 SCI Filter Wheel Mechanism Description

The Science Filter Wheel is a six-position 3" filter wheel similar to the WFS Filter Wheel Mechanism, but with no restriction on passing through the open position. The default, initialized state is the open position. The XUI graphically displays the position and state of the SCI Filter Wheel. This mechanism implements a detent encoder and three bit address switch to indicate the filter position.

SCI Filter Wheel States:

- *Open*: Filter position 0 (default)
- *User1 - User5*: User defined filter positions 1 - 5

It is possible that this wheel was not implemented in H85. This decision will be made at commissioning. (SCI FW Implemented???)

4.4.5 Camera Focus Stage Mechanism Description

The Camera Focus Stage Mechanism serves two purposes. First it allows the user to move the camera to the best focus position if the camera turns out to be afocal. Second it allows the user to move focus to correct for field curvature in the AO system.

4.5 Cabling

This section describes the system level cabling of H85. Connections between assemblies are pictured and defined below. The following cables are H85's system cables.

- 2 HVA Cables
- 4 APD Power Cables
- Utility Cable
- 85 APD Coax
- Newport FSM Cables
- 85 WFS Fiber
- Fiber Calibration Source Power/Control

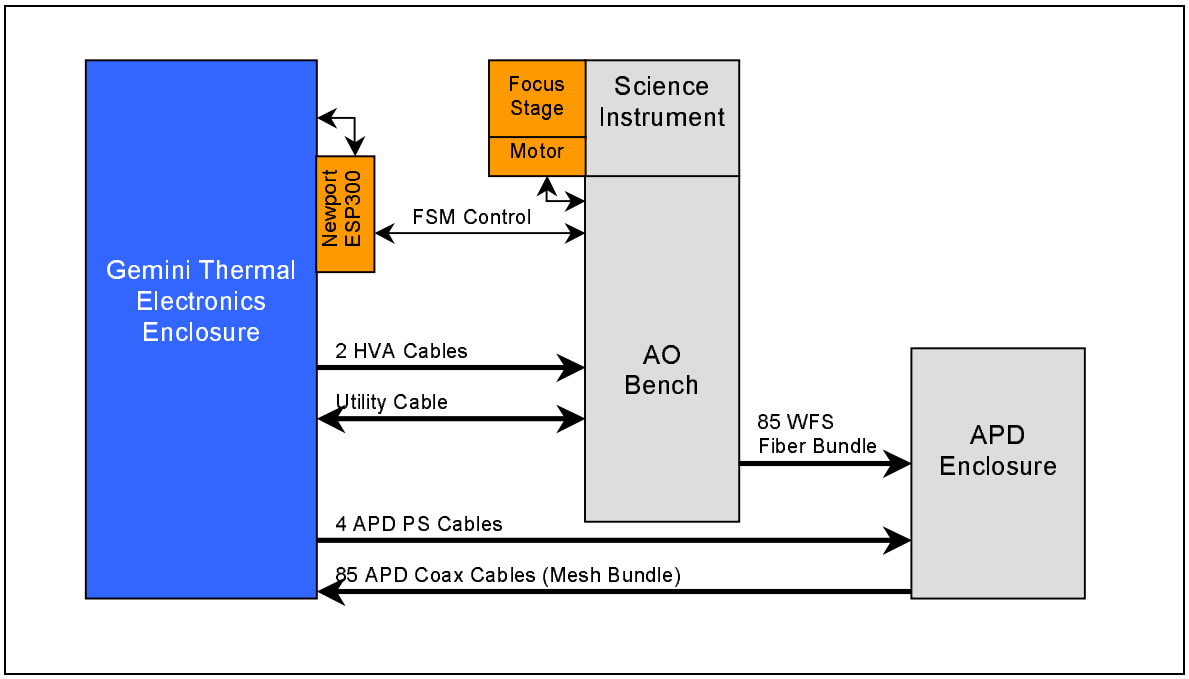


Figure 28 System Level Cabling Diagram

4.5.1 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.

4.5.2 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.

4.5.3 Utility Cable

The Utility Cable routes mechanism serial control and power signals from the thermal enclosure to the mechanisms. This is a standard 55-pin straight through IfA utility cable with an over-all braided shield. The Glenair part number is ABC 55495-4.

The Utility Cable carries the following power and control signals:

- FCS Mechanism Power, Control
- Field Steering Mirror Mechanism Power, Control
- SCI Filter Wheel Mechanism Power, Control
- WFS Filter Wheel Mechanism Power, Control
- Focus Stage Mechanism Power, Control
- Membrane Mirror Power, Control

4.5.4 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.

4.5.5 WFS Fiber Cables

The WFS Fiber Cable routes 85 fiber optic cables from the WFS in 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.

4.5.6 Newport FSM Cables

The Newport FSM Cables are used to control the Field Steering Mirror. A serial connection from the thermal enclosure connects to the Newport ESP300. From the ESP300 a cable routes the FSM control signals to the AO Bench.

4.5.7 Fiber Calibration Source Power/Control

The motor for the FCS is powered and controlled by a cable from the AO Bench to the motor.

5 Basic Troubleshooting

(TODO)

6 Service & Calibration

This section defines the service and calibration procedures for H85. These procedures include generating IMATs, servicing electronics boards in the thermal enclosure, and APD module replacement.

6.1 Calibration: Generating IMATs

Most uses 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.

6.1.1 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 3.4. Readers may like to refer to the IMAT Tab description in Section 4.3.4. 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 3.5.
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. (TODO: This procedure isn't defined anywhere. Add reference once it's defined.)
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."

6.1.2 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 3.4. Readers may like to refer to the IMAT Tab description in Section 4.3.4. 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. (TODO: This procedure isn't defined anywhere. Add reference once it's defined.)
15. Once IMAT generation is complete in the XUI Operator Tab click the FCS icon and set the Fiber Calibration Source to "Parked."

6.2 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 H85'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 4.2.2.1 and 4.2.3.1 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 4.2.2.1 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 4.2.3.1 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.

6.3 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.

(Is there some way to secure the door open while performing maintenance???)

6.3.1 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 H85 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 3.2.2.3).
5. Power down the High Voltage Power Supplies through the XUI Operator Tab's AC Power popup window (see Section 3.2.2.3).
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 3.2.2.3).
26. Power on the APD Power Supplies through the XUI Operator Tab's APD Power popup window (see Section 3.2.2.3).

6.3.2 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 H85 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 3.2.2.3).
5. Power down the High Voltage Power Supplies through the XUI Operator Tab's AC Power popup window (see Section 3.2.2.3).
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.

6.4 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.

6.5 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, h85baytech, 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, h85baytech, 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.

7 Safety Issues

This section specifies some specific safety issues for H85. These safety issues cover protection of equipment and personnel. Of course only qualified and trained personnel should handle the equipment.

7.1 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.

7.2 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.

7.3 High Voltage and High Current Areas

There are several high current and high voltage areas of H85. 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.

7.4 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.

8 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.
CFS	Camera Focus Stage
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.
FCS	Fiber Calibration Source
H85	Hokupa'a 85, an 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 H85 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.
VII	Gemini Visitor Instrument Interface.
WFS	Wavefront Sensor.
XUI	H85's X-Windows User Interface.

Figure 29 Table of Acronyms and Definitions