Tech Expo, Spring 2026 – Team 13

Radar-Based Pit Lane Monitoring System

Team: Shanay Ambani, Zach Danek, Liam Goodemote, Jathyn Price, Joshua Silverstein, Enzo Tiptur

Mentors: Zachary Schreiber, Sukesh Ranganathan

Purdue University
Polytechnic Institute

Problem Statement

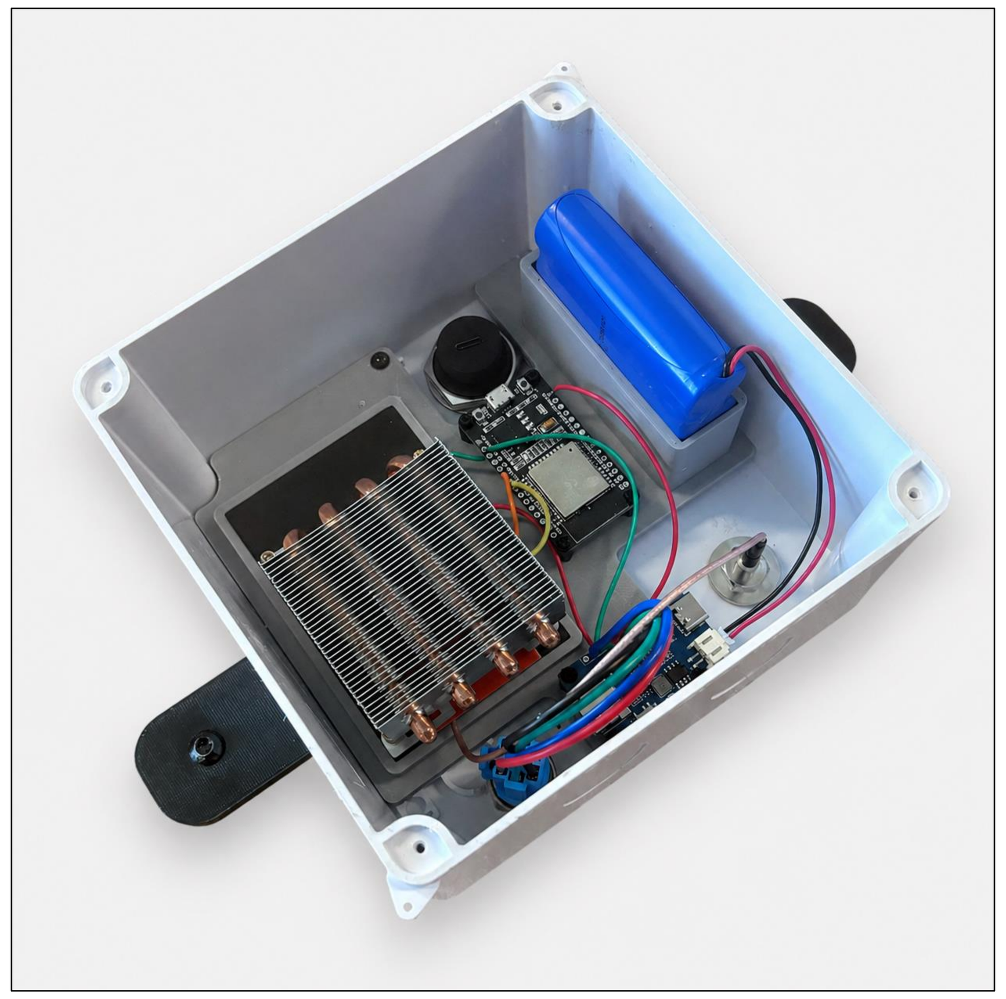
The Purdue Grand Prix Foundation (PGPF) identified a critical safety concern regarding excessive speeds of Grand-Prix karts entering the pit area during races. Previous pit operations lacked an effective system to monitor and enforce speed limits, creating potential hazards for drivers, crew members, and officials.

Customer Background

Each year at Purdue University, students compete in the Purdue Grand Prix go-kart race. The annual event started in the 1950s, governed by the PGPF, a student organization that also focuses on fundraising to provide scholarships to students, since 1965. At last year's event, each racer completed over 150 laps, reaching speeds greater than 50 kilometers per hour. The event brought in over 50 racers with their crew teams, with the number of racers expected to grow each year. During each race, crew members must occupy their assigned "pit box", a three-square meter area placed on the edges of the pit.

Requirements

The system must continually monitor drivers pit lane speeds and transmit infractions to the safety committee. The safety committee must be capable of receiving the information in a streamlined and efficient manner to effectively and immediately inform the speeding driver. The data the Safety Committee receives must include what maximum speed is achieved, the time this speed is reached, and which kart makes the infraction. In all, this project must deliver a usable product to meet the regulations associated with these needs for every racing team competing in the Grand Prix 2026.

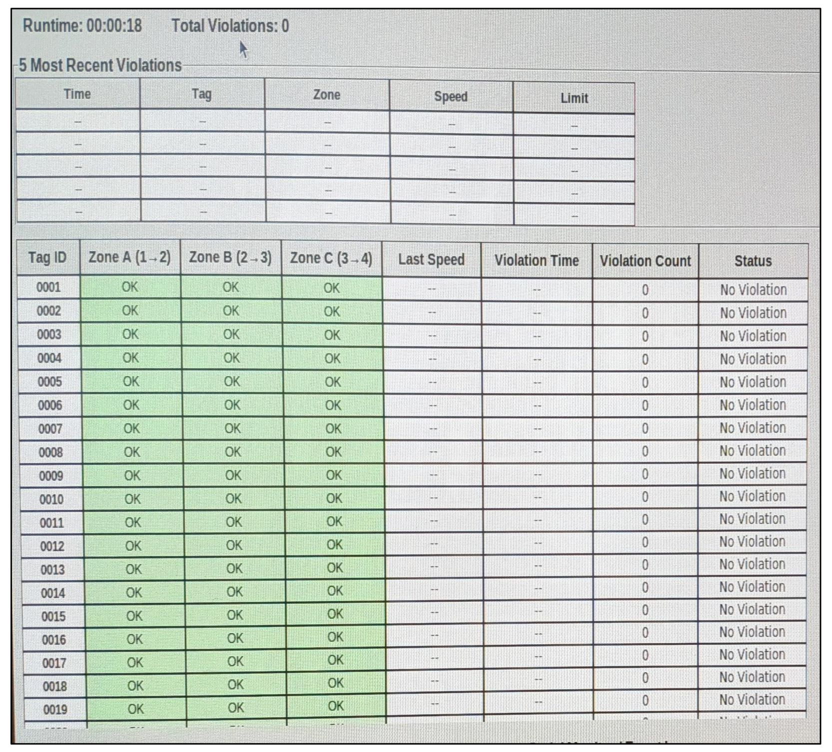


Experimentation and Concepts

Initially, IR, GPS, and RFID solutions were evaluated. Because of its dependability, ease of use, and acceptance by race stewards, fixed-point time-over-distance computation continues to be the industry standard for RFID-based speed measurement in motorsports and was used. Phase-based tracking, RSSI-based techniques, and RF Doppler estimation, on the other hand, are cutting-edge research-level methods that show promising precision under controlled conditions but are not yet appropriate for competitive racing because of their sensitivity to environmental noise, calibration needs, and regulatory restrictions. RFID offered a portable, reusable, and modular way to track pit-lane speeds with the least amount of interference. Initial prototyping included demonstrating theoretical system viability though a Simulink simulation. The simulation included: distance and angle, gain roll off and path loss, and reader Boolean status. The results concluded tag readability at 9 m, with up to 45 mph passing speed. To optimize coverage, and according to geometric analysis, the antenna is pointed at an incident angle of 124.1 degrees with respect to the vertical aluminum 80/20. According to structural study, wind stress is the primary design factor, whereas gravity-induced bending from the overhang and antenna is minor.

Final Design

The final design consists of six coordinated subsystems: four distributed RFID reading assemblies positioned along the pit lane and one central communication assembly located at the PGPF Safety Committee table. Each reading assembly is designed to reliably detect passive RFID tags on karts traveling across the full width of the pit lane. These subsystems are spaced at known locations, forming defined zones (A, B, and C) that allow precise tracking of kart movement. Each RFID reading assembly integrates a high-power antenna, an M7E RFID module, an ESP32 microcontroller, and a dedicated battery supply for portability and stability. The ESP32 handles tag acquisition and timestamping then transmits the data wirelessly to a central hub ESP32 using low-latency communication. The central hub is connected to a Raspberry Pi, which performs real-time speed calculations by comparing timestamps between zones and using known distances. The Raspberry Pi also hosts a graphical user interface (GUI) that displays kart data, including current speeds, violation alerts, zone-specific infractions, the five most recent offenders, and repeat offenders exceeding three violations, ensuring efficient race monitoring.



Testing and Results

A structured test plan was developed to validate the functionality, reliability, and performance of the final prototype. The objective of this testing effort was to verify correct hardware integration, confirm tag readability under operational conditions, and quantify system performance across distance and speed ranges representative of real-world pit lane environments. Testing was performed in progressive stages to isolate potential integration issues and validate each subsystem before advancing higher-level performance testing. The testing stages included: initial hardware integration, external antenna validation, controller transition to ESP32, static distance testing, dynamic speed testing, and repeatability and stress testing. Acceptance criteria required consistent tag detection at distances up to 10 meters and successful reads at vehicle speeds up to 30 mph with a minimum success rate of 90%. All test results were logged through serial output and stored in CSV format. Recorded parameters included: tag ID, timestamp, distance from antenna, estimated speed, and read success or failure. This structured data format enabled post-processing and statistical evaluation. Performance curves were generated to visualize system limits and identify operational thresholds. These results were used, validating compliance with project requirements and guiding potential parameter tuning such as RF power adjustment or antenna placement.