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DESIGN
BUILD
COMPETE
REPEAT

TAKING FRC ROBOTS TO THE NEXT LEVEL WITH ROS

Chris Bonomi

ABOUT ME

- Student on Team 195 from 2015-2018
  - Programming Lead 2016-2018
- Studied Computer Engineering at Florida Institute of Technology
- Software Engineer @ Lockheed Martin
- Current Lead Programming Mentor for Team 195

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WHAT IS ROS?

WHAT IS ROS?

- Robot Operating System
- Open source framework for building robotics software
- Modular message based system
- Enables developers to create robust and complex robotic systems, while still maintaining flexibility and scalability

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WHY ROS?

WHY ROS?

- Industry standard
- Modular code base
- Full C++ & Python support
- Easy data logging and recording
- Open source
- Commercial Friendly
- Large ecosystem of existing packages
- Very active community

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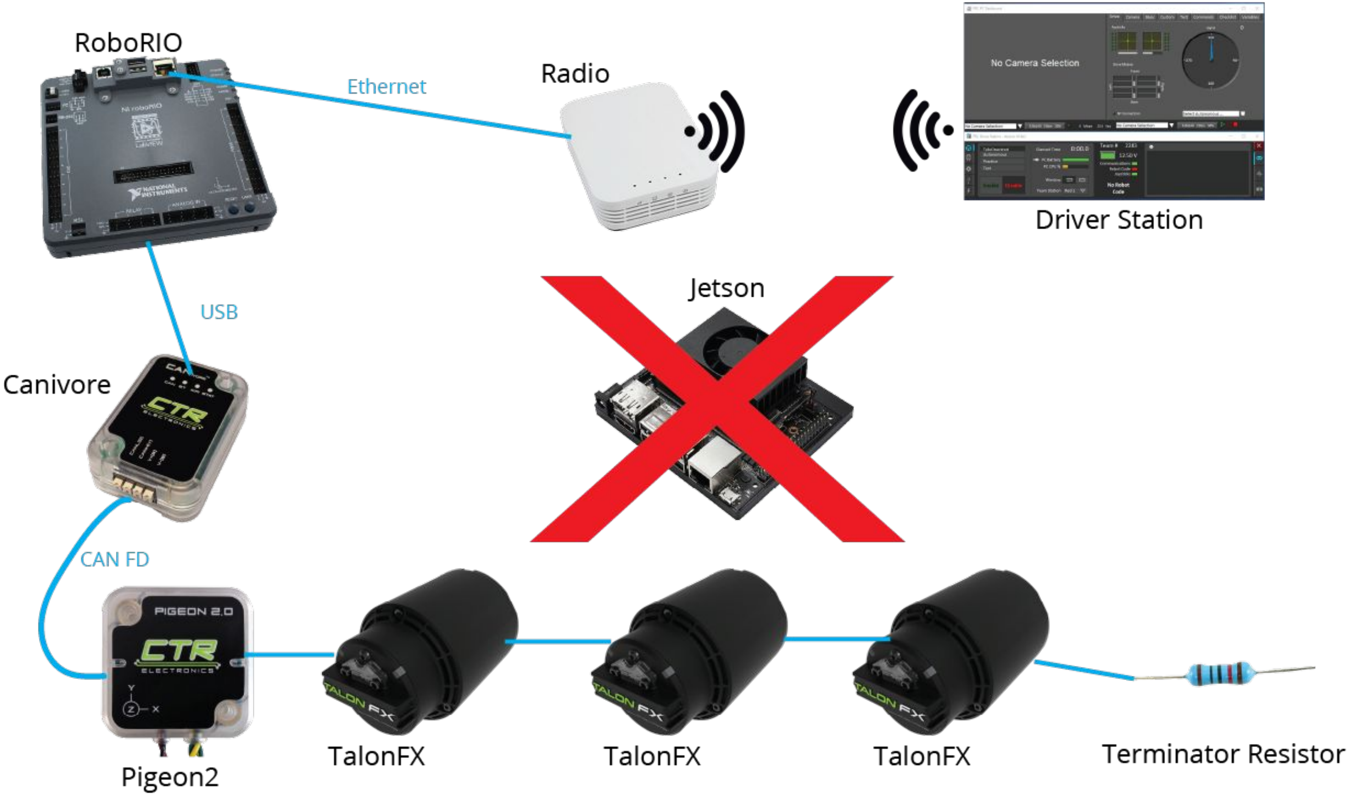
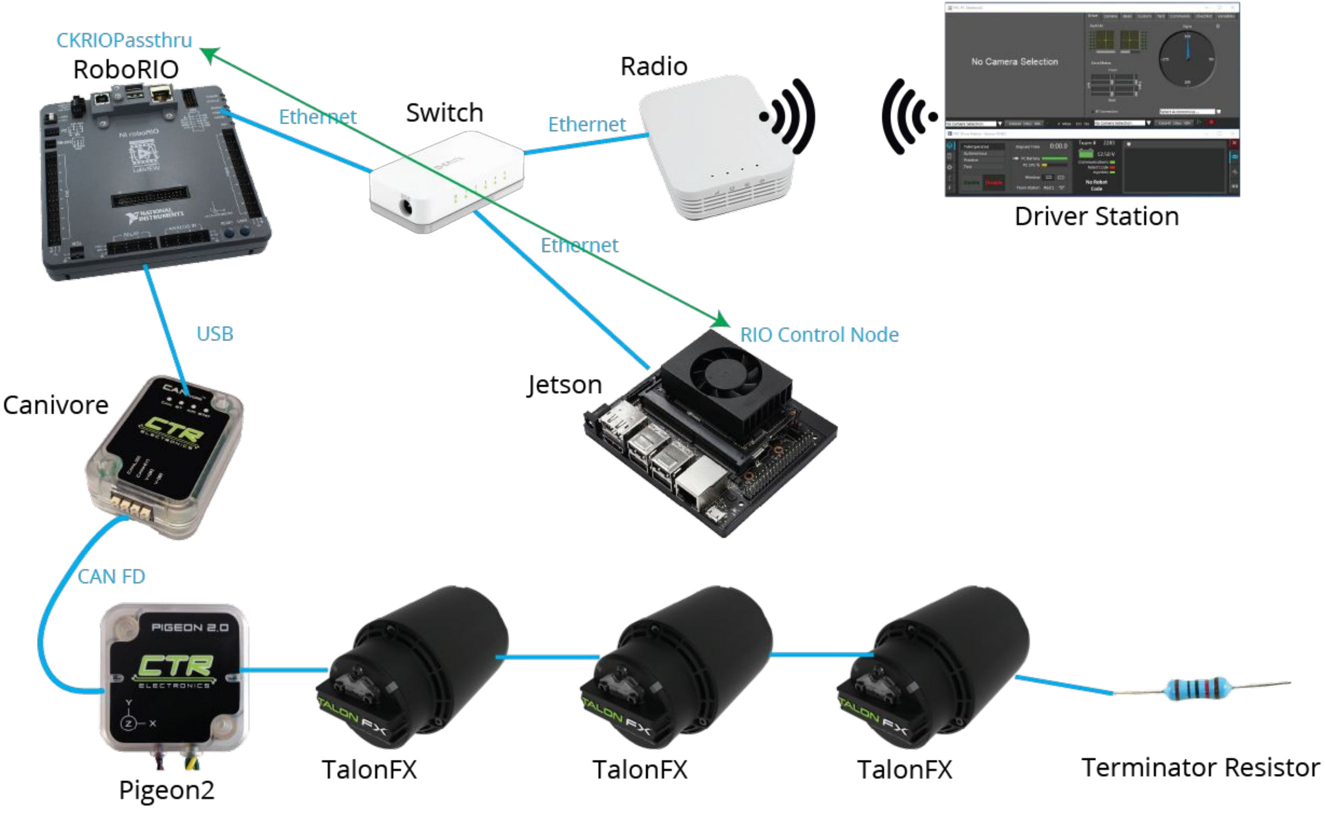
HARDWARE OVERVIEW

Standard Control System



ROS Control System

First Gen



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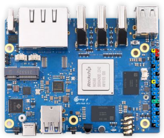
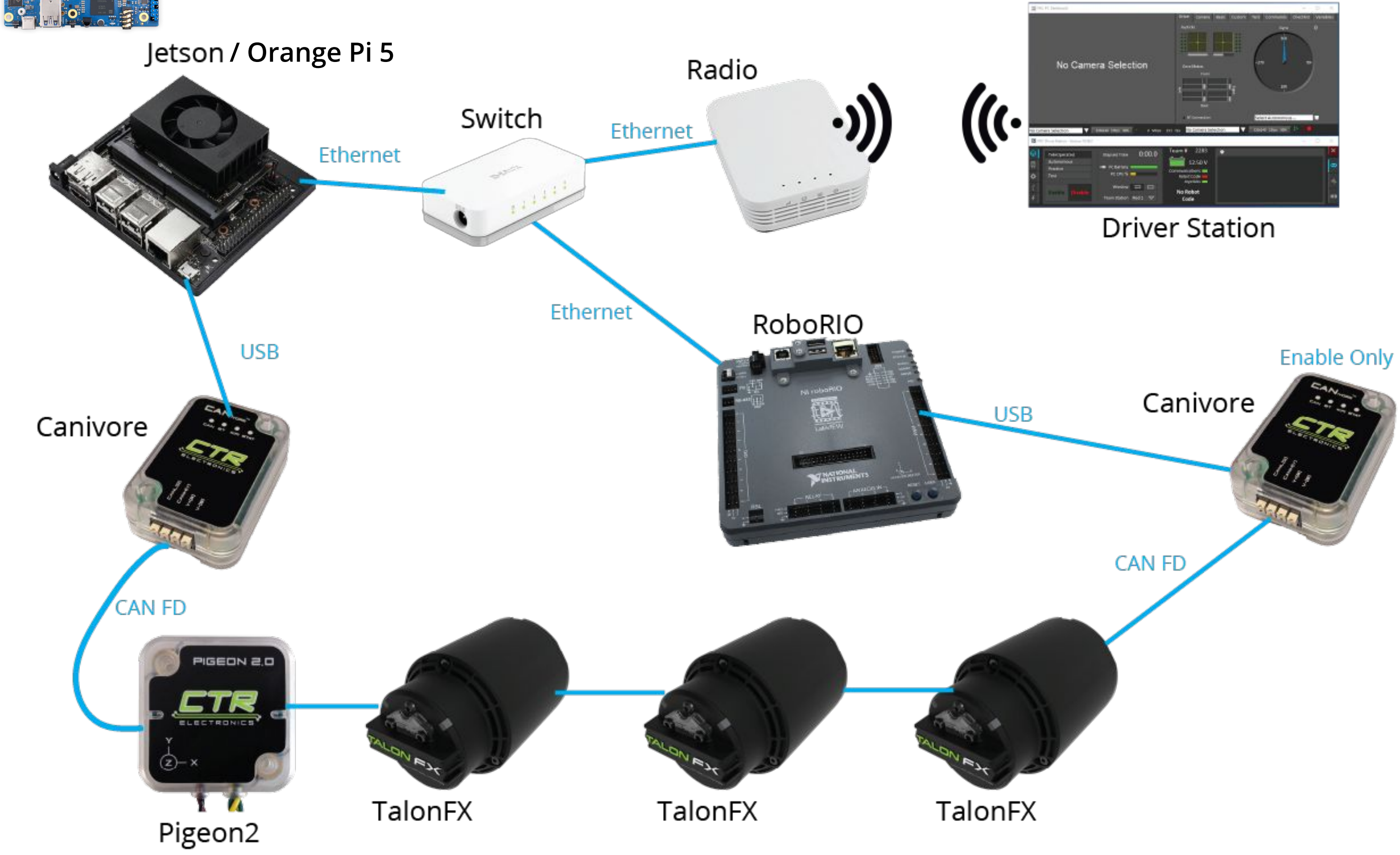
ROS Control System

Second Gen





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INTRODUCTION TO ROS2

WHAT WE USE

- 2023
  - ROS 1: Noetic Ninjemys
  - Jetson Xavier NX - Not connected directly to CAN
- New for 2024
  - ROS 2: Iron Irwini
  - Jetson Xavier NX - Connected directly to CAN
- Exploring for 2025
  - Orange Pi 5 / 5 Plus
    - Cheaper than the Jetson (~$150 vs. ~$400)
    - More powerful CPU / Non-CUDA Accelerated GPU

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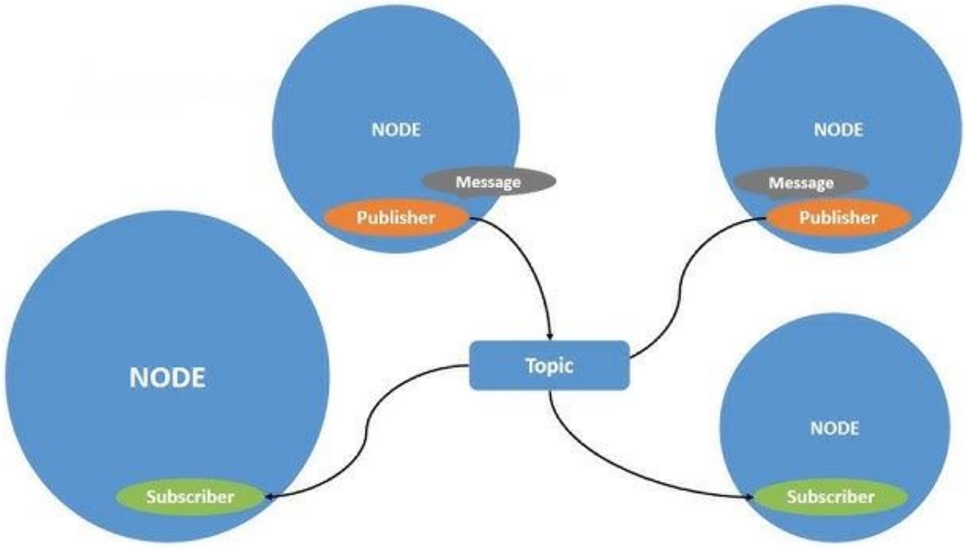
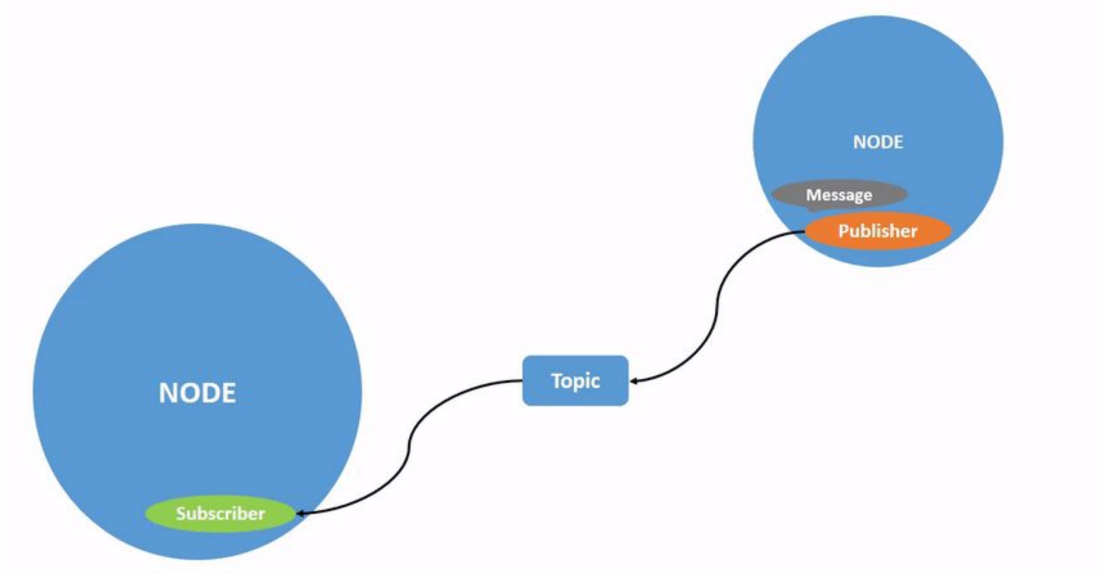
NODE-BASED ARCHITECTURE

- Distributed network of individual processes, performing specific tasks. E.x. Drivebase node, Shooter node, HMI node
- Each node can send a receive data from other nodes via topics, and can be configured with parameters



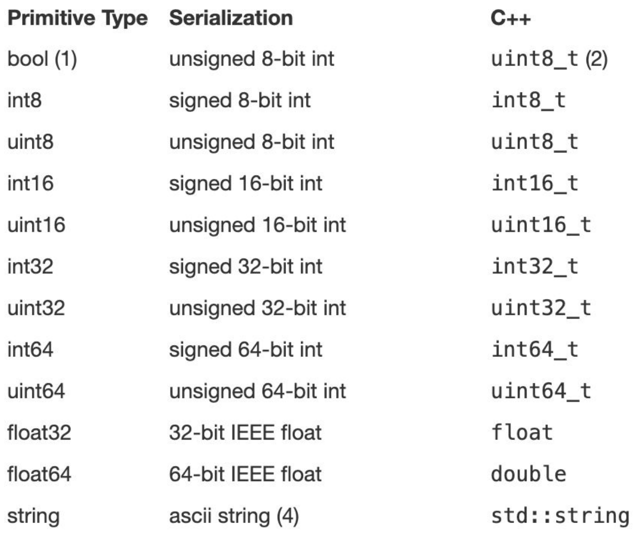
TOPICS

- One of the main ways in which data is exchanged between nodes
- A node may publish data to any number of topics while simultaneously have subscriptions to any number of topics

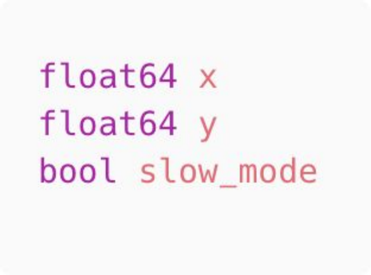


MESSAGES

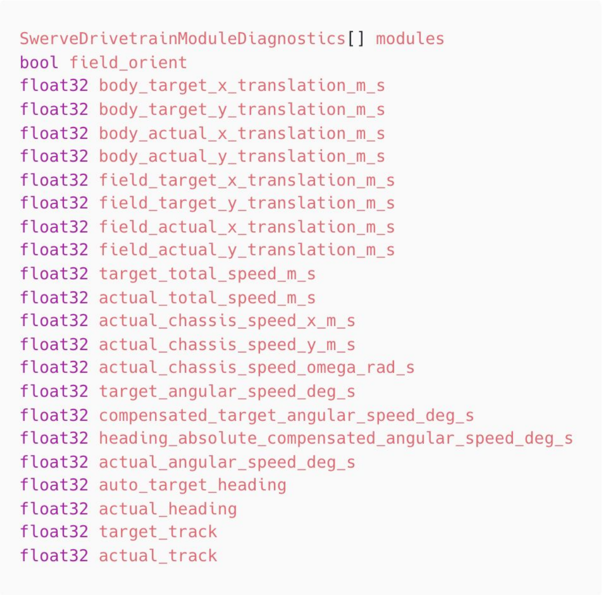
- Data structures that are sent back and forth between nodes across topics, containing information such as sensor data, controller inputs, odometry data
- ROS provides many standard message types, but also supports the creation of completely custom types



Primitive Type	Serialization	C++
bool (1)	unsigned 8-bit int	`uint8_t` (2)
int8	signed 8-bit int	`int8_t`
uint8	unsigned 8-bit int	`uint8_t`
int16	signed 16-bit int	`int16_t`
uint16	unsigned 16-bit int	`uint16_t`
int32	signed 32-bit int	`int32_t`
uint32	unsigned 32-bit int	`uint32_t`
int64	signed 64-bit int	`int64_t`
uint64	unsigned 64-bit int	`uint64_t`
float32	32-bit IEEE float	`float`
float64	64-bit IEEE float	`double`
string	ascii string (4)	`std::string`



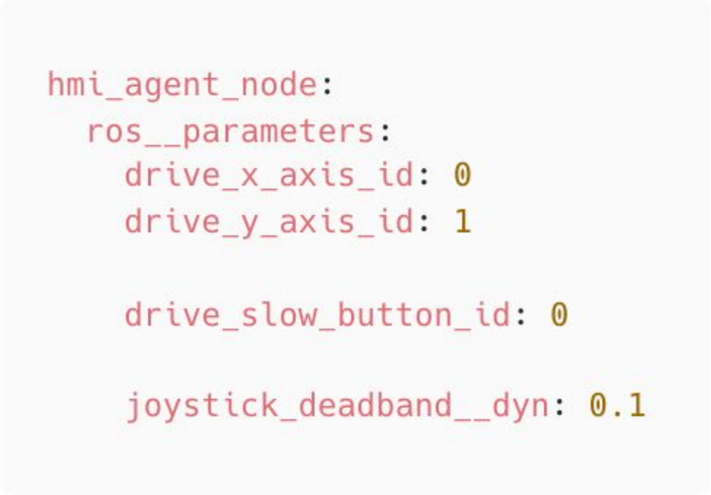
```
float64 x
float64 y
bool slow_mode
```



```
SwerveDrivetrainModuleDiagnostics[] modules
bool field_orient
float32 body_target_x_translation_m_s
float32 body_target_y_translation_m_s
float32 body_actual_x_translation_m_s
float32 body_actual_y_translation_m_s
float32 field_target_x_translation_m_s
float32 field_target_y_translation_m_s
float32 field_actual_x_translation_m_s
float32 field_actual_y_translation_m_s
float32 target_total_speed_m_s
float32 actual_total_speed_m_s
float32 actual_chassis_speed_x_m_s
float32 actual_chassis_speed_y_m_s
float32 actual_chassis_speed_omega_rad_s
float32 target_angular_speed_deg_s
float32 compensated_target_angular_speed_deg_s
float32 heading_absolute_compensated_angular_speed_deg_s
float32 actual_angular_speed_deg_s
float32 auto_target_heading
float32 actual_heading
float32 target_track
float32 actual_track
```

PARAMETERS

- Parameters are configuration values for nodes
- Configured as a YAML file, each node in ROS2 has its own set of parameters
- Supported types are: integers, floats, booleans, strings, and lists
- Parameters may be dynamically modified at runtime, allowing for easy tuning of PID gains, changing of control button layouts, etc.



```yaml
hmi_agent_node:
  ros__parameters:
    drive_x_axis_id: 0
    drive_y_axis_id: 1

    drive_slow_button_id: 0

    joystick_deadband__dyn: 0.1
```

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KEY BENEFITS

KEY BENEFITS

- Code Reusability
  - Since each node is fully modular, they can easily be shared between projects or carried over from year to year with very little to no code modification, only parameters
- Fault Tolerance
  - A code failure in a single node will cause only that node to crash, and nodes can be configured to respawn after a crash, so even in the event of a fault the rest of your code can continue to function
- Easy Live Debugging/Recording
  - Programs like PlotJuggler and Foxglove can monitor all topics in real time and plot numeric values
  - Foxglove is even capable of rendering 3D scenes and more (Demo shortly)
  - Topics can also be recorded to a standard MCAP format, for future review to identify errors i.e. failure on the field

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DEVELOPMENT ENVIRONMENT

DEVELOPMENT ENVIRONMENT

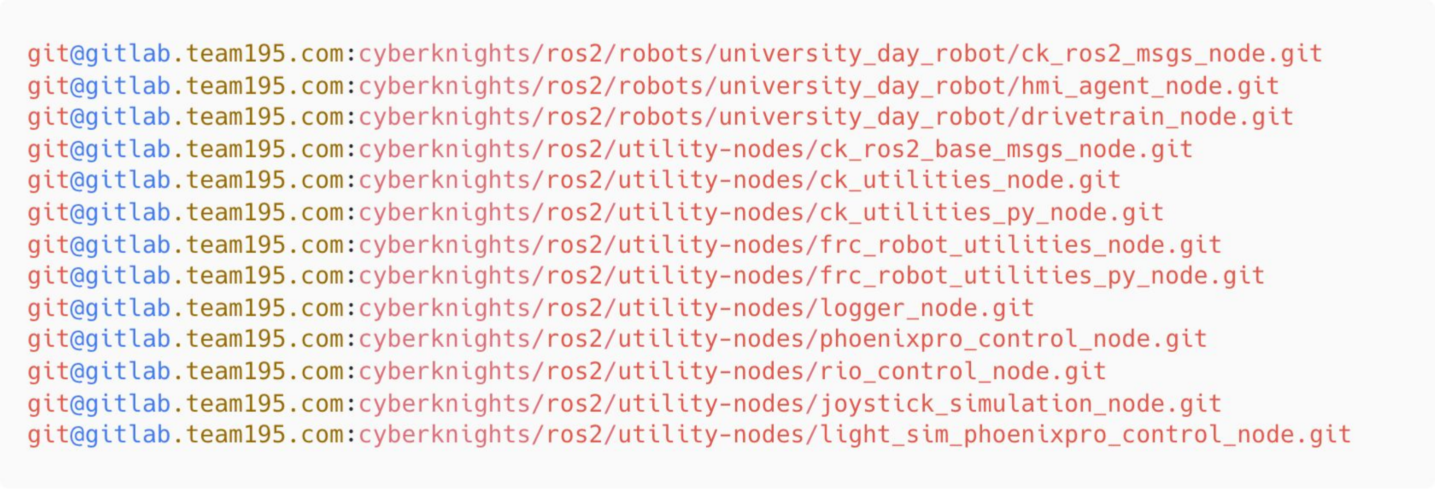
- Ubuntu Virtual Machine
  - 20.04/22.04 to resemble the operating system running on our Jetson
- Docker Container
  - All code is developed and built inside of a docker container, allowing greater control and consistency over our environment from computer to computer
  - The same container is present on the Jetson, and is where ROS runs
- Code Editing
  - All editing is done though Visual Studio Code with the following extensions
    - Dev Containers (Microsoft)
    - C++ Intellisense (Microsoft)
    - Python (Microsoft)

PROJECT LAYOUT

- Flat project structure
- Every robot project starts with 2 sub-projects
  - ros2_dev
    - Contains scripts needed for starting the container and developing/building the robot project
  - A robot sub-project E.x. university_day_robot, 2023_robot
    - Must end in “_robot”
    - Contains launch files, parameter files, and a special file called ros_projects.txt
      - This file defines all other nodes that this robot project requires to run i.e. rio_control_node
- All other node sub-projects are cloned automatically by the mkrobot script

MKROBOT SCRIPT

- One script to handle nearly all project actions
  - Clone all nodes listed in the robots ros_projects.txt file (See example)
  - Update all nodes from git
  - Create new nodes
  - Build/clean project
  - Launch project locally
  - Deploy project to robot



```
git@gitlab.team195.com:cyberknights/ros2/robots/university_day_robot/ck_ros2_msgs_node.git
git@gitlab.team195.com:cyberknights/ros2/robots/university_day_robot/hmi_agent_node.git
git@gitlab.team195.com:cyberknights/ros2/robots/university_day_robot/drivetrain_node.git
git@gitlab.team195.com:cyberknights/ros2/utility-nodes/ck_ros2_base_msgs_node.git
git@gitlab.team195.com:cyberknights/ros2/utility-nodes/ck_utilities_node.git
git@gitlab.team195.com:cyberknights/ros2/utility-nodes/ck_utilities_py_node.git
git@gitlab.team195.com:cyberknights/ros2/utility-nodes/frc_robot_utilities_node.git
git@gitlab.team195.com:cyberknights/ros2/utility-nodes/frc_robot_utilities_py_node.git
git@gitlab.team195.com:cyberknights/ros2/utility-nodes/logger_node.git
git@gitlab.team195.com:cyberknights/ros2/utility-nodes/phoenixpro_control_node.git
git@gitlab.team195.com:cyberknights/ros2/utility-nodes/rio_control_node.git
git@gitlab.team195.com:cyberknights/ros2/utility-nodes/joystick_simulation_node.git
git@gitlab.team195.com:cyberknights/ros2/utility-nodes/light_sim_phoenixpro_control_node.git
```

COMMON PROJECTS

- ckriopassthru
  - This is the project that is deployed to the RoboRIO
  - Sends and receives control signals to the Jetson
  - Serializes data with Protobuf and transmits the data with ZMQ
- rio_control_node
  - This node is responsible for communicating with the rio passthru, acting as the bridge for all other ROS nodes to send/receive commands from the RIO
- phoenix_pro_control_node
  - If using a Canivore with the Jetson, this node sends commands directly to the CTRE CAN devices, without needing to go through rio_control_node and ckriopassthru
- ck_ros2_base_msgs_node
  - This common node contains standard custom message types that are used throughout the entire robot project
- Utility Nodes
  - Common utilities implemented in both C++ and Python to be reused between nodes

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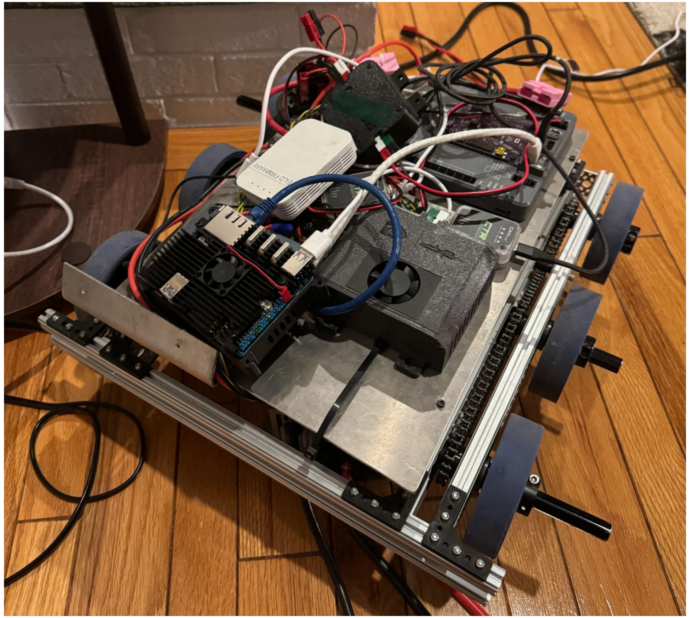
OUR LITTLE GUY

FLATTY 2!!

- Basic Differential Drive
  - 2 Falcon 500 motors
- Jetson Xavier NX Coprocessor
  - Directly connected to the robot CAN network with a USB Canivore
- VERY Messy Wires

*artists rendition



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LIVE CODING!

DELIVERABLES

- drivetrain_node (C++)
  - Subscribe to HMI signals topic to get driver control data
  - Calculate arcade drive outputs for left and right motors and apply them
  - Publish a diagnostic message to be plotted in Foxglove

- hmi_agent_node (Python)
  - Subscribe to Joystick status topic to get current joystick inputs
  - Read the values of the desired axes and buttons
  - Publish the desired control inputs on the HMI topic

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QUESTIONS?

Email:

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GitLab: