SIMBA

EXPLORING WHEREVER THE LIGHT TOUCHES

Cal Poly SLO Capstone Fall 2023 Alpha Presentation

Braedan Kennedy, Curtis Bucher, Sepp Williams, Ian Beck, Luis David Garcia, Brian Nguyen, and Tyler Bovenzi (Client)

Presentation Overview

01. Introduction

Meet the Team, Mission Statement, Objectives and Deliverables

02. Project Design

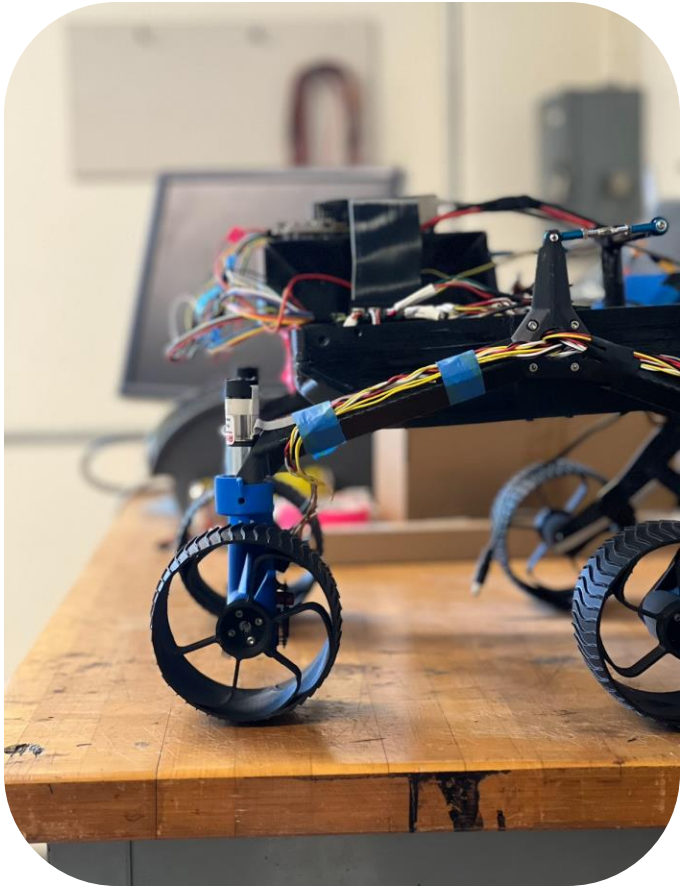
Archetypes and Use Cases, Engineering Specifications, Design Development

03. Project Management

Gantt Chart, Evaluation and Testing, Product Cost

04. Conclusion

System Summary, Acknowledgments, Questions



01.

Introduction

Meet the Team, Mission Statement, Objectives and Deliverables

Meet the Team

Braedan Kennedy
Project Lead, Software

Curtis Bucher
Digital Design

Sepp Williams
Hardware

Ian Beck
Digital Design

Luis David Garcia
Client Laison, Software

Brian Nguyen
Software

Client

Tyler Bovenzi is a Cal Poly Alumni who graduated with a degree in Computer Engineering

He worked on the *GoScout* project -- a prior version of the SIMBA rover

Mission Statement

“The **SIMBA project** aims to lower the barrier to entry for rover development by building on previous generations of Cal Poly rover projects”

—SIMBA Team

Objectives

Hardware
Create PCB with KRIA SoM

Digital Design
Port and refactor Verilog motor control code from GoScout project

Software
Implement IMU and GPS from GoScout project

Deliverables

Hardware
Fabricated and tested PCB

Digital Design
Integration of motor drivers and encoders

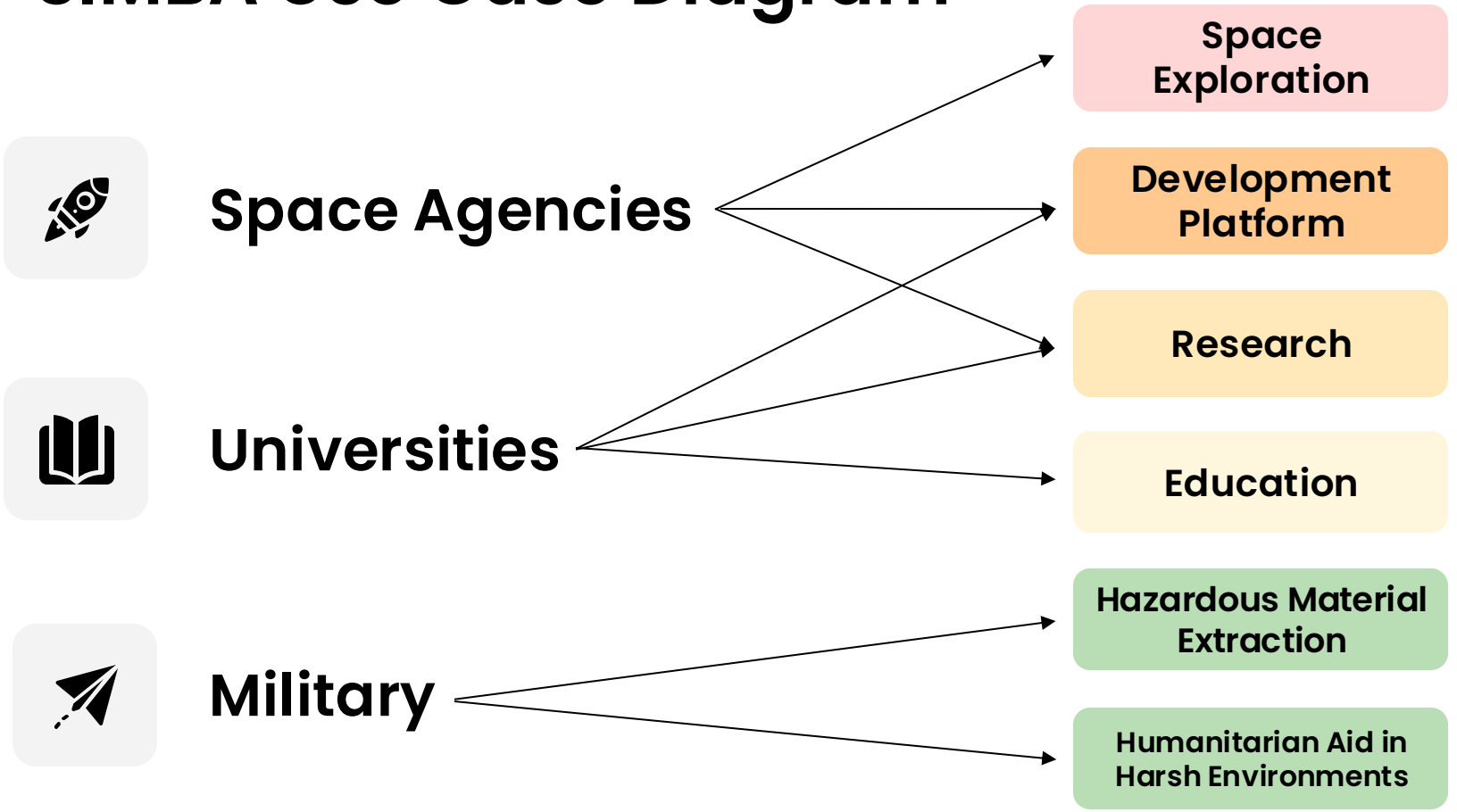
Software
Creation and verification of functioning C++ GPS and IMU libraries

02.

Design

Archetypes and Use Cases, Engineering Specifications, Design Development

SIMBA Use Case Diagram

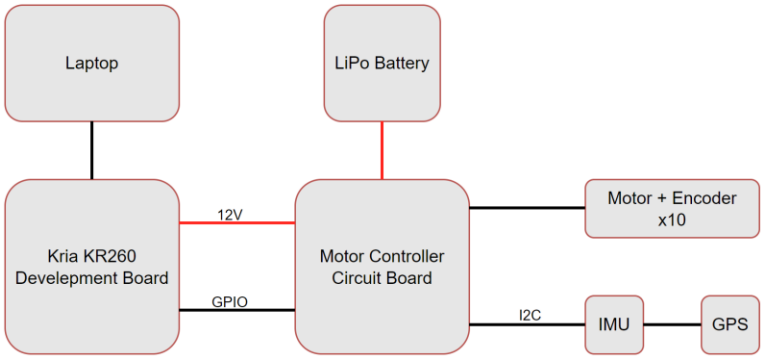


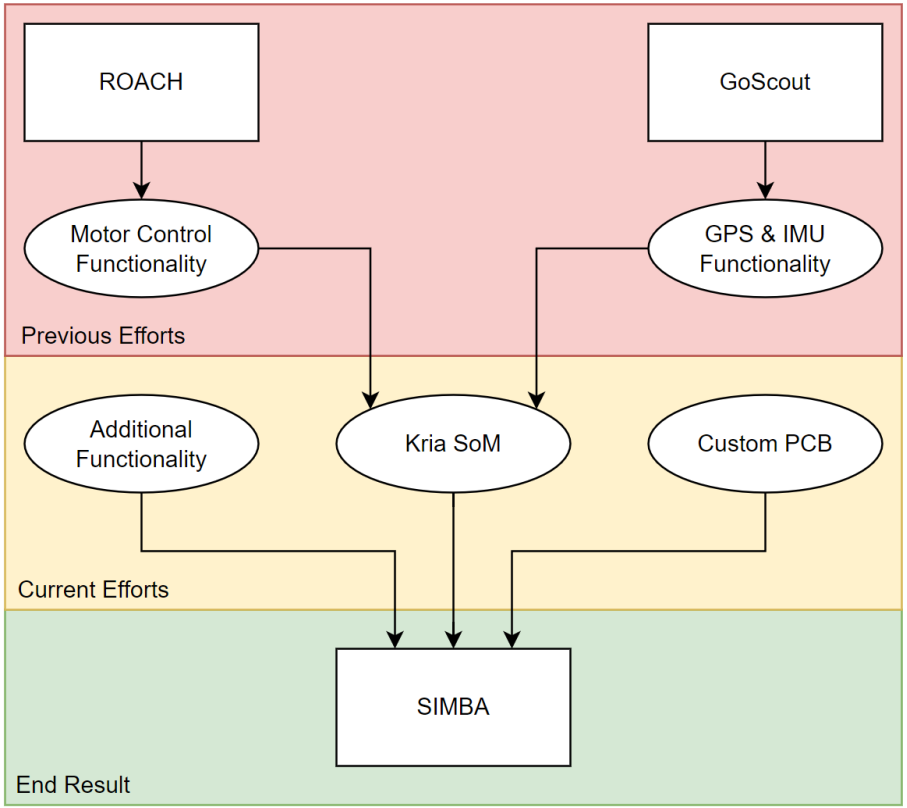
Marketing / Engineering Requirements

Spec #	Marketing	Engineering Parameter	Engineering Requirements (with units)	Tolerance	Risk	Compliance
1	Efficient	Energy Consumption	4 W	Avg	M	A, T
2	Accurate	GPS Positional Accuracy	2.5 M	Max	M	A, T
3	Accurate	Motor Control Accuracy	3000 pulses per rotation	None	M	A, T
4	Durable	Part Expected Lifetime	1 year	Min	H	A
5	Functional	Features Implemented	All legacy ROACH features	Min	M	A, S, T
6	Cheap	Production Cost	$500	Max	M	A
7	Environmental	Emissions, Supply Chain	*Zero Rover Emissions, Limited Battery Size (power efficiency)*	Max	L	A, T

Design Development Overview

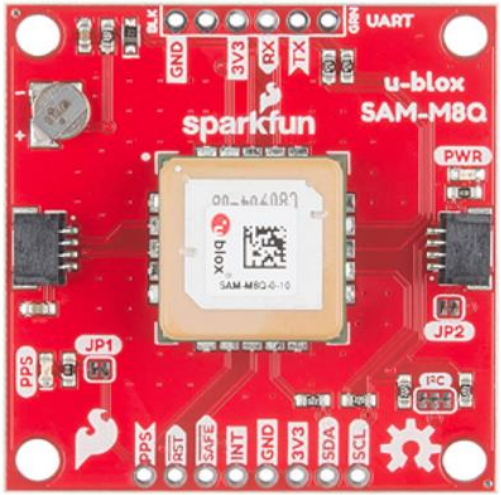
- **KRIA SoM** – Both the processor used to run rover software and FPGA used for offloading motor control and other intensive workloads
- **GPS & IMU** – Incorporate coordinate-based movements of the rover
- **PCB** – Place the entire system on a single PCB





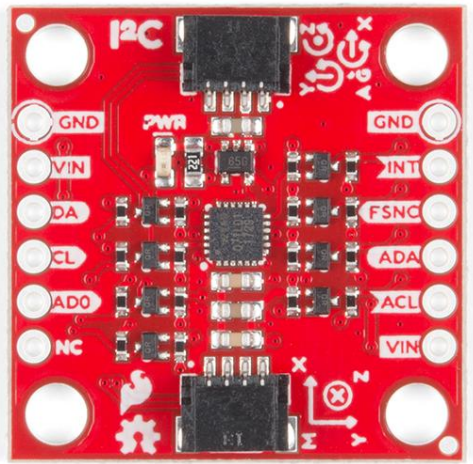
SAM-M8Q GPS

- 14 data points to determine SIMBA location (Longitude, Latitude, Height Above Sea Level, etc.)
- Power consumption: 29 mA @ 3.3V (Continuous) [5]
- I2C Communication



ICM-20948 IMU

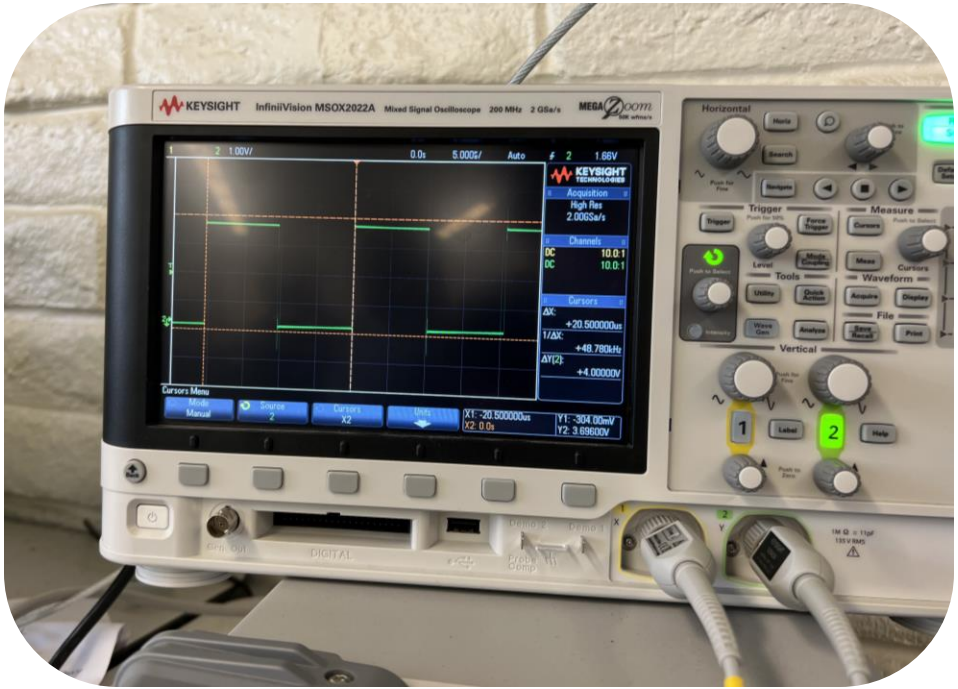
- 9-Axis Inertial Measurement Unit
- I2C Communication
- Low power at 2.5 mW [6]



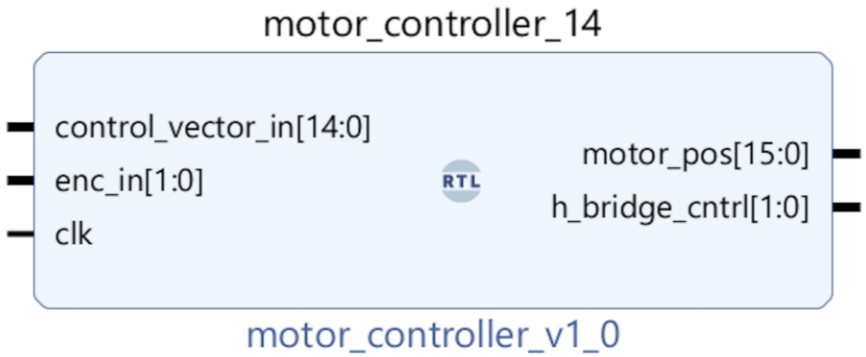
Kria Development & Motor Controllers

PWM Generator -
Receives a duty cycle value then generates a pulse-width modulated signal

H-Bridge Decoder -
Decodes direction and duty cycle values into H-Bridge compatible control signals



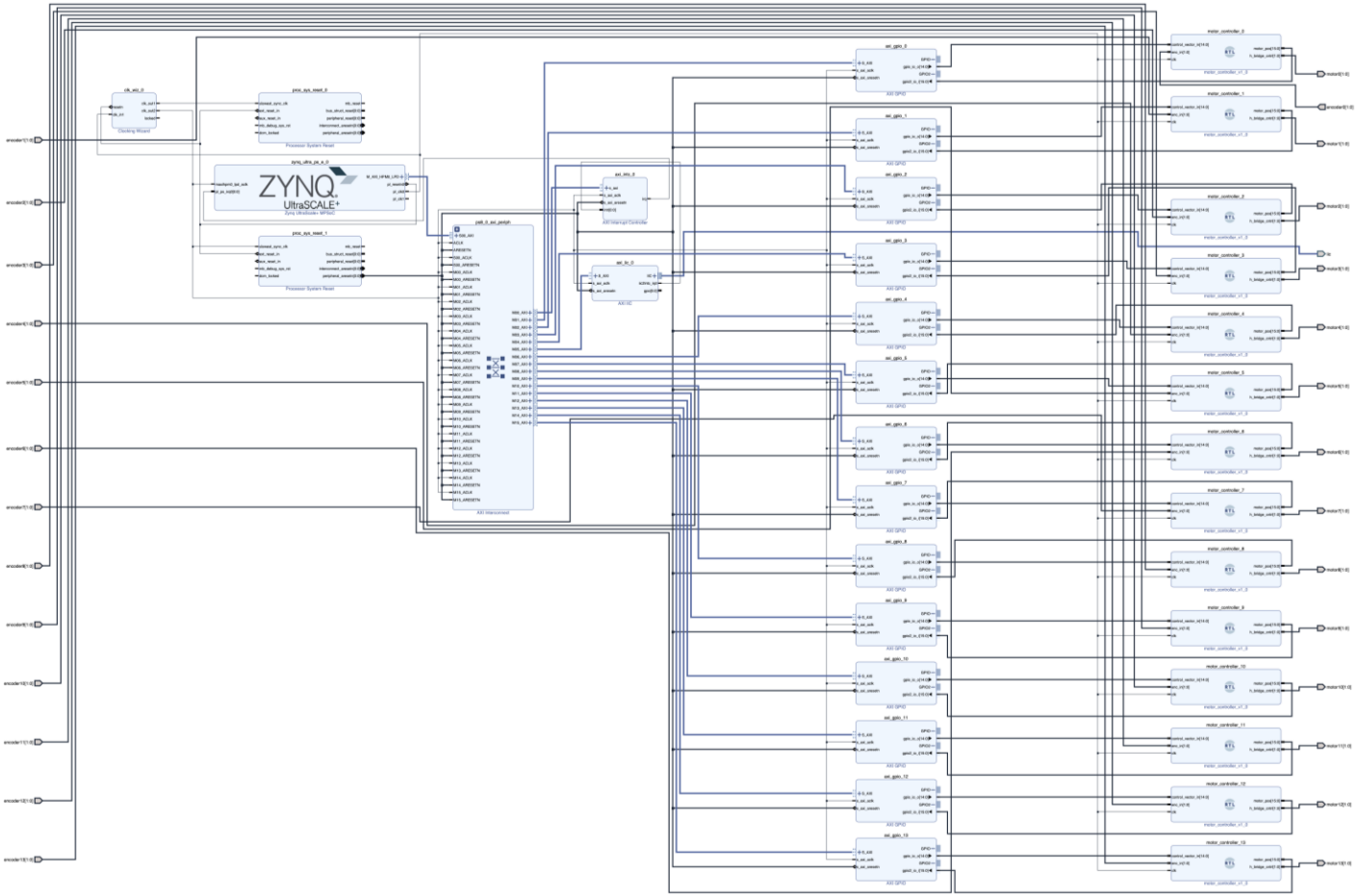
Kria Development & Motor Controllers



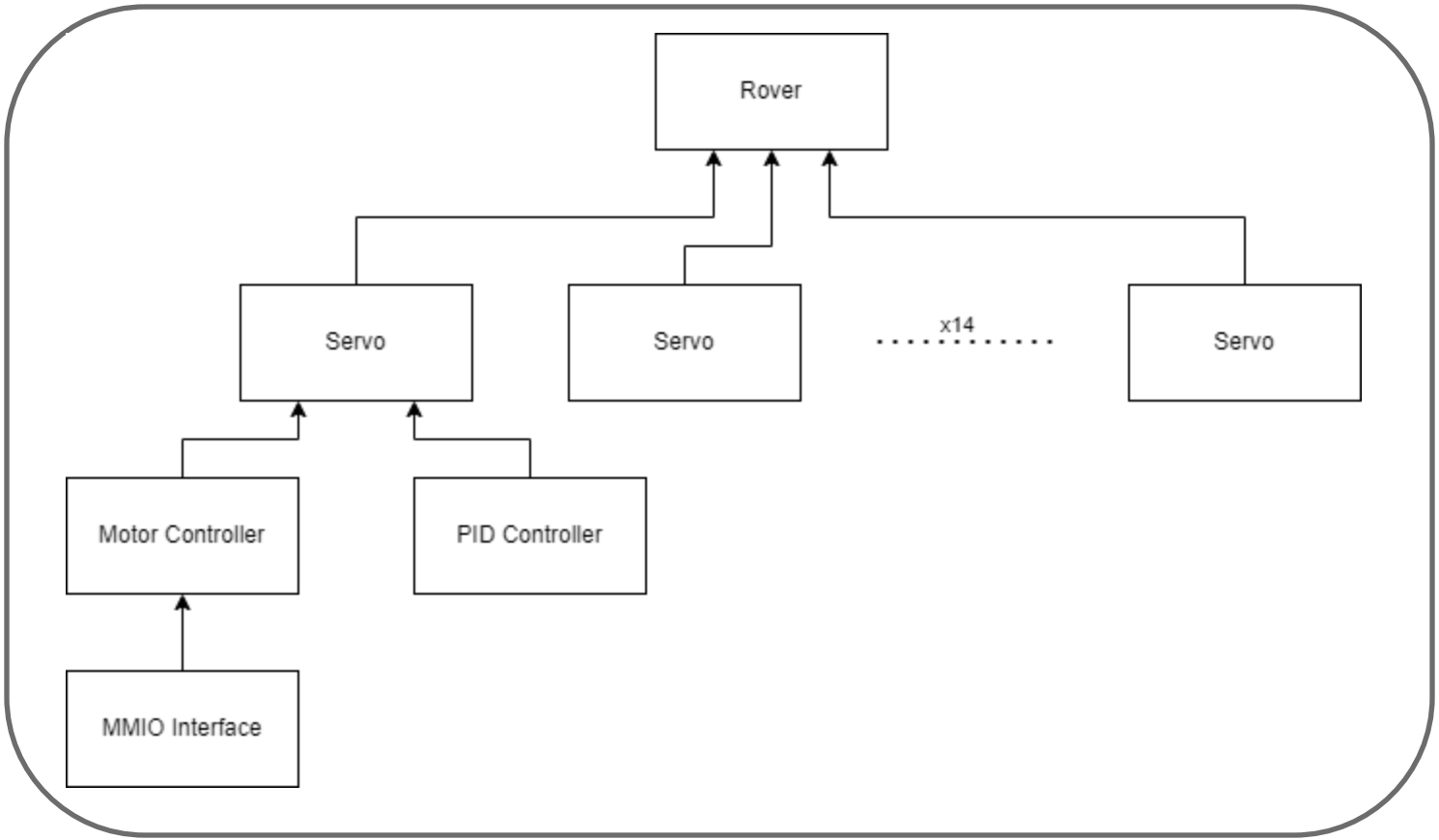
Software (C) -
Provides a software interface to the motor controller hardware, allowing users to configure duty cycle, direction, and retrieve encoder position

Quadrature Decoder -
Consumes quadrature signals from motor encoders and uses them to determine the current position of the motor

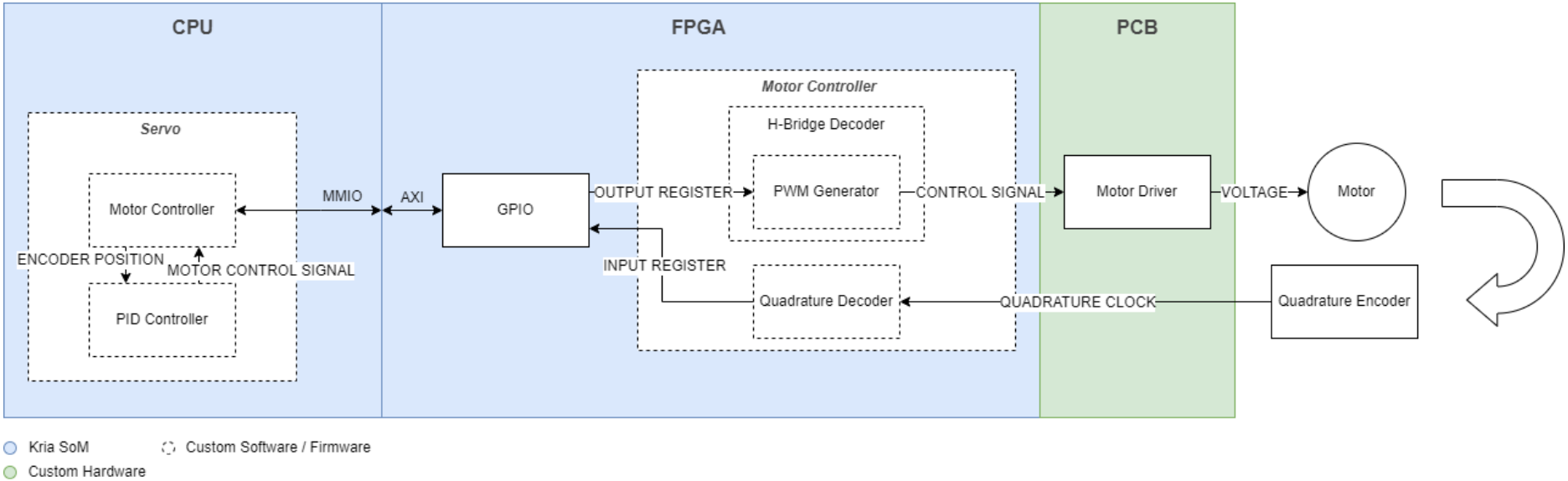
Digital Design Block Diagram



Software (C) Design Block Diagram



Closed Loop Motor Control



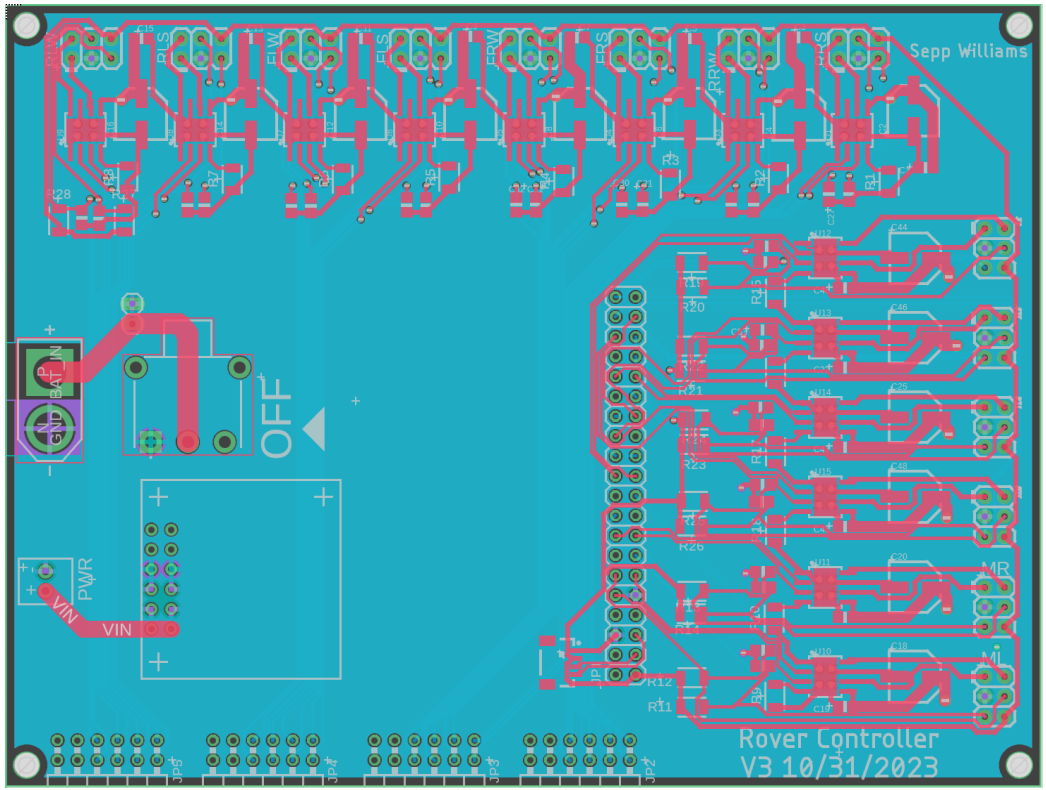
Motor Control PCB Design

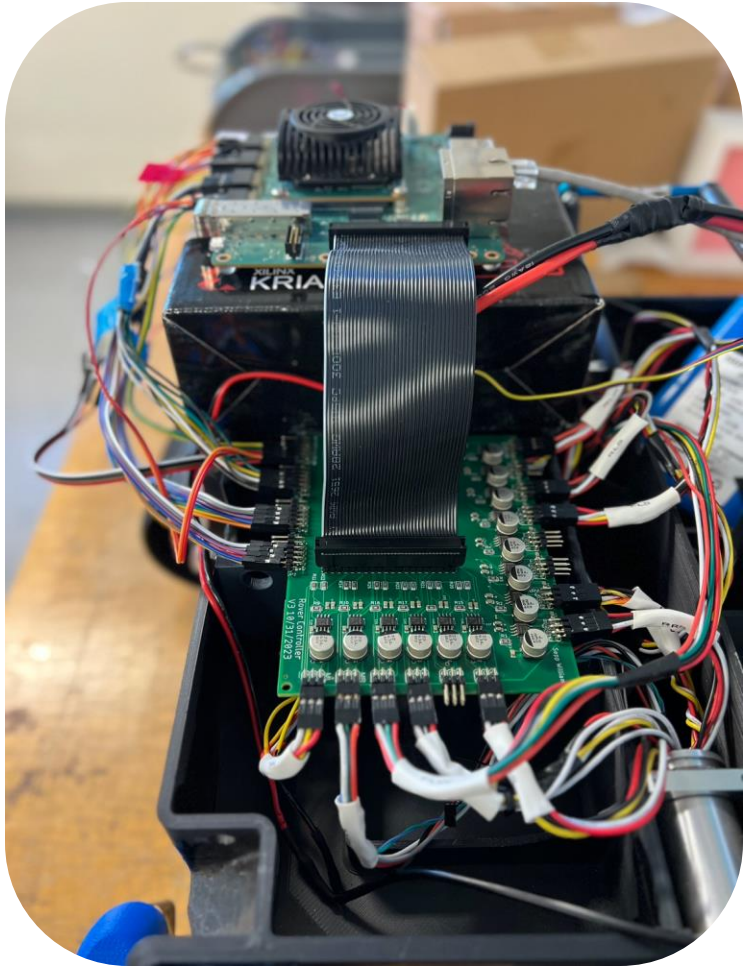
14x motor controllers
- 10x movement control
- 4x arm control

4 Layer PCB
- 2 signal layers
- 1 motor voltage plane
- 1 ground plane

12V Buck Converter
- Powers Kria KR260
- 3.3V from Kria KR260

Interfaces
- Raspberry Pi HAT header
- 4x PMOD connectors
- I2C output connector
- Battery connector
- Power Switch





Motor Control PCB Integration

Power Conversion Validation

- Tested 12V conversion prior to initial Kria KR260 connection
- Validated 3.3V and 5V return voltages from Kria KR260

Individual Motor Control

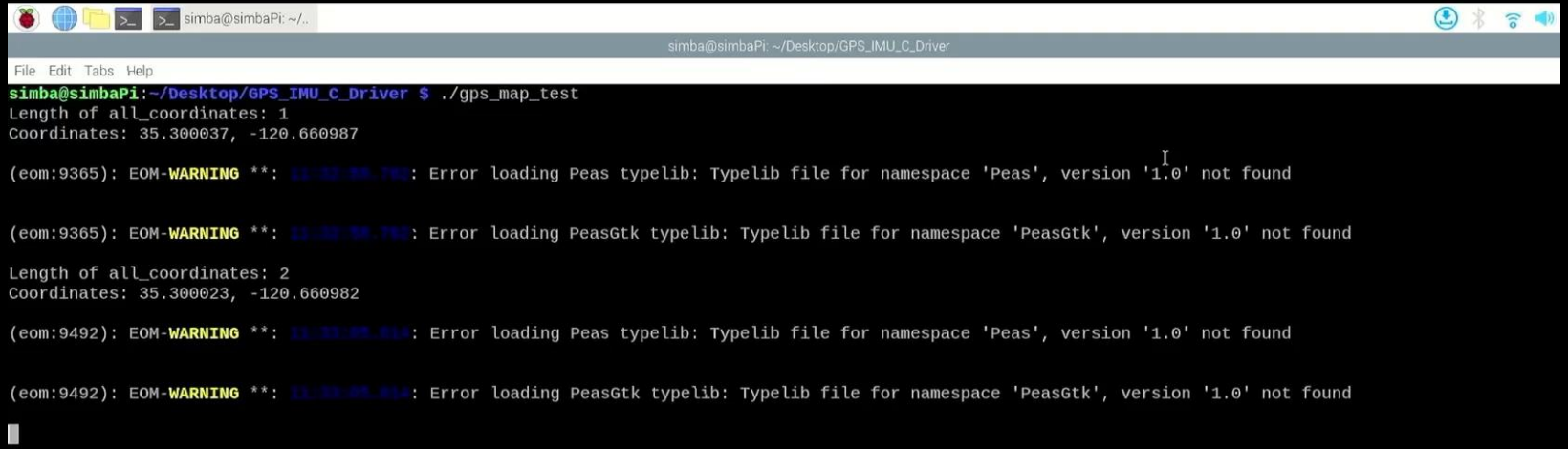
- Ensured full motor control on each motor individually from a known working Kria FPGA implementation

Full Motor Control

- Expanded to control to all motors within the FPGA and mapped to available GPIO

DEMONSTRATION TIME

GPS Demo


simba@simbaPi: ~/..
simba@simbaPi: ~/Desktop/GPS_IMU_C_Driver
File Edit Tabs Help
simba@simbaPi:~/Desktop/GPS_IMU_C_Driver $ ./gps_map_test
Length of all_coordinates: 1
Coordinates: 35.300037, -120.660987
(eom:9365): EOM-WARNING **: : Error loading Peas typelib: Typelib file for namespace 'Peas', version '1.0' not found
(eom:9365): EOM-WARNING **: : Error loading PeasGtk typelib: Typelib file for namespace 'PeasGtk', version '1.0' not found
Length of all_coordinates: 2
Coordinates: 35.300023, -120.660982
(eom:9492): EOM-WARNING **: : Error loading Peas typelib: Typelib file for namespace 'Peas', version '1.0' not found
(eom:9492): EOM-WARNING **: : Error loading PeasGtk typelib: Typelib file for namespace 'PeasGtk', version '1.0' not found

IMU Demo

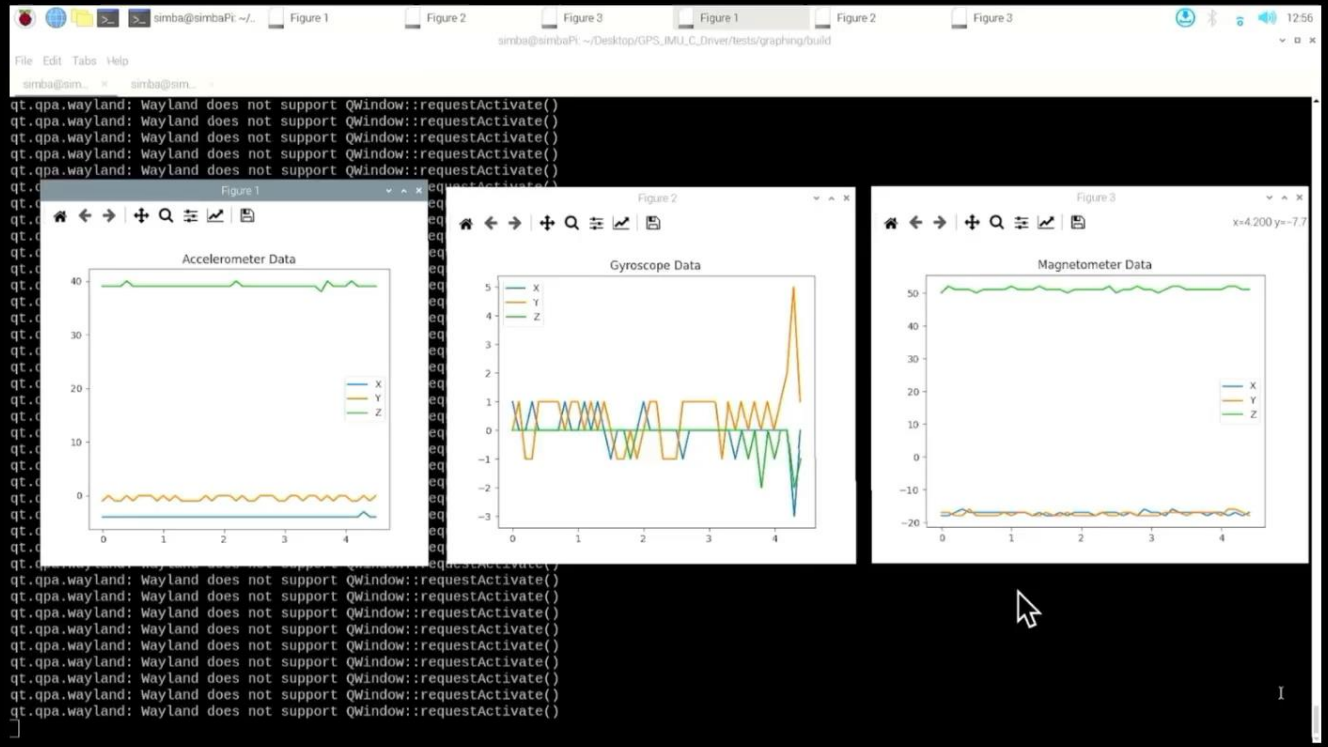
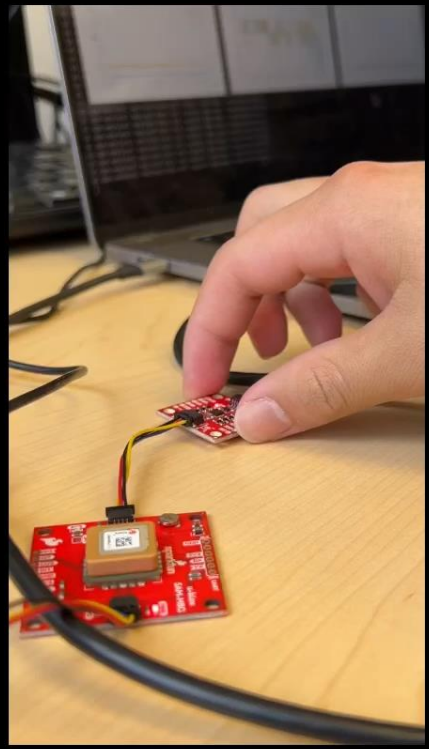
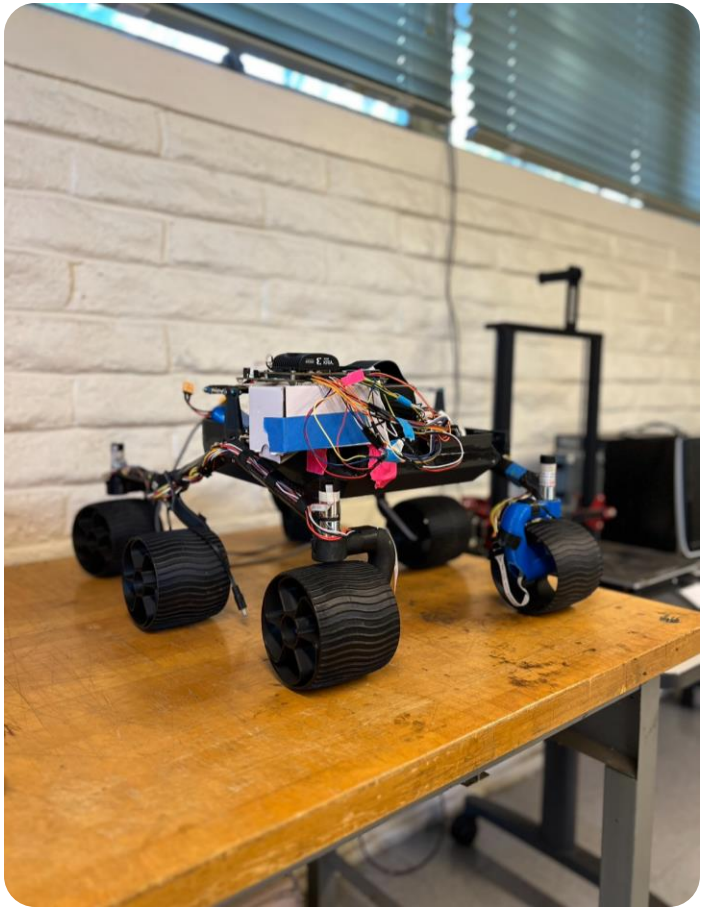


Figure 1
Accelerometer Data
X
Y
Z
Figure 2
Gyroscope Data
X
Y
Z
Figure 3
Magnetometer Data
X
Y
Z
qt.qpa.wayland: Wayland does not support QWindow::requestActivate()



Rover TIME

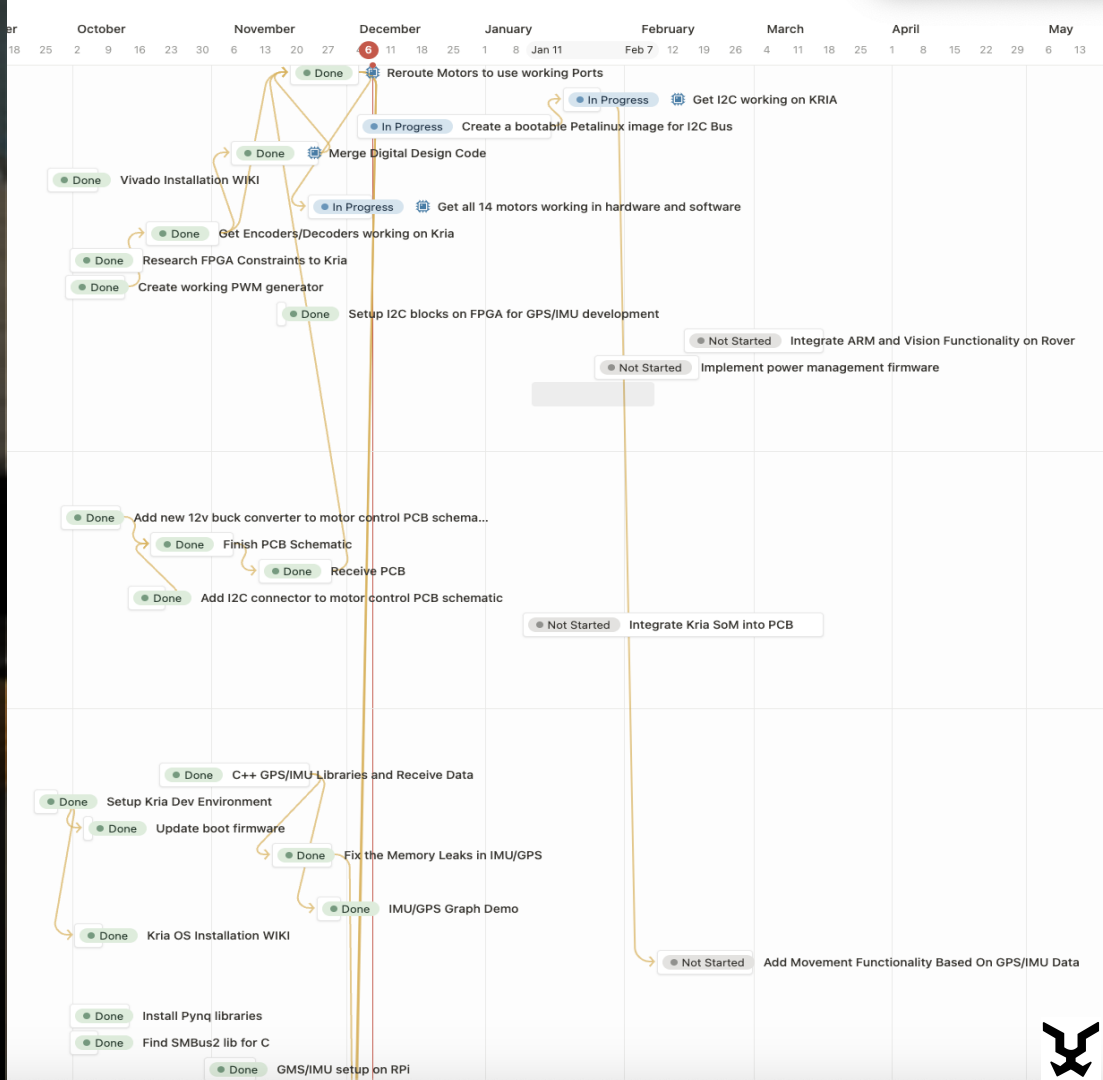


03.

Project Management

Gantt Chart, Evaluation and Testing,
Product Cost

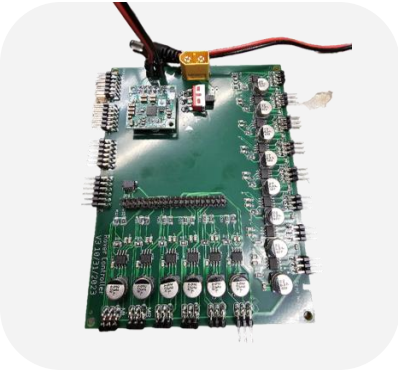
Gantt Chart


October
November
December
January
February
March
April
May
Jan 11
Feb 7
Done
Reroute Motors to use working Ports
In Progress
Get I2C working on KRIA
In Progress
Create a bootable Petalinux image for I2C Bus
Done
Merge Digital Design Code
Done
Vivado Installation WIKI
In Progress
Get all 14 motors working in hardware and software
Done
Get Encoders/Decoders working on Kria
Done
Research FPGA Constraints to Kria
Done
Create working PWM generator
Done
Setup I2C blocks on FPGA for GPS/IMU development
Not Started
Integrate ARM and Vision Functionality on Rover
Not Started
Implement power management firmware
Done
Add new 12v buck converter to motor control PCB schema...
Done
Finish PCB Schematic
Done
Receive PCB
Done
Add I2C connector to motor control PCB schematic
Not Started
Integrate Kria SoM into PCB
Done
C++ GPS/IMU Libraries and Receive Data
Done
Setup Kria Dev Environment
Done
Update boot firmware
Done
Fix the Memory Leaks in IMU/GPS
Done
IMU/GPS Graph Demo
Done
Kria OS Installation WIKI
Not Started
Add Movement Functionality Based On GPS/IMU Data
Done
Install Pynq libraries
Done
Find SMBus2 lib for C
Done
GMS/IMU setup on RPi

Testing and Evaluation

KRIA SoM

Wrote test program to exercise full functionality of SIMBA's ten movement motors



PCB

PCB used in test program to control each of SIMBA's ten movement motors

GPS & IMU

Employed functional integration testing by creating real-time plots to verify GPS & IMU data

Product Cost

Component	Cost per Part	# of Parts	Total
PCB Manufacturing	$ 5.92	1	$ 5.92
0.1uF 50V Capacitor	$ 0.10	42	$ 4.20
22uF 63V Capacitor	$ 1.27	14	$ 17.78
30K Resistor	$ 0.10	14	$ 1.40
2K Resistor	$ 0.48	14	$ 6.72
DRV8871 Motor Controller	$ 2.24	14	$ 31.36
2x3 Pin Header	$ 0.15	14	$ 2.16
2x6 Pin Header	$ 0.29	4	$ 1.14
2.1mm Power Plug	$ 5.00	1	$ 5.00
40 Pin Raspberry PI HAT Header	$ 4.52	1	$ 4.52
XT60 Battery Connector	$ 1.50	1	$ 1.50
QWIIC Connector 4-Pin	$ 0.56	1	$ 0.56
Slide Switch 5A 120V	$ 3.45	1	$ 3.45
Pololu 12V 4.5A Buck Converter	$ 24.95	1	$ 24.95
Kria KR260 Robotics Starter Kit	$ 349.00	1	$ 349.00
Jumper Wire Male to Female 6" 28AWG Bulk	$ 1.95	1	$ 1.95
			$ 461.61

04.

Conclusion

System Summary, Acknowledgments, Questions

System Summary

Hardware

- Integrated of all 14 motor drivers and encoders
- Achieved the digital design deliverable

Firmware

- Fabricated and tested PCB
- Achieved the hardware deliverable

Software

- Created and verified functioning C++ GPS and IMU libraries
- Achieved the software deliverable

Acknowledgements

THANK YOU

Any Questions?

Appendix

References

1. [1] B. Nguyen, B. Kennedy, C. Butcher, J. Williams, L. Garcia, I. Beck, “Solar Autonomous ROACH Background Research,” https://tinyurl.com/2erhdpp5 (accessed Oct. 26, 2023)
2. [2] L. La Rocca, Melopero SAM-M8Q Arduino Library, https://github.com/melopero/Melopero_SAM-M8Q/tree/master (accessed Oct. 26, 2023).
3. [3] B. Alsadik, “Kalman filter,” Kalman Filter - An Overview, https://www.sciencedirect.com/topics/earth-and-planetary-sciences/kalman-filter (accessed Oct. 26, 2023).
4. [4] B. Nguyen, B. Kennedy, C. Butcher, J. Williams, L. Garcia, I. Beck, “Archetypes and Use Cases,” https://tinyurl.com/4k2sk4a3 (accessed Oct. 26, 2023)
5. [5] “SAM-M8Q module Easy-to-use u-blox M8 GNSS antenna module Smart antenna module for easy
6. and reliable integration.” Accessed: Dec. 05, 2023. [Online]. Available: Datasheet for GPS
7. [6] “ICM-20948 Datasheet,” *TDK InvenSense*. Accessed: Dec. 05, 2023. [Online]. Available: Datasheet for IMU