TUG OF WAR ROBOT

"Pull harder. Think smarter."

TECHNICAL REPORT — PRAVEGA 2025

PROJECT TEAM

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1. Team Details

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2. Abstract

This technical report presents the design and development of a high-torque Tug of War robot for the Pravega 2025 competition at IISc Bangalore. The robot is engineered to generate maximum pulling force while maintaining superior traction on the arena surface, enabling it to outpull opponents in head-to-head elimination rounds.

The robot features a heavy-duty 4-wheel drive chassis with high-torque geared DC motors, optimized weight distribution for maximum friction, and wide-tread rubber wheels for superior grip. The control system employs high-current motor drivers capable of delivering sustained power during the pulling phase, with strategic acceleration control to prevent wheel slip.

Key design objectives include maximizing torque output, optimizing weight-to-power ratio, ensuring reliable traction under load, and implementing controlled power delivery for strategic advantage in the best-of-three format.

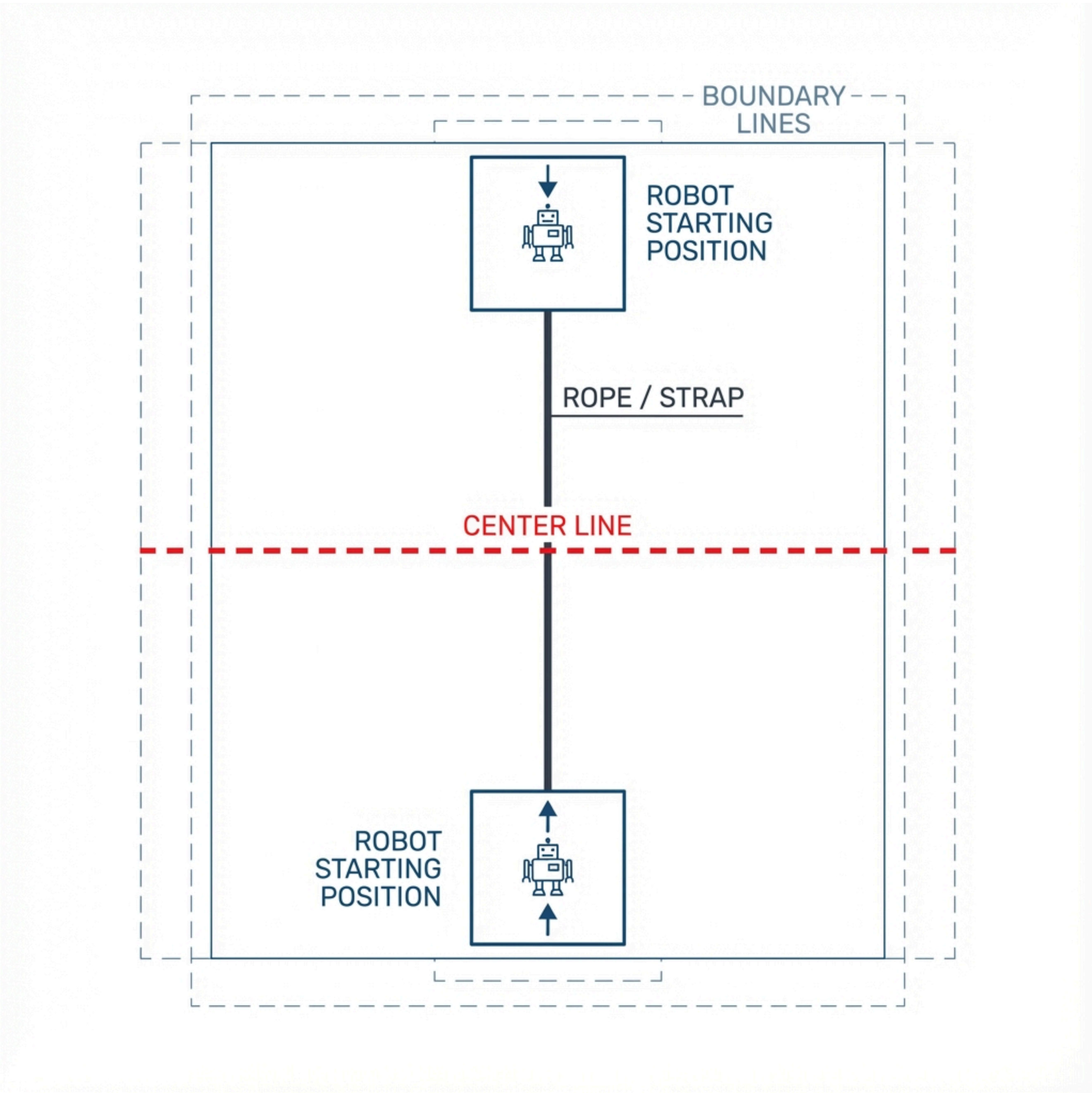

Figure 1: Tug of War Arena — Flat surface with center line, two robots connected by rope

3. Design Concept

3.1 Mechanical Design

The robot is built on a heavy-duty steel/aluminum chassis designed for maximum rigidity and weight optimization. The mechanical system focuses on torque generation and traction:

- **Chassis Frame:** Low-profile rectangular steel frame with reinforced mounting points. Weight strategically distributed for optimal center of gravity and maximum downward force on drive wheels.
- **Drive System:** 4-wheel drive with direct-coupled high-torque DC motors. Each wheel is independently driven for maximum traction and torque distribution.
- **Wheel Assembly:** Wide rubber wheels (80-100mm diameter) with aggressive tread pattern for maximum grip. Wheel material selected for high friction coefficient on arena surface.
- **Tow Hook:** Reinforced steel tow hook at front center, positioned low to prevent upward moment during pulling. Rated for forces exceeding expected pull loads.
- **Ballast System:** Removable weight plates allow fine-tuning of total weight within competition limits for optimal friction force.

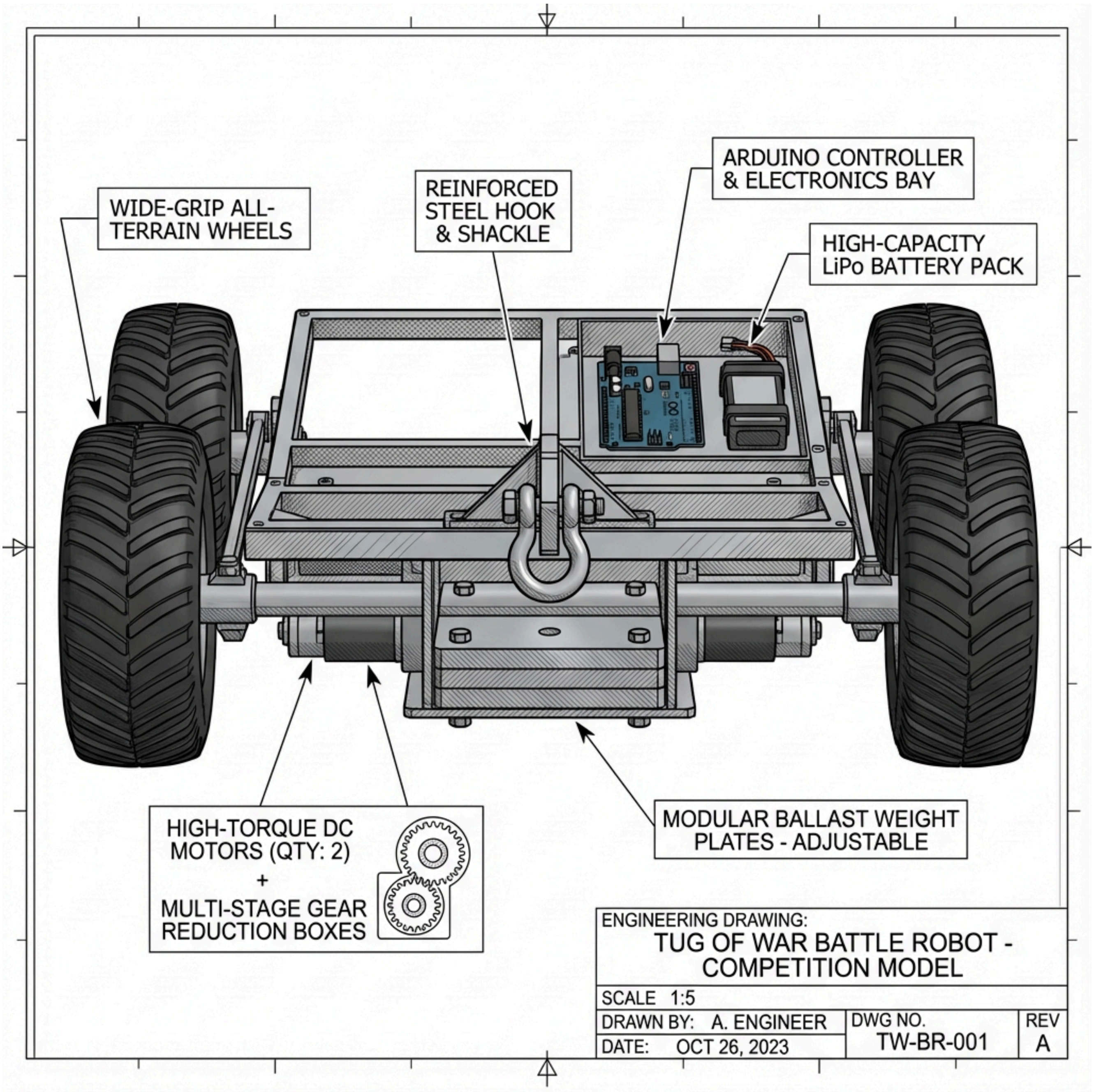

Figure 2: Robot Structure — Side view showing chassis, motors, wheels, and tow hook

3.2 Electronics & Components

- **Arduino Uno/Mega:** Main microcontroller for motor control and wireless communication.
- **BTS7960 Motor Drivers (×2):** High-current (43A) dual H-bridge drivers for handling motor stall currents.
- **775 DC Motors (×4):** High-torque 12V motors with 100:1 planetary gear reduction for maximum pulling force.
- **Wireless Module (HC-05/NRF24L01):** For remote control operation with minimal latency.
- **Current Sensors (ACS712):** Monitor motor current to detect stall conditions and prevent overheating.
- **Power Source:** 12V LiPo Battery (5000mAh, 50C) for sustained high-current delivery during pulls.
- **Kill Switch:** Emergency cutoff accessible to referees as per competition rules.

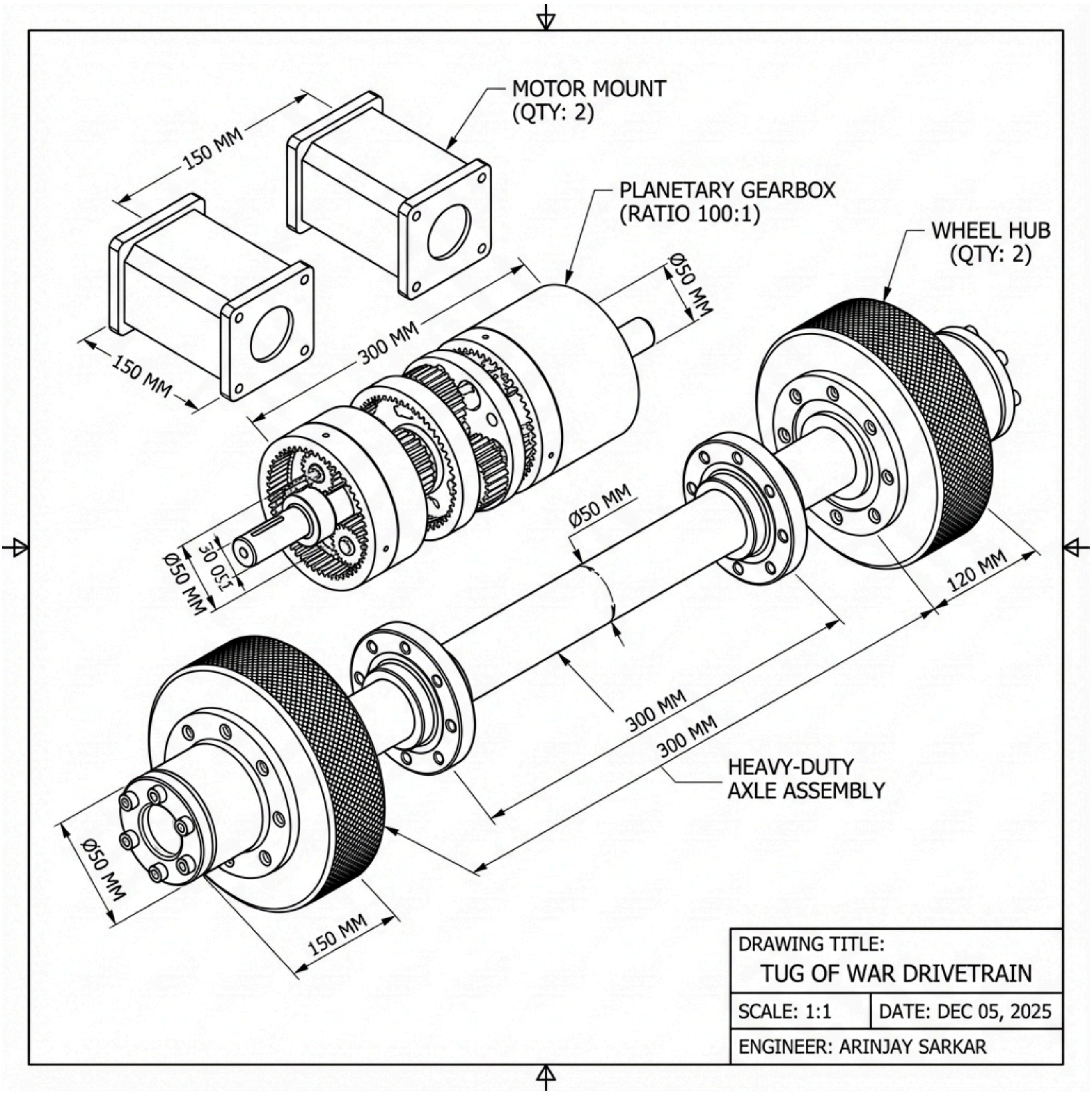

Figure 3: Drivetrain CAD — High-torque motor and gear assembly

3.3 Control Strategy

The robot employs a power-optimized control strategy for maximum pulling effectiveness:

- **Gradual Acceleration:** Prevents wheel slip at start by ramping up motor power progressively.
- **Maximum Torque Mode:** Once grip is established, motors driven at full power for sustained pull.
- **Anti-Slip Detection:** Current sensor feedback detects wheel slip; power momentarily reduced to regain traction.
- **Burst Control:** Strategic power bursts to overcome opponent's resistance at critical moments.

4. Working Principle

4.1 Torque & Traction Physics

Winning a tug of war requires maximizing the pulling force transmitted to the ground:

- **Friction Force:** $F = \mu \times N$, where μ is friction coefficient and N is normal force (robot weight).
- **Optimal Weight:** Heavier robot = more friction = more pulling capacity (within competition limits).
- **Wheel Selection:** High-μ rubber compounds maximize friction on arena surface.
- **Contact Area:** Wide wheels distribute load and increase effective grip.

4.2 Power Delivery

The drivetrain converts electrical power to mechanical pulling force:

- **Motor Torque:** High gear reduction (100:1) multiplies motor torque at wheels.
- **Stall Torque:** Motors selected for high stall torque (the maximum torque at zero RPM during pull).
- **Current Capacity:** BTS7960 drivers handle 43A continuous, supporting motor stall currents.
- **Battery Selection:** High C-rating battery delivers sustained current without voltage sag.

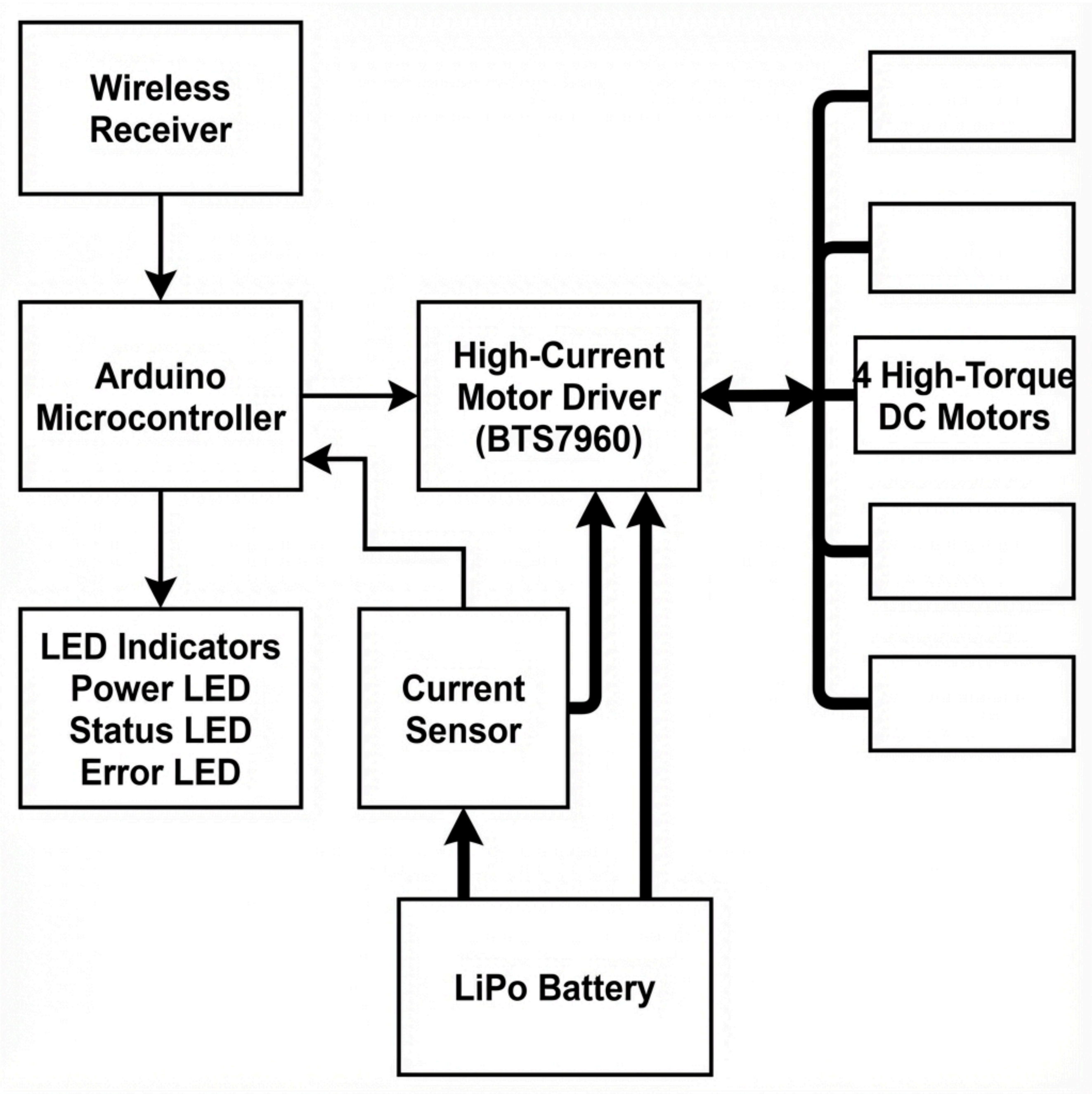

Figure 4: Control System Block Diagram — Power delivery and motor control

4.3 Control Logic

The Arduino executes the following control sequence during a pull:

1. **Standby:** Motors off; wait for start signal from operator.
2. **Ramp Up:** Gradually increase PWM from 0 to 255 over 0.5 seconds to establish grip.
3. **Full Power:** All motors at maximum PWM; sustained pulling force.
4. **Slip Detection:** If current drops suddenly (wheel spin), reduce power briefly.
5. **Burst Mode:** On operator command, momentarily increase power for tactical advantage.
6. **Emergency Stop:** Instant motor cutoff on kill switch activation.

4.4 Power Distribution Table

Phase	Motor PWM	Expected Current	Duration
Standby	0	~0A	Until start
Ramp Up	0 → 255	0 → 20A	0.5 sec
Full Pull	255	30-40A	Until win/loss
Slip Recovery	180	~25A	0.2 sec
Burst	255 (boosted)	40A+	0.3 sec

5. Innovation & Special Features

High-Torque Gearboxes

100:1 planetary gear reduction maximizes pulling force from compact motors.

Anti-Slip Control

Current sensing detects wheel slip and auto-adjusts power to maintain traction.

Strategic Ballast

Removable weight plates allow fine-tuning robot mass for optimal friction.

Low Tow Point

Hook positioned at chassis base prevents tipping moment during high-force pulls.

High-Grip Wheels

Wide rubber wheels with aggressive tread maximize friction on arena surface.

Burst Mode

Tactical power surge capability for breaking opponent's grip at critical moments.

5.1 Proposed Enhancements

Future iterations may incorporate:

- Encoder feedback for precise wheel slip detection and closed-loop traction control.
- Temperature monitoring to prevent motor/driver overheating during prolonged pulls.
- Pneumatic downforce system for increased normal force without exceeding weight limits.
- Variable gear ratio system to optimize torque vs. speed based on match conditions.

6. References

- Pravega 2025 Tug of War Competition Rulebook — IISc Bangalore
- Arduino Uno/Mega Technical Documentation
- BTS7960 High-Current Motor Driver Datasheet
- 775 DC Motor Specifications and Torque Curves
- ACS712 Current Sensor Module Documentation
- LiPo Battery Safety and High-Current Discharge Guidelines
- Friction and Traction Optimization in Mobile Robots — IEEE Publications
- Jadavpur University Robotics Club Technical Resources