3. Materials and Methods

System Design and Build Phase

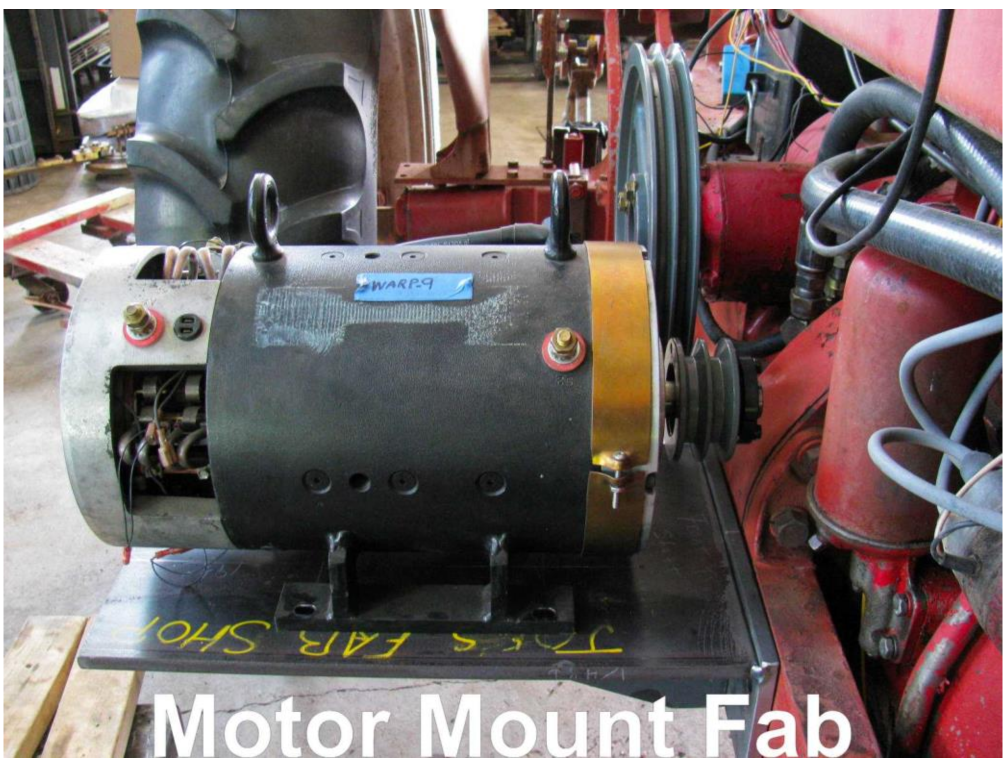
Design Objectives

The hybrid tractor was designed to integrate traditional ICE with an electric drive system, emphasizing safety, modularity, and efficiency. Critical components included a 144V battery system, Warp 9 electric motor, custom controllers, and precision torque monitoring. *(Image 1: Overall System Overview)*

Technical Overview

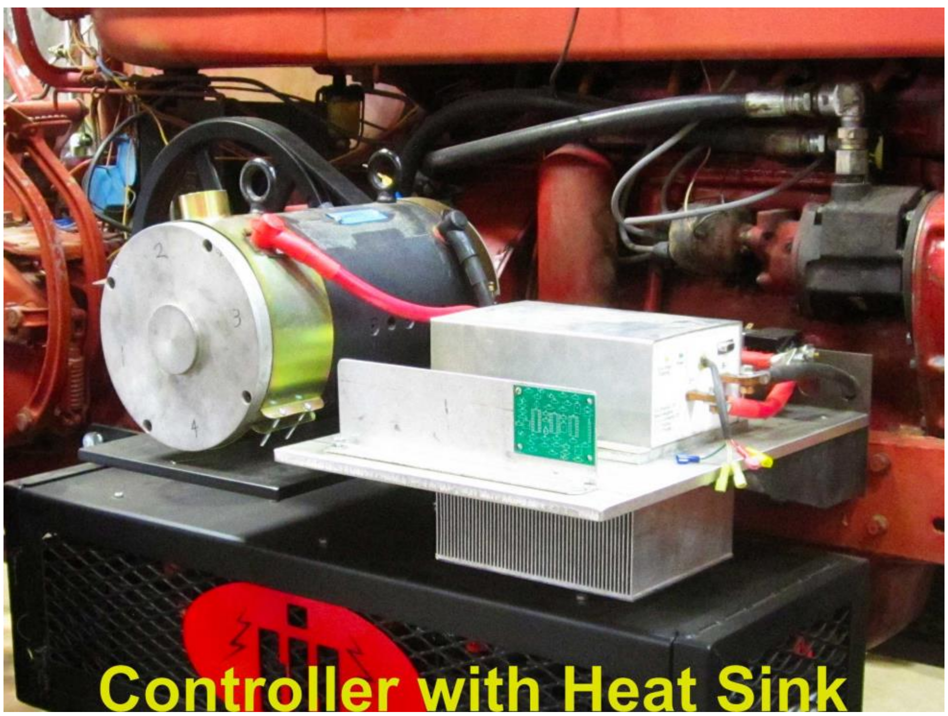
- **Battery System:** Six 12V batteries wired in series, with isolated grounding to minimize risk. *(Image 2: Battery Bank Installation)*

- **Electric Drive:** Powered by a Warp 9 motor controlled via a custom governor and electronic control unit (ECU). *(Image 3: Warp 9 Motor Mounted)*



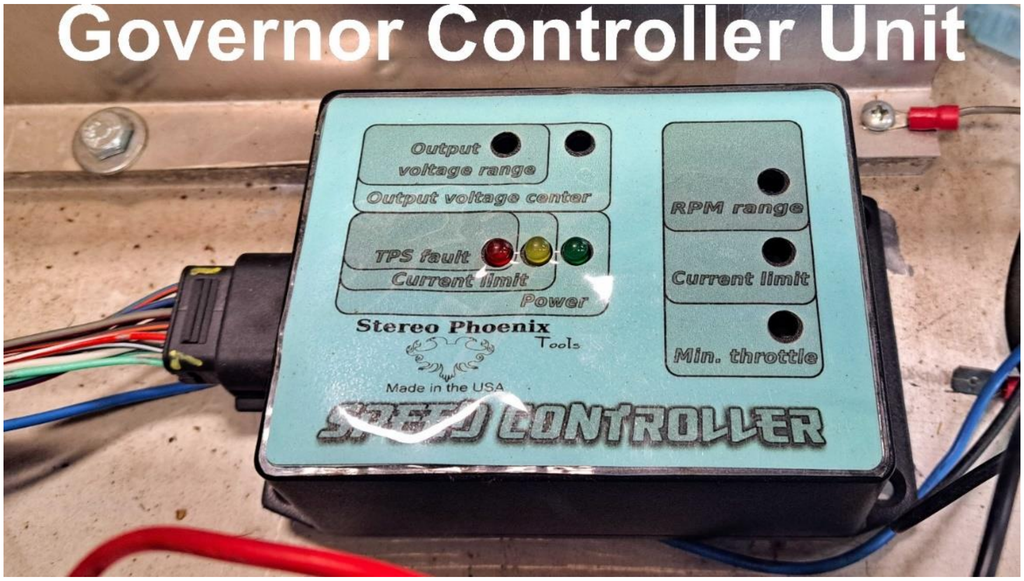
- **Cabling:** Marine-grade #2/0 cables with silicon bronze nuts and internal tooth washers for optimal conductivity and durability. *(Image 4: High-Voltage Cabling Routes)*

- **Thermal Management:** Heat sinks ensure optimal heat dissipation from the controller. High-voltage cables were wrapped in orange insulation to meet safety standards. *(Image 5: Controller with Heat Sink)*



Control System Overview

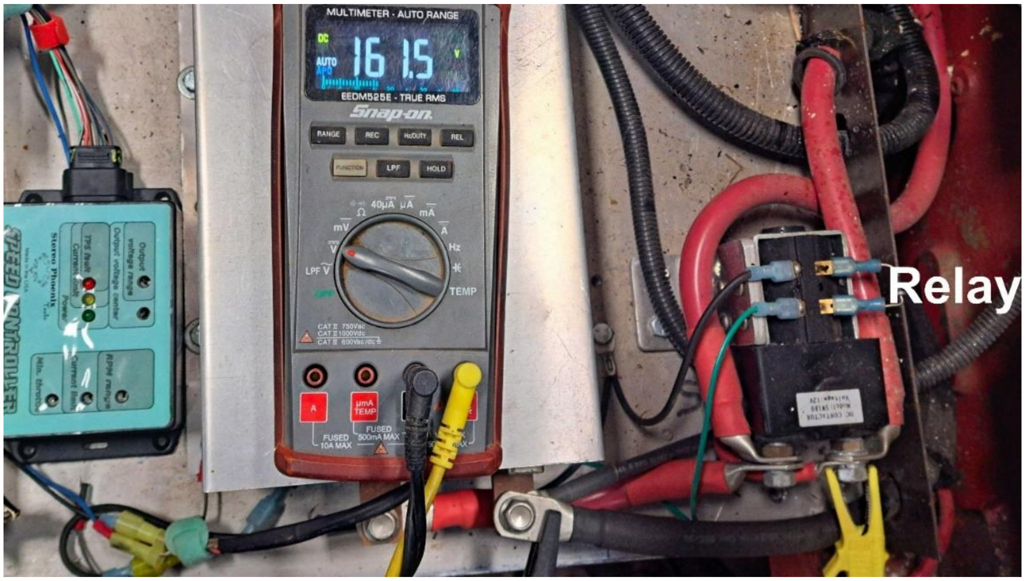
The governor-based control system is a key feature of the hybrid tractor, designed to emulate traditional mechanical governors used in gasoline or diesel engines. This system integrates seamlessly with the electric motor to regulate power output and maintain consistent speeds under varying loads. *(Image 6: Governor Controller Unit)*



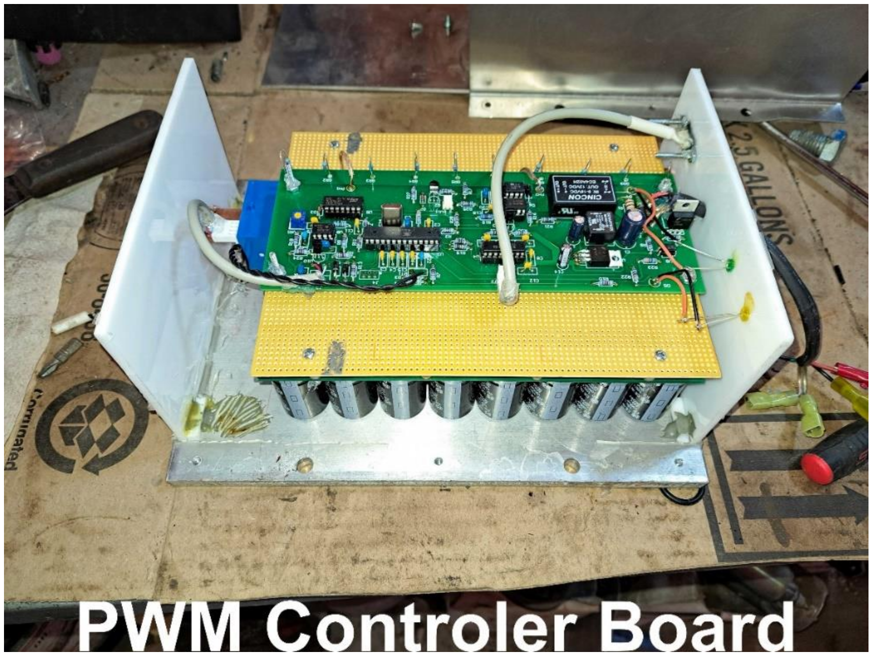
- **Functionality:**
  - The governor system monitors motor speed and adjusts current flow to maintain the desired operational speed. *(Image 7: Encoder Gear Mounted on Pulley)*

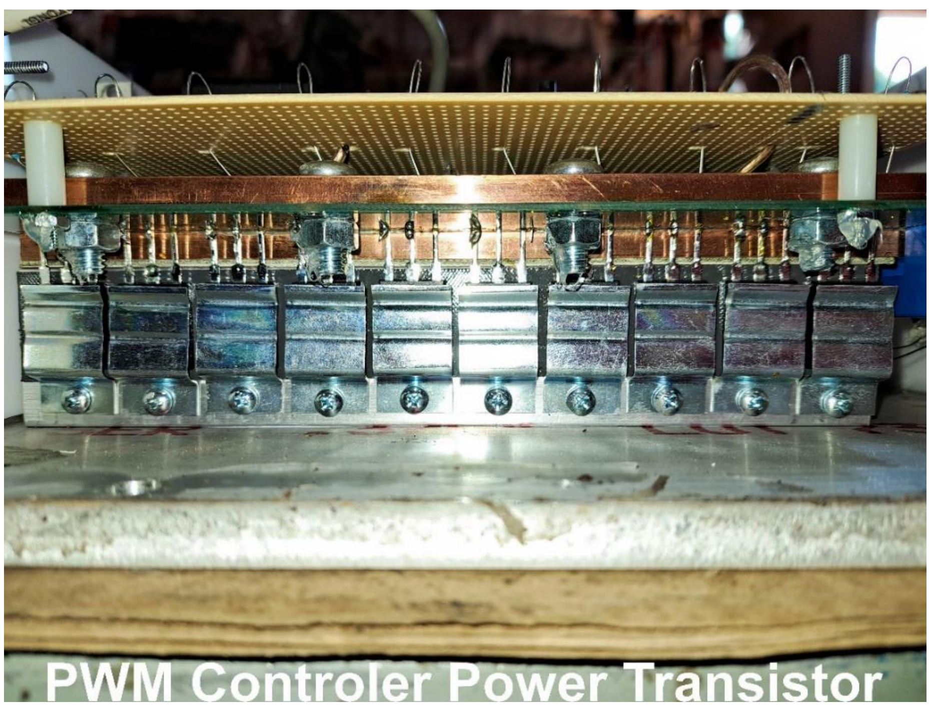
  - When the tractor encounters increased load (e.g., uphill movement), the system automatically increases power to maintain speed.
  - Conversely, it reduces power during light loads, optimizing energy consumption.

- **Safety Features:**
  - Dual safety mechanisms ensure that power output can be manually or automatically reduced in case of system faults.
  - An emergency override allows operators to cut off power instantly to prevent potential hazards. *(Image 8: Emergency Override Relay)*



- **Pulse-Width Modulation (PWM):**
  - The system uses PWM to control the electric motor's speed, modulating current flow in fine increments. *Image: PWM Controler A-B-C*





- This ensures smooth acceleration and precise throttle control for low-speed operations.

- **Advantages:**
  - Provides stability akin to traditional engines but with superior precision.
  - Enables seamless transition between electric and gasoline modes without interrupting operations.
  - Reduces operator fatigue by automating power adjustments during prolonged tasks.

Build Procedures

1. **Battery Installation:**
   - Installed 12-12V batteries with insulated boots for safety. *(Image 9: Batteries Installed with Insulated Boots)*

   - Connections torqued to 120 in-lbs using stainless steel hardware, ensuring optimal conductivity.
   - High-quality stainless steel bolts and bronze washers used to minimize vibration-related loosening.

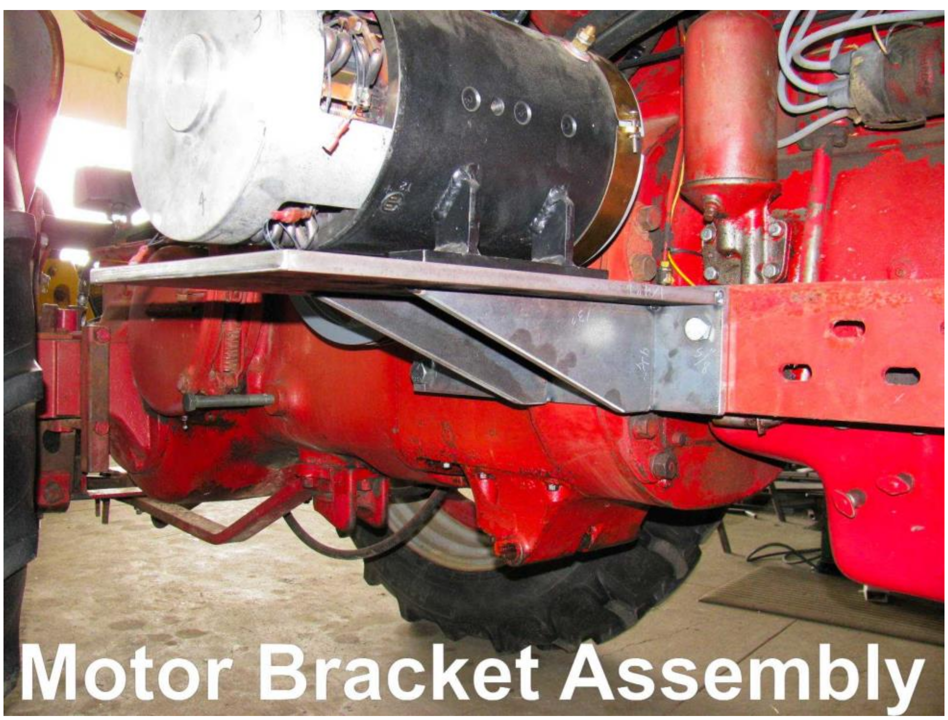
2. **Controller and Heatsink Mounting:**
   - The controller was mounted on a custom aluminum plate with pre-drilled and threaded holes. *(Image 10: Controller Mounted on Aluminum Plate)*

   - Heat sinks were attached using thermal grease to ensure efficient thermal conductivity. *(Image 11: Close-Up of Thermal Grease Application)*

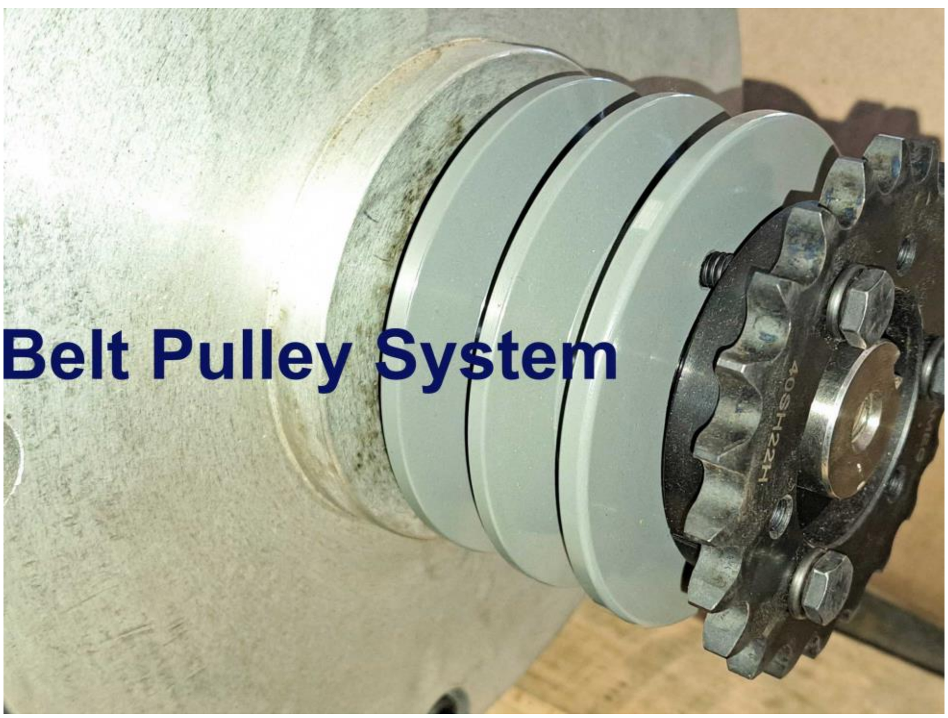
- Fasteners were countersunk into the aluminum to maintain a flat surface for heat dissipation. *(Image 12: Heat Sink Fasteners Counter-Sunk)*

3. **Motor Assembly:**

- Mounted the Warp 9 motor using a fabricated bracket. *(Image 13: Motor Bracket Assembly)*



- Connected via a belt-driven pulley system for efficient power transmission, maintaining a 4:1 gear ratio for optimal torque. *(Image 14: Belt Pulley System Connected to Motor)*



4. **Cabling and Wiring:**

    - Routed marine-grade #2/0 cables through cross-over tubes to prevent wear and ensure chemical resistance. *(Image 15: Cross-Over Tube)*