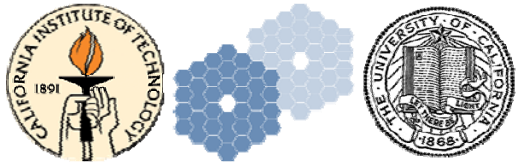


Motion Control Architecture Mini-Review

Contributors: Doug Morrison, Jimmy Johnson, Kevin Tsubota

April 16, 2010

Schedule

The agenda for the review is as follows (times are HST):

- 8:00 AM: Welcome and introductions
- 8:15 AM: Presentation
- 9:30 AM: Break
- 9:45 AM: Review Comments/ Open discussion
- 10:45 AM: Review committee closed session
- 11:15 AM: Review committee feedback to team

Agenda

- Review Committee Charter
- Scope of the Review
- Requirements Compliance
- Design Overview
  - Infrastructure
  - Device Control
  - AO Control Loops
  - Laser Control Loops
  - Data Server
- Review Committee Comments
- Summary of Concerns
- Plans for PDR

Review Committee Charter

- Reviewers:
  - Al Conrad (WMKO)
  - Rich Dekany (COO)
  - Don Gavel (UCO)
  - John Cromer (CalTech)
- Are the requirements understood?
- Does the proposed architecture satisfy the requirements?
- Is the architecture
  - Complete?
  - Technically feasible?
  - Cost effective?
- Is the architecture sufficiently mature that it can be developed to the PDR level by the 2nd Qtr of 2010?

Scope of the Review

- AO Controls software and control loops
- Not in the scope of this review:
  - Effort Estimates
  - Budget
  - Schedule

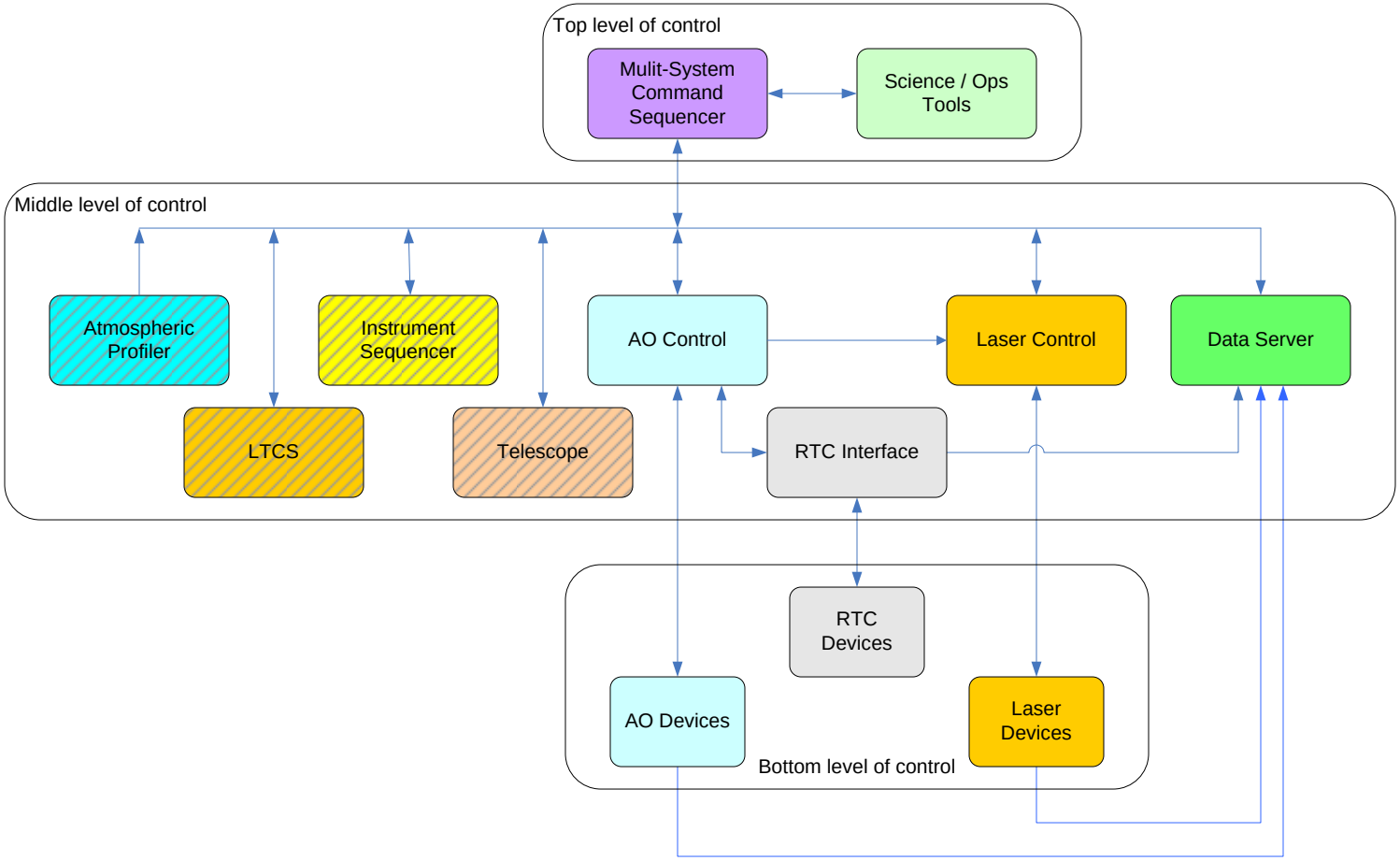
Requirements Compliance (1)

- More clarification
  - FR-1812 Acquisition Sytem data products
    - One hundred per night (TBC) acquisition images shall be stored on the NGAO data server. Images shall be in FITS file format and have standard FITS header information. The specific contents of the header are TBD.
  - FR-3369 Telemetry Recorder
    - The Data Server shall provide a telemetry data recorder capable of recording time-stamped structured data. Grouped information will be stored and retrieved in an atomic and consistent manner. Ideally the telemetry recorder should not require the manual use or creation of meta data in order to function. The maximum burst and sustained rates for the telemetry recorder are TBD.
  - FR-3367 Permanent Archival Storage of Data
    - The data server shall support permanent archival storage of both raw and processed data. A permanent archive shall include removable media. The archival mechanism must be able to write to a removable media (tapes, hot-swap disks, or a future transportable media) and possibly HQ through its network interface.
  - FR-1842 Calibration Control
    - AO Controls will provide a semi-automated capability to calibrate the AO system, to include computation of DM actuator gains, DM to WFS registrations, centroid gains, interaction matrices, WFS calibrations, etc. The term semi-automated is used here to indicate that the calibration capability shall minimize the amount of user interaction required.
  - FR-470 Sensor Calibration Measurements
    - AO controls will provide an automated capability to compute the dark frames, sky frames, and flat fields for all the various sensors in the AO system as required.
  - FR-1843 Telemetry
    - AO Controls shall provide appropriate telemetry streams for the other AO subsystems, instruments, telescope control system, and top-level MCS, as required. The list of telemetry streams required by these systems is currently unknown; as they become defined, individual requirements will be written for each stream to be generated.
  - FR-2138 Telmetry
    - LGS Controls shall provide appropriate telemetry streams for the other AO subsystems, instruments, telescope control system, and top-level MCS, as required. The list of telemetry streams required by these systems is currently unknown; as they become defined, individual requirements will be written for each stream to be generated.

Requirements Compliance(2)

- Not in compliance
  - SR-267 Telescope Software Simulator
    - The NGAO System shall include an internal telescope software simulator to facilitate diagnostic tests of the system when the telescope connection is not available.
      - Haven't thought about it yet
  - SR-30 Overheads for Observation
    - The NGAO system shall be able to start science data recording on a new object within 180 seconds of the end of the previous observation with the same science instrument.
      - Telescope slews at ~1deg/sec so we cannot achieve this is the targets are far away from each other
  - KS-52 Loss of Network Connections
    - NGAO software shall gracefully recover from the interruption of network connections, fiber optic connections or USB connections at any time.
      - May require restart of some components

Controls System Overview



Infrastructure

- KCSF (Keck Common Services Framework)
  - A data communications infrastructure adopted from ATST Common Services Framework
  - Uses services and support features found in third-party communications middleware packages which the developer is isolated from
  - Supports the Component Based Development model
    - Allows you to isolate the functional implementation of task to a single plug-and-play object that can be easily modified or redesigned without impacting the rest of the system
  - Provides the following Common Services:
    - Connection Service
    - Telemetry Service
    - Health Monitor
    - Alarm Service
    - Archive Service
    - Alarming Service
    - Configuration Service

Communication Services

- Connection Service
  - Creates a P2P connection with any named component.
  - Utilizes proxies to allow clients to treat distributed objects as local instances.
  - Full access to public interfaces and attributes of the server component.
- Telemetry Service
  - Creates pub-sub connections using named topics.
  - Topics can transmit any of the KCSF supported types.
  - Ideal for system and device status; asynchronous command completion notifications; “connection-less” events.

Notification Services

- Health Monitor
  - Provides high-level status information of infrastructure and control system components.
  - Utilizes simple “good”, “ill”, “bad” health statuses for system components.
  - Operator control GUI for at-a-glance reference and basic life-cycle control.
- Alarm Service
  - Provides detailed control system alarm and error events.
  - Alarms are defined by type, category, location, device, and severity.
  - Alarm Control GUI organizes and manages system alarms.

Recording Services

- Archive Service
  - Allows users to specify component information to be saved to the database for post-observing inspection.
  - Data is automatically stamped with time and ID and stored in the database.
  - Archive Viewer and Management tools will be provided to users.
- Logging Service
  - Allows developers to archive simple system messages to trace the execution processes.
  - Not intended for real-time review.
  - The Log Service GUI allows users to search and sort log history for specific events by date-time and device.

Configuration Service

- Defines the technical and functional run-time properties of components and hardware:
  - Types, instances, drivers, deployment
  - Initial configuration, device positions, servo rates
  - Thresholds, alarms
  - Dependencies, telemetry
  - Observing modes
- Configuration information is stored in a relational database (likely as part of the Data Server).

Configuration Service (2)

- KCSF provides a client and administrator interface to the Configuration Service:
  - Client interface is read-only and used by components and containers to retrieve associated data.
  - Administrator interface provides full (read / write) access and management functionality to the database.
- A configuration GUI will allow users to modify the contents of the database through a convenient interface.
  - Hierarchical layout
  - Create, delete, modify classes and instances
  - Save snapshots of the configuration layout
  - Not intended for dynamically changing properties at run-time.

NGAO Controller Commands

- Common NGAO controller commands:
  - ***Connect / Configure***: Connects the component to system dependencies and prepares the device for use.
    - Used to be part of *Initialize* but renamed to remove confusion with *Home*
  - ***Home***: Activates a device to home its encoder position and position itself to zero encoder count.
  - ***SetMode***: Reconfigures the controller / device for operation in a particular observing mode.
  - ***Slew***: Commands a motion control device to obtain the specified position.
  - ***Track***: Causes a tracking device to enter closed loop operation.
  - ***Acquire***: Commands a component to initiate a target acquisition sequence.
  - ***Halt***: Take a controller out of the track state, and powers off the motion control device.
  - ***Recover***: Initiates a recovery process for a faulted device (i.e. initialization.)
  - ***Disable***: Puts the controller / device in a low-power non-operating state; typically performed as part of system shutdown.
- Depending on the controller only a subset of these commands may be used

Device Control (1)

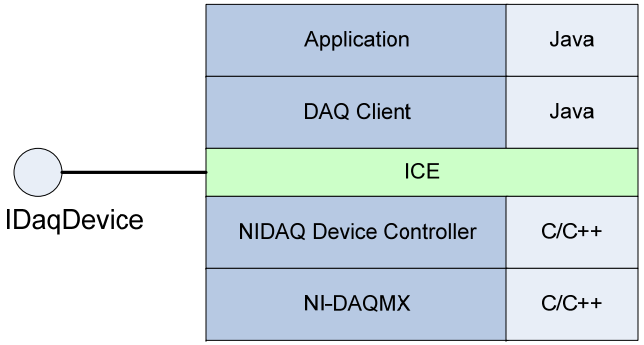
- Motion Devices
  - Any device that has to be positioned for use
  - Discrete devices
    - Uses switches to indicate one position or another, no in between, i.e. shutters
  - Non-tracking devices
    - Uses encoders for positioning information
    - Positioned then left in place with servo loops open (no power)
  - Tracking devices
    - All functionality of non-tracking device
    - Receives position updates at a fixed rate with servo loops always closed (powered)

Device Control (2)

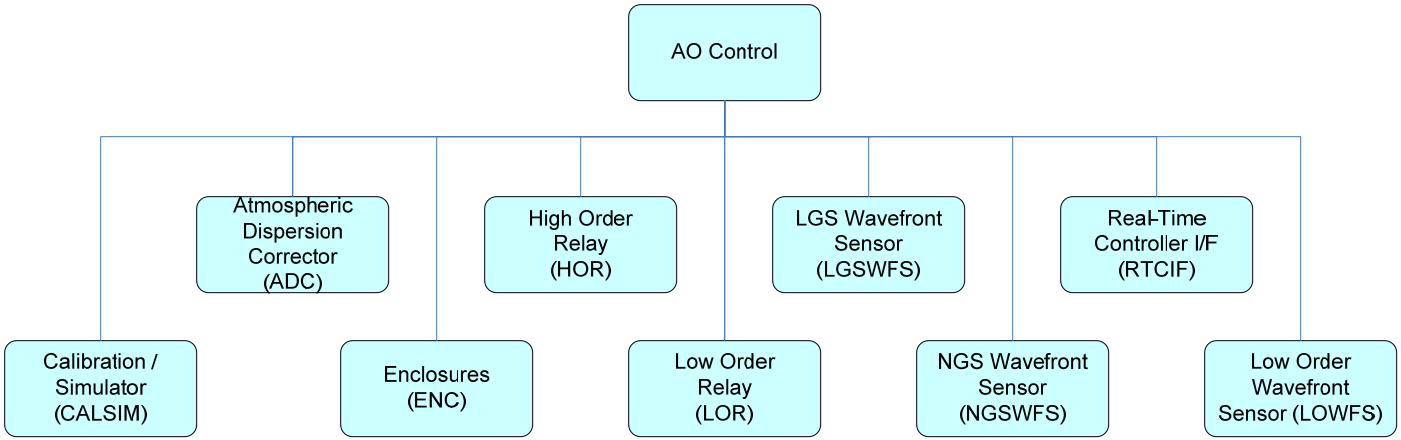
- Non-Motion Devices
  - Any device that is not creating motion and not requiring realtime control
  - Types of control
    - Remote power control
    - Camera / detector control
    - Digital input/output
    - Analog input/output
    - Remote reset control
    - Video
    - RS-232 and USB

Device Control (3)

- Architecture
  - The low level device control functions consist of one or more device drivers that implement an API to provide the most basic level of control.
  - An abstraction layer will be added above the device driver to hide all the hardware specifications and implementation of the actual hardware.
  - Additionally motion devices will include a high level generic state machine that implements the basic coordinated functions required for controlling a motion control device with an arbitrary number of degrees of freedom. A concept already used in the existing Keck AO and Interferometer systems.

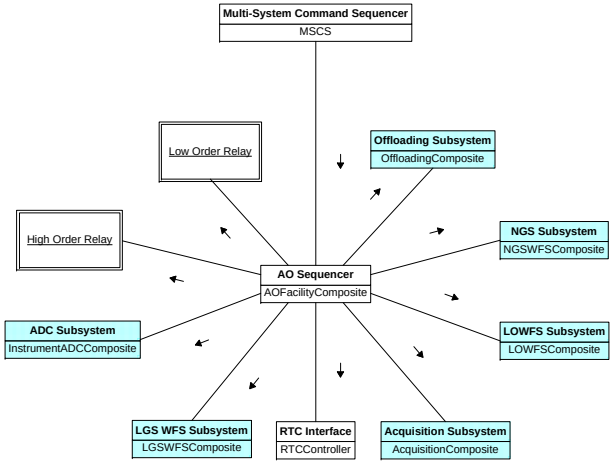


AO Control Overview



AO Control Sequencer

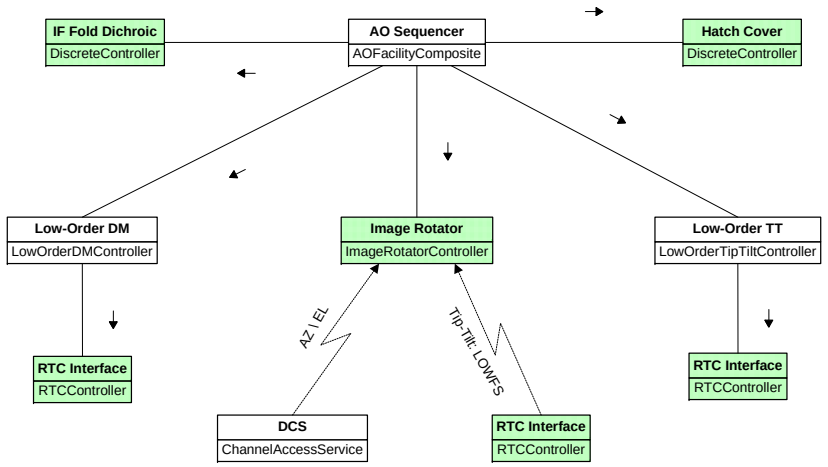
- Manages the entire AO controls system:
  - Initialization
  - Configuration
  - Acquisition
  - Observing



- Interfaces with the MSCS
- Defines the high-level control sequences
- Responds to system faults and errors

Low-Order Relay Subsystem

- Manages the devices that comprise the first relay.
  - LODM, TTM1
  - IF Fold, Hatch Cover, Rotator

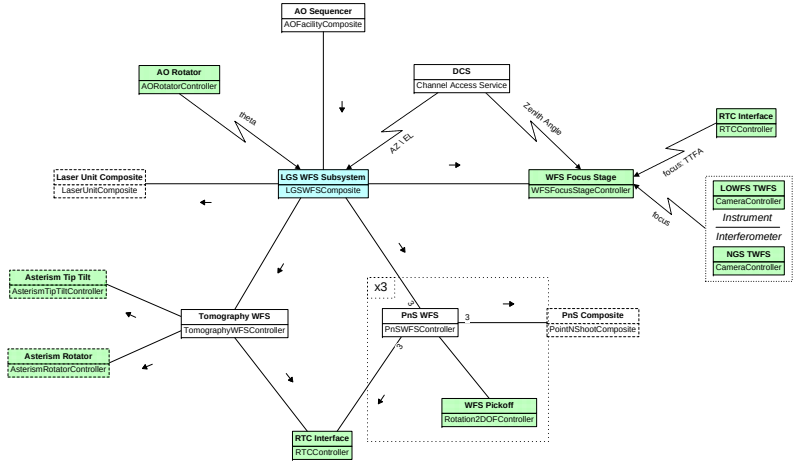


Control Loops:

- Image Rotation – Maintains the desired field / pupil orientation.

LGS WFS Subsystem

- Manages the LGS WFS system.
  - Tomography (4) and Patrolling (3)
  - Pickoffs
  - Focus Stage

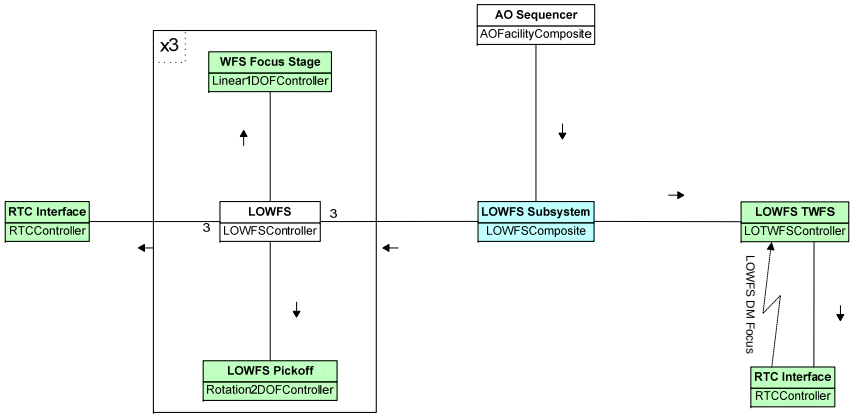


Control Loops

- Focus Tracking – Maintains optimal focus position for the WFS.
- Tip-Tilt Offloading – Offloads WFS tip-tilt buildup to the BGS.

LOWFS Subsystem

- Manages the LOWFS units.
  - TT (2), TTFA, TWFS
  - Pickoffs
  - Focus Stages

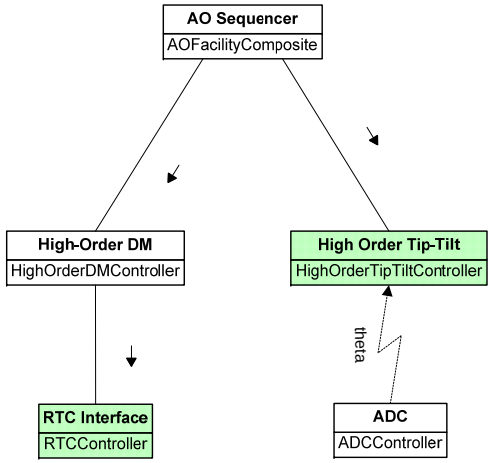


Control Loops:

- TWFS Focus and Centroiding – Provides high-accuracy focus measurements to the LGS WFS focus stage and RTC.

High-Order Relay Subsystem

- Manages the second relay devices.
  - HODM
  - TTM2

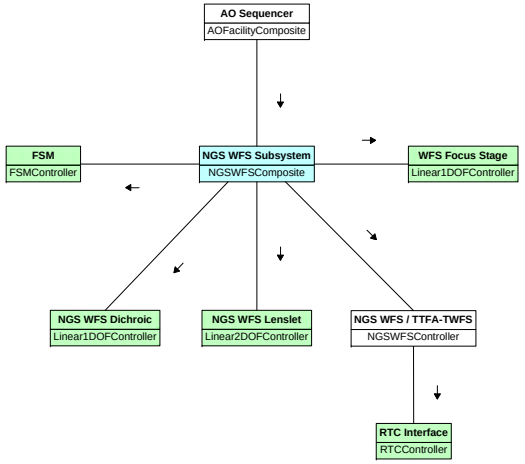


Control Loops:

- ADC Tip-Tilt Error Correction – Automatically corrects for tip-tilt error caused by the ADC.

NGS WFS Subsystem

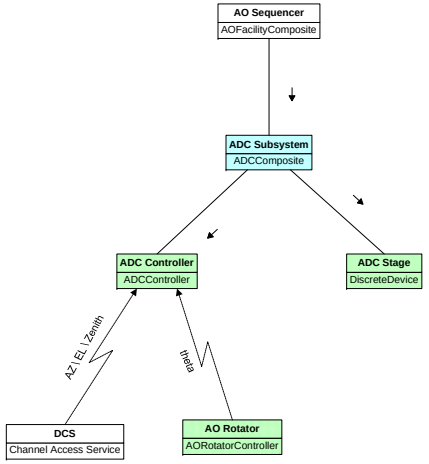
- Manages the NGS WFS system.
  - NGS WFS (TWFS / TTFA)
  - Lenslet, Dichroic, Focus Stage, FSM



- Dual role as NGS WFS and truth wavefront sensor during IF and fixed-pupil observing.
- Compensates for motion of TTM2.

ADC Subsystem

- Manages the ADC unit.
  - ADC, Stage



Control Loops:

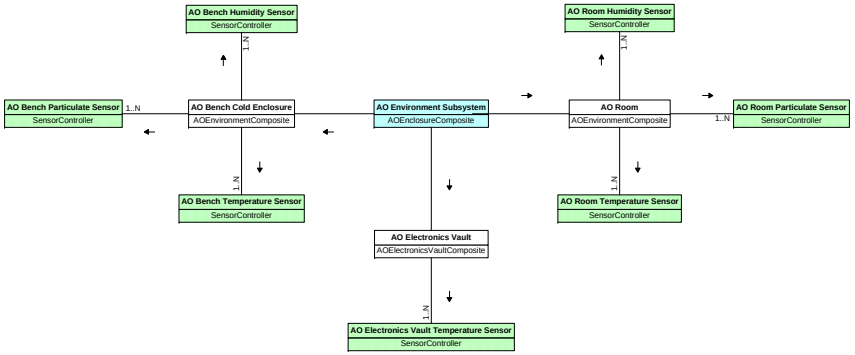
- ADC Tracking – Tracks dispersion based on the telescope zenith angle, direction and science pass band.

RTC Interface

- Implements the component interface to the RTC Control Processor.
  - KCSF → TCP / IP
- Input:
  - RTC input is provided through attributes and actions.
    - Configuration Control
    - Camera Controls
    - Power Controls
    - Loop Controls
    - Diagnostic Output Controls
- Output:
  - Output is made available through the Telemetry Service. Clients can subscribe to telemetry the same as they would other KCSF components:
    - Raw Camera Data, centroid, reconstructed wave fronts.
    - Parameters, configurations, and states.

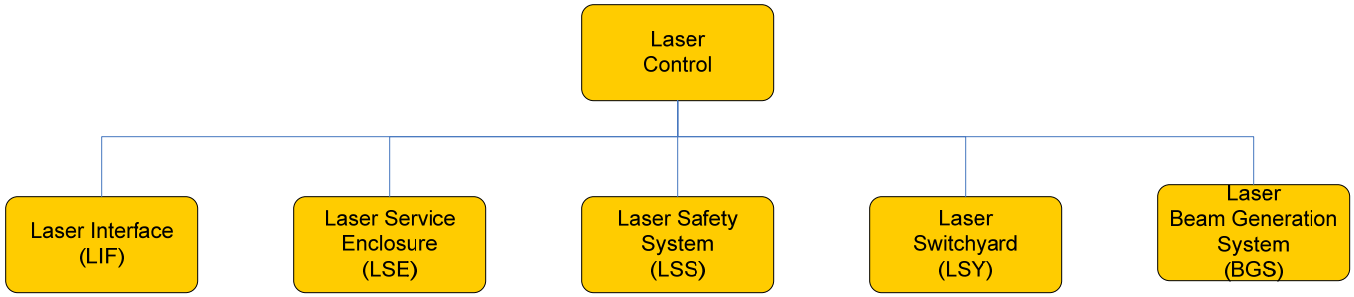
AO Enclosure

- Manages the AO enclosure sensors:
  - AO Cold Bench
  - AO Room
  - AO Electronics Vault



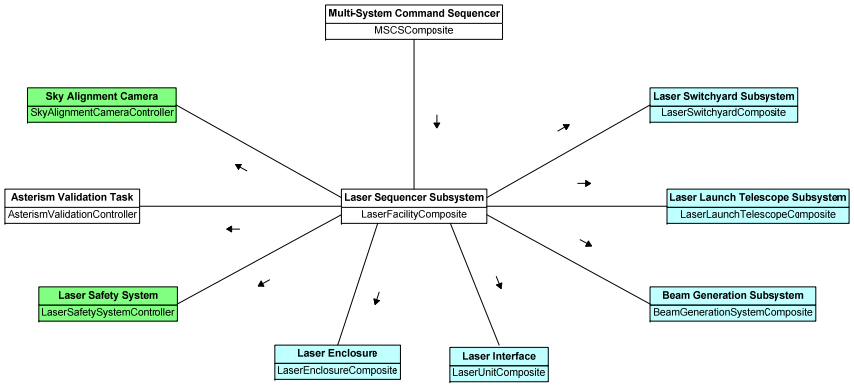
- Provides feedback to operators and technicians about the current environmental conditions of the AO facility.
- Runs at all times and is not typically shutdown at the end of the night.
- Data is not directly used by the NGAO controls system.

Laser Control Overview



Laser Control Sequencer

- Manages the entire Laser System
  - Initialization
  - Configuration
  - Acquisition
  - Observing



- Interfaces with the MSCS
- Defines the high-level control sequences
- Responds to system faults and errors

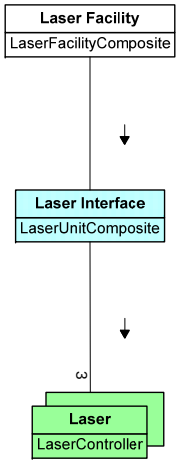
Laser Safety System

- Implements a controller interface to the Laser Safety System.
  - Actions to open and close shutters.
  - Get and set safety system permissives.

- Although the LSS will run independently of the control system, it relies on the NGAO client to provide it with the non-critical safety permissives.
  - OA and Spotter acknowledgement
  - Reduced functionality acknowledgment.

Laser Interface

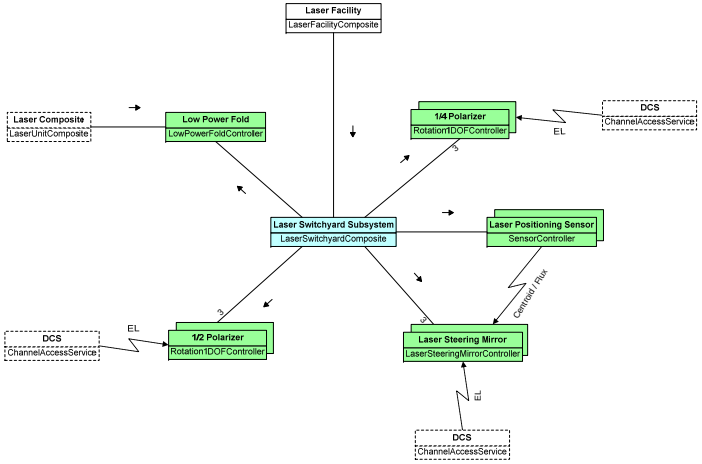
- Provides a consolidated interface to the laser control system
  - Initialization
  - Calibration
  - Propagation



- Laser units are under the control of the LSS.
- The Laser Interface Controller allows clients to treat lasers as independent system components.

Switchyard Subsystem

- Manages the devices in the laser Switchyard:
  - Low-power Fold
  - Polarizers
  - Steering Mirrors and Sensors

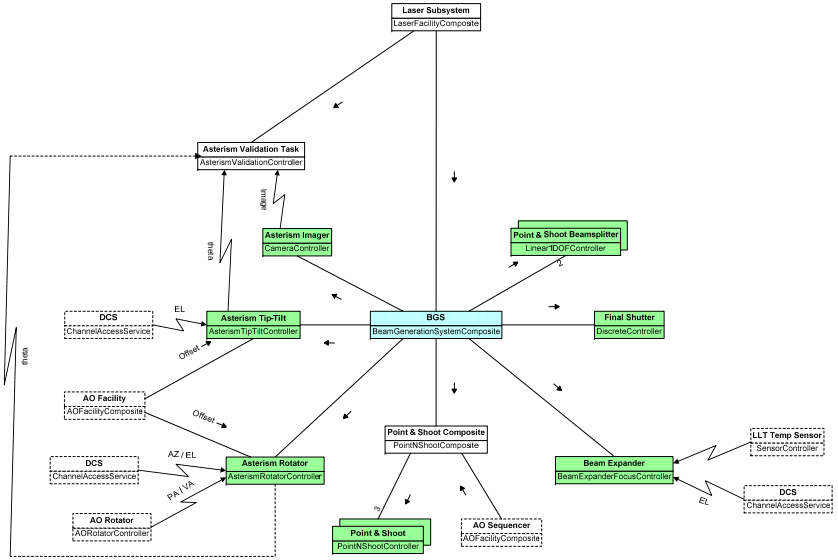


Control Loops:

- Laser Transport – Controls the propagation of the laser to the BGS.
- Laser Polarization – Controls the polarization of the laser as a function of telescope elevation.

Beam Generation System

- Manages all of the devices in the BGS:
  - Point & Shoots
  - Asterism Tip-Tilt and Rotator
  - Beam Expander
  - Beam Splitters
  - Asterism Imager

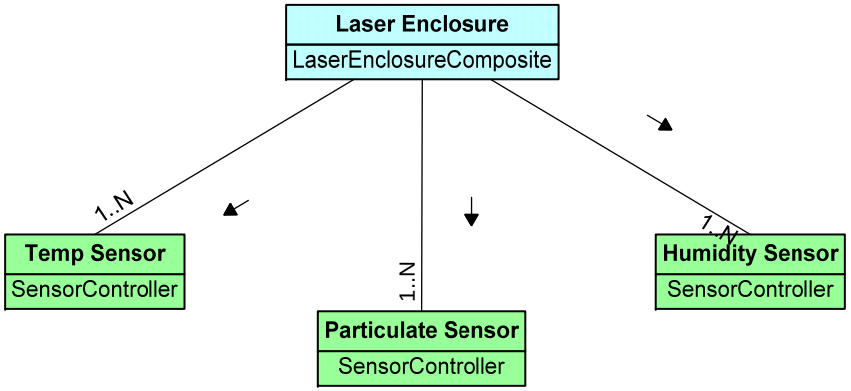


Control Loops:

- Focus Tracking – The stage will track the required laser focus.
- Rotator Tracking – The asterism rotator will match the orientation of the image rotator to maintain beacon alignment.
- Flexure Compensation – The Tip-Tilt will compensate for telescope flexure.
- Asterism Validation – Monitors the health of the laser asterism

Laser Enclosure

- Manages the Laser enclosure sensors:
  - Switchyard
  - Launch Telescope

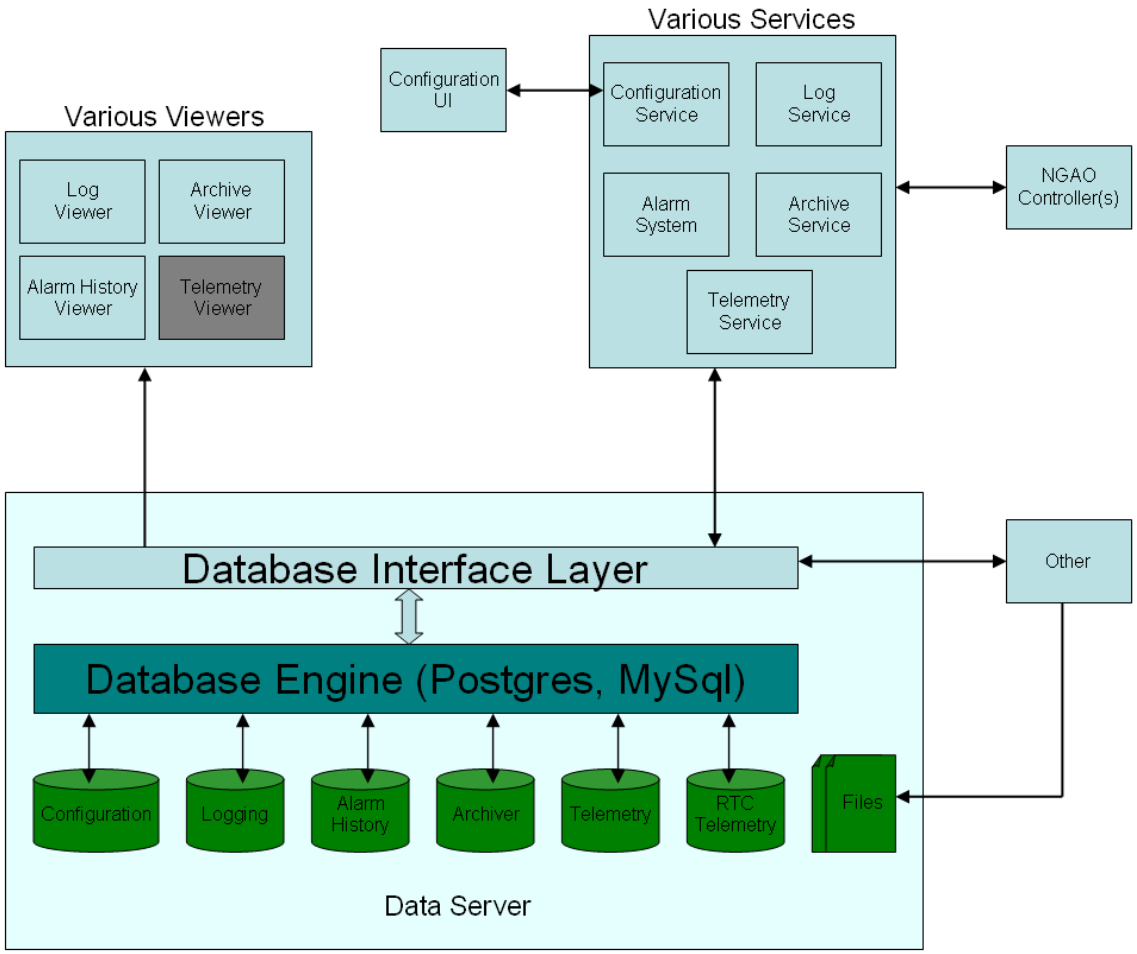


- Provides feedback to operators and technicians about the current environmental conditions of the Laser facility.
- Runs at all times and is not typically shutdown at the end of the night.
- Launch Telescope data is used by the BGS to calculate focus.

Data Server Overview (1)

- AO Controls System data storage and retrieval system
- Provides
  - Telemetry data recorder
  - Ad-hoc data recorder
  - Alarm recorder
  - General logger
  - System Configuration
- Consists of
  - Database management system (Postgres / MySql)
  - Actual databases (RAID)
  - File server for non-database files such as FITS (RAID)
- Note: high speed RTC data will be stored in its own data recording system

Data Server Overview (2)



Design Status

- Where are we?
  - Controls System design (70%)
  - High-level AO and Laser sequences (includes timing estimates) (85%)
  - Sequence, class inheritance, and deployment diagrams (70%).
  - Detailed interface and control loop documentation (65%)

BREAK

Review Comments

- Thank you to everyone for your detailed review of the materials
- Revision to documents forthcoming
- Detailed responses to individual comments are posted on the TWiki
- The following reviewer comments still need to be addressed

Review Comments (AC)

- 1a) Request for addition of warnings for errant telescope/FSM offloads
- 1b) Request to record images as fits files (RTC?)
- 1c) Rotator position calculation, DCS vs AO?
- 1d) Rotator position command latency concern
- 1g) Faint solar system differential tracking rates limited by offloading concern
- 1q) Support for “spiral” satellite avoidance information provided by Laser Clearing House

Review Comments (JC)

- 7) FR-3363: 40hz motion control tracking rate justification
- 8) FR-3109: 10hr MTBF for Data Server too low
- 16) “Home” vs “Initialize” confusion
- 17) KCSF deployment (guinea pig) concern

Review Comments (PW)

- 4.4.1) Will the HODM (high order DM) tip-tilt be a realtime controlled device or AO controlled?
- 5.4) LGS WFS provides correction for HODM
- Fig 20) Confusion about external offloading loops (open loop vs closed loop)
- Fig 22) DAR calculation and offloading needs clarification
- Fig 22) AO offset control loop sends offset to only one device based on observing mode
- Fig 23) Automated response to temperature monitoring results, i.e. room getting warm, increase fan speed
- Other) AO control of Interferometer devices
- 6.4.2) Control commanding of laser safety system

Review Comments (RD)

- Fig 5, S 5.4: Consistent terminology
- S 5.4: Use of small-amplitude TT dithering techniques not mentioned
- S 5.4.3.1: NGS FSMs will need to counter-steer TTM2 dithers motion
- General: Need to verify the control sequences will meet the allocated time allowances
- General: Your compliance matrix column headings seem different than what I expected.

Review Comments (VV)

- 5.2.2.2: Is the LOWFS rotation correction evaluated at the supervisory control – what's the cadence for this operation?
- General: I would really like to see a programmable master clock which controls the timing of all these sensors and perhaps a system that alerts AO engineers when things don't respond as they must.

Review Comment (DG)

- Section 5 AO: AO Control Sequencer should walkthrough observing operations and describe how the control system meets the needs of operations.
- Section 6 Laser: Are there control loops for wavelength control, pulse rate and width control, laser beam quality

Reviewer Feedback

- Other questions / concerns?

Summary of Concerns

- Closure of reviewer comments concerns that we raised
- Calibration procedures for most aspects of the system need to defined and documented
- ICDs need to be defined and documented
- Algorithms need to be defined and documented
- Machine and controller architecture decision
- Man power and loss of internal team AO knowledge a big concern
- Better definition of the Configuration System
- Definition / requirements for simulation system

Plans for PDR

- Continue detailing KAON 714: Control Software
- Complete supplementary material (sequence, class inheritance, interface and deployment documentation)
- Continue detailing KAON 732: Data Server
- Define Alarm System and Configuration System
- Map requirements to design document paragraphs
- Budgeting, effort estimates, scheduling
- Identify risks and mitigation plans