Season 2026 UWaterloo Robotics Preliminary Design Review

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Abstract

After a successful reveal of our 2025 Rover vehicle platform - Sparky. For the 2026 URC competition season, the UW Robotics team presents Sparky revamped with a handful of upgrades and stress testing results. This year, our team continued to focus on validating the old system benchmarking the performance and implementing a lot of new software patches for system update.

1. Introduction

The University of Waterloo Robotics Team (UWRT) is a student-led team of over 30 members from Mechatronics Engineering, Systems Design Engineering, Computer Science, and related programs, with 70% bringing prior robotics experience from FIRST, VEX, and high-school science clubs. The team operates under a three-level organizational structure shown in Figure 1: a Team Lead and Business Lead manage external relations and sponsorships, a Safety Captain ensures regulatory compliance, an Architecture Decision Committee of senior members oversees technical decisions, and general members contribute across mechanical, electrical, firmware, software, and business subteams. To build team capabilities, we implement subteam-specific onboarding training followed by peer-mentoring partnerships between new and senior members. Our outreach efforts include co-hosting local hackathons, participating in regional and national conferences, and engaging with university open-houses and high schools to inspire the next generation of robotics enthusiasts.

2. Administrative Information

2.1. Team Resources

The team operates from a dedicated design bay at the University of Waterloo, equipped with mechanical and prototyping. Additional support from university facilities, including the machine shop and paint room, enables complex manufacturing. Funding is sourced from university organizations such as WEEF and EngSoc, along with industry sponsors like Kenesto, QNX, and ProtoSpace Mfg, supporting prototyping, testing, and team operations. A financial statement is detailed in figure 2. This year, our budget is allocated to three main areas: upgrading specific rover functionality such as wheels for improved grip on rocky terrain, acquiring higher-performance components like high-torque motors, and maintaining spare components for failures during testing.

2.2. Project Managment Plan

Upon release of the URC 2026 requirements, our team break down our rover development cycle into three interconnected phases: functional validation, feature integration, and system-level testing. After PDR submission, all subsystems complete independent functional testing to validate core component performance. Prior to System Acceptance Review, we will develop a minimal viable product demonstrating core system capability across navigation, manipulation, and science tasks. After MVP validation, we will fix stability issues and conducts final system-level testing for competition readiness. The team's project schedule is detailed in the Gantt chart (Figure 3), which specifies responsible subteams, task dependencies, and critical dates.Confluence serves as the primary knowledge management system for technical documentation and meeting minutes.

Integration follows a structured bottom-up approach where subsystems are independently validated before integrated, highlighting modularity in design. System validation occurs through three progressive stages: Software-in-the-Loop testing using Gazebo simulation for algorithm validation, Hardware-in-the-Loop testing with emulated sensors for system behavior performance, and System-Level testing at the Canadesys lunar facility to evaluate rover performance in competition-realistic environments. Testing schedules for each subsystem are labeled into figure3.

3. Technical Design

3.1. System Overview

The rover is designed as three primary subsystems: the drivetrain system, the arm, and the science module. Totalling 35kg, the drivetrain system serves as the mobility platform and rover core, encompassing suspension, chassis, drive actuators, electrical box and power system, robot vision and communications. It provides a sturdy base for mounting the other two interchangeable subsystems—the arm and science module, each optimized for specific missions. The rover is powered by a 48V 22,000mAh battery, chosen for its efficiency in high-voltage applications, with power stepped down to supply the rest of the system. At the heart of the rover is a Jetson O, which handles high-level tasks such as path planning, arm trajectory control, and science data collection. For robustness, a controller board based on the STM32L552 chip is included to take over in the event of a Jetson system failure.

This year, the Rover's main Electrical housing, the drivetrain Ebox is being redesigned to comform to an improved electrical architecture and reduce weight Fabrication of complex sheet metal designs for the electrical box and dimensionally critical parts was achieved through the team's ProtoSpace sponsorship; all other components are manufactured in house by members and professionals at the UWaterloo Engineering machine shop. The chassis structure features carbon fiber members epoxied to aluminum joints, enabling modularity, ease of manufacturing, and assembly. ABS printed parts supplement and enclose the structural design. SLA printed TPU wheels were iterated to test important design improvements. A wheel testing jig is being developed to validate the implementation of molded polyurethane forms on the final product. The rover traverses terrain using a 6-wheel direct axial drive rocker bogie suspension with a differential bar. Each wheel actuator consists of a brushless DC motor, planetary gearbox, and incremental encoders. The drivetrain operates through an integrated velocity or position control loop using an ODrive motor controller. Users can interface with the system via joystick input for manual control or waypoint input for autonomous navigation, offering flexibility for different mission requirements.

Communication within the rover is managed via shielded CAN and USB connectors, ensuring long-range signal integrity. Video data and rover status are transmitted back to the ground station using a 5.8GHz directional radio mounted on a single-axis gimbal, following the competition radio guidelines. An omnidirectional 900MHz radio is reserved for critical control commands and rover fail-safe monitoring. This dual communication system ensures reliable operation in diverse mission environments. The whole system is equipped with two E-Stops at the front and the back of the rover, providing an alternative to kill the rover operation in an emergency.

The rover's 6-Dof manipulator, designed and manufactured by students on campus, features brushless DC motors with encoder feedback and harmonics gearboxes for high gear ratio reduction. Joint localization is provided by absolute magnetic encoders and proximity limit switches for end-stop definition. This year's design incorporates belt drives at various joints and a differential wrist to shift mass toward pivot points, reducing loading requirements on each arm axis and yet still be able to access all the defined arm workspace. The arm's end effector uses compliant rubber pads to enhance grasp on irregular shapes like rocks and tools. It is controlled by an inverse kinematics solver implemented through the MoveIt API, interfacing with joysticks and a graphical interface for teleoperation.

Joint control and loading performance will be tested before full assembly, with arm controls validated in Robot Operating System Simulation software RViz/Gazebo prior to deployment.

The science payload is designed to analyze the environment, collect soil samples, and conduct onboard tests to detect extant or extinct life. It features a 2-DoF microscope camera for detailed examination of rock surfaces, which the science team uses to identify potential fossils or other signs of life. Additionally, a 1-DoF sensor head collects initial data from soil samples, measuring humidity, methane, CO2, and temperature. Following initial analysis, soil samples are collected using a drill mechanism and suction tube and then deposited into test tubes for further examination. Ninhydrin tests are conducted to detect amino acids and proteins, indicating biological activity. The payload is controlled through a prototyped PCB and firmware interfacing with all sensors and actuators, with precise control facilitated via keyboard and controller commands.

The rover autonomy system comprises of 2 front Intel realsense D435 Depth camera running Yolo V7 model primarily used for object detection and avoidance. A 2 axis gimbal camera at the rear and a close up color camera mounted on the arm provides video feedback for the autonomy system to recognize the ARUCO tag and competition objects at the given location. These sensors also provide video feedback to the base station that is important for mission status validation. UWRT recently completed all the mechanical design tasks and software research and development for all the main subsystems, and we are currently working on assembling the system and testing its integration to ensure its full functionality.

3.2. Competition Strategy

3.3. Platform Architecture

A significant architectural change this year is the integration of QNX, our new sponsor providing embedded real-time operating system (RTOS) solutions. QNX is a microkernel-based RTOS optimized for low-latency, deterministic performance—critical for time-sensitive robotics applications.

Previously, our rover relied on multiple discrete low-level hardware control boards, each with custom firmware. This year, we are consolidating the hardware stack by transitioning to off-the-shelf control boards (e.g., commercial development boards) that interface with a Raspberry Pi 4B running QNX. This unified architecture reduces firmware complexity, improves maintainability, and leverages QNX's robust real-time capabilities.

Hardware boards communicate with the central compute module via standardized communication protocols: I2C for low-bandwidth sensor data, SPI for high-speed data transfers, and UART for serial debugging. This modular approach decouples hardware-specific logic from high-level control algorithms, enabling the team to develop and test components independently before system integration.

3.4. Test and Validation

References

A. appendix

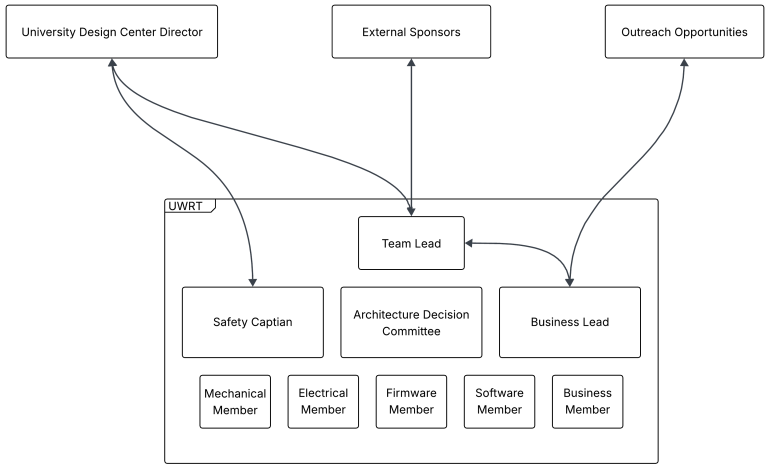

Figure 1. UWRT employs a three-level organizational structure. The Team Lead oversees primary communication with university administrators and sponsors, while the Safety Captain ensures compliance with safety standards. The Business Lead manages outreach initiatives and sponsorship agreements. Senior members form an Architecture Decision Committee that reviews and approves all architectural decisions and purchase requests. The third level consists of general team members across mechanical, electrical, firmware, software, and business disciplines who continuously develop and implement new rover features using state-of-the-art algorithms.

URC PDR Budget

UWRT Actual Income to Date

Name	Description	Balance(USD)
W24 - WEEF Funding	Drivetrain Manufacturing Costs	2840
	PDB & Localization Board Development	710
	Autonomous Driving Sensors	710
	Tools & Space Organization	710
	Total	4970
F24 - WEEF Funding	Project Drivetrain	1065
	Project Arm	1775
	Project Autonomy	659.2847
	Project Science	355
	Bay Safety	123.54
	Total	3854.2847
S25 - WEEF Funding	Manufacturing and Raw Materials	994
	Electrical Manufacturing	355
	Motor Controllers	497
	Compute and Sensors	284
	Bay Improvement	142
	Total	2130
Other	UWaterloo - Giving Day Student Teams Funding	887.5
	UWaterloo - Existing Dean's Funding	3390.96
	QNX by Blackberry - Mission Control Sponsor	3550
	Total	7828.46

UWRT Anticipated Income to Date

Name	Description	Balance(USD)
Other	W25 - WEEF Funding	3391.386
	2025 Dean's Funding	2130
	Total	5521.386
	Total Income	$ 24,304.13
Currency Pair	CAD/USD	0.71
		Date: 2025-12-02

UWRT Project Expenses

Expense Categories	Amount
Drivetrain Subsystem	$ 3,000.00
Arm Subsystem	$ 5,000.00
Rover Communication System	$ 1,500.00
Science Subsytem	$ 2,000.00
Rover Power System	$ 1,000.00
Ground Station	$ 500.00
Transportation and team Merchandise	$ 4,000.00
Total	$ 17,000.00

Figure 2. UWRT Season 2026 Budget: income (left) and expenses by project (right).

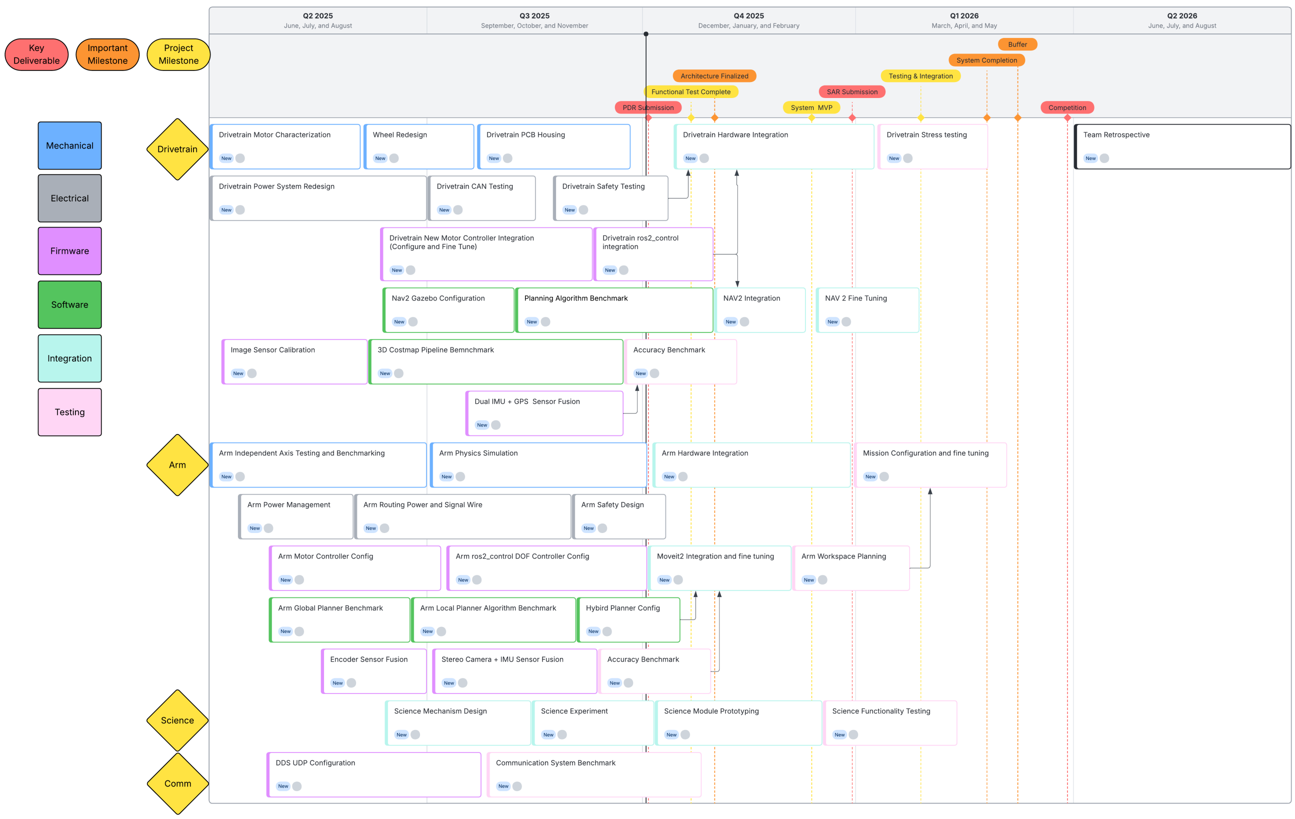

Figure 3. The Gantt chart illustrates the UWRT S26 project timeline and is organized into two sections. The top section displays key project deadlines, color-coded as follows: red indicates URC competition deadlines, orange marks system functionality milestones, and yellow represents project completion deadlines. The bottom section presents the detailed task timeline for each subteam—Mechanical, Electrical, Firmware, Software, Integration, Testing, and specialized subsystems (Drivetrain, Arm, Science, and Communications)—with color-coded task tracking. The team has structured the project around three major milestones. First, the team focuses on validating the functionality of all primary components, including both commercial off-the-shelf and custom-designed parts. Following PDR document submission, the team will lock in the system architecture for the season. The second milestone targets the system's minimal viable product (MVP). Finally, the team will conduct fine-tuning and stress testing to optimize system performance for the University Rover Challenge competition.

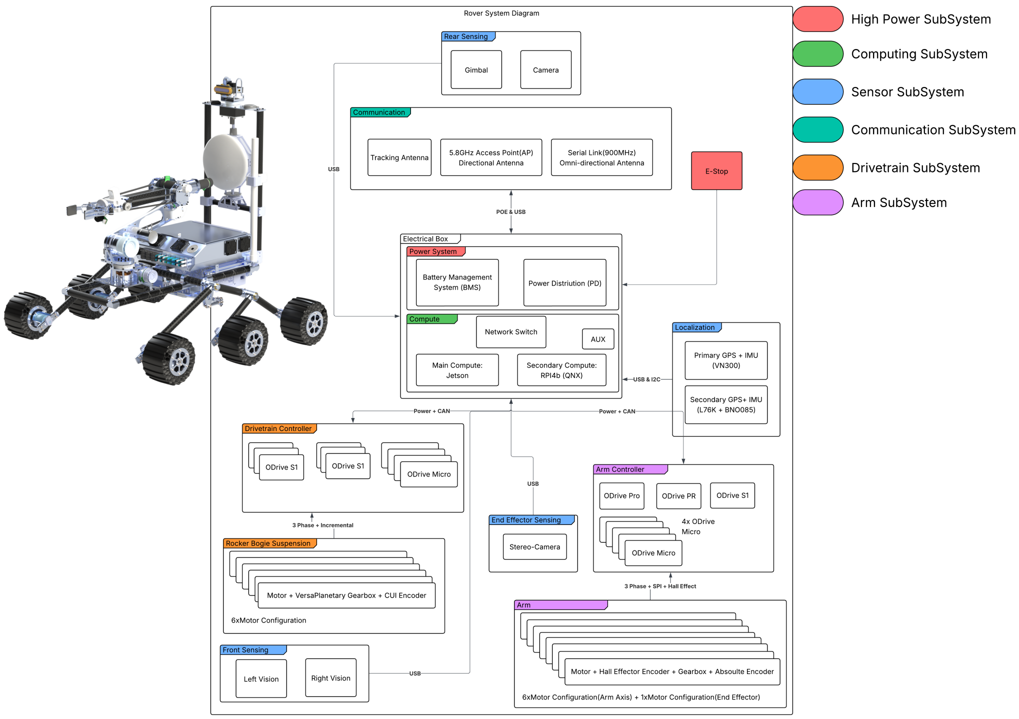

Figure 4. This figure shows the main system diagram for the whole rover system. The center is the Electrical Box containing all the main electronics. BMS is for cell balancing. PD is for over-voltage protection, over-current protection, and state of charge monitoring. Jetson is our main controller solving all the kinematics. Raspberry Pi 4B loaded with QNX serves as an IO expansion board and low-level controller. Communication Module transmits UDP packets and communicates with the ground station. The Rear Sensing Module serves as an overview camera for livestreaming the rover status to the ground station. E-Stop performs the critical safety functionality and cuts the high power rail under emergency. Localization has a dual GPS + IMU configuration providing high accuracy location results after sensor fusion. Front Sensing uses two cameras to perform obstacle avoidance and path planning. Drivetrain and Arm systems are described in their own architecture diagrams.