# Motion Control Architecture Mini-Review

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# Schedule

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

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

# Agenda

- Review Committee Charter
- Scope of the Review
- Requirements Compliance
- Motion Control
  - Types
  - Locations
  - Architectures
- Design Status
- Review Committee Comments
- Summary of Concerns
- Plans for PDR

# Review Committee Charter

- Reviewers:

  Don Gavel (UCO, chair)

  Alex Delacroix (CalTech)

  Tomas Krasuski (WMKO)
- 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

- Motion control electronics architecture
  - Control of actuated devices used throughout the various NGAO subsystems
- Not in the scope of this review:
  - Overall architecture of the NGAO control system or the top-level design of the NGAO control system
  - Motion control required for real-time wavefront correction (DMs, T/T) under control of the RTC
  - Software controls
  - Effort Estimates
  - Budget
  - Schedule

# Requirements Compliance

- Locating all of the relevant requirements has proven challenging
  - Every subsystem was reviewed for requirements relating to motion control
- PD Requirements Review (Phase II) week of 1March, continued into week of 7March
  - Impact on motion controls has yet to be assessed
- More effort required to
  - Verify all requirements have been identified
  - Determine compliance
  - Address deficiencies in requirements and compliance
- No areas of non-compliance have been identified

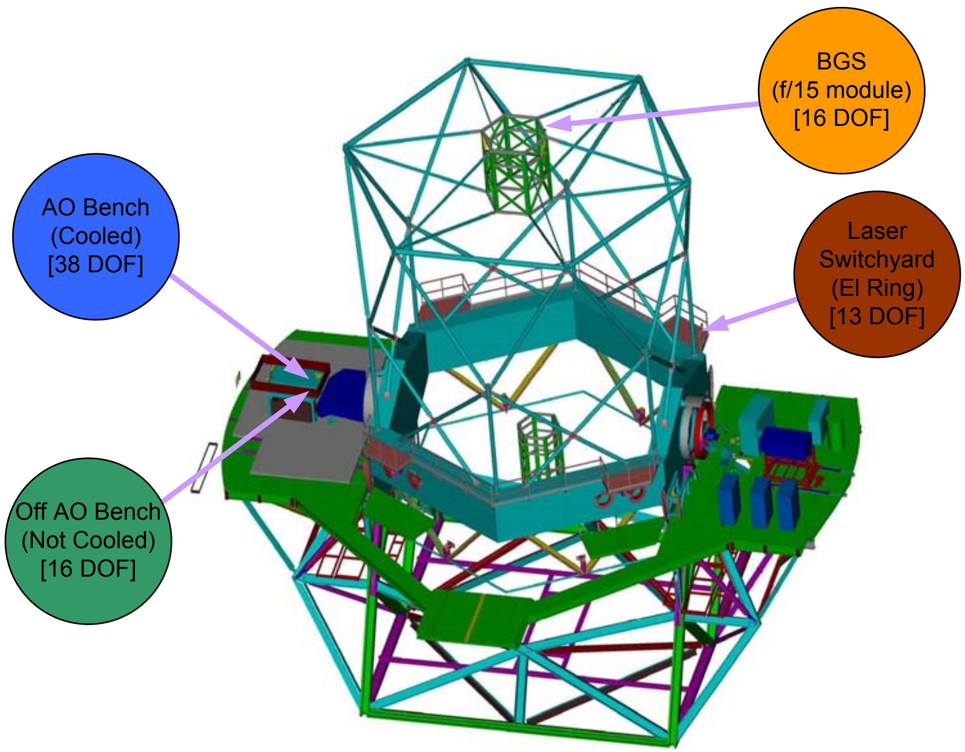
# Motion Control Types (1)

- Shutters
  - Simple in/out devices with very loose positional requirements
  - Actuators other than motors (e.g., solenoid, pneumatic, etc.) may be considered
  - Switches or hard stops may be used to define the positions, encoders not required
  - Knowledge of actual position when moving, although desirable, is not required
- Low precision, non-tracking
  - A dichroic or fold, for example, that is either in the beam or out of the beam
  - Moved during configuration, not during an observation
  - Position with encoder
- Medium precision, non-tracking
  - Higher precision, still primarily single axis devices
  - Moved during configuration, not during an observation
  - Likely combine this category with Type 1 devices
- High precision, non-tracking
  - aligning a lenslet or focusing a unit
  - moved during configuration or acquisition, not during an observation

# Motion Control Types (2)

- Tracking
  - position calculated from and synchronized to external information (telescope az/el, etc)
  - servo loops closed during an observation, command rates of 25mS to 100s of seconds
  - generally more stringent requirements on servo loop performance
    - want smooth motion, small following error, minimal overshoot
  - various levels of precision required
  - ADC, rotators
- Extremely high precision tracking and non-tracking
  - coordinated motion with other DOF(s)
  - may be constantly moving during an observation, update rates of 1Hz or faster
  - generally requires a high precision actuator, not a servo motor
  - examples include steering mirrors and tip/tilt stages
- Pickoff arms - coordinated high precision non-tracking
  - most demanding DOF
  - position calculated from and synchronized to external information (telescope az/el, etc)
  - coordinated motion with other DOF(s)
  - spatial position constraints to avoid collision
  - mechanical design may require the device to servo in position

# Location Overview

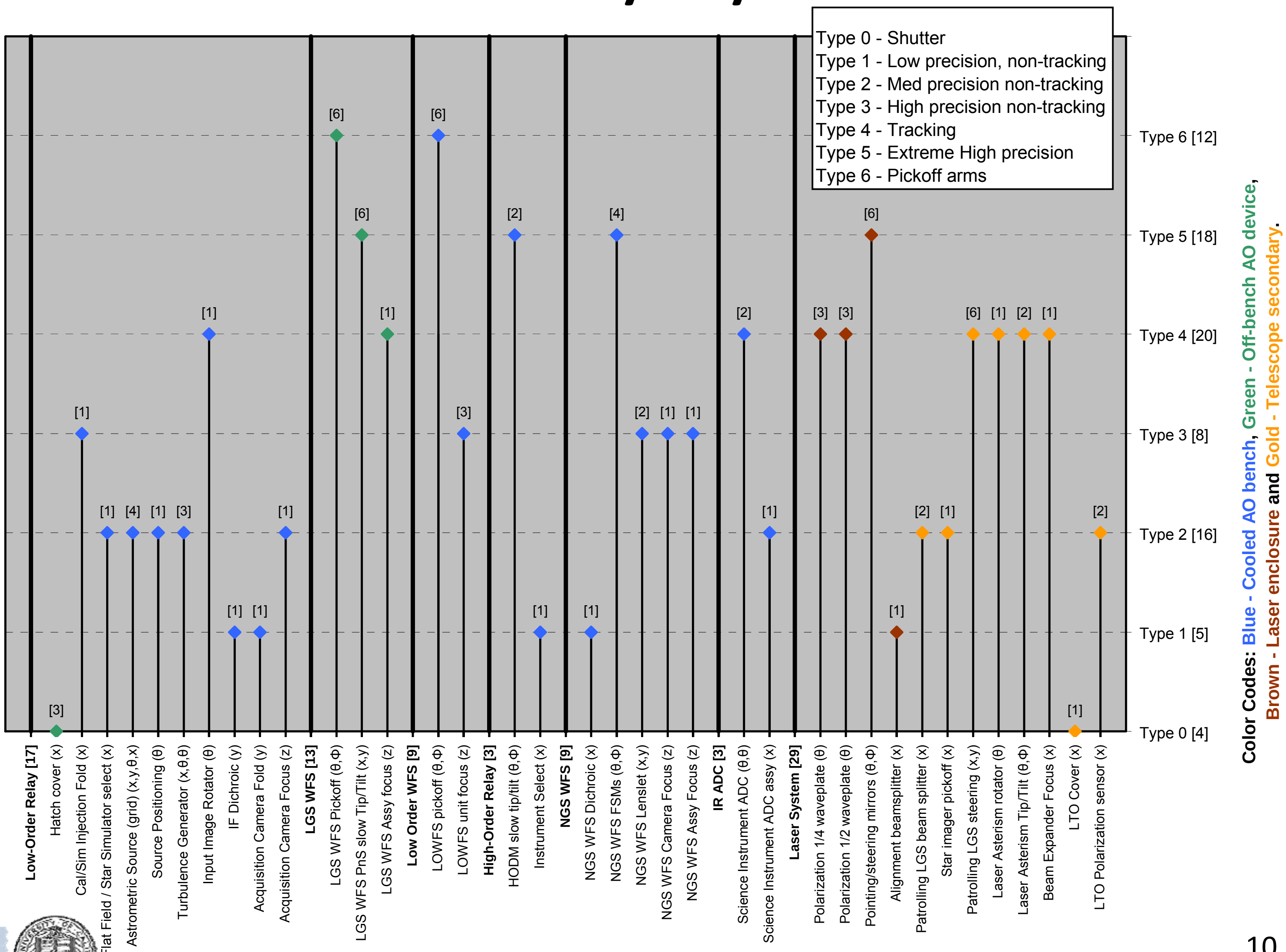



**Current NGAO System Total: 54 AO + 29 Laser = 83 DOF**

**Original Estimate: 150+ DOF**

**Existing K2AO system: 29 AO + 22 Laser = 51 DOF**

# Device Summary by Location



# Motion Control Architecture (1)

- Centralized
  - All components are rack-mounted in a single location
  - Individual cables flow from the rack to each DOF
  - Primary approach taken throughout the observatory
  - Pros
    - Familiarity
    - Straight forward heat / power management
    - Single starting point for troubleshooting
    - Potential for reuse of SW and/or HW
  - Cons
    - Cabling – lots of it to a single location
    - Longer cables may exclude use of low cost PWM amplifiers
    - Scalability due to space constraints
  - Proposed use
    - AO Electronics Vault
      - Most AO devices
    - Telescope Secondary or Laser Service Enclosure
      - Laser Beam Generation System devices
      - Laser Switchyard devices if equipment in LSE

# Motion Control Architecture (2)

- Distributed
  - Equipment located in close proximity to actuator
  - Several options with varying amounts of distributed equipment
    - Distributed amplifier, central controller
    - Distributed controller and amplifier
    - Smart motor: controller and amplifier integrated into motor
  - Pros
    - Significant reduction in cabling effort
    - Very scalable
    - Possible improvement in servo bandwidth
    - Short cables allow use of lower cost PWM drives for some axes
    - Allows partial system reset which may reduce the recovery time
      - all stages may not require homing
  - Cons
    - Distributed thermal loads
    - Troubleshooting requires knowledge of physical layout with multiple device locations
    - Integration with E-stop system
  - Propose use of smart motors for low/moderate precision non-tracking devices

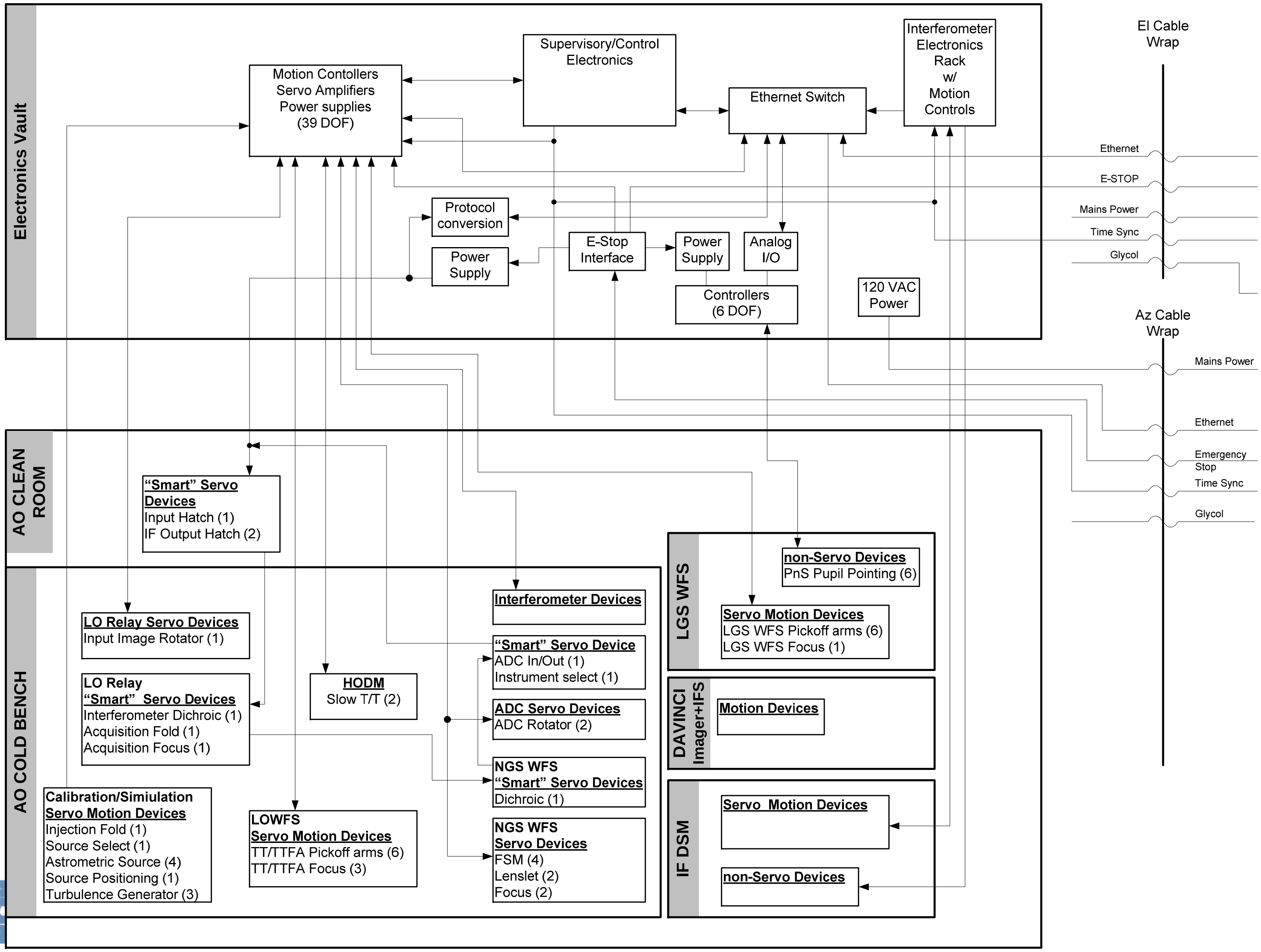
# Design Status (1)

- Controllers
  - Use of programmable, multi-axis controllers with Ethernet
    - Delta-Tau PowerPMAC a possibility
  - Use of coordinate systems for multi-axis stages
  - Prefer distributed control system to communicate via engineering units (mm, field position), not encoder counts
    - Translation at the controller level
- Actuators
  - must operate in specified environment: -15°C in cold box, -10°C on secondary
  - DC motors (brush or brushless)
  - Drive or load position encoding, precision dependant
  - Precision actuators (piezo t/t stages, linear piezo, voice coil, etc)
  - Smart motors
  - Normally closed (open when triggered) end of travel switches
- Crates / processors
  - Separate embedded processors (VxWorks) likely not required
  - Higher level server to handle communications and monitoring functions

# Design Status (2)

- Observatory E-stop interface
  - Part of the motion control requirements
  - Will likely remove power to all motion amplifiers
  - Preferably preserve encoder/limit switch power to easy recovery
- Cables will need to remain flexible at operating temp
  - Combine multiple axes on single cable where possible
  - -15°C in cold box, -10°C on secondary
  - Attention needed on pickoff arms and devices mounted to an in/out or focus stage to provide adequate range of travel
  - Motors supplied with an integral cable could be a challenge
- Instrument mechanisms
  - Not part of NGAO motion control design
  - Imager+IFS (DAVINCI) has its own motion controls
  - Interferometer DSM supported by IF ancillary electronics rack and IF control system
  - Interferometer will have devices on AO bench
    - Devices will be controlled by NGAO to eliminate any impact on non-IF AO observing
    - Details not known

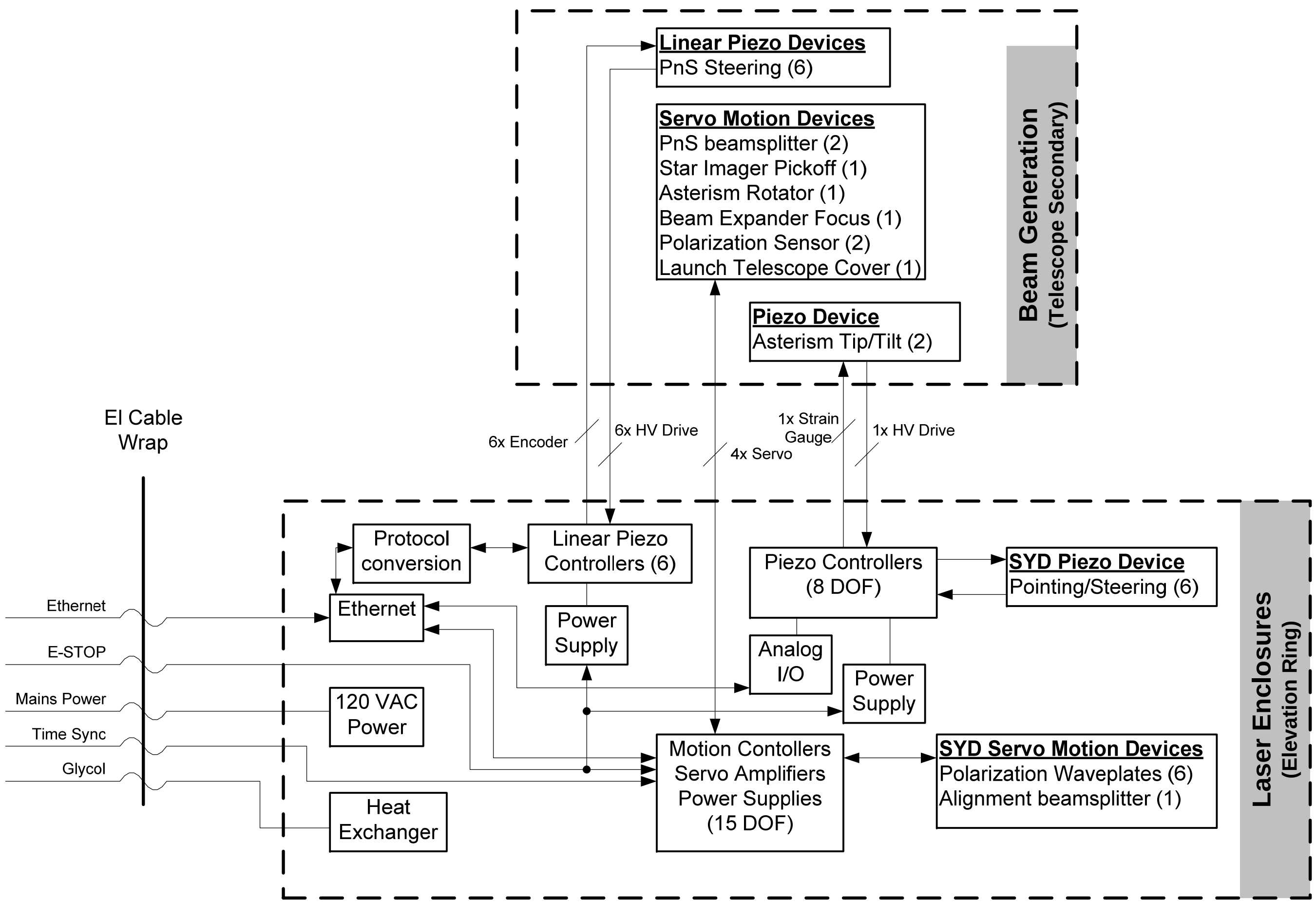
# Proposed Layout of AO Controls on Left Nasmyth



# Proposed Layout of AO Controls on Left Nasmyth

- Multi-axis servo controllers located in e-vault
- Smart motors used for intermittent, low or moderate precision devices
  - 6 of these motors inside the cold box, 3 outside
  - Continuous power dissipation of ~0.9 W each
  - Stages must accept NEMA frame motor
  - Requires power supply and terminal server port
  - estimate ~$400/axis savings (procurements) over centralized approach
- 32 servo devices on cold bench
  - anticipate ~15 W (total, 0.5 per device) of power for encoders alone
  - some DOF in the Cal/Sim unit may have dedicated controllers
- 13 devices in AO Room
  - 7 servo motors, 6 piezo (or equivalent)
- Cabling
  - Anticipate around 16 cables between cold box and e-vault
    - Assumes 2 DOF per servo motor cable
    - Cold box will have bulkhead connectors; environmental seal but not hermetic
- Interface with facility Emergency Stop
  - Prevent motion to protect personnel and equipment
  - Keep encoders/limits powered if possible to speed recovery
- Volume ~ 22U (half 7 foot rack), similar to existing AO system

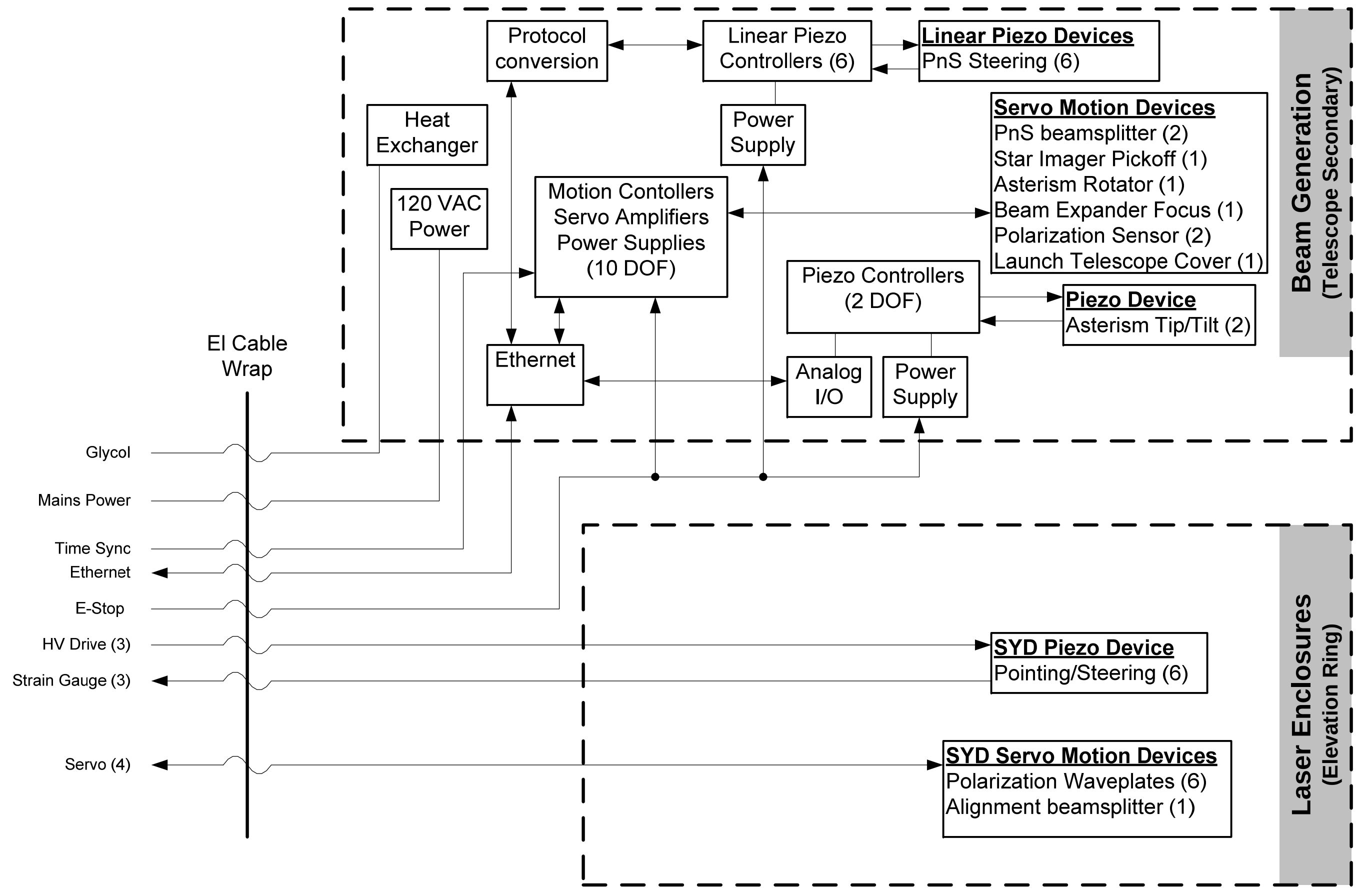
# Proposed Layout of Laser devices w/ controllers in LSE



# Proposed Layout of Laser devices w/ controllers in LSE

- Motion controllers for laser switchyard and beam generation system located in LSE
- Pro:
  - Limited requirement on Elevation cable wrap
  - Space, power and glycol are  available in LSE
- Con: cables between secondary and LSE
- Cabling
  - Anticipate 18 cables between LSE and secondary
    - 12 of the 18 for the linear piezo devices, may be able to combine into fewer cables
  - Only infrastructure cables (power, Ethernet, time sync, e-stop) between LSE and e-vault
- Volume: 15U of 19” rack (~0.12 m^3)

# Alternate Layout of Laser devices w/ controllers on Secondary



# Alternate Layout of Laser Devices w/ controllers on Secondary

- Controllers for BGS devices located on secondary, Switchyard controlled from e-vault
- Pro: Minimal cabling to secondary
- Con:
  - Space and mass on secondary
  - Will require (custom?) cooled enclosure for electronics
  - LSE cables in elevation wrap
- Cabling
  - Requires infrastructure cables (power, Ethernet, time sync, e-stop) between secondary and e-vault
  - 10 motion cables between LSE and e-vault (el wrap)
- Volume: 10U of 19” rack (0.08 m^3)

# Alternate Layout of Laser devices w/ all controllers in E-vault

- Controllers for all laser devices located in E-vault (not illustrated)
- Pro:
  - Heat/power management
- Con:
  - Some equipment still likely in LSE or secondary
    - Would require cooled enclosure
  - 40m cables from secondary to e-vault, through elevation wrap
    - Devices must meet spec
    - Voltage drop across cable must be managed
    - Differential drivers required for encoders
      - Actuators with single-ended encoders would require design of custom driver board
  - LSE cables in elevation wrap
- Cabling
  - 18 cables between secondary and e-vault
    - may be able to reduce this to 12
  - 10 cables between LSE and e-vault
- Volume: 15U of 19” rack (0.12 m^3) in e-vault

# BREAK

# Review Committee Comments(1)

- Mahalo to everyone for your detailed review of this material
- Revision to documents forthcoming

# Review Committee Comments(2)

- Need definition of terms
  - Reviewers noted inconsistency of naming
  - Project needs to publish preferred names and definitions
- Need agreement on required controls (tracking) and precision of devices
  - Perhaps some differing ideas about definition of tracking
    - Servo loops closed during observation
- Recycling of existing equipment (OBS)
  - Not likely despite apparent compatibility
  - Much is obsolete or would require upgrade
- Concern about smart motors inside cold enclosure
  - Not a significant heat source, compared to traditional motors
  - Some in-house testing is required to verify manufacturer claims
  - Changing the design to conventional servo motors straight forward

# Review Committee Comments(3)

- Comment regarding controls split between AO and IF in current system
  - NGAO will control all devices on AO bench
  - NGAO will control all hatches
    - Eliminate problems in existing distribution of control
    - NGAO will need the output hatches closed during observing (and presumably daytime prep/stabilization)
  - NGAO is required for IF observing, the converse is not true. IF should not be required for NGAO to work
- Is there any allocation for expansion?
  - Not in the strict sense of x% free channels
    - Need guidance from the project
  - Adding smart motors to the ring is easy
    - Probably a limit based on communication bus speed
  - Depending on choice of controller, expansion would only be limited by available rack space

# Review Committee Comments(4)

- Type and amount of diagnostics was questioned
  - This needs work.
  - At present, no additional hardware is anticipated
- Heat analysis of Cold Enclosure
  - Estimate of steady state load provided
    - ~20W of encoder
    - Active limit switches have negligible contribution
  - Active state much harder to predict
    - Need payload information from subsystems designers to estimate required motor power
    - Need duty cycle information for devices with intermittent motion
  - Work with Mechanical engineers to estimate thermal constants of enclosure
  - Need analysis of how thermal gradients , bench ‘seeing’, local hot spots, etc. impact performance

# Review Committee Comments(4)

- Reviewer suggests a survey of existing motion systems for ‘likes’ and ‘dislikes’
  - Worthwhile
  - Some of this is already included given the experience of the team on both AO an IF
- Reviewer comment on missing reference on pg13 of KAON 715
  - Typo, should be KAON 643 section 7.6 (not 6.7), will be corrected
- Reviewer responded to concerns about probe arm limit switches
  - Updated design that uses load cells to determine direction of travel
  - This helps recover from a limit condition
  - Concern about interface to motion control system
  - Still a concern about homing these stages
- Reviewer concern about flow-down requirements listed in KAON 715
  - These are flow-down, not functional requirements
  - Not aware of a decision to manage this type of requirement in Contour

# Reviewer Feedback

- Any questions?
- Detailed responses to individual comments are (or will be) posted on the TWiki

# Summary of Concerns (1)

- Better collaboration between subsystem design teams
- Need agreement on required controls and precision of devices
  - Need completion of Master Device List with all relevant information
- Need better understanding of pickoff arm controls (homing)

# Summary of Concerns (2)

- Nearly every subsystem requires motion control
  - Insufficient detail on some subsystem designs
- Need to understand goals for DD and I&T
  - Which team is responsible for what
    - How much duplicate equipment is required in California
    - What level of performance validation is performed by subsystem designers
- Understand cabling requirements
  - Clean enclosure
    - work out baseline for connectors/cables
  - Telescope cable wraps

# Plans for PDR

- Work with Systems Engineering to get a complete approved set of requirements
- Work with subsystem designers to complete the Motion Control design
- Decide on location of laser control electronics
- Provide estimates for power/volume/mass
- Maintain KAON 682 (Master Device List)
- Complete KAON 715 (Preliminary Motion Control Design)
- Identify risks and mitigation plans
- Budget and Schedule

# Review Comittee Session

- Given the short time to the PDR, we request an informal report via email, rather than a formal write-up
  - this will decrease the turn around time and limit additional effort required by the reviewers
- If the reviewers prefer a formal write-up, please provide this within a week