Keck Adaptive Optics Note 668

Keck Next Generation Adaptive Optics
Device Control Architecture

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Version: 2.0, 13 January, 2010

1. Introduction

This document describes the device control architecture for the Keck Next Generation Adaptive Optics system. By device control, we mean the control of any device or subsystem that is not creating motion, and is not one of the devices requiring real-time control for wavefront sensing and correction. This includes power control, environmental control, camera control, mirror control, general sub-system control (e.g., the laser units, the RTC) and the controls infrastructure.

We also need to define what we mean by architecture, since this can be misleading. We are presenting the electronics concepts and approaches we plan to use to support the design of the NGAO control system. The NGAO system is made up of numerous devices, many of which are part of the control system and must be controlled in some fashion. This document looks at all of the controllable devices in the system (as defined above) and the types of electronics that will be required to control them. We identify commonalities in the types of control required and provide summaries of how these devices will be controlled. We also discuss several of the NGAO components and their control in more detail. We are not discussing the overall architecture of the NGAO control system or the top-level design of the NGAO control system.

We begin with a brief overview and layout of the NGAO system. This is followed by a table of all the known devices to be controlled with a short description of each. Next we summarize all of the common control types and describe our approach for implementing the control.

These discussions are based on the NGAO system architecture as defined in the System Design Manual (KAON 511) and amended by KAON 642 (NGAO Design Changes in support of the Build-to-Cost Guidelines). The requirements driving this architecture are listed in Section 8.

2. Overview

The NGAO system is distributed throughout the telescope, with major components and subsystems located on the Nasmyth platform, the elevation ring, and behind the secondary. Components will also be located off-telescope, in the computer room. A diagram showing the layout of the system is provided in Figure 1 and described in more detail below.

The science path optics, acquisition camera, NGS wavefront sensor and low order wave front sensor assembly are located on the AO bench, which is cooled to -15C. The entire AO system is enclosed in a clean room and 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. The enclosure will be partitioned to create an electronics vault and an ante-room to facilitate clean entry (similar to the existing AO enclosure). The electronics vault will have environmental controls, but not require the tight temperature and humidity controls present in the AO enclosure or cooled bench. This layout will relax the constraints on mounting the electronics equipment. Due to limits on cable lengths, some equipment will need to be located in the clean room, in close proximity to the cooled enclosure. These would include, for example, the camera controllers and the MEMS DM controllers. Some distributed motion controllers may be located in the clean room as well.

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 units, 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 will be located in the AO electronics vault and computer room.

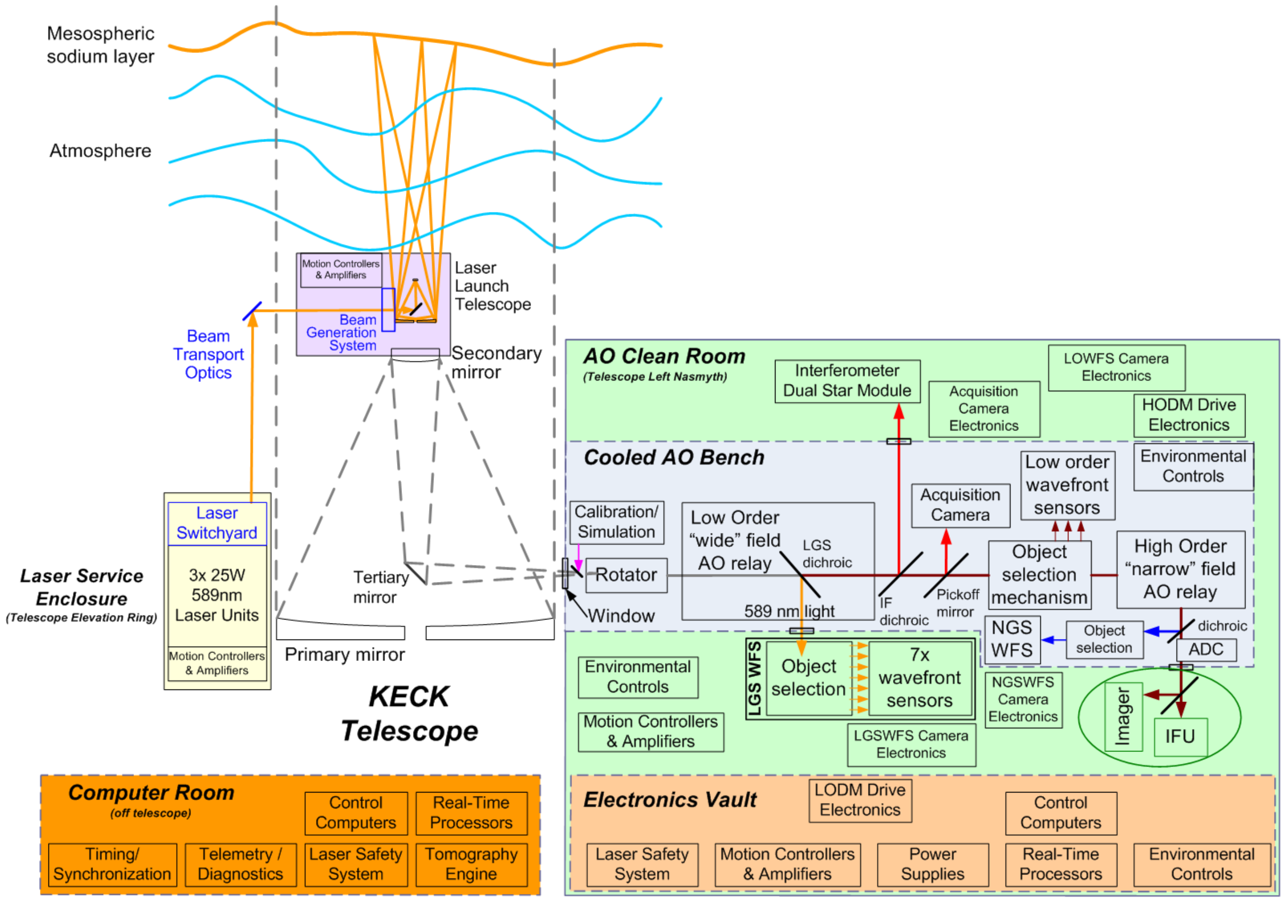

Figure 1: The layout of the NGAO system.

There will equipment will be located off of the telescope, in the K2 computer room, as well. Several workstations will be required for the overall NGAO control system: AO control and Laser control. The tomography engine, the bulk of the real-time processors, the telemetry system disk farm and the timing/synchronization system will all be in the computer room.

The hardware for low level motion control and device control will consist of dedicated controllers, input/output modules and control computers. Much of this will likely be located in the AO enclosure electronics vault on the telescope, but due to the distributed nature of the anticipated architecture, equipment will be housed throughout the facility.

3. Required Types of Control

Device control is, in general, low speed without tight timing constraints; the commands are frequently single events (e.g., GUI button press) and are expected to be executed on the timeframe of seconds. Ethernet will be the primary means of communicating with devices for control. If a device does not have an Ethernet interface, there may be simple Ethernet solutions which exist (e.g., terminal servers to communicate with RS-232 based devices, or digital I/O modules with an Ethernet interface to generate digital I/O signals). This approach has a number of benefits:

- Control can easily be distributed as needed
- Cabling issues associated with centralized control can be minimized
- Solutions based on an industrial computer and real-time operating system, e.g., VxWorks and VME crates, can be minimized to those areas requiring tight real-time control which do not fall under the device control architecture discussed in this document.
- Ethernet-based solutions are easily interfaced to the NGAO control system.
    - To reduce software integration efforts, Ethernet devices should support an industrial protocol (Modbus TCP/IP, Fieldbus, etc) rather than a web (HTTP) based interface whenever possible.

Table 1 shows all of the components to be controlled, their location, the type of control, how the control is achieved and the command source for this control. For completeness, Table 1 lists all the known interfaces and highlights the interfaces relevant to this document in yellow. This table is current as of the publication date of this document. For the most recent version, reference KAON 682: NGAO Master Device List. For some devices, such as the lasers, the 'Control Method' is Ethernet. These devices require no additional hardware to complete the interface with the NGAO Control System. Other devices will need some hardware to complete the control interface. In some cases, a number of copies of the interface will be required. For example, there are seven cameras in the LGS WFS unit and each will require the same control interfaces. The types of control required by the components or subsystems are discussed below. In the following section, we discuss options for implementing the various types of control in more detail.

Component/Sub-Assembly	Location(s) of components	Required Control	Control Method or Signal type	Command Source / Destination
Calibration/Simulation sources	Cold bench/ AO room/ E-vault	on/off	Digital Output/custom	Control System
		intensity	Analog output	Control System
		feedback	Analog Input	Control System
Wide-field (Woofer) DM	Cold bench E-vault	HV actuator interface	high voltage	woofer amp
		DM command	custom (vendor spec'd)	RTC
		HV PSU control	custom (vendor spec'd)	Control System via RTC **(2)**
		configuration/diagnostic	custom (vendor spec'd)	Control System via RTC **(2)**
		AC on/off	remote power controller	Control System
Wide-field (Woofer) T/T	Cold bench E-vault	HV actuator interface	high voltage	woofer T/T amp
		T/T command	Analog output	RTC
		voltage ramp	Analog output	Control System
		AC on/off	remote power controller	Control System
UTT mirrors	LGS WFS assy AO room E-vault	HV actuator interface	high voltage	UTT amp
		UTT command	Analog output	RTC
		voltage ramp	Analog output	Control System
		AC on/off	remote power controller	Control System
LGS WFS cameras (vis) (7)	AO room E-vault	detector clock/data	proprietary/vendor supplied	camera electronics
		readout	Camera Link **(1)**	RTC
		configuration/diagnostic	Camera Link **(1)**	Control System via RTC **(2)**
		instrument temp readout	COTS controller	Control System
		AC on/off	remote power controller	Control System
Acquisition camera	Cold bench AO room E-vault(?)	camera clock/data/video	proprietary/vendor supplied	camera electronics
		readout	Camera Link **(1)**	RTC
		configuration/diagnostic	Camera Link **(1)**	Control System via RTC **(2)**

Component/Sub-Assembly	Location(s) of components	Required Control	Control Method or Signal type	Command Source / Destination
		instrument temp readout	Analog Input	Control System
		AC on/off	remote power controller	Control System
LOWFS T/T (3)	Cold bench E-vault	HV actuator interface	high voltage	T/T amp
		T/T command	custom (vendor spec'd)	Motion Control System
		voltage ramp	Analog Input/COTS controller	Control System
		AC on/off	remote power controller	Control System
LOWFS DMs (3)	Cold bench	HV actuator interface	high voltage	MEMS DM amp
	AO room	DM command	custom (vendor spec'd)	RTC
	AO room	HV PSU control	custom (vendor spec'd)	Control System via RTC **(2)**
		configuration/diagnostic	custom (vendor spec'd)	Control System via RTC **(2)**
		AC on/off	remote power controller	Control system
LOWFS cameras: TTFA (NIR) TT 2x (NIR) TWFS (vis)	Cold bench AO room E-vault	detector clock/data	proprietary/vendor supplied	camera electronics
		readout	USB **(1)**	RTC
		configuration/diagnostic	USB **(1)**	Control System via RTC **(2)**
		instrument temp readout	COTS controller	Control System
		ion pump control	COTS controller	Control System
		AC on/off	remote power controller	Control System
Narrow-field (Tweeter) DM	Cold bench AO room	HV actuator interface	high voltage	tweeter amp
		DM command	custom (vendor spec'd)	RTC
		HV PSU control	custom (vendor spec'd)	Control System via RTC **(2)**
		configuration/diagnostic	custom (vendor spec'd)	Control System via RTC **(2)**
		AC on/off	remote power controller	Control System
Narrow field (Tweeter) slow T/T		HV actuator interface	high voltage	tweeter T/T amp
		T/T command	Analog output	Motion Control System
	Cold bench E-vault	voltage ramp	Analog output	Control System
		AC on/off	remote power controller	Control system
NGS WFS camera (vis)	Cold bench AO room	detector clock/data	proprietary/vendor supplied	camera electronics
		readout	Camera Link **(1)**	RTC
		configuration/diagnostic	Camera Link **(1)**	Control System via RTC **(2)**
		instrument temp readout	COTS controller	Control System
		AC on/off	remote power controller	Control System
AO Bench environmental	Cold bench	temp command/feedback	PLC	Control System
		humidity command/feedback	PLC	Control System
		particulate sensor readout	PLC/Analog Input	Control System
		surveillance camera	video/Ethernet	Control System
		Lights: AC on/off, local/rem	Digital Output/custom	Control System
Clean-room environmental	AO room	temp command/feedback	PLC	Control System
		humidity command/feedback	PLC	Control System
		particulate sensor readout	PLC/Analog Input	Control System
		surveillance camera	video/Ethernet	Control System
		HEPA: AC on/off, local/remote	Digital Output/custom	Control System
		Lights: AC on/off, local/rem	Digital Output/custom	Control System
E-vault environmental	E-vault	Glycol flow sensor **(3)**	Analog input	Control System
		temp sensor readout	Analog Input	Control System

Component/Sub-Assembly	Location(s) of components	Required Control	Control Method or Signal type	Command Source / Destination
Motion DOF	Various	motor interface	servo motor/encoder signals	motion control amps
		command/feedback	Ethernet/CPU bus	Motion Control System
		local/remote	Digital Output/custom	Control System
		fault readback	Digital Input	Control System
		AC on/off	remote power controller	Control System
Lasers / Switchyard	Telescope elevation ring	command/feedback	Ethernet	Control System
		Safety control/shutdown	Digital Input	Laser Safety System
		Beam dump/Calorimeter	Analog Input	Control System
Laser Enclosure environmental	Telescope elevation ring	temp sensor readout	COTS controller	Control System
		humidity sensor readout	COTS controller	Control System
		particulate sensor readout	Analog Input	Control System
		surveillance camera	video/Ethernet	Control System
Laser Safety System (LSS)	E-vault / computer room	feedback	RS-232	Control System
		laser shutdown	Digital Output	Laser Safety System
		emergency stop	Digital Input	Facility Emergency Stop
		maintenance/diagnostic	Ethernet	Control System
Laser Beam Transport and Beam Generation System Diagnostics	Telescope Structure / Secondary	asterism imager	video/Ethernet	Control System
		beam wavefront sensor	Ethernet **(1)**	Control System
		power meter	Analog Input/COTS controller	Control System
		polarization sensor	Analog Input	Control System
		sky alignment camera	Ethernet **(1)**	Control System
		beam position sensing	Analog Input	Control System
		AC on/off	remote power controller	Control System
Laser Launch Telescope Assembly	Telescope Secondary	temp sensor readout	COTS controller	Control System
		humidity sensor readout	COTS controller	Control System
Control computers	Various	remote reset	remote reset controller	Control System
		time synchronization	IRIG-B/NTP/IEEE1588	Timing system
		serial console/diagnostics	RS-232	Control System
		AC on/off	remote power controller	Control System
Real-Time Control System	Various	Real-time commands	Various, vendor dependant	Various
		Various, non-realtime	Ethernet	Control System
		remote reset	remote reset controller	Control System
		serial console/diagnostics	RS-232	Control System
		synchronization	LVDS	Timing system
		AC on/off	remote power controller	Control System
Timing/Synchronization	Computer Room / E-vault	UTC synchronization	GPS (IRIG-B?)	Observatory time system
		serial console/diagnostics	RS-232	Control System
		AC on/off	remote power controller	Control System

NOTES:
1 - This control method is preliminary, the final choice may be different
2 - Depending on the hardware interface, these commands might be accessed through the RTC
3 - This sensor should monitor the primary supply to the left Nasmyth platform

Table 1: Component Control Requirements

3.1. Vibration Sensing

A hardware approach was originally envisioned to provide the necessary data to mitigate the effects of vibration in the facility. Subsequently, a specialized control technique (parametric oscillator) has been chosen and no specific hardware is necessary. Reference KAON 680 on vibration mitigation.

3.2. Calibration/Simulation

This system requires an interface to remotely power these sources, control their intensity and read back the actual intensity of the stimulus. Analog input and output will be required to implement these functions. These interface requirements will need to be revisited once the design has stabilized.

3.3. Wide-field (woofer) Deformable Mirror

The working assumption is that the DM will be a CILAS SAM416. This system requires a configuration/diagnostic interface and a remote power interface. The high voltage power supply is supplied by CILAS and controlled through the same interface as the DM actuator commands. The RTC will be required to provide an interface for these commands.

3.4. Wide-field Tip/Tilt

The wide-field tip-tilt stage will be controlled by a servo amplifier driven by the RTC. This system requires a remote power interface and the ability to ramp up or down the output voltage of the power supply. Analog output may be required to implement the voltage ramp function if it is not provided by the manufacturer.

3.5. Uplink Tip/Tilt

The uplink tip-tilt stages will be controlled by servo amplifiers driven by the RTC. This system requires a remote power interface and the ability to ramp up or down the output voltage of the power supply. Analog output may be required to implement the voltage ramp function if it is not provided by the manufacturer.

3.6. Laser Guide Star Wave Front Sensor Cameras

These cameras will likely be SciMeasure units using a Camera Link interface. This system requires a configuration/diagnostic interface, a remote power interface and an interface for camera head temperature readout. The interface for these functions may be shared with the data interface. If so, the RTC will be required to provide an interface for these commands. Depending on the location of the RTC, a Camera Link to fiber converter may be required.

3.7. Acquisition Camera

This system requires a configuration/diagnostic interface, a power control interface and the ability to read out internal sensors (temperature) for this equipment. The camera will likely be a SciMeasure unit with a Camera Link interface as described in the LGS WFS section. Depending on the location of the RTC, a Camera Link to fiber converter may be required.

3.8. Low Order Wave Front Sensor Tip/Tilt

The LOWFS tip-tilt stages will be controlled by servo amplifiers driven by the RTC. This system requires a remote power interface and the ability to ramp up or down the output voltage of the power supply. Analog output may be required to implement the voltage ramp function if it is not provided by the manufacturer.

3.9. Low Order Wave Front Sensor Deformable Mirror

These DMs will likely have 1000 actuators and be supplied by Boston Micromachines. This system requires a configuration/diagnostic interface and a remote power interface. The high voltage supply is part of the DM control electronics and is controlled via the command interface via the RTC.

3.10. Low Order Wave Front Sensor Camera/Detector

The detector and controller for these cameras have not yet been selected, but Hawaii detectors and the Teledyne Sidecar ASIC are under consideration for the three IR cameras. The forth camera (TWFS) operates in the visible spectrum and will probably be different. Each detector system requires a configuration/diagnostic interface and a power control interface. The IR cameras require an interface to a COTS controller for internal (dewar) temperature monitoring and control, and possibly an interface to an ion pump controller. The interface for control of these cameras will need to be revisited once the design is understood.

3.11. Narrow-field (tweeter) Deformable Mirror

This DM will likely have 4000 actuators and be supplied by Boston Micromachines This system requires a configuration/diagnostic interface and a remote power interface. The high voltage supply is part of the DM control electronics and is controlled via the command interface via the RTC.

3.12. Narrow-field (tweeter) Slow Tip/Tilt

The narrow field DM will be mounted on a slow tip-tilt stage for dithering. The dithering will be controlled by the NGAO motion control system. This stage will likely be implemented using a piezo type actuator. This system will require a remote power interface and the ability to ramp up or down the output voltage of the power supply. Analog output may be required to implement the voltage ramp function if it is not provided by the manufacturer.

3.13. Natural Guide Star Wave Front Sensor

This camera will likely be a SciMeasure unit using a Camera Link interface as described in the LGS WFS section. Depending on the location of the RTC, a Camera Link to fiber converter may be required.

3.14. AO Bench Environmental

The bench will require temperature and humidity control as well as monitoring of particulate levels, a video surveillance camera and control of the lighting. Much of this will be accomplished via Programmable Logic Controller (PLC) or possibly analog inputs. The PLC will communicate via Ethernet and ModbusTCP. Control of the lighting will require a digital output command to a custom contactor assembly.

3.15. Clean-room Environmental

The clean room will require temperature and humidity control, monitoring of particulate levels, a video surveillance camera and control of the lighting and circulation. Much of this will be accomplished via PLC or analog inputs. The need to monitor and control the environment of the clean-room when warming or cooling the AO bench may allow a single PLC may control both locations. The control of the lighting and circulation will require digital output commands to a custom contactor assembly.

3.16. Electronics Vault Monitors

The electronics vault will require temperature monitoring, either via a COTS controller or an analog input.

3.17. Motion Control

The NGAO Motion Control System is responsible for positioning of devices. The NGAO device control system will be required to power on/off components of the motion control system, provide a local/remote capability and read back any discrete fault information.

3.18. Laser Units

The lasers will have an Ethernet command/feedback interface to the NGAO Control System. The commands and protocols shall be defined in the Laser Interface Control Document with the manufacturer.

3.19. Laser Service Enclosure Environmental

The lasers are self contained and do not require a controlled environment to operate. The Laser Service Enclosure environment needs to be monitored to support servicing of the lasers, tracking of performance, and for protection of personnel per laser safety standard ANSI Z136.1. Temperature, humidity and particulate levels will be monitored and a video surveillance camera will be placed in the enclosure. Environmental control and monitoring will be accomplished via COTS controllers and/or analog inputs/outputs.

3.20. Laser Safety System

The laser safety system will have an RS-232 or Ethernet interface for status feedback to the control system and an Ethernet port for maintenance/diagnostics.

3.21. Laser Launch Facility

Equipment will be required to generate the required asterism and propagate the laser beams from the laser system. The NGAO Motion Control System is responsible for positioning of devices in the Laser Launch Facility. The Device Control System is responsible for monitoring the condition of the three laser beams and possibly environmental data within the LLF. This equipment will consist of cameras, power meters, photo diodes and position sensing devices. Control of these devices will fall under the categories of Ethernet, analog input/outputs, COTS controllers, power control and possibly video.

3.22. Control Computers

The many control computers, whether workstations or embedded systems, will require remote power control, remote reset, and possibly an interface for a serial remote console. These various processors will need a UTC time reference.

3.23. Real-Time Control System

The computers that comprise the Real-Time Control system, whether workstations or embedded systems, will require a method to accept non-realtime commands from the NGAO control system, remote power control, remote reset, and possibly an interface for a serial remote console. These computers will all be connected to the network as well as direct connections to the real-time devices. Synchronization of the distributed components in this subsystem is required to the sub-nanosecond level. The subsystem will also need a UTC time reference.

4. Control Method/Interface/Signal Type

This section discusses the various signals and types of control that were identified in the section above and how these will be connected to the Ethernet.

4.1. Remote Power Control

The largest classification of control is simple on/off of 120 VAC devices. Remote control of the power to individual devices has proven extremely valuable in the existing AO, Laser and Interferometer systems. Approximately 20 devices requiring this type of control have been identified.

This function will be accomplished primarily through COTS devices. Products by two vendors (Pulizzi and APC) are currently used at the observatory, each with its own benefits.

It will be necessary to create a more customized solution based on solid state relays and digital controls to handle some of the devices, such as the clean-room circulation/HEPA filtering and to integrate emergency stop functionality.

4.2. Camera / Detector Control

Control of the various cameras and detectors used in the system is complicated by the fact that some of the cameras have control interfaces that are part of the data readout interface, as is the case with Camera Link. For these cameras, the control functions will be implemented directly by the RTC, but the RTC is required to make specific control commands available to the NGAO control system for initiation of these functions.

For the other cameras and detectors, the control interface will depend on the specific controllers that are selected. The Sidecar ASIC, which is under consideration for the LOWFS, interfaces to the RTC via USB. This scenario is similar to the cameras with the Camera Link interface where the device is controlled through RTC. A camera controller with an Ethernet interface, or the requirement for a dedicated server, would be an example of a system where the RTC might not be required to implement configuration and diagnostic functionality; the NGAO control system could talk directly to the camera controller (or server).

The control requirements for each camera must be analyzed on a case by case basis once the design is understood.

4.3. Discrete (Digital) Input/Output

Several options exist to implement this requirement. A VME or PCI card could be used in conjunction with a CPU, as is done in the current system. Alternatively, Ethernet (or serial) I/O modules exist (Acromag, B&B and others) that perform the same function without requiring a CPU/Backplane. The use of distributed modules could simplify wiring.

Digital inputs and outputs will be required to control custom on/off devices, provide remote reset capability for equipment and read back the state of equipment.

4.4. Analog Input

As with the digital I/O, a VME or PCI card could be used in conjunction with a CPU, as is done in the current system. Alternatively, Ethernet (or serial) I/O modules exist (Keithley, B&B and others) that perform the same function without requiring a CPU/Backplane. This approach will accommodate both voltage and current type sensors. The use of distributed modules could simplify wiring.

Analog inputs will be required to digitize signals from sensors. Examples are environmental temperature sensors and intensity feedback from the stimulus sources.

4.5. Analog Output

Analog signals can be generated via a peripheral card installed in a VME system or by a stand-alone module connected to the Ethernet. Channel density, speed and latency requirements will probably dictate the type of source.

Analog outputs may be required to modulate the intensity of stimulus source intensity and to ramp the output of high voltage power supplies. This could also be used as the control command for low bandwidth, open loop PZT devices.

4.6. COTS Controllers

A number of off the shelf controllers will be required to provide monitoring/control the environment and instruments. In some cases, a sensor will be connected to an analog input described above. In other cases, controllers such as a Lakeshore temperature controller, Varian ion pump controller, or similar device will used. These controllers will be fitted with either a serial or Ethernet interface to allow connection to the control system.

4.7. Remote Reset control

Another functionality that has proven useful is the ability to remotely reset equipment, specifically VME backplanes, without cycling power. The existing design (119-70-00) is a 1U package, based on a digital I/O module with a serial interface, which implements eight optically isolated outputs, each with local/remote capability. The outputs are the emitter and collector of the opto-isolator transistors. Internal configuration can include a pull up resistor and/or grounding the low side of the transistor. The serial to I/O module used in this design is obsolete, so a replacement module will need to be sourced.

4.8. Video

Video encoders (servers) manufactured by Axis communications are currently used at the observatory and can be used for NGAO as well. These simple devices convert an analog video signal to Ethernet, allowing web based viewing/configuration. The Interferometer uses software to processes the network video stream and obtain centroids that are used for automatic beam train alignment.

4.9. RS-232 and USB

The goal is communicate with every controllable device via Ethernet. To accomplish this, some equipment will require a protocol converter. Lantronix terminal servers are currently used for RS-232 and RS-422/485 devices. Lantronix also produces a USB server, should that functionality be required.

4.10. Ethernet

Devices will connect to the Ethernet via a managed switch. Managed switches allow creation of ‘V-LANs’ that help route network traffic and optimize data flow. Currently HP products are used.

4.11. Time Distribution / Synchronization

Two types of synchronization are required for NGAO. First, many of the components will need a precise UTC reference. In addition, the distributed components of the RTC subsystem have an extremely tight internal synchronization requirement. Fortunately, this does not extend to the UTC reference.

Existing observatory infrastructure distributes a GPS time signal via the IRIG-B protocol. Each system requiring a UTC reference makes use of a local VME decoder board. This method is capable of delivering microsecond level accuracies, if care is taken to account for propagation delays in the cabling. Components with relaxed requirements, generally servers and PCs, use the Network Time Protocol (NTP) to synchronize their local clock. It is not clear if this is done at any time other than boot-up, so the initial millisecond level accuracy degrades rapidly. It is also not clear how the local NTP server is synchronized to UTC.

There have been investigations into the use of the Precision Time Protocol (PTP, IEEE-1588) within NGAO (and the Telescope Drive Control Upgrade project), as an alternative to IRIG-B, to synchronize distributed equipment to a master clock and Universal Coordinated Time (UTC) as derived from Global Positioning System (GPS) satellites. PTP uses Ethernet messages to determine (and manage) the offset between distributed equipment and a master clock. Synchronization with sub-microsecond accuracies is readily achievable. Adoption of PTP would greatly reduce the amount of IRIG-B hardware at the possible expense of additional network infrastructure. This work is ongoing and a final decision has not been made.

A custom system will need to be engineered to synchronize the RTC components. Precision high frequency oscillators and careful attention to propagation delays will be required. Fiber-optic may be used for signal transport to ease transmission line effects over long distances. It is assumed that this work will be handled by RTC design team, collaborating with Keck engineers to ensure the system can be integrated into the facility.

5. Safety

In order to protect personnel and equipment, several mechanisms will be implemented to stop run-away equipment and to prevent remote operations of equipment.

An NGAO emergency stop (e-stop) system will be designed to protect personnel and equipment with a single human action. Two separate systems will be required, one to disable all motion control devices, another to disable all laser devices. The Laser Safety System will accept as an input the facility e-stop. The NGAO e-stops are considered local to the NGAO System as they do not trigger a facility wide shutdown. Trigger point(s) will be accessible to the AO bench and throughout the LGS facility, possibly on remote pendants.

The system will be designed to provide lockout capability and/or local/remote capability. When needed, personnel will be able to easily disable the remote interface to equipment, to prevent unexpected remote control.

6. Maintenance

The system shall be implemented with a workable and maintainable physical layout. The architecture must consider the requirements for maintenance and troubleshooting the system, including the possibility of additions to the system. In order to reduce maintenance efforts, the system shall provide interchangeable/swappable components where practical. Ideally, a Plug-and-Play or in-system configurable approach will be used which requires no configuration prior to installation in the system. The system shall include as much diagnostics, preferable available remotely through the control system, as practical.

7. Conclusion

This document describes the comprehensive list of all devices (KAON 682) requiring non-realtime and non-motion control. This is the foundation that will be used to build the detailed Electronics Control design. The sections above detail the control requirements, how those requirements break down to a specific type of interface, and how each interface will be made available on the NGAO Control System via the network. There are still some unknowns relating to the camera/detector/sensor interfaces. As the design of these components progresses, these interfaces and any required hardware to support the interface will be identified and documented.

8. Requirements

The relevant functional requirements are listed below. The architecture described above provides the necessary infrastructure to support all of these requirements. The list below is current as of the publication of this document. For the current (and complete) list of requirements, see the Contour Requirements Database (linked under the System Requirements section of the NGAO TWiki).

Short Name	ID	Description	Addressed in section(s)
AO General Device Control	FR-1828	AO Controls shall provide a control function for all non-motorized devices in the system capable of computer control. The devices to be controlled include: detectors, mirrors, the RTC, and the environmental system for the AO enclosure. The control function shall provide, at a minimum, power control, device configuration and basic device control (initialize, standby, start, stop, power up/down, read status, etc.), unless these functions are not available. The motorized devices are addressed in a separate requirement on motion control.	Entire document.

AO Detector Control	FR-1829	AO Controls shall provide a configuration control function for all the detectors in the system. In addition to the basic device control functions, the detector control shall include the setting of exposure times and frame rates, bias fields and flat fields, filter and gain settings, and shutter control, if applicable. As of this writing, the known detectors in the system requiring control are: Vibration sensor LGS WFS cameras (7) NGS acquisition camera LOWFS tip-tilt sensors (2) LOWFS TWFS camera LOWFS TTFA camera NGS WFS camera	3.1, 3.6, 3.7, 3.8, 3.10, 3.13, 3.21.
AO Mirror Control	FR-1830	AO Controls shall provide a configuration control function for all the electronically controlled mirrors in the system (i.e., the deformable mirrors and tip-tilt mirrors). The mirror control shall include the basic control functions such as power control, drive voltage control, initialize, and standby. If not provided by the RTC, the mirror control shall include the ability to move the mirror to a desired static position or shape. As of this writing, the known mirrors in the system requiring control are: The wide-field relay DM/TT stage The narrow-field relay DM stage, slow TT stage (slow TT stage may be part of motion control) The LOWFS DM/TT stages (3) The UTT mirror(s) (1, 4, or 7, TBD)	3.3, 3.4, 3.5, 3.8, 3.9, 3.11, 3.12
AO RTC Control	FR-1831	AO Controls shall provide a configuration control function for the RTC. In addition to the basic control functions (initialize, standby, start, stop, etc.), the RTC control function shall include the setting/readback of all RTC parameters, such as reconstructor arrays, centroid offsets, centroid gains, loop gains, etc., and loop control for all the AO correction loops in the system (includes both go-to and feedback loops).	3.23
AO Environmental Control	FR-1832	AO Controls shall provide a configuration control function for all the environmental control devices in the system that require remote computer control. As of this writing, the specific devices and functionality are unknown, but are thought to include control of: power, temperature, humidity, particulates and instrument cooling (e.g., glycol).	3.14, 3.15
LGS General Device Control	FR-2143	LGS Controls shall provide a control function for all non-motorized devices in the LGS facility capable of computer control. The devices to be controlled include: detectors, mirrors, and the environmental system for the Laser Service Enclosure. The control function shall provide, at a minimum, power control, device configuration and basic device control (initialize, standby, start, stop, power up/down, read status, etc.), unless these functions are not available. The motorized devices are addressed in a separate requirement on motion control.	3.18, 3.19, 3.20, 3.21

LGS Detector Control	FR-2144	LGS Controls shall provide a configuration control function for all the detectors in the system. In addition to the basic device control functions, the detector control shall include the setting of exposure times and frame rates, bias fields and flat fields, filter and gain settings, and shutter control, if applicable. As of this writing, the known detectors in the system requiring control are: Far field beam diagnostics and pointing cameras Near field wavefront diagnostics cameras Power meters	3.21
LGS System Control	FR-2146	LGS Controls shall provide a configuration control function for the laser system. In addition to the basic control functions (initialize, standby, start, stop, etc.), the laser control function shall include the setting/readback of all laser parameters	3.18
LGS Environmental Control	FR-2147	LGS Controls shall provide a configuration control function for all the environmental control devices in the laser Service Enclosure that require remote computer control. As of this writing, the specific devices and functionality are unknown, but are thought to include control of: power, temperature, humidity, particulates and instrument cooling (e.g., glycol).	3.19

9. Revision History

Date	Version	Author	Description
15Jul09	1	EW/EMJ	First Release
26Aug09	1.1	EW	Minor edits, figure updates
27Aug09	1.2	EW/EMJ	Incorporate EMJ feedback
31Aug09	1.3	EW/EMJ	Update figure 1, more detail in section 3.8
1Sept09	1.4	EW/EMJ	Add relevant Contour requirements
2Sept09	1.5	EW/EMJ	Add relevant Contour laser system requirements
4Sept09	1.6	EW/EMJ	Update intro, Revise table 1, Revise fig 2(remove MC), add component section
8Sept09	1.7	EW/EMJ	More edits… Combine section 3 & 4, revise table 1
11Sept09	1.8	EW/EMJ	add sections for Laser Service Enclosure and Laser diagnostics, rework camera stuff
18Sept09	1.9	EW/JC/EMJ	Incorporate feedback from JChin
13Jan10	2.0	EW	Update Figure1; update Table1; vibration sensing not required (3.1); 3.14 and 3.15 will be controlled by a PLC; add timing/synchronization (3.22, 3.23, 4.11); add note about Contour Requirements Database under section 8