Keck Next Generation Adaptive Optics
Preliminary Electronics Design
KAON 701

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Revision History

Date	Version	Author	Description
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Table of Contents

1. Introduction

This document describes the preliminary electronics design of the NGAO system. We begin by tracing the optical path of the AO system and present the relevant information for each subsystem. Next we look at the Laser Guide Star facility followed by support equipment and the science instrument. The final sections summarize requirements compliance and address cost, risks and schedule. This design is heavily dependant on the decisions made by the subsystem designers. As some of these designs are still evolving, some parts of this design are lacking detail.

This document attempts to cover all aspects of the design, with the exception of the motion control which will be covered in a separate document.

2. References

2.1. Referenced Documents

Documents referenced are listed in Table 1. Copies of these documents may be obtained from the source listed in the table.

Ref. #	Document #	Revision or Effective Date	Source	Title
1	KAON 511	0.3	WMKO	NGAO System Design Manual
2	KAON 572	0.1	WMKO	Instrument Baseline Requirements Document
3	KAON 574	1.0	WMKO	NGAO Systems Engineering Management Plan
4	KAON 642	April 10, 2009	WMKO	NGAO Design Changes in Support of Build-to-Cost Guidelines
5	KAON 643	1.4	WMKO	Motion Control Architecture Study
6	KAON 659	1.1	WMKO	Laser Launch Facility Beam Generation System
7	KAON 661	1.1	WMKO	Laser Launch Facility Switchyard
8	KAON 662	1.1	WMKO	Laser Launch Facility Beam Transport Optics
9	KAON 668	2.0	WMKO	Device Control Architecture
10	KAON 682	1.1	WMKO	Master Device List
11	KAON 692	Dec09	COO	LGS WFS Preliminary Design

Table 1: Reference Documents

2.2. Acronyms and Abbreviations

Table 2 defines the acronyms and abbreviations used in this document.

Acronym/Abbreviation	Definition
ADC	Atmospheric Dispersion Compensator

BGS	Laser Beam Generation System
BTO	Laser Beam Transport Optics
COTS	Commercial Of The Shelf
DM	Deformable Mirror
IF	Keck-Keck Interferometer
K1	Keck 1
K2	Keck 2
KAON	Keck Adaptive Optics Note
LGS	Laser Guide Star
LLF	Laser Launch Facility
LOWFS	Low Order Wave Front Sensor
LVDS	Low Voltage Differential Signaling
MEMS	Micro Electro-Mechanical Systems
NGAO	Keck Next Generation Adaptive Optics System
NGS	Natural Guide Star
WFS	Wave Front Sensor
WMKO	W. M. Keck Observatory

Table 2: Acronyms and Abbreviations

3. Overview

The NGAO system is comprised of a cascade relay AO system, laser guide star facility, science instrument and support equipment, as illustrated in Figure 1. These systems combine to produce high Strehl performance over the near-IR wavelengths and modest Strehl into the visible for objects too faint to be used as guide stars. Multiple laser guide stars and tomographic reconstruction techniques are used overcome the effects of focus anisoplanatism. Additional laser guide stars are used to sharpen the natural guide stars used to remove tilt anisoplanatism.

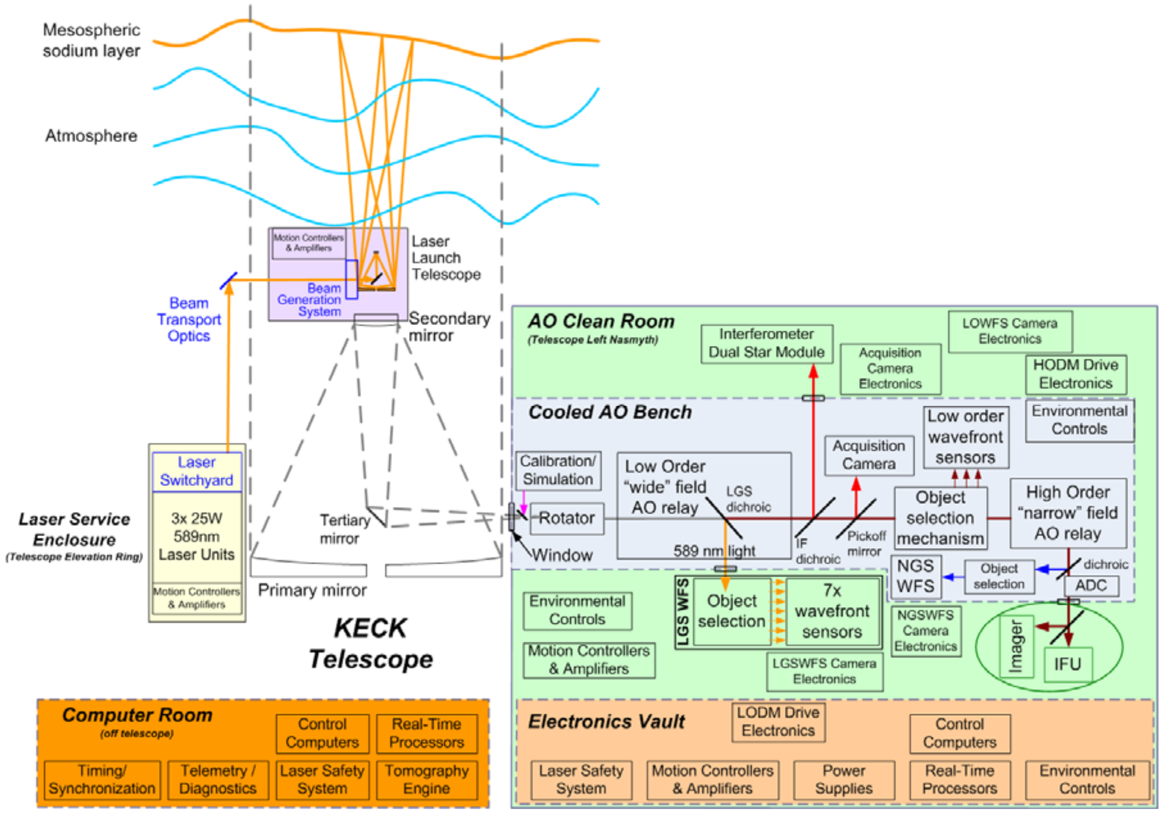

Figure 1: NGAO Block Diagram

Following the optical path, the electronics design for each subsystem is introduced, including cabling and support equipment. This document itemizes internal and external interfaces needed to accommodate the subsystem hardware. Internal interfaces are those within the NGAO system. External interfaces are those that extend to the Telescope or Facility. Mechanical, infrastructure and software interfaces are listed (in addition to electronics). None of these sections are all-inclusive; rather they are intended to capture the needs of the electronics. Mechanical interfaces include cabling and rack space requirements, not the mechanical mounting of the various optics or enclosures. The infrastructure section includes glycol and power required to support the electronics design.

4. AO System

4.1. Overview

The AO system and instrument(s) are located on the telescope's left Nasmyth platform at the f/15 focus. The AO system (optics bench) is enclosed and cooled to -15C to reduce the thermal emissivity of the optical surfaces. Windows are provided to isolate this enclosure from the dome environment. The science path optics, acquisition camera, NGS wavefront sensor and Low Order Wave Front Sensor (LOWFS) assembly are located on the cooled AO bench. The entire AO system is located in a clean room that is maintained at dome ambient temperature with controlled humidity. The science instrument(s), the LGS WFS and the Interferometer Dual Star Module (DSM) are located in this clean room. An electronics vault and an ante-room to facilitate clean entry (similar to the existing AO enclosure) will be joined to the clean room. The electronics vault will have environmental controls, but not require the tight temperature and humidity controls present in the clean room or cooled bench.

The following sections trace the optical path and detail the electrical design for the various AO subsystems.

4.2. AO Input Hatch

4.2.1. Overview

The hatch provides physical protection for the AO input window and will also prevent any light from exiting the AO enclosure during non-AO observing. The hatch is located on the telescope side of the elevation journal, as shown in Figure 2 below.

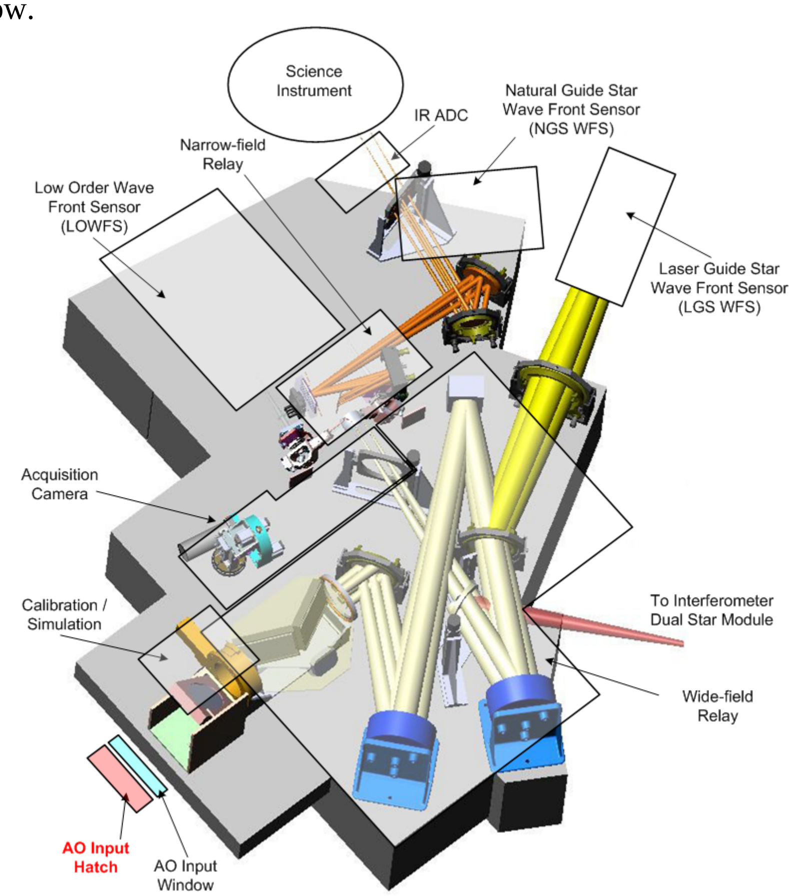

Figure 2: Location of AO Input Hatch

The mechanics of this assembly will likely not be changed from the current design. The state command will be provided by the NGAO control system, not the Interferometer control system as in the current implementation.

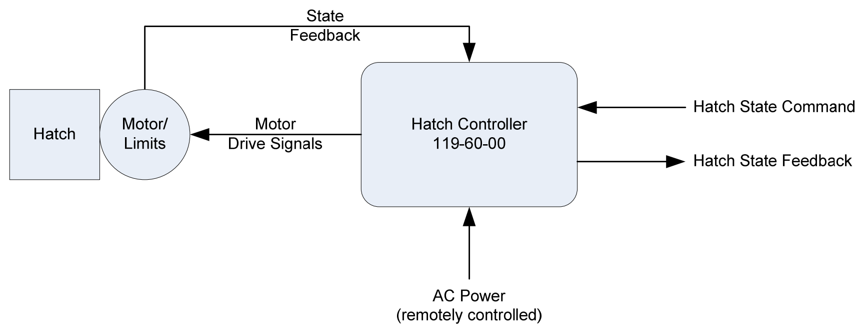

Figure 3: Schematic of AO Hatch

The current implementation, shown in Figure 3, uses a custom Keck designed box that interfaces a COTS motor controller to the motor, its limits, and the discrete I/O of the control system. There is no position feedback; the hatch position is only known when a limit switch on the rod-screw actuator is triggered at full open or full closed. The hatch controller requires a position state command input (open/close), a controller input (reset) and provides three outputs: open, closed, and amplifier fault. From the state outputs, four conditions are known: open (open switch triggered), traveling (neither switch triggered), closed (closed switch triggered) and fault (both switches triggered – physically impossible). The amplifier fault output comes directly from the COTS controller. The controller provides a local/remote capability and the ability to locally open/close the hatch.

To interface this system with the NGAO control system, a custom cable will need to be fabricated to allow access to the control signals that are currently connected to an I/O board in the Interferometer Ancillary crate.

This control method could be upgraded by replacing the motor with a SmartMotor. The actuator uses a NEMA 23 motor, so mechanically this would be an easy changeover. The wiring would change to wire the limit switches to the SmartMotor and provide the RS-232 link. The existing motor wiring could be used to provide power to the SmartMotor. A risk that would need to be addressed is the small amount of heat generated by the controller in the idle state. The benefits of this upgrade would be to provide continuous position feedback when the actuator is in motion and not require any digital I/O.

The hatch and its actuator are located on the telescope side of the right elevation journal. The control electronics will be located in the AO electronics vault. There are no unusual environmental requirements; the controller currently operates in the AO electronics vault.

4.2.2. Requirements and compliance

Open/close time
Power-on (or reset) hatch state
Feedback (open/closed/traveling ?)

4.2.3. Support equipment

3U of rack space are required for the hatch controller. This box also controls the hatches protecting the M5 and M7 coude mirrors. AC mains power to the box is currently controlled by the IF Pulizzi.

4.2.4. Cabling

The hatch is currently cabled and operating under control of the Interferometer control system. It is desirable to control the hatch from the NGAO control system to avoid the confusion and possibility for human error that exists in the current system. The change would require fabrication of a custom cable to allow interfacing to the NGAO control system. This cable would require six conductors and interface to an I/O module.

4.2.5. Internal Interfaces

i. Mechanical
The rod-screw actuator requires a NEMA 23 motor.

ii. Electrical/electronic
Motor drive: 32VDC with a 20 kHz PWM frequency
Motor controller: 15A continuous and 30A peak
Limit switches: 15V, current limited to ~5mA
Two digital inputs (command) opto-isolated, 5V, 2mA sinking
Three digital outputs (feedback), opto-isolated 5V
5V supply to power the opto-isolators
One channel of AC mains remote control

iii. Software
Open/close control
State feedback
Interface to AC mains remote control

4.2.6. External Interfaces

i. Mechanical
Refer to drawing 1632-C0200 and the 1632 drawing series
3U of rack space are required to mount the controller

ii. Infrastructure
120VAC mains; 500 watts (max), intermittent with small stand-by load

iii. Electrical/electronic
None

iv. Software
None

4.3. Calibration/Simulation

This subsystem is still in the early design phase and there is not enough information available to outline the required electronics. The devices listed below are expected, based on the current understanding of the design. This section will be completed prior to the PDR.

4.3.1. Overview

The calibration/simulation subsystem will provide the necessary equipment for alignment, calibration and diagnostics: standard sources for flux and wavelength calibration of instruments; astrometric source(s) for instrument field distortion calibration; simulated NGS and LGS sources for calibration, testing and alignment; and atmospheric simulation. These sources will likely be located in the AO electronics vault and connected to the module via fiber-optic cables. In addition to the various illumination sources, motion stages will be needed to select between the modes, position the output and control the atmospheric simulation (turbulence generation). The module is located above the AO rotator inside the cold enclosure, as shown in Figure 4. A fold mirror will be inserted in front of the rotator to direct the light into the AO system.

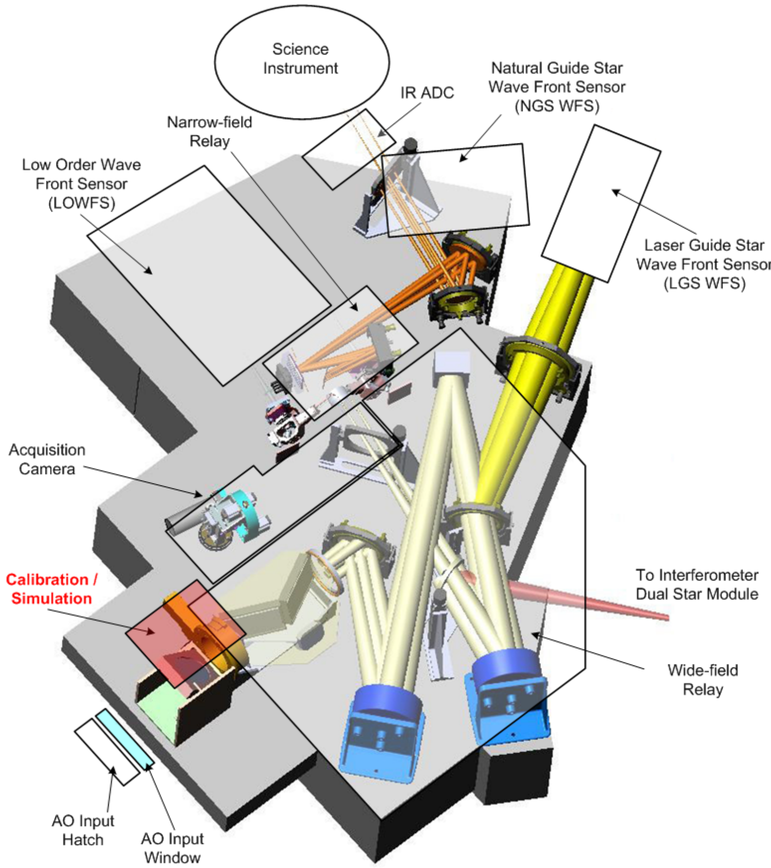

Figure 4: Location of Calibration/Simulation Unit

Cal source positioning
Cal source lamp (0.6 – 2.5um)
Inst radiometric cal source positioning
Inst radiometric cal source
Astrometric grid positioning
Astrometric grid illumination
NGS source positioning
NGS source (white light)
LGS source positioning
LGS source (580-600 nm)
Atmospheric simulator positioning
Atmospheric simulator illumination
Intensity controls
Remote power controls

4.4. Wide-field Relay

4.4.1. Overview

The controllable components in the wide-field relay, shown in Figure 5 below, include the image rotator, a deformable mirror on a tip/tilt stage and the interferometer pickoff dichroic translation stage. Components in this subsystem require a number of controls including motion, RTC and device control as described below.

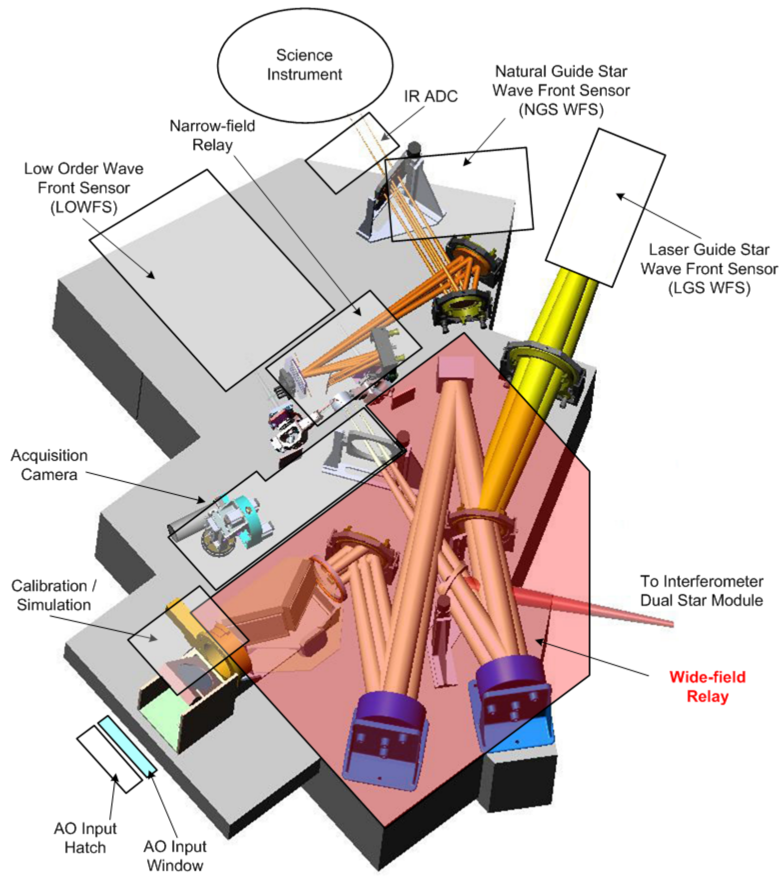

Figure 5: Location of Wide-field Relay

Control of the image rotator will be discussed in the motion control document.

The Deformable mirror will likely be a Cilas SAM416 22x22 actuator mirror. The control system will be required to provide power control and infrastructure support for this equipment. Control of the high voltage output is provided though the amplifier housekeeping/diagnostic Ethernet interface. The DM will be mounted on a tip/tilt stage with piezo actuators. The control system will need to provide power control and possibly an analog signal to ramp the output of the high voltage power supply, if this function is not provided by the power supply manufacturer.

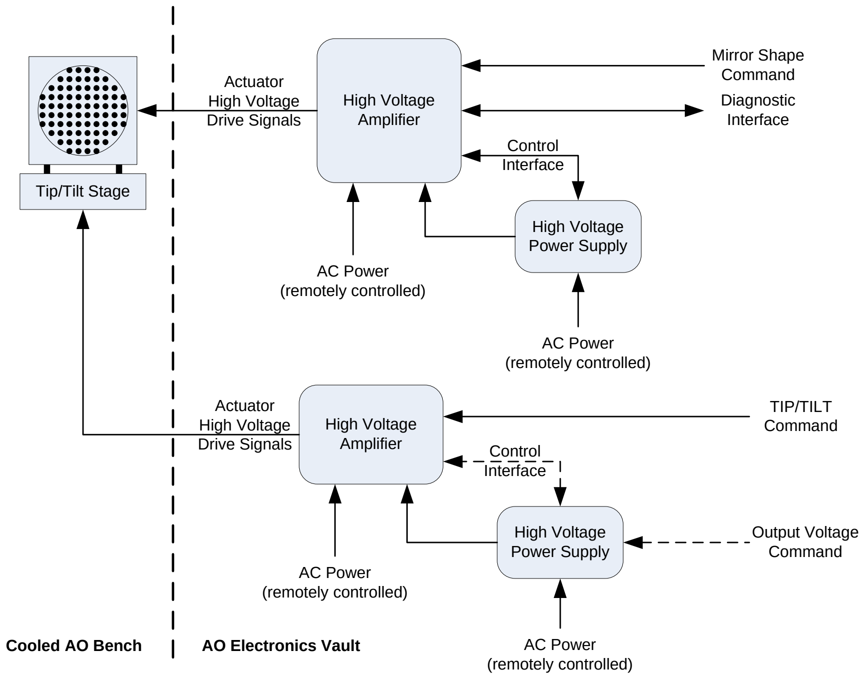

Figure 6: Schematic of Wide-field Relay

A pickoff dichroic will be mounted on a translation stage to allow the optic to be inserted during interferometer observing. Control of this stage will be discussed in the motion control document.

The stages listed above will all be on the cooled optical bench. The control components will be located in either the electronics vault or the AO clean room.

4.4.2. Requirements and compliance

4.4.3. Support equipment

The rotator will require a motion control channel, as detailed in the motion control design document.

The DM support electronics will require 10U of rack space in the electronics vault, 7U for high voltage amplifier (including a 1U cooling fan box) and 3U for its power supply. Two channels of remote power control will be required, one for each rack box.

The T/T stage will require an amplifier and possibly a high voltage power supply if it is not integrated into the amplifier. 2U of rack space is estimated for this equipment. One or two channels of remote power control and possibly an analog signal to control the high voltage output will be required.

The interferometer dichroic stage will require a motion control channel, as described in the motion control design document.

4.4.4. Cabling

The image rotator will require a cable for the motor/encoder signals. This cable will be required to pass through the wall of the cold box.

The Cilas DM requires thirteen cables, each with 35 conductors. Two of the conductors are assigned as an interlock to protect equipment and personnel from high voltages. These cables are terminated with a 41 pin circular connector (MS 3126E 20 41P) that mates with the high-voltage amplifier. The signal voltage on the cables can reach +/- 400 VDC with respect to ground and 800 VDC with respect to an adjacent conductor. Each of these cables will need to pass through the wall of the cold box. The standard length is 20 meters, although 100m is possible. This will allow the amplifier and associated power supply to be located in the electronics vault.

A fiber optic cable will be required to connect the high voltage amplifier to the wavefront controller. This 2.5 Gbit/s sFPDP (serial Front Panel Data Port protocol) connection is required for the mirror shape commands. In addition, a 1 Gbit/s Ethernet connection is required for housekeeping.

The tip/tilt stage will require between one and three cables, depending on stage design and cable fabrication method, to pass through the wall of the cold box. The destination is the electronics vault. Voltage levels are expected to be on the order of 100VDC, both to ground and between conductors. There are no known limits on cable length. **More information is required.**

A cable will be required to connect the tip/tilt high voltage amplifier to the RTC/wavefront controller.

The dichroic translation stage will require a cable for the motor/encoder signals. This cable will be required to pass through the wall of the cold box.

4.4.5. Internal Interfaces

i. Mechanical
2 motion control cables though the cold box wall (bulkhead connection)
13 DM cables through the cold box wall (MS 3126E 20 41, 1.25" dia.)
1 to 3 Tip/tilt cables though cold box wall (bulkhead connection)

ii. Electrical/electronic
Image rotator motor/encoder/reference location signals
+/- 400 VDC DM Actuator signals
T/T actuator signals, 100VDC (?)
IF dichroic motor/encoder/limit switch signals
3 channels of AC mains remote control

iii. Software
Motion control
Rotator: tracking
IF dichroic: in/out
Voltage ramp control for HV power supplies
AC mains remote control

4.4.6. External Interfaces

i. Mechanical
10U (6U amplifier, 1U fans & 3U power supply) of rack space is required for the DM electronics.
2U (??) space is required for the T/T electronics.

ii. Infrastructure (power, pneumatic, glycol, etc.)
120 VAC / 500W+500W for DM amp/psu
120 VAC / 50 (???) W for T/T amp/psu

iii. Electrical/electronic
1 fiber-optic: DM command interface (sFPDP protocol)
1 Gbit/s Ethernet: DM housekeeping
T/T command interface
Time synchronization signal

iv. Software
Telescope position information from DCS (for rotator)

4.5. Laser Guide Star Wave Front Sensor (LGS WFS)

4.5.1. Overview

The LGS WFS assembly is located in the AO clean room, adjacent to the cooled AO bench, as shown in Figure 7. A window assembly in the cold box allows light to enter the WFS assembly. The function of the LGS WFS is to make wavefront phase measurements of the turbulence-induced distortions seen by the set of seven 589 nm LGS as they propagate downward back to Earth. The LGS WFS sends this data to the NGAO real-time-control (RTC) subsystem. The RTC uses the fixed asterism data to perform tomography in the science field and compute drive signals for the low and high order deformable mirrors. The data from each patrolling LGS WFS is used to drive a deformable mirror in the corresponding LOWFS channel, sharpening the low-order natural guide stars. The tip-tilt information from each of the seven LGS WFS is used to drive a corresponding fast TT mirror in the LGS WFS itself. Reference KAON 692 – LGS Wavefront Sensor Preliminary Design.

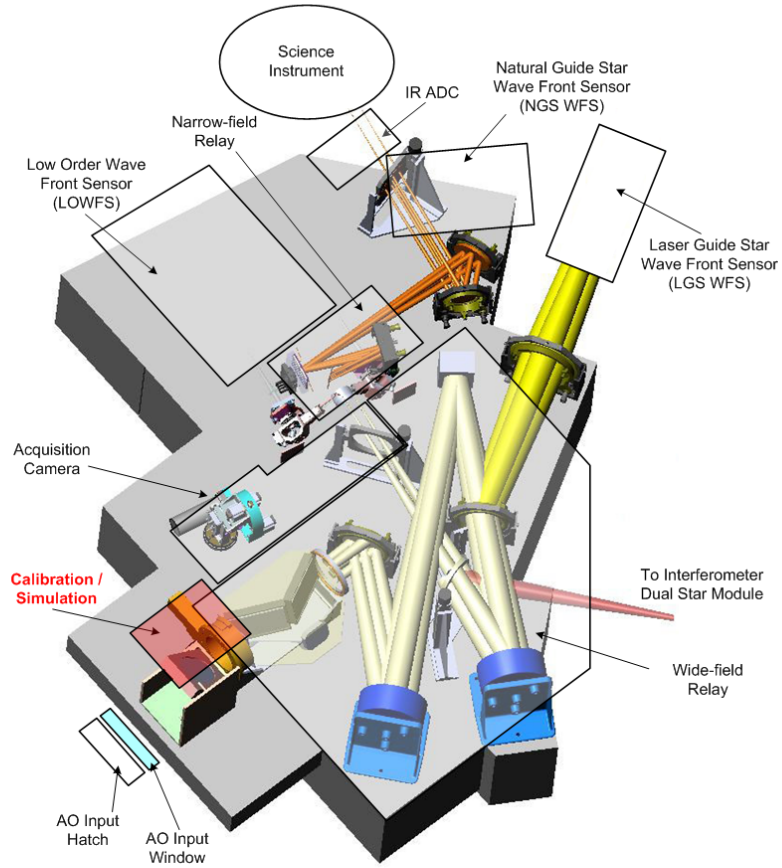

Figure 7: Location of LGS Wave Front Sensor

The LGS WFS assembly contains seven similar WFS units. Four are used to sense the fixed asterism, three for the patrolling guide stars. Each unit has a fast tip/tilt mirror (controlled by the RTC), relay optics, lenslet array and detector. Unique to each patrolling WFS is a theta-phi pickoff arm required to direct light from an arbitrary location in the field into the sensor optics. The patrolling WFS may also require an additional (slow) tip/tilt stage to position the pupil on the detector. This would not be under RTC control. Figure 8 shows a single (patrolling) channel of the WFS. The entire assembly must be translated along the optical axis to adjust for focus changes induced by variation in the distance to the atmospheric sodium layer. This effect is due both to a natural drift in the sodium layer altitude and the current zenith angle of the telescope.

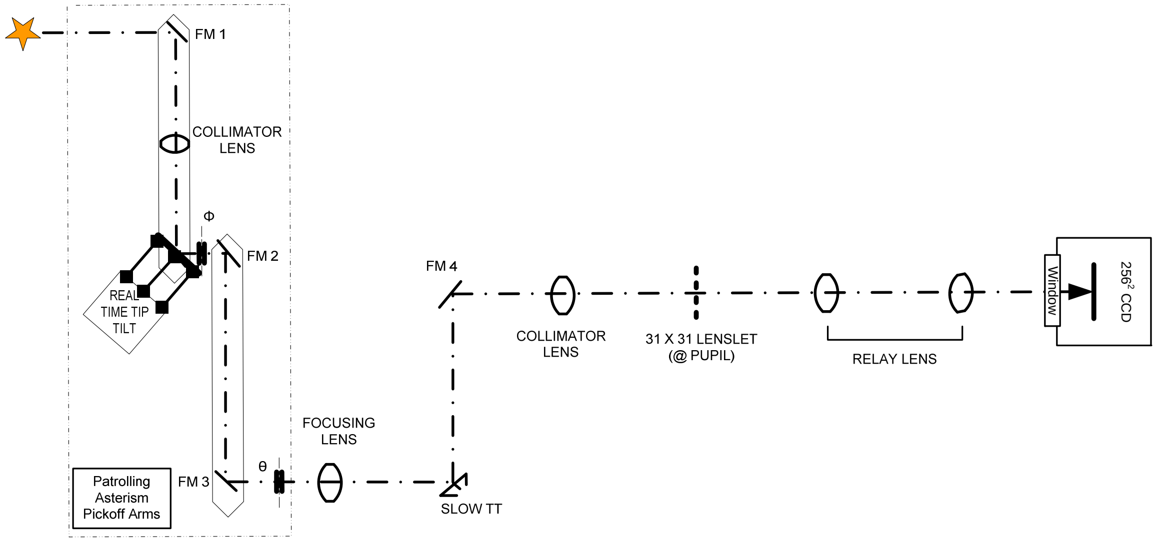

Figure 8: Schematic of Single LGS WFS Channel (adapted from KAON 692)

4.5.2. Requirements and compliance

4.5.3. Support equipment

The pickoff arms, slow tip/tilt stages (if required) and the assembly focus stage will all require motion control channels, as detailed in the motion control design document.

The RTC tip/tilt stages will require an amplifier and possibly a high voltage power supply if it is not integrated into the amplifier. 6U of rack space is estimated for this equipment (2U/6axis amplifier). One or two channels of remote power control and possibly an analog signal to control the high voltage output will be required.

The camera electronics will likely need to be located in the clean room, physically close (within 3m) to the camera heads. This will necessitate a rack or enclosure for this equipment. Glycol (or other method) will be needed to extract the heat from this enclosure. Assuming SciMeasure cameras, the electronics consists of several cards installed in a 3U backplane. It is anticipated that two cameras could be controlled per backplane. This implies a space requirement on the order of 12U. One channel of remote power control is required for this equipment. Communication to the RTC will be via fiber-optic. Converters between copper and fiber may be required if the camera boards do not support fiber.

4.5.4. Cabling

There will likely be four cables required to connect the camera head to its electronics: two coax (video) and two multi-conductor bundles (clocks/command data). Depending on the camera head/detector, there may be four coax cables for a total of six cables. These cables have a 3m length limit.

A fiber-optic connection will be required from the camera electronics to the control system. Each camera will communicate via CameraLink (full) over fiber optic to the RTC located off the telescope in the computer room.

The tip/tilt stages will require between one and three cables, depending on stage design and cable fabrication method. The destination is the electronics vault. Voltage levels are expected to be on the order of 100VDC, both to ground and between conductors. There are no known limits on cable length.

An interface between the tip/tilt high voltage amplifiers and the RTC/wavefront controller is required. One approach would be a tip/tilt control processor that will communicate with the RTC and provide analog signals to the high voltage amplifiers. In this configuration, a single fiber will be required to the computer room and 4U (?) will be required for the control processor.

The dichroic translation stage will require a cable for the motor/encoder signals. This cable will be required to pass through the wall of the cold box.

4.5.5. Internal Interfaces

i. Mechanical
   Cabling to motion controllers

ii. Electrical/electronic
   T/T actuator signals, 100VDC (?)
   Low voltage T/T command signals (0-10 VDC)
   Low voltage detector clock/data signals (TTL, LVDS, video, etc)
   10 (or 7) motion control channels
   3+ channels of AC mains remote control

iii. Software
   Motion control
      Patrolling LGS probe arms
      Assembly focus – tracking
      Patrolling LGS pointing
   AC mains remote control
   Camera control (exposure, frame rate, etc)

4.5.6. External Interfaces

i. Mechanical
   6U (??) tip/tilt amplifier electronics (RTC)
   4U tip/tilt control processor
   2U (??) slow T/T electronics (motion control)
   12U Camera electronics (within 3m of LGS WFS)

ii. Infrastructure (power, pneumatic, glycol, etc.)
120 VAC / 150(???) W for T/T amp/psu
120 VAC / 150(???) W for T/T control processor
Camera head glycol, ?? GPM flow requirement
120 VAC / 200W for camera electronics
Camera electronics (rack/enclosure) glycol, ?? GPM flow requirement

iii. Electrical/electronic
1 communication fiber, T/T processor to RTC
7 CameraLink fibers to RTC (computer room)

iv. Software

4.6. Acquisition Camera

4.6.1. Overview

The acquisition camera facilitates the fine alignment of the AO system and the identification of the various guide stars. The camera is fed via a pickoff mirror that is inserted into the beam after the wide-field relay. As this pickoff sends the entire field to the acquisition camera (and completely blocks the beam from entering the LOWFS and narrow-field relay), it is only inserted during the acquisition phase of the observing sequence. A motorized focus mechanism is also required for the camera. The location of the acquisition camera and its pickoff are highlighted in Figure 9, below.

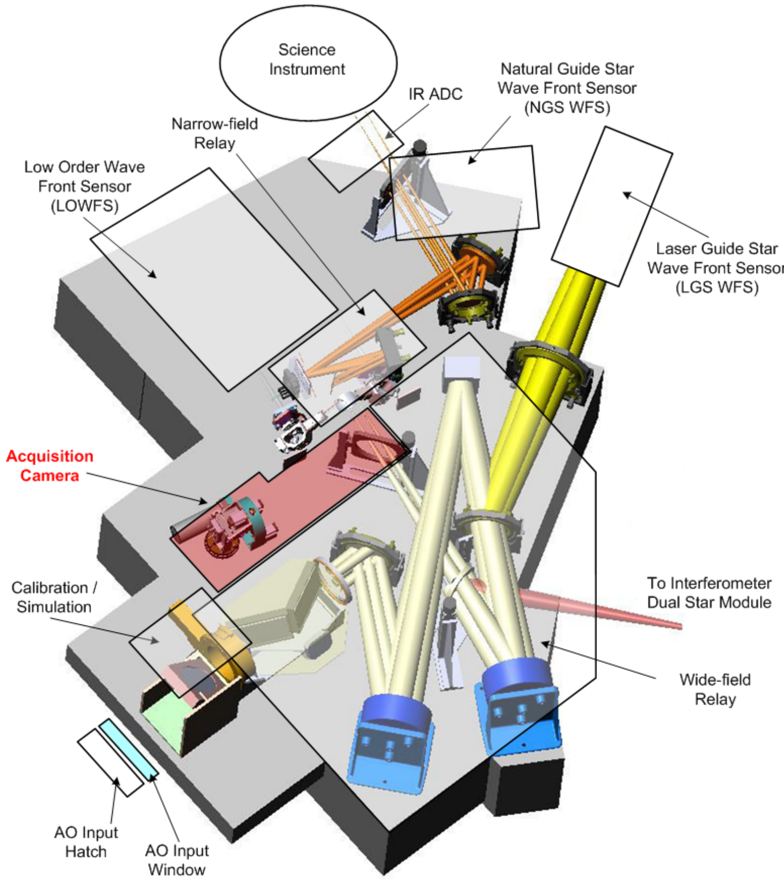

Figure 9: Location of Acquisition Camera and related optics

The motion control associated with the pickoff mirror and the camera focus will be discussed in the Motion Control document.

A schematic of the camera is shown in Figure 10, below. The current scheme is to use the same SciMeasure camera used in the MAGIQ guider system.

The camera will be detecting visible wavelength light. In order to maintain sensitivity, the camera head will likely require glycol cooling. This will also insure that any heat generated by the camera is removed directly from the cold bench, not radiated into the conditioned environment. The camera electronics will likely communicate via Camera Link to the control system. The MAGIQ system requires a small converter box to put the Camera Link signals onto a fiber optic cable for transport to the computer room.

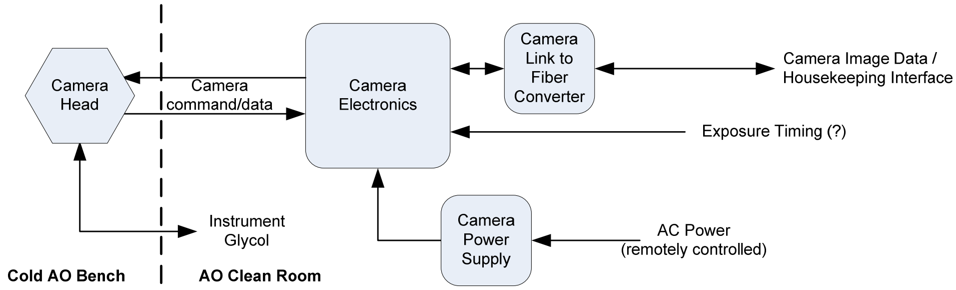

Figure 10: Schematic of Acquisition Camera

The camera head and motion stages will be mounted on the cold AO bench. The servo electronics will either be in the clean room or the electronics vault. The camera electronics will likely be in the AO clean room given the length constraints normally associated with camera cabling (~3m).

The MAGIQ camera uses the digital I/O in motion controller to perform the exposure control. More research is needed to understand the current design and how it applies to the NGAO requirements.

4.6.2. Requirements and compliance

4.6.3. Support equipment

The pickoff stage and the camera focus mechanism will require motion control channels, as detailed in the motion control design document.

The camera electronics will likely need to be located in the clean room, physically close (within 3m) to the camera head. This will necessitate a rack or enclosure for this equipment. Glycol (or other method) will be needed to extract the heat from this enclosure. The space requirement is probably on the order of 3U. One channel of remote power control is required for this equipment.

4.6.4. Cabling

The motion stages will require cables for the motor/encoder signals. These cables will be required to pass through the wall of the cold box.

Assuming the SciMeasure camera, there will be four cables required to connect the camera head to its electronics. These cables have a 3m length limit. It is unlikely that bulkhead connectors can be used with these cables, both for electrical signal integrity and mechanical construction reasons. The cold box pass through will need to clamp the cables to maintain the integrity of the enclosure seal.

A fiber-optic connection will be required from the camera electronics to the control system. The location of the control computer(s) is currently TBD, but will likely be the computer room.

4.6.5. Internal Interfaces

i. Mechanical
2 motion control cables though the cold box wall (bulkhead connection)
4 camera cables through the cold box wall (clamped seal)

ii. Electrical/electronic
motor/encoder/limit switch signals
Low voltage detector clock/data signals (TTL, LVDS, video, etc)
120 VAC mains remote control

iii. Software
Motion control
AC mains remote control
Camera control (exposure, frame rate, etc)

4.6.6. External Interfaces

i. Mechanical
3U rack space in clean room
Space for motion controllers (where?)

ii. Infrastructure (power, pneumatic, glycol, etc.)
Camera head glycol, ?? GPM flow requirement
Camera electronics (rack/enclosure) glycol, ?? GPM flow requirement
120 VAC / 30W for camera electronics

iii. Electrical/electronic
Camera Link fiber to control system (computer room)

iv. Software
Acquisition sequence / telescope state (?)

4.7. Low Order Wave Front Sensors (LOWFS)

This subsystem is still in the early design phase and there is not enough information available to outline the required electronics. The devices listed below are expected, based on the current understanding of the design. This section will be completed prior to the PDR.

4.7.1. Overview

The LOWFS assembly includes two NIR tip-tilt sensors, a NIR tip-tilt-focus-astigmatism sensor (TTFA) and a visible truth wavefront sensor (TWFS). Light from three natural guide stars feeds these four sensors. The T/T sensors each have their own star; the TWFS will use the visible NGS light while the TTFA uses the NIR light from the same NGS. Each star will be AO corrected using a MEMS

DM internal to the assembly. This correction is maximized using the patrolling LGS beacons positioned near each star. The TWFS is used to calibrate biases that arise when using LGS in an AO system. This assembly is located on the cooled AO bench, as shown in Figure 11.

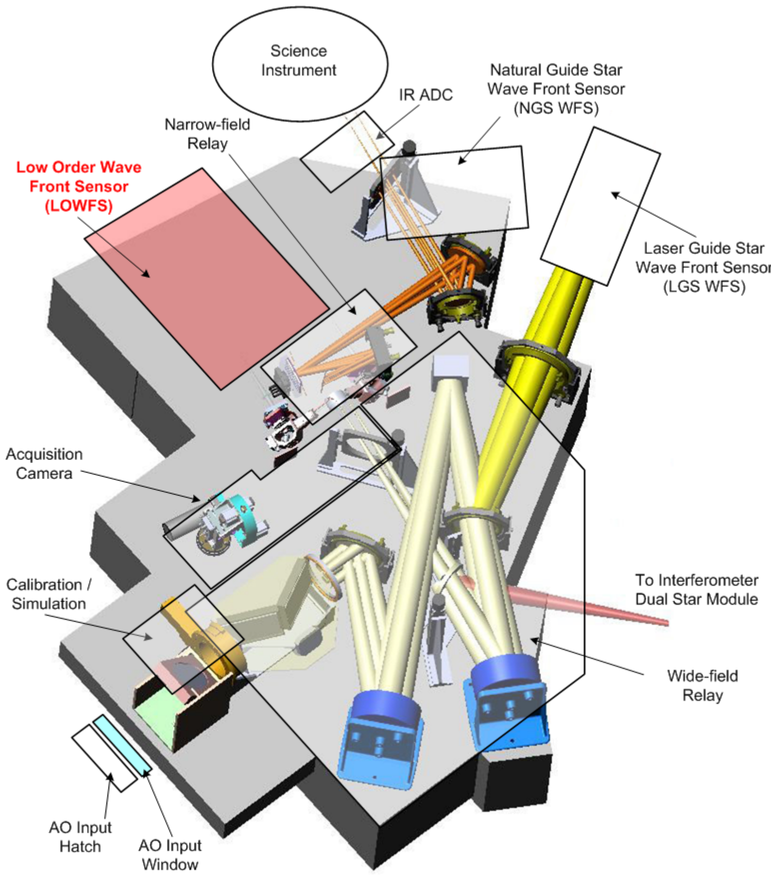

Figure 11: Location of LOWFS

TT Pickoff (2)
TWFS/TTFA pickoff (1)
TT mirrors (3)
TT amplifier
TT PSU
Unit focus (3?)
TWFS Lenslet
TTFA Lenslet
TWFS Assy rotator
DM (3)
DM control electronics
TT cameras (2 – IR)
TWFS camera (IR)
TTFA camera (visible)
IR camera electronics (3)

Visible camera electronics (1)
IR instrument temp/pressure monitor/control
Remote power control

4.8. Narrow-field Relay

4.8.1. Overview

The Narrow-field relay provides high order correction to the science beam. The corrective element is a 4k-actuator MEMS (Micro Electro-Mechanical System) deformable mirror, produced by Boston Mircomachines. This deformable mirror is mounted on a slow tip/tilt stage for field steering. The location of this subsystem is shown in Figure 12, below.

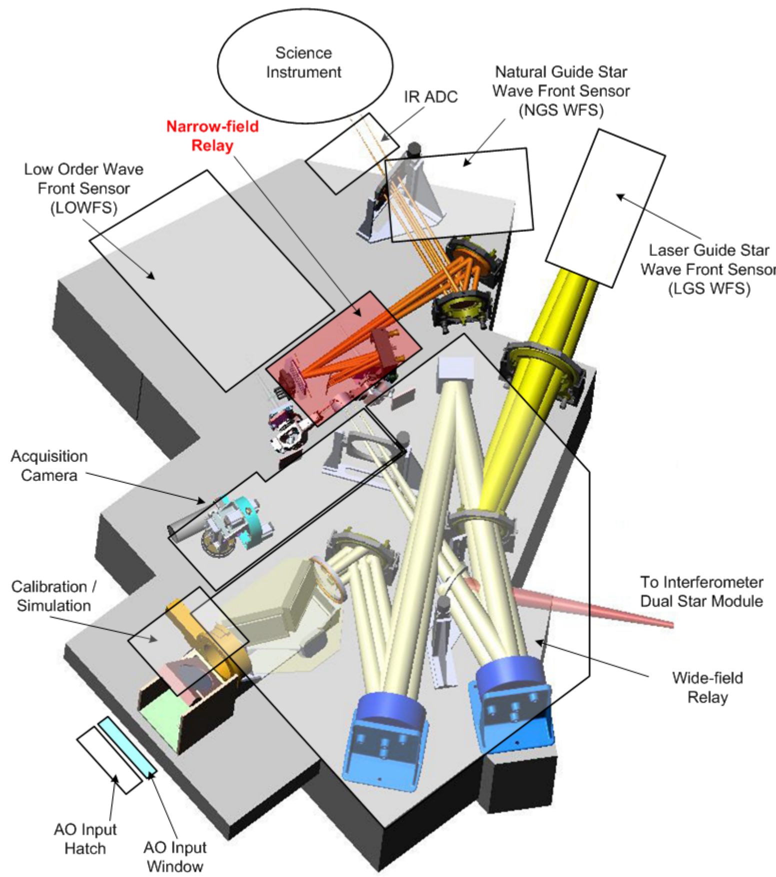

Figure 12: Location of Narrow-field Relay

Figure 13 shows the subsystem components. The DM has a single electronics box that contains the high voltage power supply and amplifiers. The tip/tilt stage will require an amplifier and power supply. Both the DM electronics and the tip/tilt electronics will require remote power control. The DM electronics includes the power supply and the control interface provides the functions to control the output voltage. The tip/tilt stage may require an analog signal to control the output voltage if that functionality is not included in the amplifier.

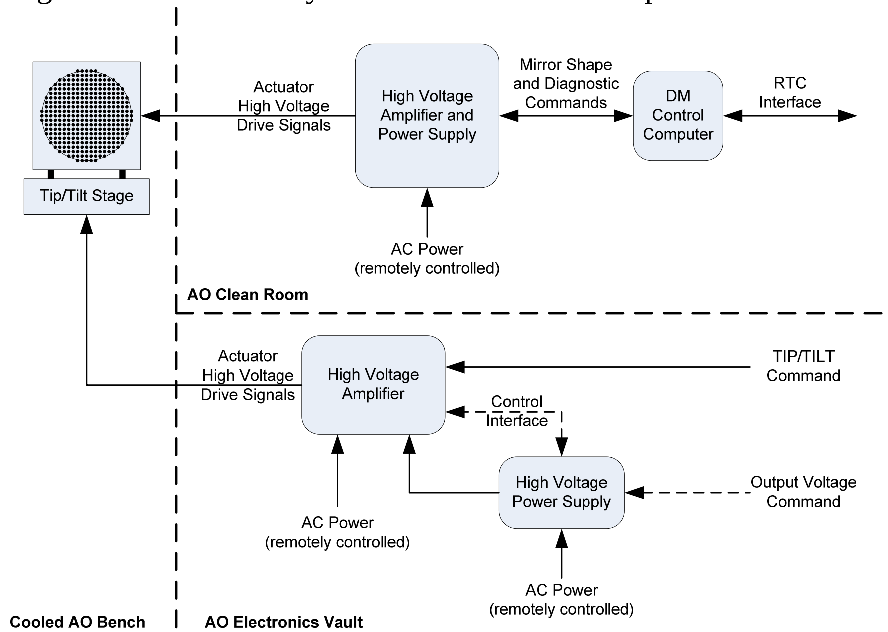

Figure 13: Schematic of Narrow-field Relay

The DM and tip/tilt stage are mounted on the cooled AO bench. Due to cable length restrictions, the DM electronics (and real-time controller) must be located in the AO clean room. The tip/tilt electronics can most likely be located in the electronics vault. Details about the tip/tilt stage and controls will be presented in the motion control document.

4.8.2. Requirements and compliance

4.8.3. Support equipment

Rack space will be required in the clean room to house the DM amplifier crate. This crate is 3U, 15 inches deep and 17 pounds. Additional space will likely be required for the real-time computers, as discussed in section 6.3.

Rack space in the electronics vault will be needed for the tip/tilt electronics.

4.8.4. Cabling

The MEMS DM cabling presents a significant challenge. The four cables that connect the DM to the high-voltage amplifier are limited in length to 2.5m. Further more, these cables are a 64mm wide flat cable terminated on each end with 528pin ‘megarray’ connectors. These cables will require a pinch type seal in the wall of the cold box as bulkhead connectors are not feasible. Care must be taken routing these cables as tight bends or creases can destroy them. There is some concern about how the connectors will function at the cold temperature. Maintaining the registration of these fine pitch connections over the temperature change from ambient to -15°C could be problematic if the coefficients of expansion are not well matched. Testing will be required to qualify these connectors at the low operating temperature. There is no concern, from an electrical noise/interference standpoint, with sandwiching multiple cables on top of one another.

The DM electronics is connected to the real time computer I/O card with an 80 conductor cable. The length of this cable cannot exceed 2m meters. The data is transmitted using LVDS (Low Voltage Differential Signaling). It may be possible to convert these signals to fiber optic and send the commands directly from the RTC.

4.8.5. Internal Interfaces

i. Mechanical
   4 flat DM cables through cold box (clamped seal)
   1 (or 3) Tip/Tilt cables through cold box (bulkhead connection)

ii. Electrical/electronic
   DM actuator signals, 0-250VDC (to ground and between adjacent actuators)
   T/T actuator signals, 100VDC (?)
   DM drive signals (LVDS, 3.5mA current loop, ~1.25V common mode)
   T/T drive signals
   120VAC mains remote control

iii. Software
   AC mains remote control
   HV power supply interface

4.8.6. External Interfaces

i. Mechanical
   3U of rack space in clean room (DM electronics)
   xU of rack space in clean room (DM control computer)
   Xx rack space in electronics vault (T/T electronics)

ii. Infrastructure (power, pneumatic, glycol, etc.)
   Cooling for rack in clean room
   120VAC/20A service

iii. Electrical/electronic
   DM control computer to RTC fiber

iv. Software

4.9. Natural Guide Star Wave Front Sensor (NGS WFS)

4.9.1. Overview

The NGS WFS assembly is comprised of a pickoff dichroic (to send visible light to the WFS), a field selection mechanism, lenslet assembly and a camera with a motorized focus mechanism. As shown in Figure 14, this subsystem is located after the narrow-field relay.

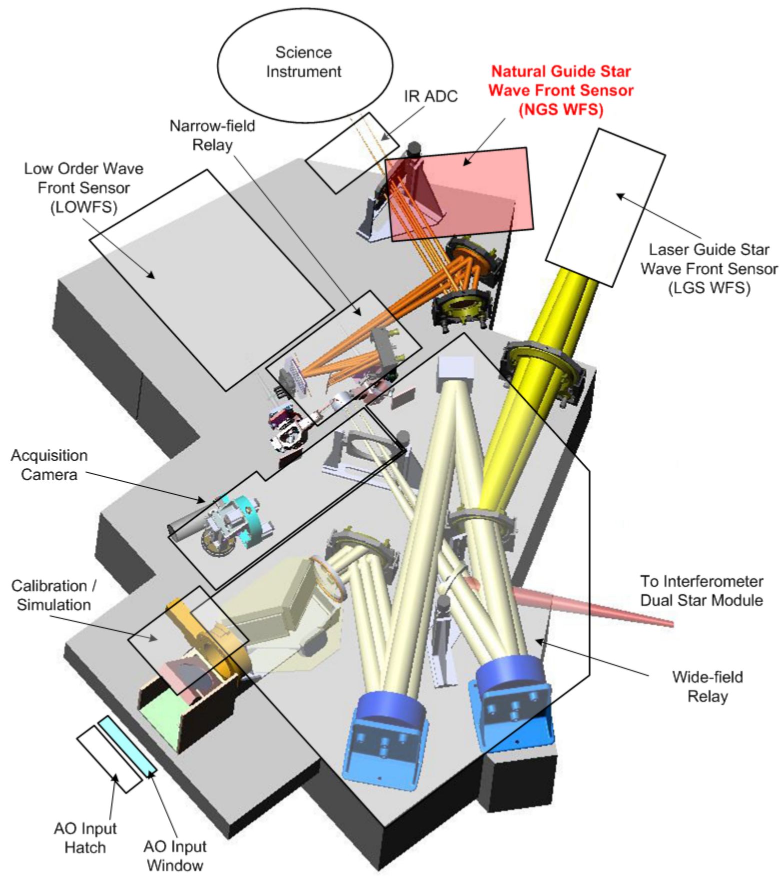

Figure 14: Location of NGS WFS

The motion controls associated with the pickoff dichroic, field selection mechanism, lenselet assembly and focus mechanism will be discussed in the Motion Control document.

A schematic of the camera is shown in Figure 15, below. The camera will be detecting visible wavelength light. In order to maintain sensitivity, the camera head will likely require glycol cooling. This will also insure that any heat generated by the camera is removed directly from the cold bench, not radiated into the conditioned environment. The camera electronics will likely communicate via fiber based Camera Link to the control system.

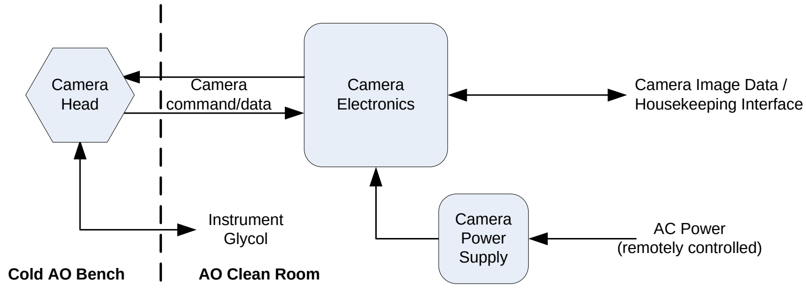

Figure 15: Schematic of NGS WFS

The camera head and motion stages will be mounted on the cold AO bench. The servo electronics will either be in the clean room or the electronics vault. If the camera electronics are not integrated into the camera head, they will likely be in the AO clean room given the length constraints normally associated with camera cabling.

4.9.2. Requirements and compliance

4.9.3. Support equipment

The moveable stages will require motion control channels, as detailed in the motion control design document.

The camera electronics will likely need to be located in the clean room, physically close (within 3m?) to the camera head. This will necessitate a rack or enclosure for this equipment. Glycol (or other method) will be needed to extract the heat from this enclosure. The space requirement is probably on the order of 3U. One channel of remote power control is required for this equipment.

4.9.4. Cabling

The motion stages will require cables for the motor/encoder signals. These cables will be required to pass through the wall of the cold box.

There will be at least one, perhaps two cables required to connect the camera head to its electronics. These cables will likely have a length limit of a meter or two. It is unlikely that bulkhead connectors can be used with these cables, both for electrical signal integrity and mechanical construction reasons. The cold box pass through will need to clamp the cables to maintain the integrity of the enclosure seal.

A connection, most likely fiber, will be required from the camera electronics to the control system. The location of the control computer(s) is currently TBD.

4.9.5. Internal Interfaces

i. Mechanical
8 motion control cables though the cold box wall (bulkhead connection)

2 camera cables through the cold box wall (clamped seal)

ii. Electrical/electronic
Motion stage motor/encoder/limit switch signals
Low voltage detector clock/data signals (analog, LVDS, etc)

iii. Software
Camera control (exposure, frame rate, etc)

4.9.6. External Interfaces

i. Mechanical
XX rack space in clean room
Space for motion controllers (where?)

ii. Infrastructure (power, pneumatic, glycol, etc.)
Camera head glycol, ?? GPM flow requirement
Camera electronics (rack/enclosure) glycol, ?? GPM flow requirement

iii. Electrical/electronic
120 VAC mains remote control

iv. Software

4.10. Science Instrument Atmospheric Dispersion Compensator

4.10.1. Overview

An Atmospheric Dispersion Compensator (ADC) is required for the science instrument. As shown in Figure 16, this is the last component along the optical path located on the cooled AO bench.

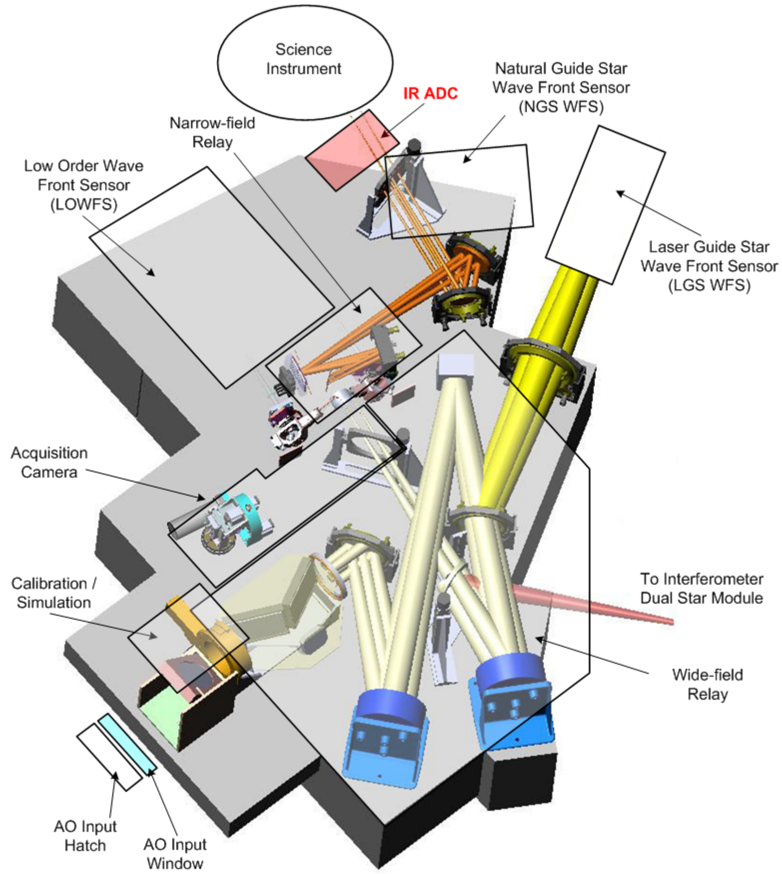

Figure 16: Location of Atmospheric Dispersion Compensator

A motion control channel is required to insert/remove the ADC and two more channels are required to rotate and translate the optical elements. Aside from the required cabling, there is no impact on the electronics design.

4.10.2. Requirements and compliance

Video surveillance (FR-28)

4.10.3. Support equipment

The moveable stages will require motion control channels, as detailed in the motion control design document.

4.10.4. Cabling

The motion stages will require cables for the motor/encoder signals. These cables will be required to pass through the wall of the cold box.

4.10.5. Internal Interfaces

i. Mechanical
   3 motion control cables though the cold box wall (bulkhead connection)

ii. Electrical/electronic
Motion stage motor/encoder/limit switch signals

iii. Software

4.10.6. External Interfaces

i. Mechanical
Space for motion controllers (where?)

ii. Infrastructure (power, pneumatic, glycol, etc.)

iii. Electrical/electronic

iv. Software

4.11. Cold (Bench) Enclosure

4.11.1. Overview

The bench enclosure surrounds the most of the AO system, allowing it to be cooled to -15°C. The humidity inside the enclosure will also need to be controlled to prevent condensation when warming or cooling the AO system. Particulate levels in the enclosure will be monitored.

Lighting inside the bench will be remotely controlled, but have a local switch. The control interface will provide feedback to the MCS as to the state of the lights and local/remote status.

A web-accessible surveillance camera will be installed in the enclosure to aid in the monitoring of the system and provide visual feedback. This camera will include remote pan-tilt-zoom control. An Ethernet connection will be required. Ideally this equipment will support Power over Ethernet (PoE) so discrete power wiring can be avoided. Remote power control must be available for this camera to reduce heat loading on the enclosure.

An Ethernet interface will be required to allow communication with the climate controller. This will allow the MCS to set and monitor the temperature and humidity inside the enclosure and control of the air circulation.

4.11.2. Requirements and compliance

Lighting and outlets
Video surveillance (FR-28)

4.11.3. Support equipment

4.11.4. Cabling

4.11.5. Internal Interfaces

i. Mechanical
ii. Electrical/electronic
iii. Software

4.11.6. External Interfaces

i. Mechanical
ii. Infrastructure (power, pneumatic, glycol, etc.)
iii. Electrical/electronic
iv. Software

Bench enclosure

Temperature controls
Humidity controls
Particulate sensor
Circulation
Lights
Surveillance

4.12. AO Clean Enclosure

4.12.1. Overview

The AO clean enclosure contains the bench enclosure (cold box), the LGS WFS, the interferometer feed optics (Dual Star Module) and the science instrument. Some electronics will be located in this area due to cabling constraints. This enclosure will be maintained at the dome ambient temperature, around zero Celsius. The humidity inside this enclosure will need to be controlled when warming or cooling the bench enclosure to prevent condensation. Particulate levels within the enclosure will also need to be monitored. The room will be equipped with a surveillance camera, remotely controlled lighting and air filtering/circulation.

Temperature and humidity data should be available from the HVAC controller via an Ethernet or serial interface.

Several digital I/O channels will be required to handle the lighting and circulation. Both of these will have a local/remote capability and provide state feedback to the MCS. As it may be required to periodically circulate the air (through a HEPA filter), based on the measured particulate levels, it is desirable to separate the lighting and circulation functions. Two outputs and four inputs will be required.

These signals should be optically isolated. The existing AO system does not provide feedback about the local/remote state. Reference 118/128-75-01

A web-accessible surveillance camera will be installed in the room to aid in the monitoring of the system and provide visual feedback. An Ethernet connection will be required. Ideally this equipment will support Power over Ethernet (PoE) so discrete power wiring can be avoided.

4.12.2. Requirements and compliance

USP backup is required for this equipment, ~30min run time
Thermal runaway protection – shunt trip
Telephone line
Emergency lighting
Lighting and outlets

4.12.3. Support equipment

Device	Subsystem	Space (rack U)	Dissipated Power (W)
camera electronics	LGS WFS	12	200
camera electronics	acquisition camera	3	50
camera electronics	LOWFS		
DM controller/amplifier	LOWFS	3	40
DM controller/amplifier	narrow-field relay	3	40
camera electronics	NGS WFS	3	50
	Total	**24**	**380**

Table 3Table 3 summarizes the space required for rack mounted equipment and the anticipated power required for the equipment.

Device	Subsystem	Space (rack U)	Dissipated Power (W)
camera electronics	LGS WFS	12	200
camera electronics	acquisition camera	3	50
camera electronics	LOWFS		
DM controller/amplifier	LOWFS	3	40
DM controller/amplifier	narrow-field relay	3	40
camera electronics	NGS WFS	3	50
	Total	**24**	**380**

Table 3: Clean Room Rack Space Summary

All of this equipment requires UPS backup, requiring ~0.25 kWh of capacity.

4.12.4. Cabling

4.12.5. Internal Interfaces

i. Mechanical
ii. Electrical/electronic
iii. Software

4.12.6. External Interfaces

i. Mechanical
ii. Infrastructure (power, pneumatic, glycol, etc.)
iii. Electrical/electronic
iv. Software

4.13. Electronics Vault

4.13.1. Overview

The electronics vault (e-vault) provides an isolated location for equipment racks. This is necessary to manage the heat generated by this equipment and to provide access that is not restricted by clean-room protocol.

The vault temperature will be maintained at 17° C. A hardware alarm will be triggered at ~28° C that will remove power from the majority of the electronics in the vault to prevent damage from overheating in the event that the cooler fails. An Ethernet connection to the temperature controller will allow remote monitoring of status and fault conditions. The racks will be air cooled, although some components may require dedicated cooling given there expected heat load.

Additional monitoring should be implemented to provide remote access to rack temperatures and glycol flow. This monitoring should be independent of as much infrastructure as possible, especially power and network, to allow access to the vault conditions under unusual fault situations. Alarms can then be established to notify operators and avoid hard shutdowns and the associated recovery effort. An analog input module that supports power over Ethernet and has a dedicated connection to the computer room would be a possible solution.

For reference, the design of the existing e-vault incorporates several protections against overheating the equipment. When the temperature in the OBS rack exceeds 45° C or there is no airflow, power is removed from the motion control amplifiers and OBS/SC VME crate. In addition, the vault temperature controller will trigger a shunt-trip breaker and cut UPS power to the vault when a threshold of ~28° C is exceeded. Both the circuit breaker and the OBS monitoring hardware may require a manual reset to a clear a fault. Given the extent of the shutdowns, it can be difficult to understand the source of the problem until personnel are present in the e-vault.

Power to the vault will be provided in three forms: commercial, clean and UPS. Commercial power will be used for lighting, air handling and cooling. Clean power will be used for electronic equipment that can tolerate power outages. UPS power will be used for the remaining outage sensitive electronic equipment.

i. Assembly location. Highlight location of assembly/component on block diagram with brief overview description.
ii. Design description. Describe design approach. Include functional layout with schematic or other diagram describing design, trade studies, design choices & background info.
iii. Physical layout. Show physical layout and locations of all associated parts.

4.13.2. Requirements and compliance

Room temp 17C (?) control
Room temp monitor
Glycol flow monitor (global to left Nasmyth)
Thermal runaway protection – shunt trip
UPS for equipment, ~30min run time
Telephone line
Lighting and outlets

4.13.3. Support equipment

Table 4 summarizes the space required for rack mounted equipment and the anticipated power required for the equipment.

Device	Subsystem	Space (rack U)	Dissipated Power (W)
Hatch control	wide-field relay	3	
DM amplifier/PSU	wide-field relay	10	1000
DM Tip/Tilt amplifier/PSU	wide-field relay	2	50
Tip/Tilt amplifiers (RTC)	LGS WFS	6	150
Tip/Tilt control processor	LGS WFS	4	150
IF Electronics	Interferometer	32	800(est)
Tip/Tilt amplifier/PSU (RTC)	LOWFS	4	150
Near-field Instrument	Science Instrument		
Laser System Devices	Laser		
Motion controllers	all		
Ethernet	all	1	700
LSS remote PLC node	Laser Safety System	20	500
	Total	**82**	**3500**

Table 4: Electronics Vault Rack Space

Most of the equipment listed in the table will require UPS backup. About 1.75 kWh of capacity will be required.

4.13.4. Cabling

4.13.5. Internal Interfaces

i. Mechanical
ii. Electrical/electronic
iii. Software

4.13.6. External Interfaces

i. Mechanical
ii. Infrastructure (power, pneumatic, glycol, etc.)
iii. Electrical/electronic
iv. Software

5. Laser Guide Star Facility

5.1. Overview

The Laser Guide Star Facility provides the facilities for propagation of the laser beams. The LGSF includes the lasers, Laser Service Enclosure, Laser Launch Facility, Launch Telescope and any safety related system for propagation of laser beams. The Laser Service Enclosure(s), housing the laser systems, are located on the elevation ring of the telescope. The Laser Launch Facility receives the laser beams and generates the asterism and propagates the beams from the behind the secondary. Some of the electronics required for this system, such as the Laser Safety System Programmable Logic Controller may be located in the AO electronics vault.

5.2. Laser Units

5.2.1. Overview

The NGAO system requires ~75W of CW laser power. This will be achieved using three 25W laser units. These units, along with switch yard optics are housed in an enclosure mounted to the telescope elevation ring, as show in Figure 17. Each laser unit will have a shutter to block the output, an Ethernet (or serial) interface and several discrete inputs.

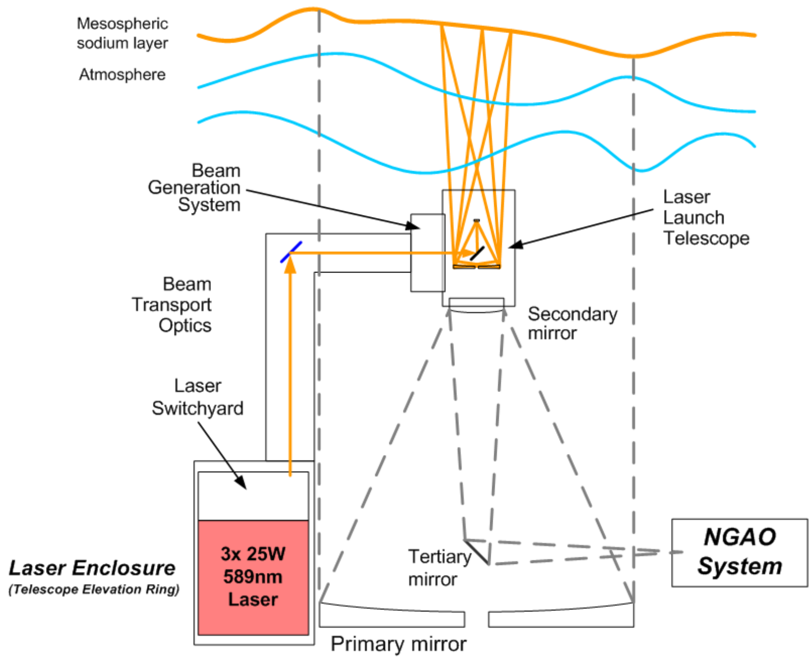

Figure 17: Location of Laser Units

Lasers (3)

  Command/feedback

5.3. Switchyard

5.3.1. Overview

The Switchyard is located within the Laser Enclosure attached to the elevation ring, as shown in Figure 18. It receives the beams from the laser systems, formats them and sends them on to the Beam Transport Optics (BTO). The Switchyard ensures the laser beams are properly formatted and aligned to the BGS. The Switchyard compensates for pointing errors due to the changing gravity vector as the telescope moves in elevation. It also provides polarization controls, safety shutters, and a switchable element to dump most of the beam power to produce a low power alignment beam.

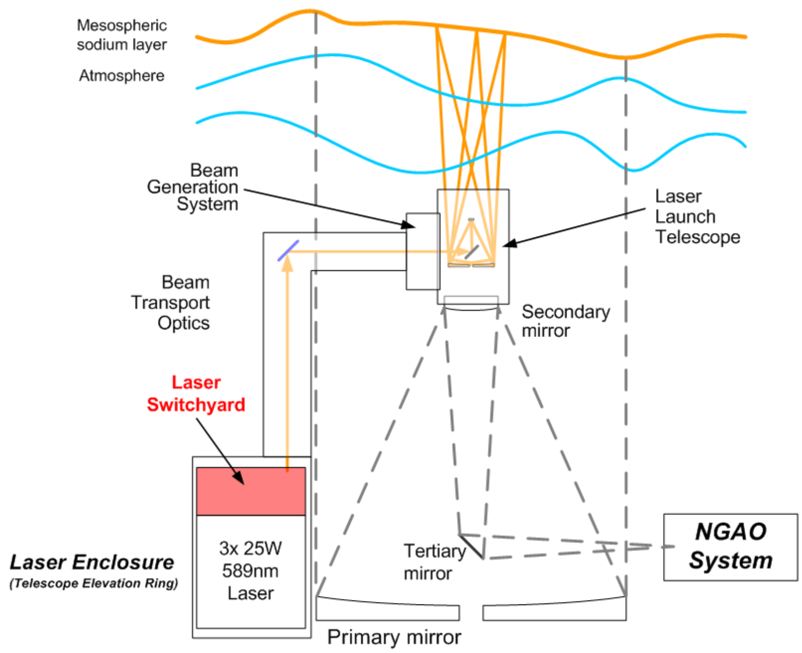

Figure 18: Location of Laser Switchyard

Twelve axes of motion control are required for the Switchyard steering mirrors, wave plates and beam splitter. Details regarding these devices will be discussed in the Motion Control document.

A deployable beam splitter will be used to divert laser light to a beam dump. This will allow the laser system to operate at full power while only a small fraction of the yellow light will be transmitted through the beam splitter and enter the beam transport optics. The beam dump will have a calorimeter or power meter for diagnostics. By monitoring the throughput from the switchyard to the launch telescope, the condition/degradation of the optical path can be tracked.

There is discussion of including a low power laser to facilitate system alignments without the presence of 25W+ of 589nm light. Inclusion of this source would only require 120VAC power; there are currently no requirements for motion stages or remote control of this alignment laser.

Reference the Laser Launch Facility Switchyard Preliminary Design (KAON 661) for more details.

5.3.2. Requirements and compliance

5.3.3. Support equipment

The motion devices will require motion controllers and amplifiers. Both servo amplifiers and high-voltage PZT amplifiers will be needed.

5.3.4. Cabling

Motion control cabling for six rotators and one linear stag will be required. These will all be servo motors. To control the three tip/tilt mirrors, motion control cabling will be needed for six peizo actuators. Depending on the architecture, these cables might be short – within the laser enclosure, or longer – running through the elevation wrap to the AO electronics vault.

The analog signal from the calorimeter will need some cabling.

5.3.5. Internal Interfaces

i. Mechanical
 7 servo motion cables
 6 peizo motion cables

ii. Electrical/electronic
 Servo motor / encoder / limit switch
 Peizo actuator (0-120VDC)
 Calorimeter: 0-10V analog signal

iii. Software
 Motion control
 Calorimeter readback
 AC mains remote control

5.3.6. External Interfaces

i. Mechanical
 Space for motion controllers (AO e-vault or Laser Enclosure)
 Space for analog input or COTS controller (2U)

ii. Infrastructure (power, pneumatic, glycol, etc.)
 Glycol for beam dump, 75W
 Glycol for cooling electronics (??)

iii. Electrical/electronic
 120VAC power

iv. Software

5.4. Beam Transport Optics

5.4.1. Overview

The Beam Transport Optics (BTO) subsystem is responsible for delivering the laser light from the Switchyard to the Beam Generation System. In the current design, there are no electrical/electronic components in this system. Interlock switches will be required to prevent propagating laser light when the light pipe(s) are open for service and a connection to the LSS e-stop (FR-1996). Status indicators are also required (FR-1997), at access points to the BTO, to inform personnel of the presence of laser light. They would be part of the Laser Safety System and not covered by this document. All of the actuated steering mirrors and diagnostics are located in either the Switchyard or Beam Generation System. For completeness, the BTO location is shown in Figure 19, below. Reference the Laser Launch Facility BTO Preliminary Design (KAON 662) for more details.

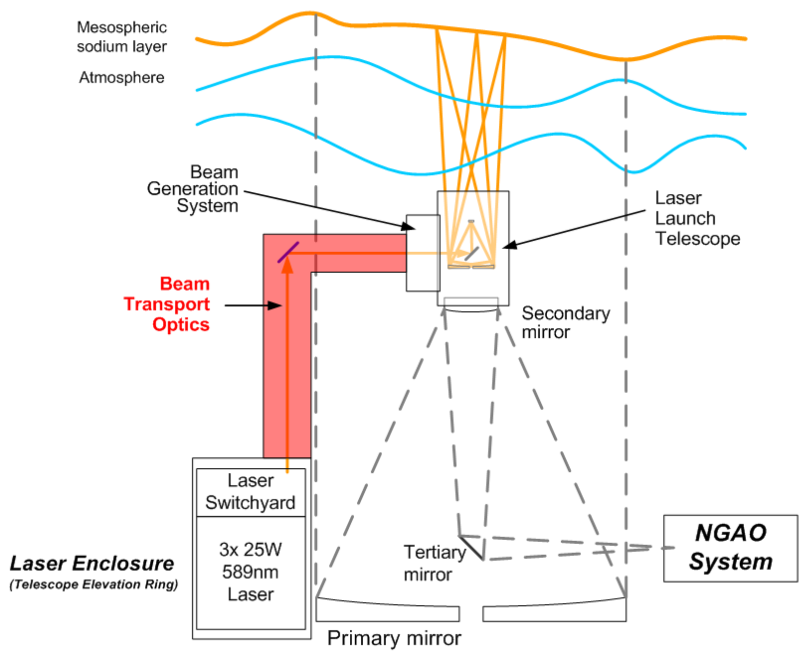

Figure 19: Location of Beam Transport Optics

5.5. Beam Generation System

5.5.1. Overview

The Beam Generation System (BGS), highlighted in Figure 20, is located within the secondary f/15 module on the telescope. It receives the laser beams from the Beam Transport Optics (BTO), formats them into the required asterism, directs them into the launch telescope and provides the beam pointing on the sky.

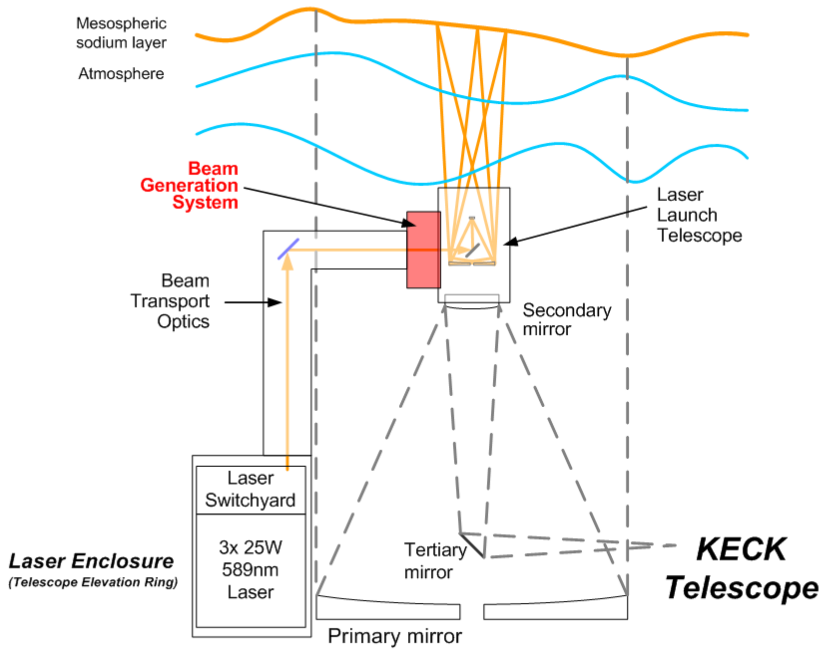

Figure 20: Location of Beam Generation System

The BGS requires a number of movable optics to divide the three incoming beams into the seven beams required for the sky beacons, position the beams into the required asterism and then reformat the result to be compatible with the Launch Telescope Assembly. A number of sensors and cameras are required to provide diagnostic and feedback information about beam quality, alignment and output power.

There are 16 motorized actuators in the BGS. Reference the motion control document for a complete description of the moving devices. The cabling requirements for the motion control aspect of this subsystem depend heavily on the location of the motion controller(s) and amplifiers. This decision has yet to be made, so the two options will be presented. A number of the motion stages will not be actuated with servo motors. Instead piezo actuators will be used. The piezo actuators will require different controls and cabling than the servo motors.

Several cameras will be needed to analyze the beam quality, create the asterism, and verify the alignment of the asterism on the sky. The cameras have not been chosen, but it is anticipated that Ethernet ready cameras with integrated electronics will be meet the requirements.

Reference the Laser Launch Facility Beam Generation System Preliminary Design Document (KAON 659) for a more comprehensive discussion of the BGS.

5.5.2. Requirements and compliance

5.5.3. Support equipment

The moveable stages will require motion control channels, as detailed in the motion control design document. If the distributed option is chosen, some sort of enclosure/heat exchanger will be required for the motion controller/amplifiers located on the secondary. If the centralized approach is chosen, space for the equipment will be required in the electronics vault. Both servo amplifiers and high-voltage pzt amplifiers will be needed.

Remote AC power control will be needed for the motion controls and for the various cameras and sensors.

Analog inputs will be required to digitize the signal from the power meter, position sensing diodes (PSD) and polarization sensor. The PSD used in the past have been from On-Trak Photonics, Inc. The amplifiers provide a +/-10 volt signal for each axis of the sensor.

5.5.4. Cabling

If distributed control is implemented, a single dedicated cable (fiber or CAT-5) will be required to communicate the command/feedback information from the AO electronics vault to the distributed controller on the telescope secondary. Glycol will be required to cool the motion controller and the amplifiers. Short cables will then connect the amplifiers to the motion stages. This option significantly reduces the cabling at the expense of cooling requirements and possibly more weight, as compared with the centralized option.

If centralized control is implemented, 16 motion cables will need to be run from the AO electronics vault to the telescope secondary. These cables are on the order of 40m in length. A significant cost and installation effort would be associated with this approach. The benefit would be no additional weight (of controller/amps) on the secondary and no excess heat to remove from the telescope.

5.5.5. Internal Interfaces

i. Mechanical
   14 servo motion control cables (distributed architecture)
   2 piezo motion control cables (distributed architecture)

ii. Electrical/electronic
   Motion stage motor/encoder/limit switch signals
   8 Analog inputs (power meter, polarization sensor, 3x beam position sensor[x,y])

iii. Software
Motion control
AC mains remote control
Camera control (exposure, frame rate, etc)

5.5.6. External Interfaces

i. Mechanical
14 servo motion control cables to AO e-vault (centralized architecture)
2 peizo motion control cables to AO e-vault (centralized architecture)
1 fiber-optic cable for motion controller (distributed architecture)
3 Ethernet for cameras
1 Ethernet for analog input module

ii. Infrastructure (power, pneumatic, glycol, etc.)
Glycol to cool motion controller (distributed control option)
Glycol for the beam dump (dissipate 75 watts)
6 Clean 120VAC power for diagnostic equipment < 15A total
120VAC power for motion amps (distributed control option)

iii. Electrical/electronic
AC power control

iv. Software

5.6. Launch Telescope

5.6.1. Overview

The laser launch telescope is a vendor supplied unit that accepts the formatted laser beams from the BGS and projects them on the sky. The unit is fitted with several temperature transducers to provide information for temperature compensation and dewpoint warning.

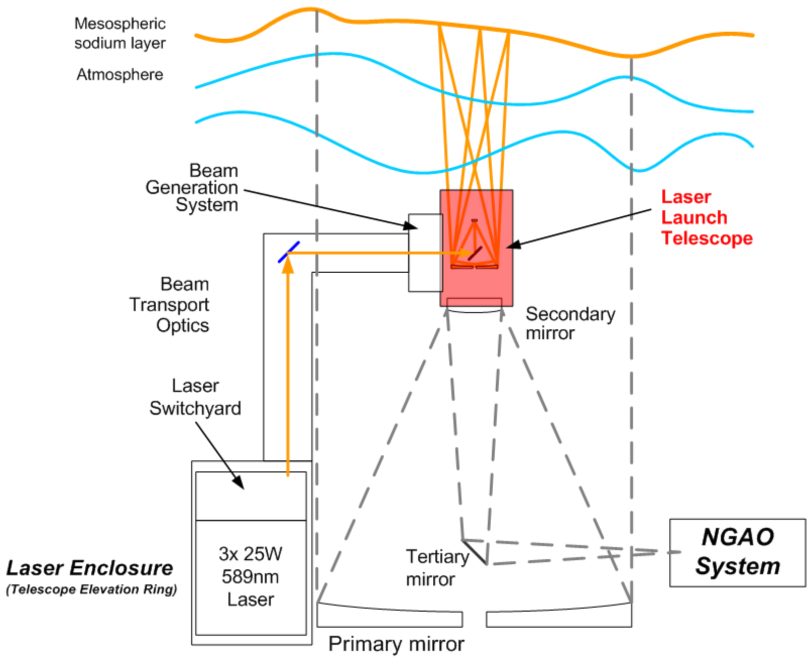

Figure 21: Location of Laser Launch Telescope

5.7. Laser Safety System

5.7.1. Overview

A safety system is needed to ensure the NGAO laser facility operates safety and in accordance with regulatory standards for operating lasers. The standards help to ensure safety for internal personnel and equipment, as well as external assets such as aircraft and space vehicles.

Similar systems have been developed for the K1 and K2 laser systems. The NGAO design will leverage the technology and knowledge gained from these two systems. As with the existing systems, the NGAO system will be PLC based. It and have two nodes, one in the AO enclosure and one in the computer room. Reference the LSS preliminary design on the NGAO Twiki: [LaserPDRPhase/NGAO_Safety_System_Preliiminary_Design.doc]

5.7.2. Requirements and compliance

Interface w/ local e-stop (FR-1323)
Interface w/ observatory e-stop
Interface w/ OEI video processor (FR-2092)
Interface w/ Laser Units (FR-2107) differential TTL
Interface w/ LGS Control system (FR-2084)
Interface w/ MCS (FR-2076) Ethernet
LSE Smoke detector – tied to LSS (FR-1324)

5.7.3. Support equipment

The system will have two nodes, connected by a dedicated 2-wire communication link.

The primary node, with the PLC, will be located in the computer room. This node will require ~10U of rack space and < 500W of 120VAC power.

The second node will be located in the AO electronics vault. This node will require ~20U of rack space and < 500W of 120VAC power.

5.7.4. Cabling

The cabling requirements for the IO points of the LSS are covered in the LSS design documents. Of relevance to the electronics design is the cable connecting the two nodes, the AC power cabling and the external communications cabling. The inter-node cable requires two conductors and will need to pass through the azimuth cable wrap. The appropriate cabling will be required to interface the LSS with the observatory e-stop chain. The LSS will communicate via Ethernet with the LGS control system and MCS.

5.7.5. Internal Interfaces

i. Mechanical
   Cabling
ii. Electrical/electronic
   Signal levels/voltages
iii. Software

5.7.6. External Interfaces

i. Mechanical
   Rack space
   Cables/cable requirements
ii. Infrastructure (power, pneumatic, glycol, etc.)
iii. Electrical/electronic
   Motion channels
   Remote power/reset
   Observatory e-stop
iv. Software

Laser safety system
    Status feedback
    Programming/diagnostics
    Remote power control
20U (estimated) rack space requirement in AO e-vault
10U (estimated) rack space requirement in computer room
500W in AO
500W in computer room

5.8. Laser Service Enclosure

5.8.1. Overview

5.8.2. Requirements and compliance

Laser enclosure

- Temp sensor
- Humidity sensor
- Particulate sensor
- Surveillance camera (FR-1327)
- UPS power (3-phase) (FR-1907, 2kW)
- UPS power for TBD minutes
- Shunt-Trip for emergency shutdown (FR-1330)
- Telephone extension (FR-1309)
- Emergency lighting (FR-1322)
- Smoke detector – tied to LSS (FR-1324)
- Lighting and outlets (FR-1310 and 1312)

6. Support Equipment

6.1. Motion Control

6.1.1. Overview

The NGAO system currently has 90 axes of motion control, located throughout the system. The motion control architecture and the specifics of that design are discussed in a separate document, which has not been finalized pending further work on the subsystem designs. It is safe to assume that the architecture will include both centralized and distributed motion controllers with either centralized or distributed servo amplifiers. Actuators will include servo motors (brushed and brushless), peizo-electric forcers and peizo resonant motors. These will provide motion in linear, rotational and tip/tilt stages. The controllers and drive electronics will be unique for each type of actuator. Reference the motion control architecture study (KAON643) and the NGAO master device list (KAON682) for more information.

6.1.2. Requirements and compliance

Local/remote, lockout/tagout capability

6.1.3. Support equipment

Controllers will likely require a programming interface, either serial or Ethernet, a command/feedback interface, discrete I/O lines for feedback/status and remote power control. Rack space and perhaps cooling will be needed to house this equipment. Equipment will be required to locally disable motion devices during servicing. When disabled, the hardware will allow the installation of tags and/or locks to protect personnel and equipment.

6.1.4. Cabling

6.1.5. Internal Interfaces

i. Mechanical
   Cabling
ii. Electrical/electronic
   Signal levels/voltages
iii. Software

6.1.6. External Interfaces

i. Mechanical
   Rack space
   Cables/cable requirements
ii. Infrastructure (power, pneumatic, glycol, etc.)
iii. Electrical/electronic
   Motion channels
   Remote power/reset
iv. Software

6.2. Control Computers

Remote power control
Remote reset
Serial diagnostics/console
Ethernet

6.3. Real-Time Control Computers

6.3.1. Overview

The real-time control computers realize the low order wave front sensing, tomography, high-speed data capture for diagnostics and actuator command generation functions. A significant amount of equipment is required to perform these tasks.

The current approach is to locate the bulk of the RTC including the computing engines, disk subsystem, command generation, control processors and timing generation equipment off-telescope in the computer room. The necessary connections to the Nasmyth equipment will be made with dedicated fiber-optic cables, or in some cases, the AO Ethernet backbone.

6.3.2. Support equipment

Time infrastructure

Remote power control
Remote reset
Serial diagnostics/console

6.4. Time Infrastructure (Synchronization)

Components of the NGAO system are required to be synchronized. In some cases synchronization with absolute (UT) time is necessary, for instance event logging or computation of field positions during acquisition. In other cases, extremely tight synchronization between components is required, for instance between cameras, the RTC and the DMs. Components may be located in the off-telescope computer room, the Nasmyth deck of the telescope, and possibly the elevation ring or the secondary.

The observatory currently uses GPS and IRIG-B to synchronize systems to UT. VME boards decode the IRIG-B signal and create the necessary interrupts to synchronize the processor. This method is appropriate for microsecond level accuracy, assuming compensation for propagation delays from the GPS receiver. Network Time Protocol (NTP) is also used for servers. This provides millisecond level accuracy.

It is clear that the existing methods will not meet the stringent requirements of the RTC side of NGAO. A dedicated/custom solution will be required to achieve the sub-nanosecond synchronization required between distributed components.

6.5. Communication Infrastructure

Network requirements
Terminal server requirements

6.6. Off-Telescope Cabling

In this section, an attempt is made to summarize the cabling leaving the left Nasmyth area of the telescope. The destination is likely the computer room. These cables must be routed through the azimuth cable wrap.

Fiber pair for Ethernet switch uplink
3x fiber pair for IF/Ohana
Cat-5 for e-vault monitor
~20x fiber pair for RTC
Coax (?) for timing signal
Cable for LSS AO node (1 twisted pair)

7. Instrument

7.1. Overview

For this document, two instruments are considered: the Interferometer and the Narrow-field Imager + Integral Field Spectrograph. The following sections provide an overview of both instruments and details of (or references to) their interface with the NGAO system.

7.2. Interferometer

7.2.1. Overview

The NGAO system is required to support the Keck-Keck Interferometer. The existing AO system provides a collimated output to the Dual Star Module (DSM) for the Nuller and Visibility (V^2) modes and a converging beam for the ASTRA and OHANA modes. Mode specific injection modules are located on the AO bench.

The preliminary NGAO design will support the ASTRA/OHANA modes by providing a focused beam to the DSM, as shown in Figure 22. The DSM will support the OHANA injection module. The collimated output is not provided by the preliminary NGAO design. The V^2 mode will be superseded by a subset of the ASTRA mode and the Nuller mode will not be supported.

Note that the interfaces listed below are based on the current configuration. The ASTRA project continues to evolve and add equipment as each subsystem is developed and integrated. It is likely that additional equipment, especially cabling, will be required to support the astrometry mode of ASTRA.

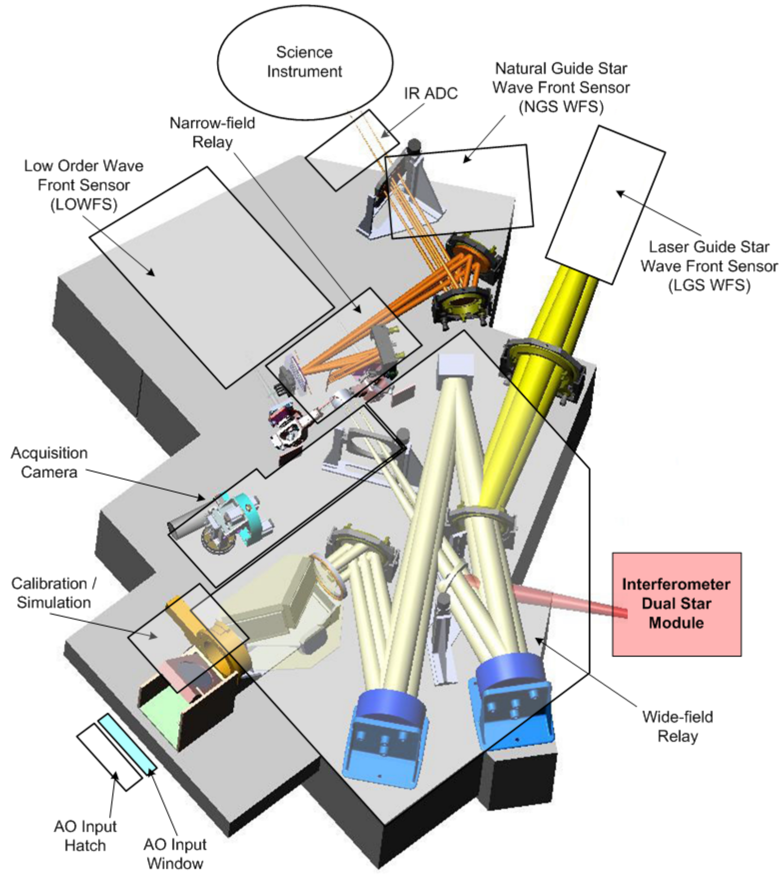

Figure 22: Location of Interferometer DSM

7.2.2. Requirements and Compliance

Two accelerometers on the AO bench (INT-169)

7.2.3. Support Equipment

7.2.4. Cabling

The existing design requires numerous cables to many devices. Cables run from the AO electronics vault to the DSM, AO bench, telescope primary, telescope secondary, telescope tertiary and the Coude M5, M6 and M7 mirrors.

7.2.5. Internal Interfaces

i. Mechanical
   Cabling
ii. Electrical/electronic
   Video
   Accelerometer (+/-10 V, differential)
   Shutter/target (15V DC)
   Hatch covers (< 32V DC, 20kHz PWM)
   Servo motor (<40V DC)

Pico-motors (130V pulses, 1kHz, negligible current)
Ethernet
RS-232 serial
8x remote power control

iii. Software

7.2.6. External Interfaces

i. Mechanical
~35U rack space in e-vault (existing design)
Cabling (from IF rack in e-vault)
3 twin-ax + 1 field bus to secondary – through el wrap
3 twin-ax + 1 field bus to tertiary – through el wrap
6 twin-ax + 3 field bus to primary – through el wrap
1 twin-ax + 1 field bus to DSM
2 twin-ax + 1 field bus to cold AO bench
4 motion control to M6 doghouse
4 motion control to Coude crypt (M7) – through az wrap
5 motion to DSM
6 video to DSM
8 shutters (6pos flat cable) to DSM
2 shutters to M6
1 shutter to M5
1 serial (4pos flat) to DSM
1 picomotor low voltage (25pos round) to DSM
M5 hatch
M7 hatch – through az wrap
1 coax for IRIG-B
1 VME remote reset
1 serial for PMAC

ii. Infrastructure (power, pneumatic, glycol, etc.)
800W (est.) 120VAC, UPS backed, in e-vault
200W (est.) 120VAC, UPS backed, in AO clean room

iii. Electrical/electronic
4 RS-232 serial ports (to terminal server)
2x CPU console, Pulizzi, laser source
4 Ethernet (100BASE-T)
2x CPU, 2x Video server
3 fiber pairs to basement control room
1x accelerometers, 2x OHANA
IRIG-B time signal

iv. Software

7.3. Narrow-field Imager + Integral Field Spectrograph

7.3.1. Overview

This instrument is being designed/built as part of the NGAO project and falls under the build to cost guidelines (KAON 642). This instrument will be located in the AO clean enclosure as shown in Figure 23.

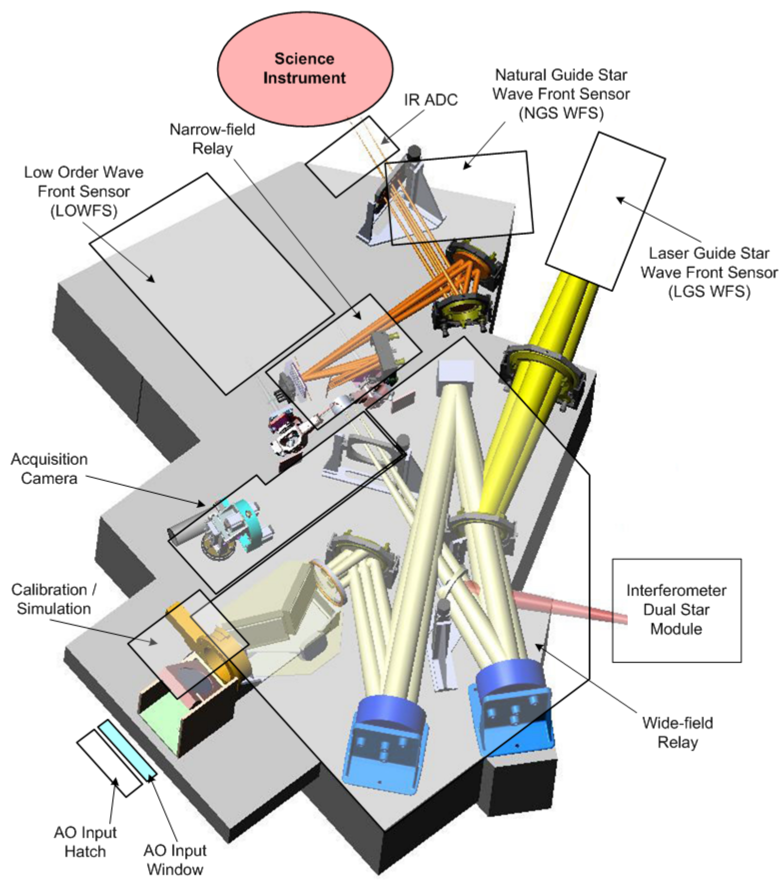

Figure 23: Location of Narrow-field Science Instrument

7.3.2. Reference external documents

8. Requirements (non)compliance

9. Cost analysis

9.1. Overview/Summary

Table 5 shows a summary of the estimated cost of the infrastructure on a sub-system basis. The following sections break down these costs. See section 12 for details of the cost estimation.

Subsystem	Cost
AO Hatch	$562
Wide-field Relay	$4,231
LGS WFS	$5,587
Acquisition Camera	$1,299
LOWFS	
Narrow-field relay	$517
NGS WFS	$3,109
IR ADC	$1,005
Cold Enclosure (bench)	$1,544
AO Enclosure	$1,406
Electronics Vault	$904
Laser Switchyard	$3,232
Laser BGS	$9,057
Laser Launch Telescope	
Laser Safety System	
Laser Enclosure	
Motion Control	
Control Computers	
RTC	
Time Infrastructure	
Communications Infrastructure	
Interferometer	
Narrow-field Science Instrument	
Total	**$32,453**

Table 5: Subsystem Cost Summary

9.2. AO Hatch Cost

Aside from the infrastructure, there is little cost associated with this system as only a small modification to the existing equipment is required. The actual cost may be different depending on the I/O architecture.

Item	Quantity	Unit Cost	Total Cost
Rack space (U)	3	$34	$102
Hatch Controller Break-out Cable	1	$100	$100
I/O (network?)	6	$32	$192
Network (?)	1	$91	$91
AC power control	1	$77	$77
Total			**$562**

Table 6: AO Hatch Costs

9.3. Calibration/Simulation Cost

9.4. Wide-field Relay Cost

Item	Quantity	Unit Cost	Total Cost
Rack space (U)	12	$34	$408
DM Cold cables	13	$0	$0
DM Cold Box Feed-through	13	$62	$806
DM high-voltage cables ($95 in connectors)	13	$150	$1,950
DM command/control cables	2	$25	$50
Tip/Tilt Cold cables	1	$0	$0
Tip/Tilt Cold Box Feed-through	1		$0
Tip/Tilt high-voltage cables	1		$0
Tip/Tilt command cable	1	$25	$25
Rotator cold servo cable	1	$120	$120
Rotator warm servo cable	1	$215	$215
Dichroic cold servo cable	1	$120	$120
Dichroic warm servo cable	1	$215	$215
AC power control	3	$77	$231
Network ports	1	$91	$91
Total			**$4,231**

Table 7: Wide-field Relay Costs

9.5. LGS WFS Cost

Item	Quantity	Unit Cost	Total Cost
Rack space (U)	24	$34	$816
Rack Glycol	1	$200	$200
Pickoff servo cable	6	$120	$720
Assembly Focus servo cable	1	$120	$120
RTC T/T cables	14	$50	$700
RTC T/T fiber-optic	1	$50	$50
Slow T/T cables	6	$50	$300
Camera signal cables	28	$50	$1,400
Camera CameraLink fiber-optic	7	$50	$350
Camera Glycol	7	$100	$700
AC power control	3	$77	$231
Total			**$5,587**

Table 8: LGS WFS Cost

9.6. Acquisition Camera Cost

Item	Quantity	Unit Cost	Total Cost
Rack space (U)	3	$34	$102
Rack Glycol	1	$100	$100
Pickoff cold servo cable	1	$120	$120
Pickoff warm servo cable	1	$215	$215
Camera signal cables	3	$50	$150
Camera CameraLink cable (fiber)	1	$50	$50
Camera Glycol	1	$100	$100
Focus stage cold servo cable	1	$120	$120
Focus stage warm servo cable	1	$215	$215
AC power control	1	$77	$77
Total			**$1,249**

Table 9: Acquisition Camera Costs

9.7. LOWFS Cost

9.8. Narrow-field Relay Cost

Item	Quantity	Unit Cost	Total Cost
Rack space in clean room (U)	3	$34	$102
DM high-voltage cables (supplied by DM vendor)	4	$0	$0
DM cmd/control cables (supplied by DM vendor)	1	$0	$0
Rack space in e-vault (U)	2	$34	$68
Tip/Tilt Cold cables	1	$0	$0
Tip/Tilt Cold Box Feed-through	1		$0
Tip/Tilt high-voltage cables	1		$0
Tip/Tilt command cable	1	$25	$25
AC power control	3	$77	$231
Network ports	1	$91	$91
Total			**$517**

Table 10: Narrow-field Relay Costs

9.9. NGS WFS Cost

Item	Quantity	Unit Cost	Total Cost
Rack space (U)	3	$34	$102
Rack Glycol	1	$100	$100
Dichroic cold servo cable	1	$120	$120
Dichroic warm servo cable	1	$215	$215
Pickoff cold servo cable	4	$120	$480

Pickoff warm servo cable	4	$215	$860
Lenselet cold servo cable	2	$120	$240
Lenselet warm servo cable	2	$215	$430
Focus cold servo cable	1	$120	$120
Focus warm servo cable	1	$215	$215
Camera signal cables (included from vendor)	2	$0	$0
Camera CameraLink cable	1	$50	$50
Camera Glycol	1	$100	$100
AC power control	1	$77	$77
Total			**$3,109**

Table 11: NGS WFS Assembly Costs

9.10. ADC Cost

Item	Quantity	Unit Cost	Total Cost
ADC cold servo cable	3	$120	$360
ADC warm servo cable	3	$215	$645
Total			**$1,005**

Table 12: ADC Costs

9.11. Cold Enclosure Cost

Item	Quantity	Unit Cost	Total Cost
remote Light interface box (p/o AO enc box)	1	$50	$50
remote Light interface wiring	1	$50	$50
I/O	3	$32	$96
Video camera; PTZ, network ready	1	$1,000	$1,000
Network Cabling	3	$25	$75
Network	3	$91	$273
Total			**$1,544**

Table 13: Cold Enclosure Costs

9.12. AO Clean Enclosure Cost

Item	Quantity	Unit Cost	Total Cost
remote HEPA/Light interface box	1	$150	$150
remote HEPA/Light interface wiring	1	$100	$100
I/O	6	$32	$192

Video Camera, network ready	1	$500	$500
Network Cabling	4	$25	$100
Network	4	$91	$364
	Total		**$1,406**

Table 14: AO Clean Enclosure Costs

9.13. Electronics Vault Cost

9.14. Laser Switchyard Cost

Item	Quantity	Unit Cost	Total Cost
Motion Control Cables (internal)	6	$120	$720
Motion Control Cables (external)	6	$235	$1,410
Piezo motion cables (external)	6	$76	$456
Glycol (motion controller/amp) (required?)	1		$0
Ethernet cables (e-vault to Laser Enclosure)	2	$50	$100
Glycol (beam dump)	1	$200	$200
Analog input	1	$87	$87
AC power control	1	$77	$77
Network ports	2	$91	$182
	Total		**$3,232**

Table 15: Laser Switchyard Costs

9.15. Laser BGS Cost

Two tables are presented below. The first,

Item	Quantity	Unit Cost	Total Cost
Servo Motion Control Cable (internal)	14	$120	$1,680
Servo Motion Control Cable (external)	14	$395	$5,530
Piezo motion cable (internal)	2	$71	$142
Piezo motion cable (external)	2	$84	$168
Ethernet cables (e-vault to secondary)	4	$50	$200
Glycol (beam dump)	1	$200	$200
Analog input	8	$87	$696
AC power control	1	$77	$77
Network ports	4	$91	$364
	Total		**$9,057**

Table 16, shows the cost associated with a traditional centralized motion control system with the controller and amplifiers located in the AO e-vault. The second,

Item	Quantity	Unit Cost	Total Cost
Servo Motion Control Cable (internal)	14	$120	$1,680

Servo Motion Control Cable (external)	14	$145	$2,030
Piezo motion cable (internal)	2	$71	$142
Piezo motion cable (external)	2	$71	$142
fiber for motion controller	1	$50	$50
Glycol (motion controller/amp)	1	$200	$200
Ethernet cables (e-vault to secondary)	4	$50	$200
Glycol (beam dump)	1	$200	$200
Analog input	8	$87	$696
AC power control	1	$77	$77
Network ports	4	$91	$364
Total			**$5,781**

Table 17, shows the cost associated with a distributed architecture where the controller and amplifiers are located in the secondary socket. Note that despite the savings on material and installation (not listed) costs, careful analysis of the weight, volume and thermal characteristics of this architecture will be needed before it can be recommended.

Item	**Quantity**	**Unit Cost**	**Total Cost**
Servo Motion Control Cable (internal)	14	$120	$1,680
Servo Motion Control Cable (external)	14	$395	$5,530
Piezo motion cable (internal)	2	$71	$142
Piezo motion cable (external)	2	$84	$168
Ethernet cables (e-vault to secondary)	4	$50	$200
Glycol (beam dump)	1	$200	$200
Analog input	8	$87	$696
AC power control	1	$77	$77
Network ports	4	$91	$364
Total			**$9,057**

Table 16: BGS Cost, Centralized MC

Item	**Quantity**	**Unit Cost**	**Total Cost**
Servo Motion Control Cable (internal)	14	$120	$1,680
Servo Motion Control Cable (external)	14	$145	$2,030
Piezo motion cable (internal)	2	$71	$142
Piezo motion cable (external)	2	$71	$142
fiber for motion controller	1	$50	$50
Glycol (motion controller/amp)	1	$200	$200
Ethernet cables (e-vault to secondary)	4	$50	$200
Glycol (beam dump)	1	$200	$200
Analog input	8	$87	$696
AC power control	1	$77	$77
Network ports	4	$91	$364

Total	**$5,781**

Table 17: BGS Cost, Distributed MC

10. Risks and mitigation

This section must be completed for PD.

10.1. Early procurement / long-lead items

10.2. In-house testing / feasibility studies

11. Plans/schedule for Detailed Design Phase

This section must be completed for PD.

12. Appendix: Cost assumptions

12.1. Rack space

The standard Interferometer rack is a Bud Industries ER-16526 with 45U of space. External dimensions are 84 (7feet) x 22 x 30.75 (HxWxD), weight is 210 pounds. Cost is ~$1k. This does not include cooling, power distribution strips, grounding bar, mounting hardware or labor. Estimate $500 for everything except labor.
~$35/U

12.2. AC power control

APC7901 remote switching power distribution unit (PDU) 20A, 1U 8x20A -> $579 (website), Ethernet ready
Add $35 cost of 1U rack space for a total of $614.
~$77/channel

The Pulizzi IPC3402 switching PDU, 1U 8x20A, was $599 in Feb07. Eaton has acquired Pulizzi and it is not clear if this device is still available or supported.

APC7932 remote switched PDU 30A, zero-U (70"x2.19"x1.73"), 24x 5-20R -> $879 (website)
~$37/channel

APC7931 remote switched PDU 20A, zero-U (70"x2.19"x1.73"), 24x 5-20R -> $799 (website)
~$34/channel

12.3. Ethernet digital I/O module

Acromag 983EN-4012 Modbus TCP/IP bidirectional I/O module
12 channels / $375
~$33/channel

12.4. Ethernet Analog input module

Acromag 968EN-4008 Modbus TCP/IP, 16bit, industrial grade module
8 channels / $695
~$87/channel

12.5. Network

HP ProCurve 3500 intelligent switch (J8693A)
44 auto-sensing ports 10/100/1000; 4 dual-personality ports; PoE support; up to 4 10-GbE ports; 1U; 142W idle, 705W max, 1144 BU/hr max
~4K; if 10-GbE uplink module is required, add ~2k
~$91/port (~$137/port)

12.6. Connectors

Amphenol
PT07C xx-xxS – pressurized jam-nut ~$57, 1 in^3/hr @ 30psi
PTB-PS-20-41 bulkhead $61
PT06A-SR strain relief straight cable $53(S)/$42(P)

Souriau
`851 06 R 20 41 P 50 (MS 3126 E 20 41 P) (for DM)`

Crimp contact sealing: <8cm^3/hr @ 1bar differential (0.5 in^3/hr at 14psi)

851 07 P xx x xx jam nut w/ straight backshell for potting, solder
851 07 RP xx x xx jam nut w/ straight backshell for potting, crimp

12.7. Warm Servo cable

Connectors
  MS pins -> $42
  MS sockets -> $53
Cable: $2/foot * 20 feet -> $40
Labor: $40
~$175

12.8. Cold Servo cable

Connectors:
  MS jam-nut bulkhead -> $60
  Stage end (guess) -> $10
Cable: $2/foot * 5 feet -> $10
Labor: $40
~$120

12.9. Long Servo cable (secondary to e-vault)

Connectors
  MS pins -> $42

MS sockets -> $53
6m(top spider) + 16m(wrap to spider) + 7m(el wrap) + 10m(wrap to e-vault) = 39m => 130feet
Cable: $2/foot * 130 feet -> $260
Labor: $40
~$395

12.10. Piezo cable e-vault to laser enclosure

Connectors:
2x LEMO 2 position -> $15
Cable (RG-174): $0.1/foot * 50 feet -> $5
Labor: $40
~$75