RECOMMISSIONING WIND TUNNEL FLOW SENSOR ARM

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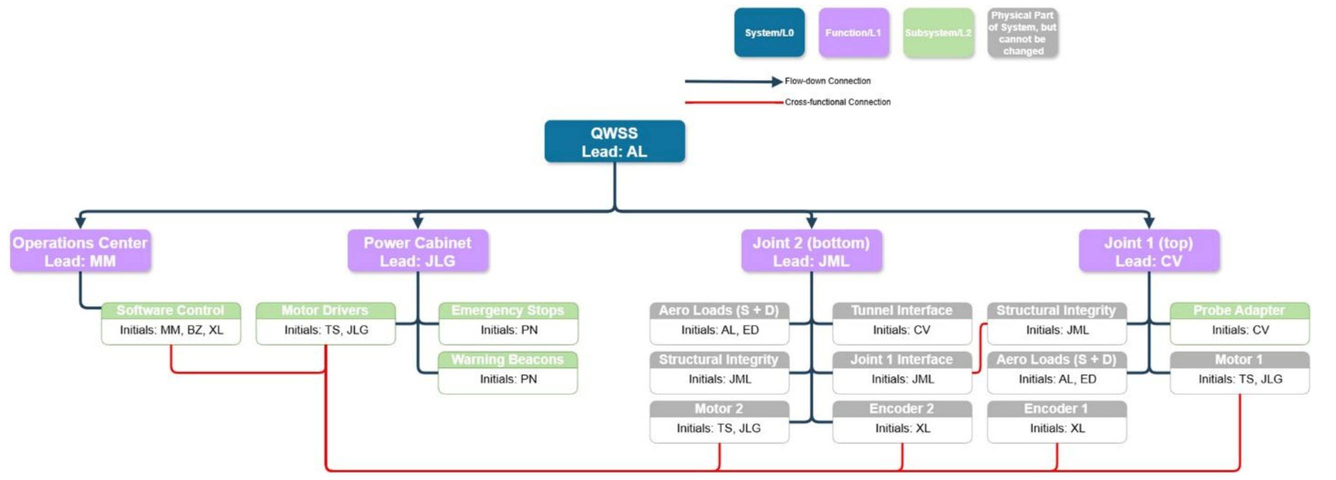
Introduction

- The project aims to retrofit and modernize the Mk 16 Quantitative Wake Survey System (QWSS) for use in the Kirsten Wind Tunnel (KWT).
- The QWSS provides quantitative, detailed, and unique flow visualization for KWT customers.
- The system was originally built by Boeing, and some hardware was inherited by the team.
- Major components redesigned or built include the probe assembly, the operation center, and the power cabinet.
- The system integrates updated control, power, and safety features to meet modern standards.

Objectives

- Recommission the Mk16 QWSS to enable wake profile characterization in the Kirsten Wind Tunnel.
- Achieve point-to-point traversal within 30 seconds and maintain positional accuracy within 0.2 inches.
- Ensure reliable operation under dynamic pressures up to 100 psf.
- Redesign key hardware including the probe interface, power cabinet, and motor control system.
- Integrate encoder-based position tracking and safety features such as visual and auditory warnings.
- Develop software for external control and data collection using open-source platforms.

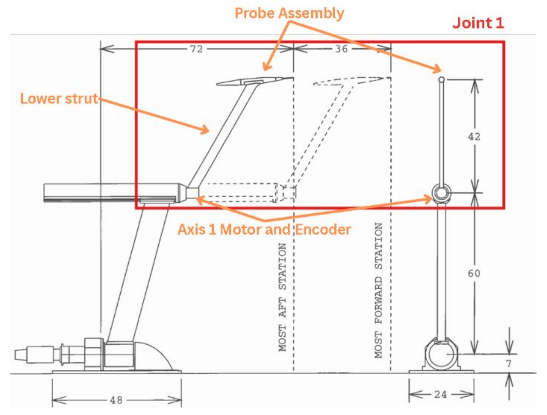
System Architecture

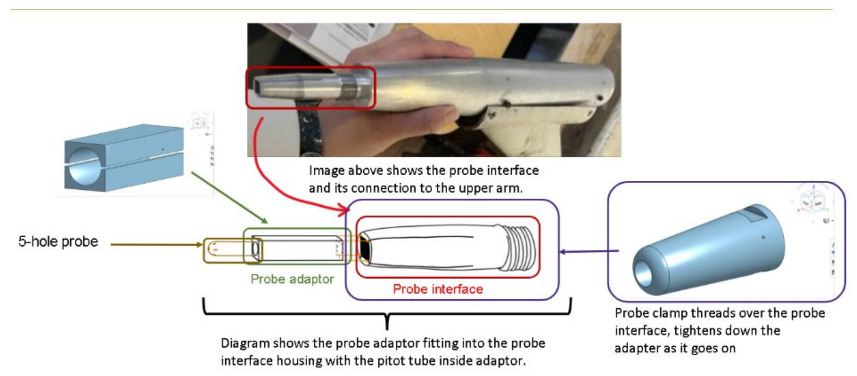


- The QWSS system is divided into several subsystems to meet mission requirements, enabling accurate probe positioning, controlled movement, and reliable data collection in the Kirsten Wind Tunnel.
- The Operations Center serves as the control hub, integrating software for real-time communication and performance monitoring across all components.
- The Power Cabinet distributes power to all subsystems and includes key safety features such as Emergency Stops and Warning Beacons.
- Joint 1 connects the system to the probe, ensuring precise alignment and positioning via Motor 1 and the Probe Adapter.
- Joint 2 handles large-scale movement using Motor 2, enabling full planar motion of the arm for test section coverage.

Joint 1 Design

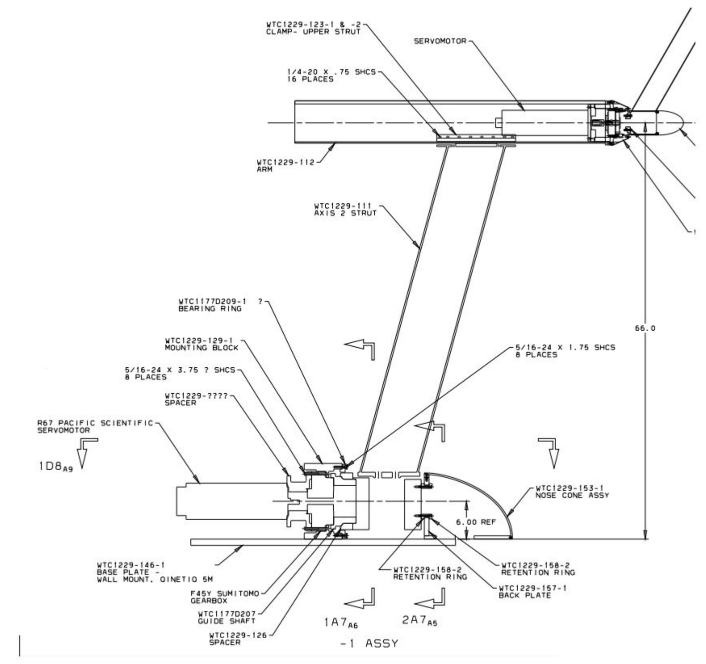
- Joint 1 includes the probe assembly, lower strut, Axis 1 motor, and encoder.
- Two lower strut versions exist (42 in and 60 in); this project uses the 42 in version.
- The probe adaptor allows support for different probe sizes.
- The probe clamp provides even clamping force to securely hold the probe.
- The clamp threads onto the Boeing-provided probe interface and tightens to lock the probe.
- The design ensures secure and stable probe positioning during wind tunnel tests.





Joint 2 Design

- Joint 2's structural design remains unchanged; only the motors, drivers, and wiring have been updated.
- End stops were implemented to prevent collision with the wind tunnel walls.
- The end stops are designed in a specific configuration and placed strategically along Joint 2.
- Fully dimensioned diagrams show the side profile, strut, and arm of Joint 2 to demonstrate how the design meets spatial and mechanical constraints.

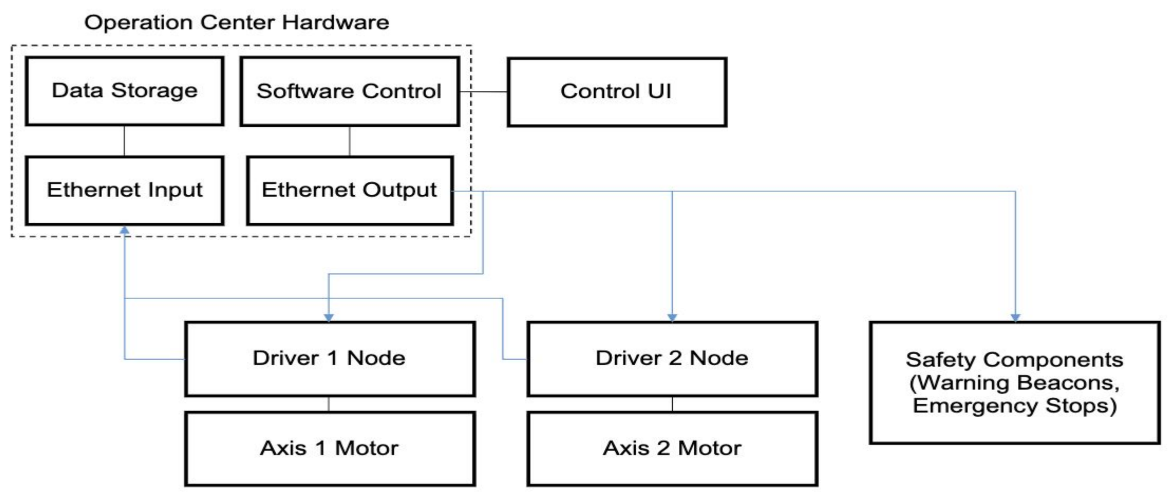


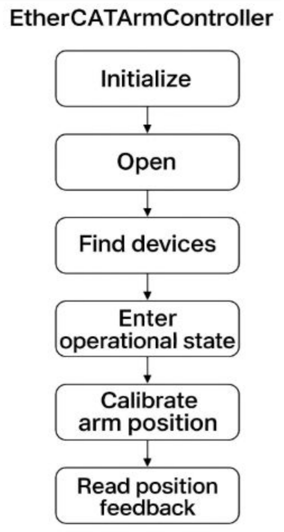
Power Cabinet Design

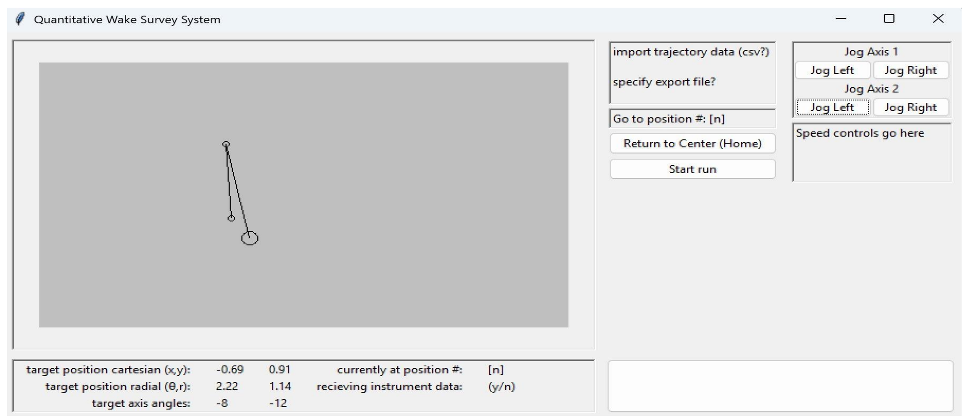
- External housing for components necessary to implement and operate QWSS
- Custom assembled and wired to meet customer & safety requirements
- Diagrammed in KiCad (EESchema) prior to assembly
- 20" x 20" x 10 Cabinet Dimension
- Safety: NEMA Enclosure & IEC-61010
- Shielded cables + protected plugs/pins
- Major components protected with filters + circuit breakers

Software Control

- The control software is developed in Python and runs on an Intel NUC 11 industrial PC (IPC), located inside the power cabinet. This IPC is remotely accessible from the KWT Control Center.
- The Graphical User Interface (GUI) allows users to input a target area of interest and arc point density, which the system uses to generate corresponding G-code for arm movement. Users may also directly input G-code or control the arm via manual jog controls.
- The GUI provides a live preview of the arm's current and target positions, along with numerical feedback on joint positions, motion status, and sensor readings.
- The generated or inputted G-code is passed to a backend decoder, which translates the motion instructions into low-level driver commands, specifying position and speed for each axis.
- The decoded driver commands are sent over EtherCAT, a deterministic real-time communication protocol supported by the selected motor drivers
- The system can be initialized either by physical limit switches or by manual homing (aligning to center), with both options setting the zero reference point for further motion.







Future Work and Acknowledgments

- Design additional probe adapters to support a wider range of sensors for various aerodynamic testing scenarios.
- Add real-time data logging and visualization tools into the GUI to assist with post-test analysis and streamline reporting.

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Power Cabinet Layout

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BOEING

Major Components

- Axis 2 Motor Driver (DPEANIU-C100A400)
- Axis 1 Motor Driver (FMP060-25-EM)
- Axis 1 Power Supply
- IPC
- Ethernet Switch

Safety Components

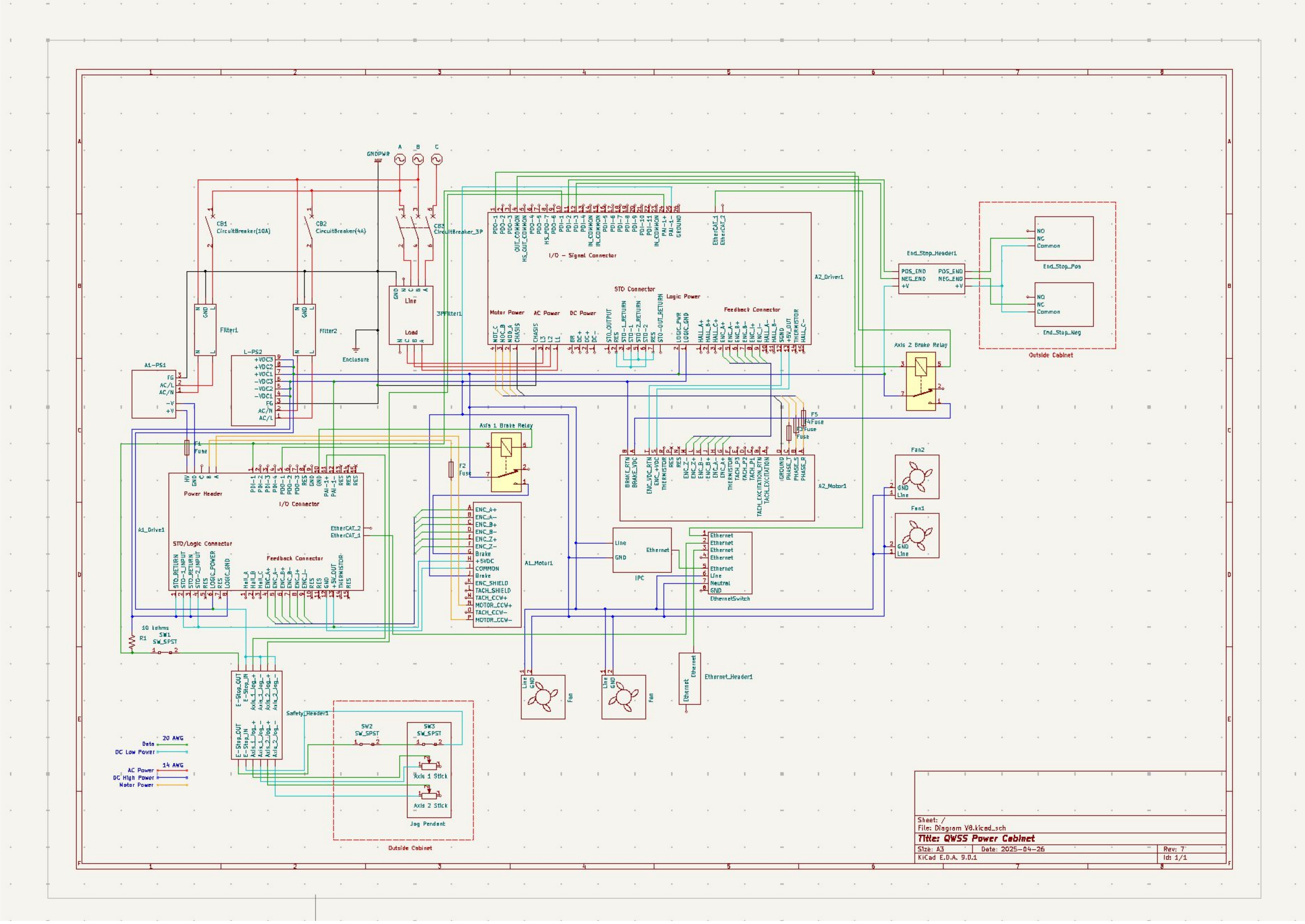
- Circuit Breakers (3)
- Filters (3)
- Emergency Stops (3)
  - 1 on Power Cabinet (for workers stationed at cabinet)
  - 1 on Jog Pendant (for mobility)
  - 1 permanent location at operation center
- Warning Beacons (2)
- Fans (4)
- Wire Gauge (via NEMA Enclosure & IEC-61010)
- Axis 1 + 2 Relays
- Axis 1 + 2 End Stops

Outside Cabinet Components

- Jog Pendant: (Joysticks: Controlling arm Motion + E-Stop for emergency situations while working around the traverser section)
  - Buck Converter -> Step down 24V to 10V for joystick to analog input connection
- Operation Center Box: Emergency Stop + Warning Beacons for emergency situations while working from the computer operation center.

Additional Information

- 20" x 20" x 10" Dimension
- Majority Components back mounted to metal plate for troubleshooting accessibility



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