DEVELOPMENT OF A COLLEGIATE ROBOTIC FOOTBALL CONFERENCE (CRFC) TEAM THROUGH SENIOR PROJECTS

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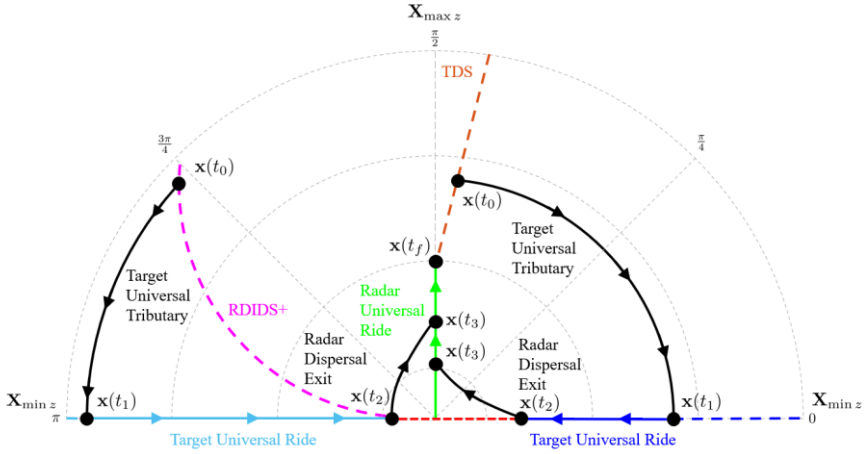
PROFESSIONAL BACKGROUND

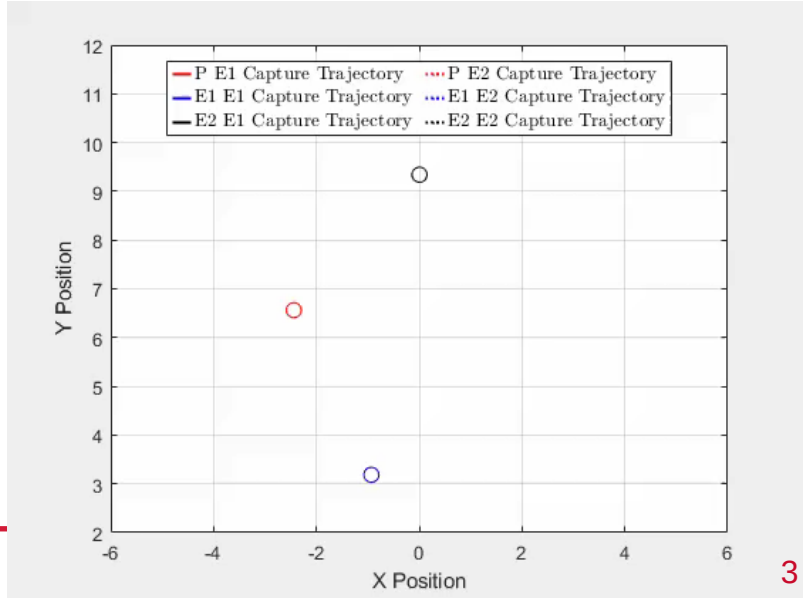
Brian Swanson, PhD

- 2013 - Kings High School, Kings Mills, OH
- 2017 - BSEE Ohio Northern University, Ada, OH
- 2020 - MS University of Cincinnati, Cincinnati, OH
- 2024 – PhD University of Cincinnati, Cincinnati, OH
- 2024- Hired as Assistant Professor at Miami!

RESEARCH BACKGROUND

- Develop controller for dynamic adversarial systems
  - Optimal control theory and differential game theory
    - ❖ **Mathematical framework to develop guaranteed optimal controllers!**
  - Graduate work focused on singular surfaces
    - ❖ **Non-intuitive behaviors that guarantee optimality!**
  - Looking to take theoretical solutions to practical implementations
  - Develop heuristic methods to calculate “good enough” controllers

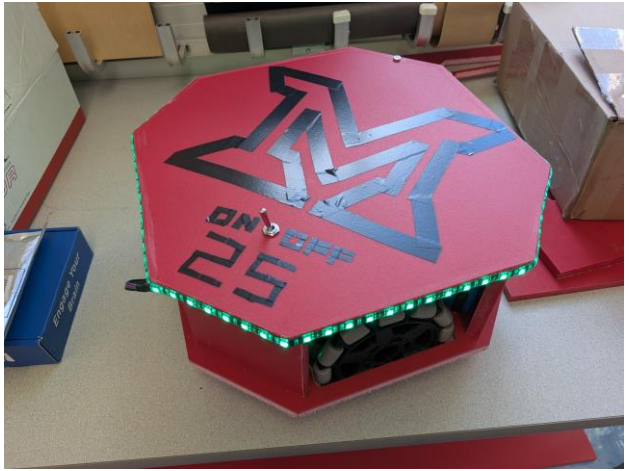




OVERVIEW

- **CRFC Background**
  - Participating institutions
  - Events
  - Rules
- **Senior Project 2024-2025**
  - Design specifications
  - Calculations
  - Design
  - Engineering lessons learned
- **Senior Project 2025-2026**
  - Design specifications
  - Initial calculations and design
- **Future Direction**

- **Collegiate Robotic Football Conference (CRFC)**
  - Founded by Ohio Northern and University of Notre Dame
  - 12 teams to date
  - Ran by CRFC organization
  - Compete in two annual events
    - Fall combine
    - Spring national championship

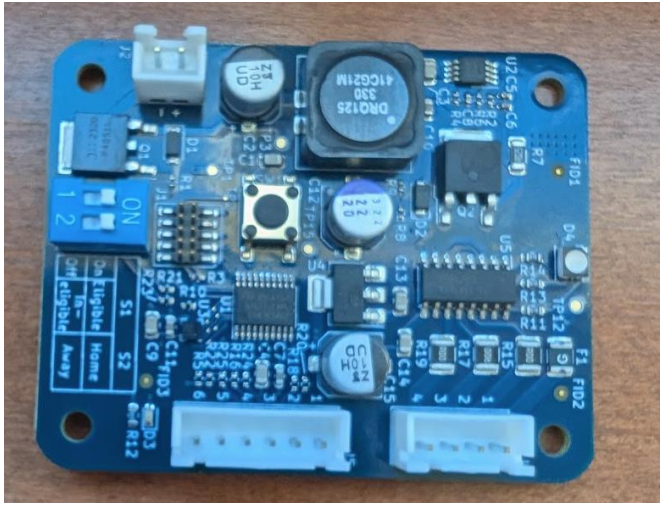


CRFC EVENTS

- Fall Combine
  - **Saturday November 15th, 2025, 9:00 am**
  - **@ Notre Dame University**
  - **Streamed live on YouTube**
    https://www.youtube.com/@CRFC./featured
  - Positional challenges (QB, WR, RB, Line)
  - General challenges (Most weight, fastest, etc.)
- Spring National Championship
  - Saturday April 5th, 2026 @ Notre Dame University
  - **Streamed live on YouTube**
  - Seeding determined by winner of combine
  - **Compete for the Brian Hederman Memorial trophy**

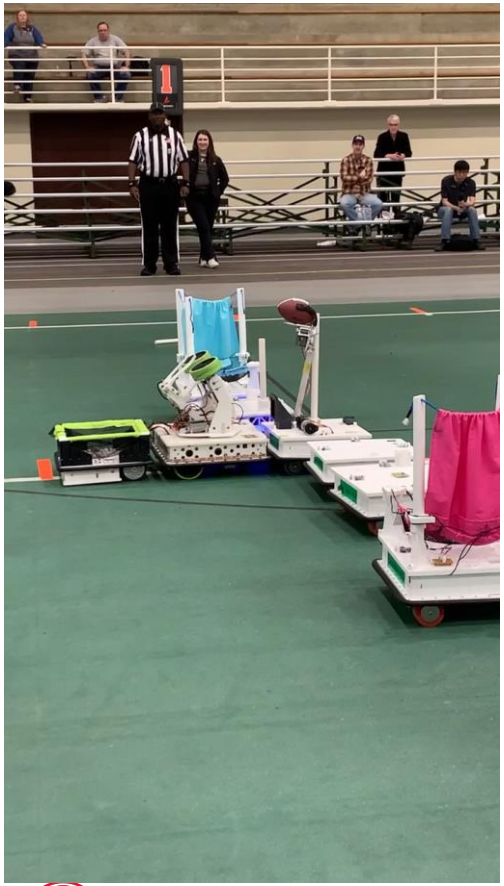
CRFC RULES

- Spelled out in official CRFC rulebook (updated annually)
- Gameplay
  - 8 on 8 game between teams of remotely controlled robots
  - Adheres to official NCAA football rules
  - Ball-carrying robots quipped with tackle sensor and status LED's
  - Can pass and throw the ball – fumbles and interceptions happen too!
  - Extra points for completing passes
- Design Rules
  - Max 24V circuitry
  - Mechanical kill switch
  - Baseplate material and height
  - Max 30lb weight (45lb for QB and K)
  - Players must fit within 16"x16"x24" box (except K and C)
  - K and C have additional constraints



CRFC Proprietary Tackle Sensor

CRFC IN ACTION



SENIOR PROJECT 2024-2025

- **Project Goal – Design a robot that is eligible to compete in all CRFC events**
  - Safety rules
  - Weight and height constraints
  - Material constraints
  - Circuitry constraints
  - Tackle sensor integration
  - Wireless communication
  - Motor control algorithm

2024-2025 Senior Design Team

NECESSARY CALCULATIONS

- To complete the design of this robot, students were expected to calculate
  - Necessary torque and rpm for motors
  - Necessary capacity of batteries
  - Total weight of robot

MOTOR SELECTION CALCULATIONS

Motor Calculations:

$\mu_f = 0.8$ *(Coefficient of Friction)*

$F = m * a$

$F_g = 13.6078\,kg * 9.8\,m/s^2 = 133.36\,N$ *(Gravitational Force)*

$F_f = 133.36\,N * 0.8 = 106.69\,N$ *(Frictional Force)*

$F_a = (13.6078\,kg * 0.9 m/s^2) = 12.247\,N$ *(Acceleration Force)*

$F_{TOT} = F_f + F_a = 106.69\,N + 12.247\,N = 118.937\,N$ *(Total Force)*

$\tau_{TOT} = F_{TOT} * r$

$\tau_{TOT} = 118.937\,N * 0.0762\,m = 9.063\,Nm$ *(Total Torque)*

$\tau = 9.063\,Nm / 4 = 2.266\,Nm$ *(Torque per Motor)*

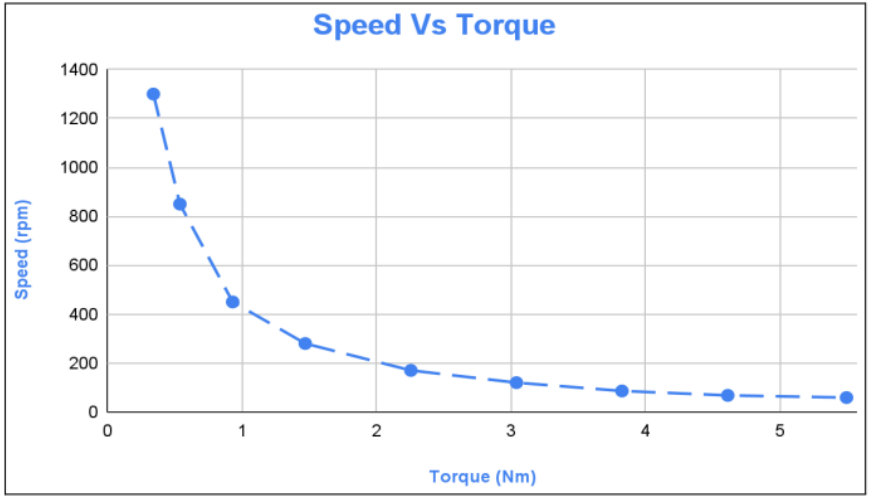
$\omega_{rpm} = (4.5\,m/s^2 / 0.0762\,m) * (60\,s / 1\,min) * (1\,rev / 2\pi\,rad) = 563.935\,rpm$ *(Required RPM)*

$W = 563.935 * (2\pi\,rad / 60\,s) = 59.06\,rad/s$ *(Angular Speed)*

$P = \tau * W = 2.266\,Nm * 59.06\,rad/s = 133.83\,W$ *(Power per Motor)*

$I = P / V = 133.83\,W / 24\,V = 5.5763\,A$ *(Current Draw per Motor)*

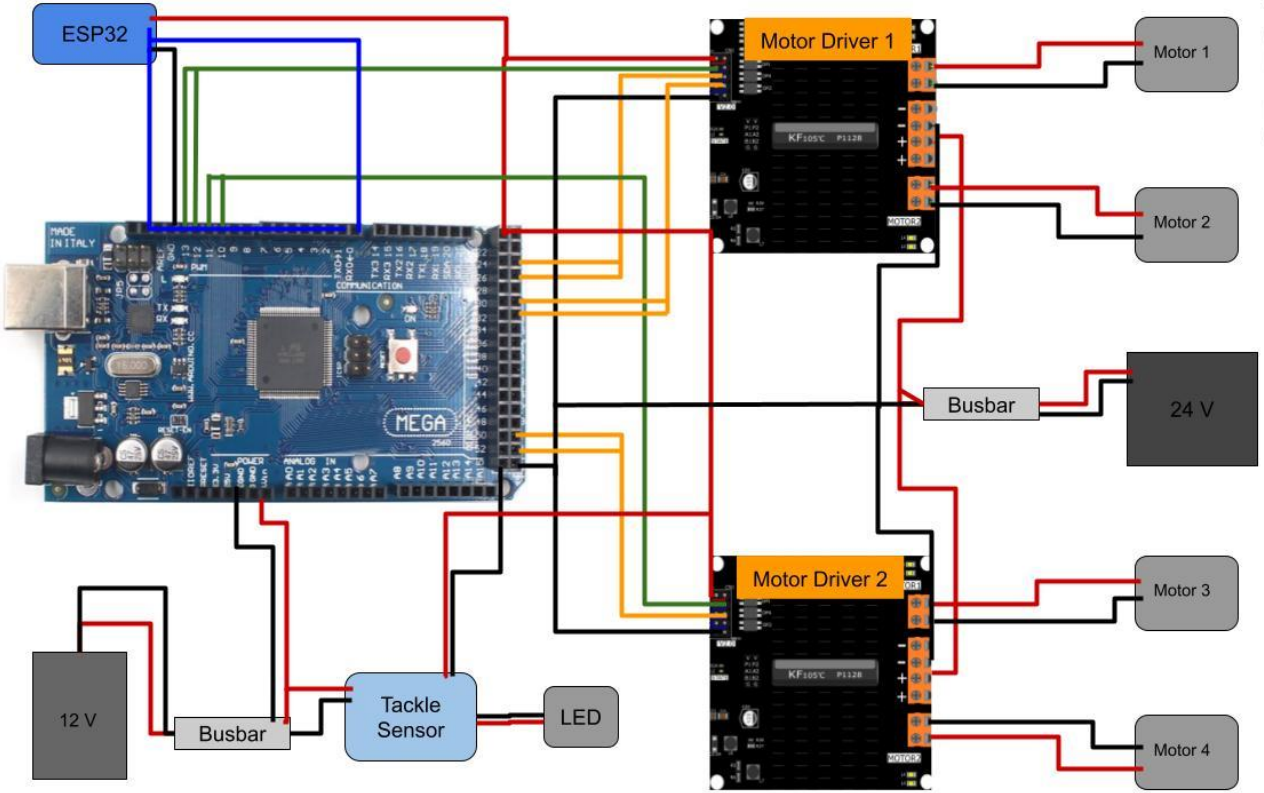
Motor (Gear Ratio)	Speed (rpm)	Torque (Nm)
6.3 : 1	1300	0.343
10 : 1	850	0.54
19 : 1	450	0.932
30 : 1	280	1.471
50 : 1	170	2.256
70 : 1	120	3.04
100 : 1	86	3.824
131 : 1	68	4.61
150 : 1	59	5.492



ELECTRONICS

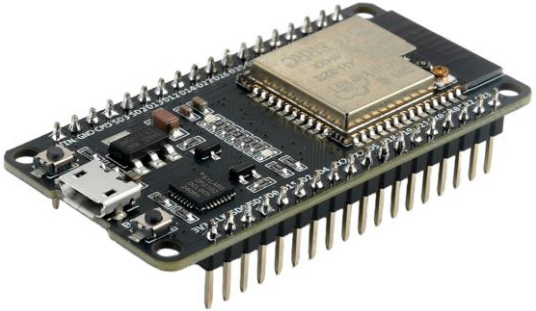
- The complete electrical system consisted of the following components:
  - Arduino Mega microcontroller – motor control
  - ESP32 microcontroller – Bluetooth communication with PS4 controller
  - Motor drivers
  - Tackle sensor module
  - Batteries
  - Kill-switch
  - Motors

SYSTEM SCHEMATIC

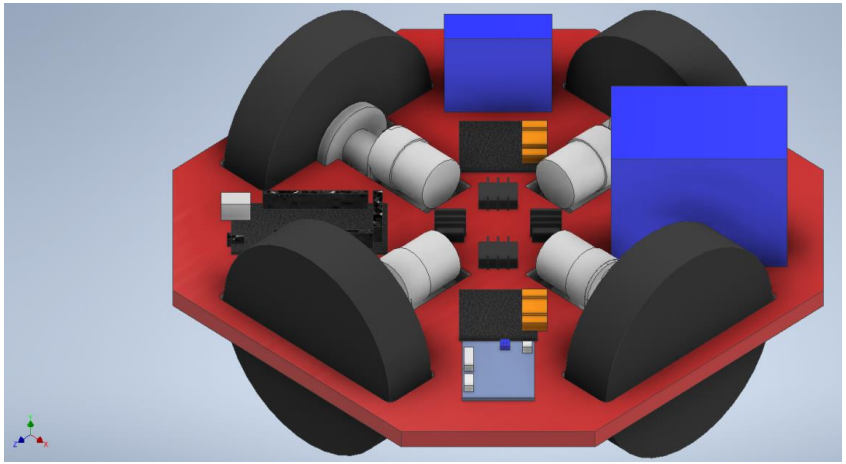


CONTROL ALGORITHMS

- ESP-32
  - Bluetooth communication with PS4 controller
  - USART transmit to Arduino Mega
- Arduino Mega
  - USART receive from ESP-32
  - Motor control algorithm (omniwheels)



MECHANICAL CAD



CAD INCLUDES ELECTRONICS, BATTERIES, MOTORS, etc.

PAINFUL LESSONS

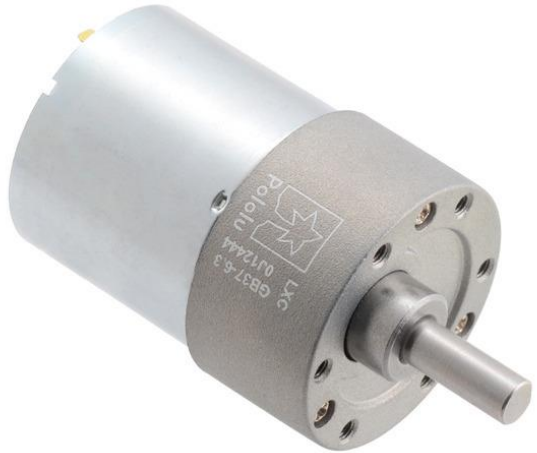
- A week before the final design expo, disaster struck!
- Arduino 5V regulator failure
  - Fully charged battery exceeded maximum input voltage
- Fix – Individual regulators for each microcontroller
  - Isolate each component!

- **Project Goal – Design a QB module to attach to existing robot**
  - Variable distance
  - Variable direction
  - Receiver detection
  - Throw/handoff option
  - Modularity
- Auxiliary goals
  - Improve Bluetooth connectivity issues
  - Basic maintenance

Calvin University QB

INITIAL CALCULATIONS & DESIGN

- Once again, students needed to calculate RPM and torque for launch motors
- Students encountered RPM vs Torque problem
  - Introduced to gearing and gear motors
  - Discussion of stall current/torque, no-load current, and motor efficiency



General specifications

Gear ratio:	6.25:1
No-load speed @ 24V:	1600 rpm
No-load current @ 24V:	0.1 A
Stall current @ 24V:	3 A[3]
Stall torque @ 24V:	3.5 kg·cm[3]
Max output power @ 24V:	14 W
No-load speed @ 12V:	820 rpm[4]
No-load current @ 12V:	0.08 A[4]
Stall current @ 12V:	1.7 A[4]
Stall torque @ 12V:	1.9 kg·cm[4]
Motor type:	24V

Performance at maximum efficiency

Max efficiency @ 24V:	53 %
Speed at max efficiency:	1300 rpm
Torque at max efficiency:	0.55 kg·cm
Current at max efficiency:	0.58 A
Output power at max efficiency:	7.4 W

INITIAL DESIGN

- Students have ordered parts and are beginning their first prototype
- Focused on developing a method to feed ball into the launcher
  - Also want to have a “trap door” that allows for hand-offs
  - Design may evolve to allow for quick passes to beat the blitz

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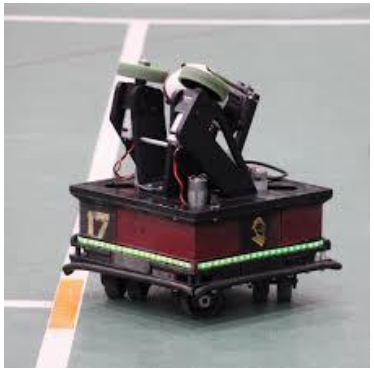

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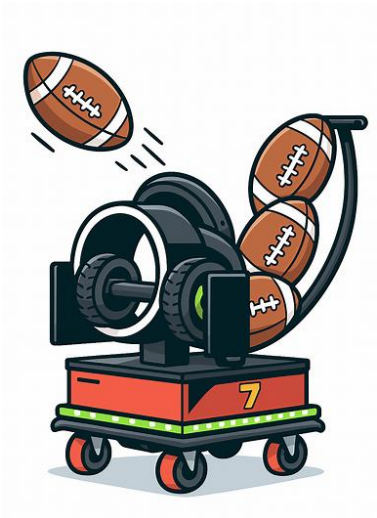

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FUTURE WORK & DIRECTION

- Marry Miami robotics club with senior projects
  - Robotics club – develop full team
  - Senior projects – develop specific functionality (e.g. QB target tracking)
- QB compete in 2026 Fall Combine
- **Full Team compete in 2028 National Championship!**

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