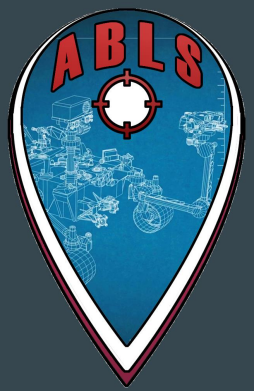
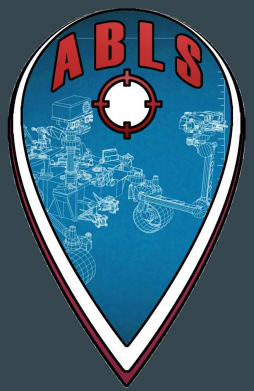
WCP09 - Autonomous Beacon Location System (ABLS)

Sponsor:
Lockheed Martin





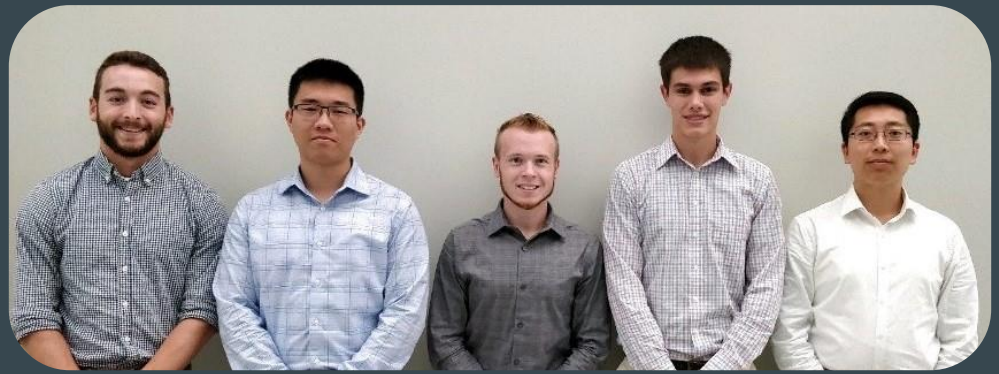
WCP09 ABLS Team Personnel

Team Members (Left to Right):

- Jonathan Felder - ME - Logistics Manager
- Joseph Bourque - EE - Systems Engineer
- Ethan Terwilliger - EE - Finance Manager
- Haosen Zheng - CoE - Project Manager
- Henry Chen - CoE - Integration and Test Manager

Team Advisors:

- Sponsor: Lockheed Martin
- Industry Mentor: Alfredo Iturralde
- Faculty Advisor: Professor Jack Maynard



WCP09 ABLS Agenda

- Executive Overview
- Problem Definition
- Design Description
- Risk Analysis
- Project Finances
- Project Schedule
- Conclusion

WCP09 ABLS Executive Overview

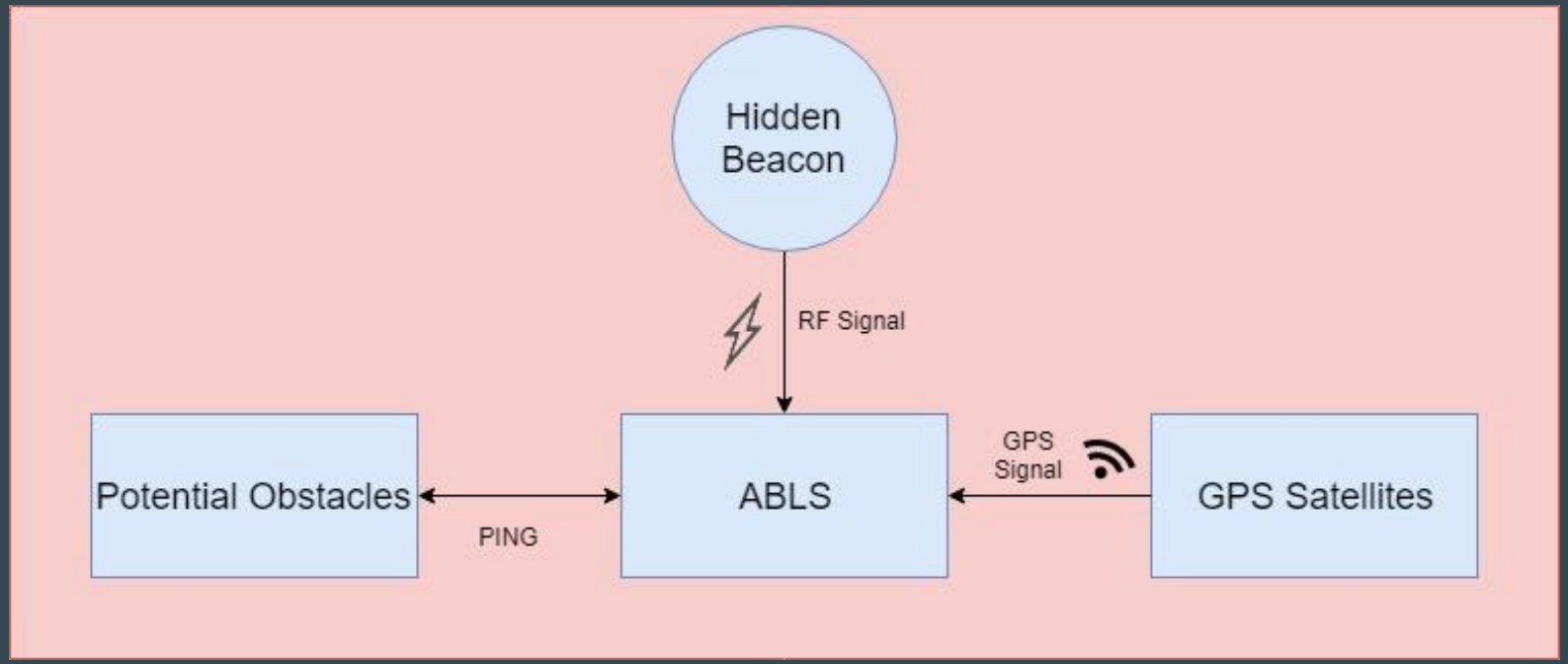
- Proof of concept project
- Hypothetical Scenario
  - High volume of lost hikers
  - Limited park services personnel
  - Autonomous solution desired to find hikers
  - Location is a park near Binghamton, New York

WCP09 ABLS Problem Definition

Park services request a system that includes a beacon, a base station, and a semi-autonomous vehicle that will map the route to the signaling beacon to aid in future rescue operations.

The ABLS solution is to create an semi-autonomous ground based vehicle that will relay first person video and GPS data to a base station to map the route to the beacon.

WCP09 ABLS Context Diagram



WCP09 ABLS Key Customer Requirements

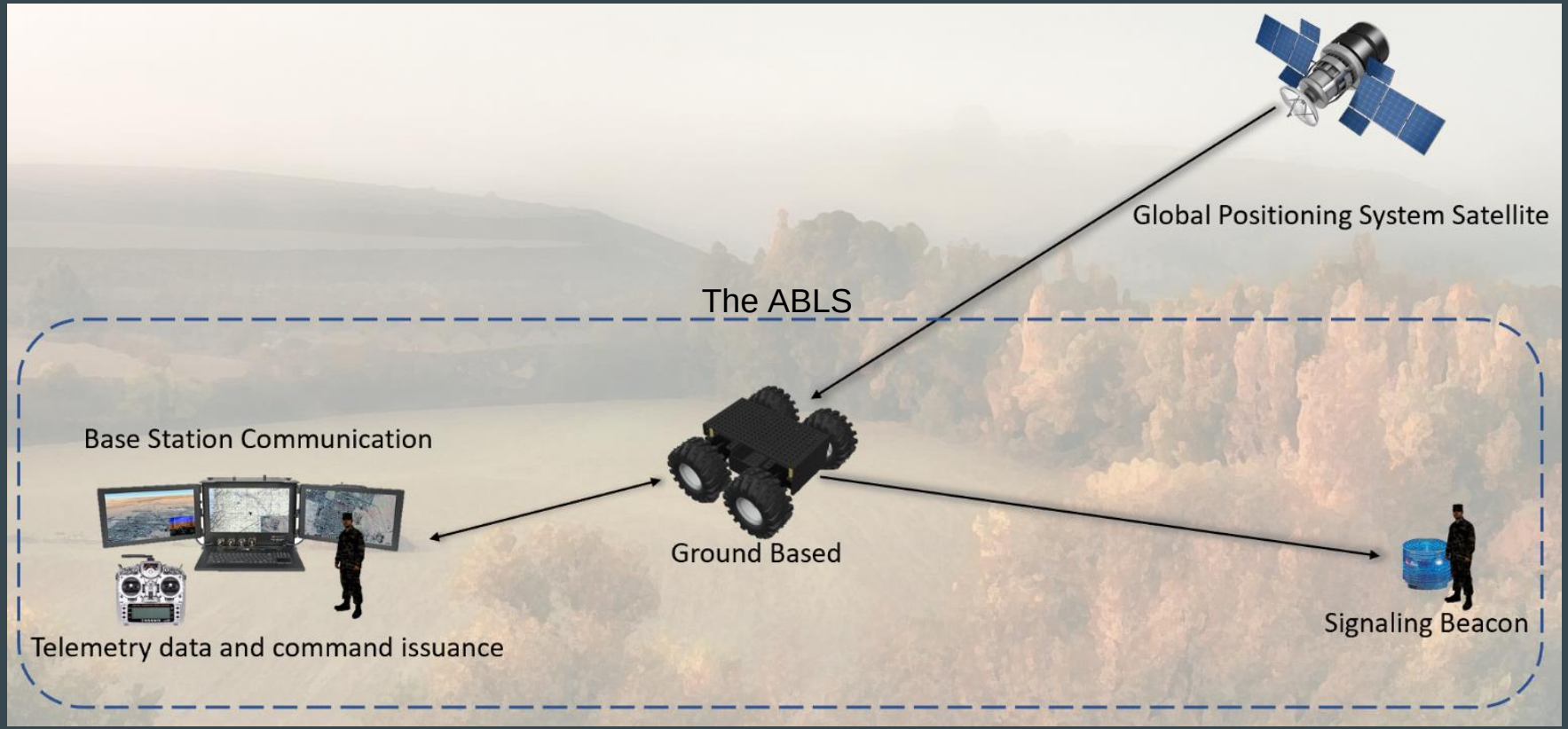
- Shall be autonomous ground-based or air-based vehicle
- Shall be capable of locating a signaling beacon
- Shall display telemetry data:
  - Distance traveled
  - Direction and speed
  - Battery life
- Shall navigate around obstacles, handle various terrains
- Shall comply with FCC/FAA regulations
- Shall have 20+ minute run time

- Shall provide operator and safety manual

WCP09 ABLS Key Derived Requirements

- Shall have remote control override
  - Trace: Shall be autonomous
- Shall have low battery warning
  - Trace: Shall run for 20 minutes
- Shall require amateur radio license to operate
  - Trace: Operator shall obtain amateur radio license
- Vehicle shall have emergency off switch

WCP09 ABLS Concept of Operations



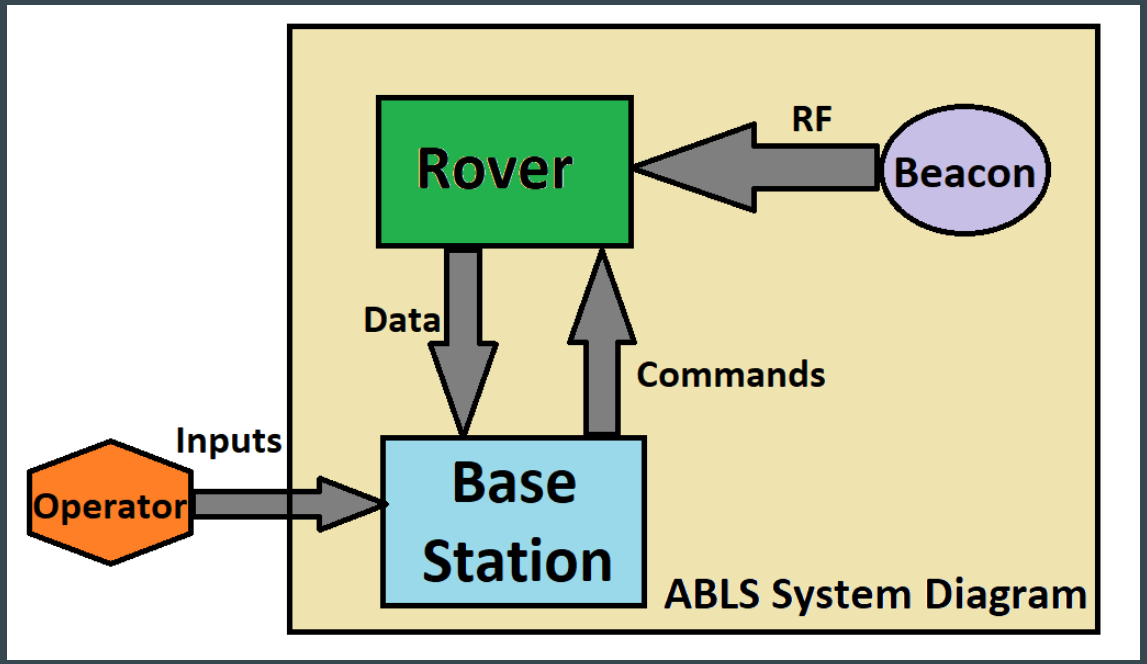
WCP09 ABLS Proposed Design

- Rover selected due to less risk
  - Do not have to comply with FAA rules/regulations
  - Do not have to worry about air obstacles
  - Easier to control if needed
- Computer/electrical engineers have experience with rovers
- Rover design is more cost effective to implement
  - Do not have to worry about replacement parts

WCP09 ABLS System Diagram

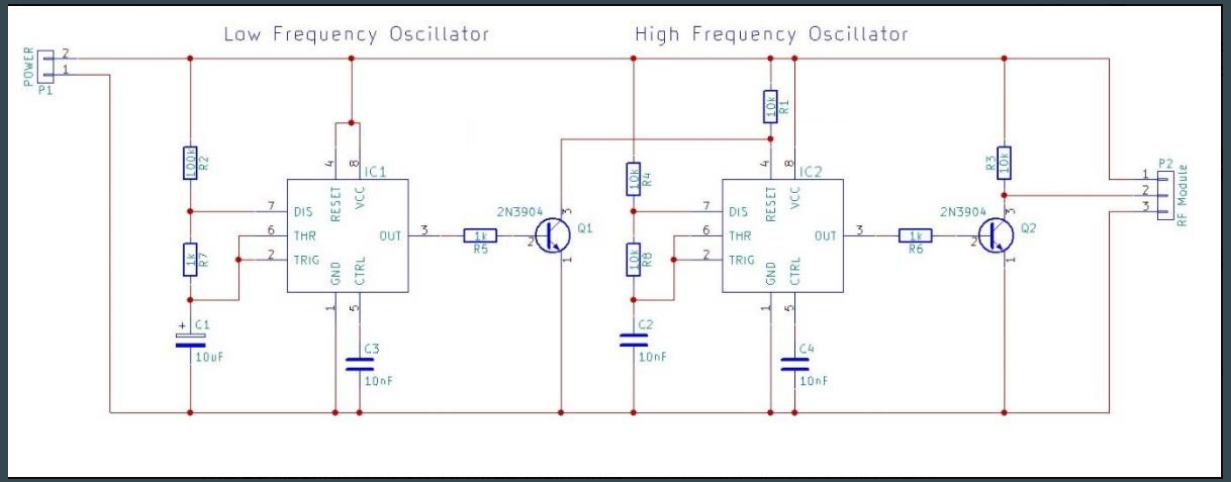
- 3 large subsystems

- Communication with transmit and receive modules



WCP09 ABLS Beacon Design

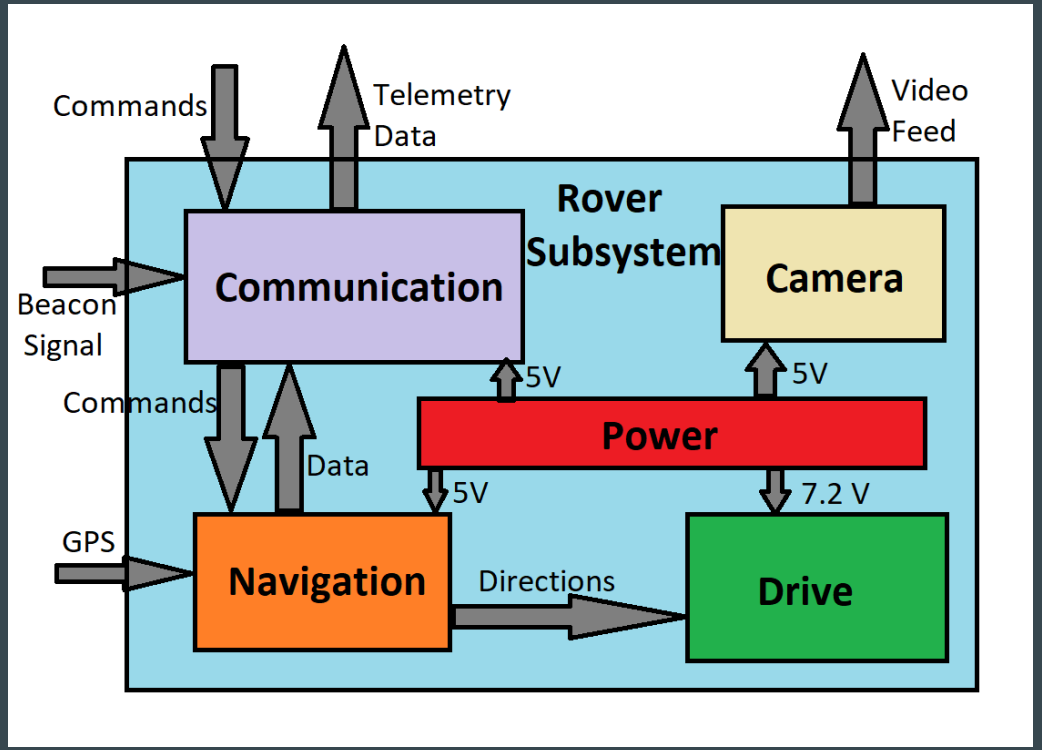
- Two solutions
  - 555 timer circuit
  - Raspberry Pi Zero with RF transmitter module



https://www.hackster.io/diy-hacking/rf-beacon-how-to-build-a-433-mhz-rf-transmitter-187a7b

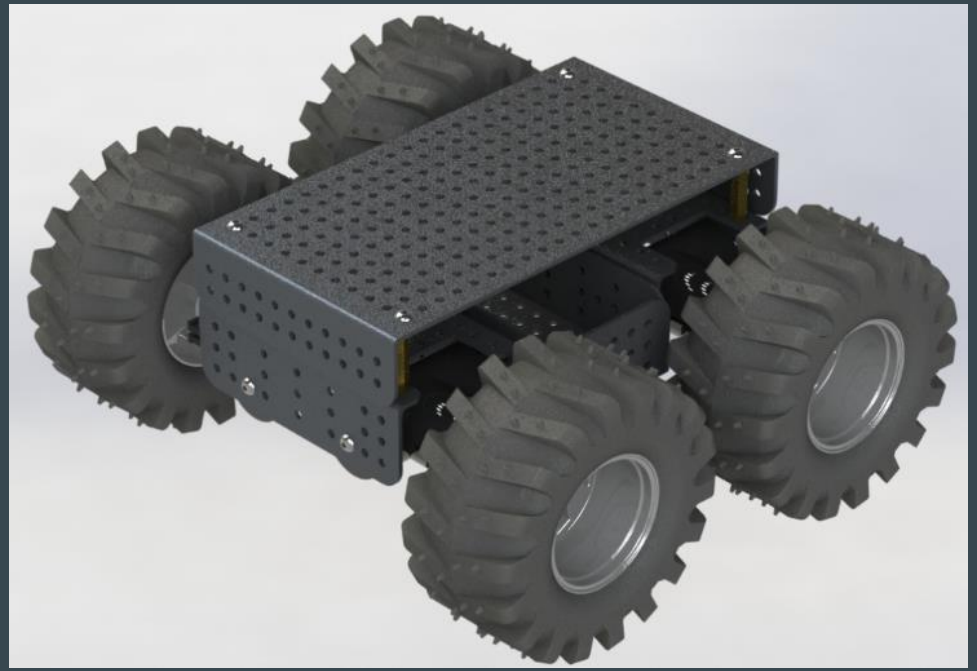
WCP09 ABLS Rover System Diagram

- Self navigation
- Circuitry enclosed in plastic casing



WCP09 ABLS Rover Chassis

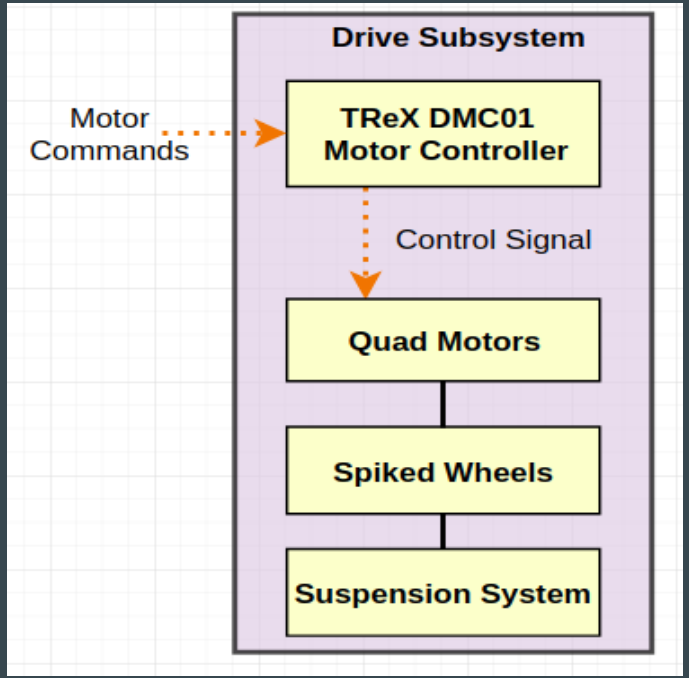
- Size: 11" × 12" × 5"
- Weight: 4.1 lb
- Ground clearance: 2.5"



https://grabcad.com/library/dagu-wild-thumper-4wd-chassis-1

WCP09 ABLS Drive Subsystem

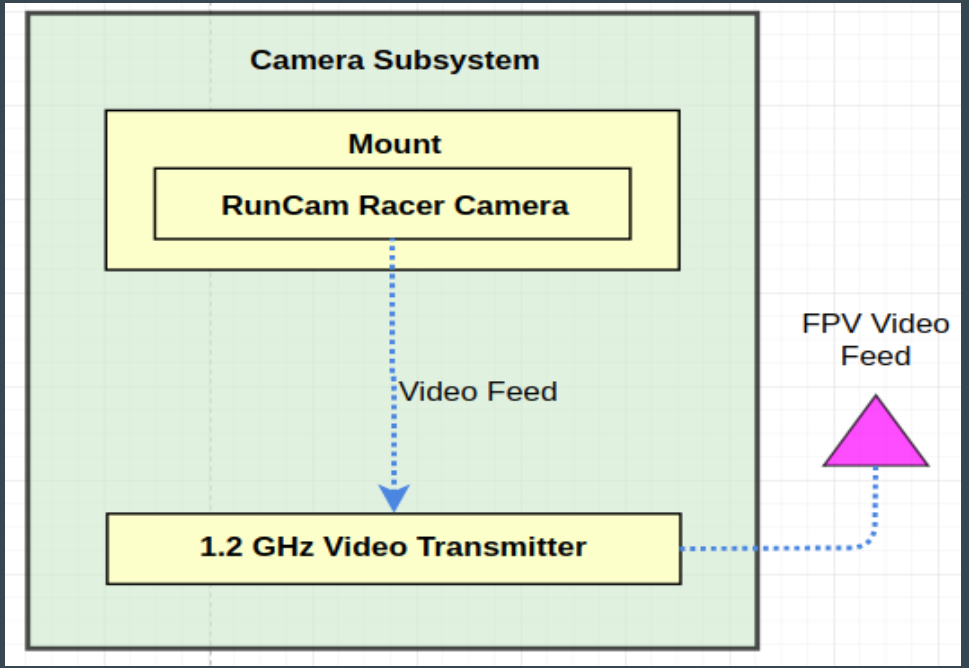
- Rover comes with motors, wheels and suspension system
- Motor Controller interfaces between commands and signals



WCP09 ABLS Camera Subsystem

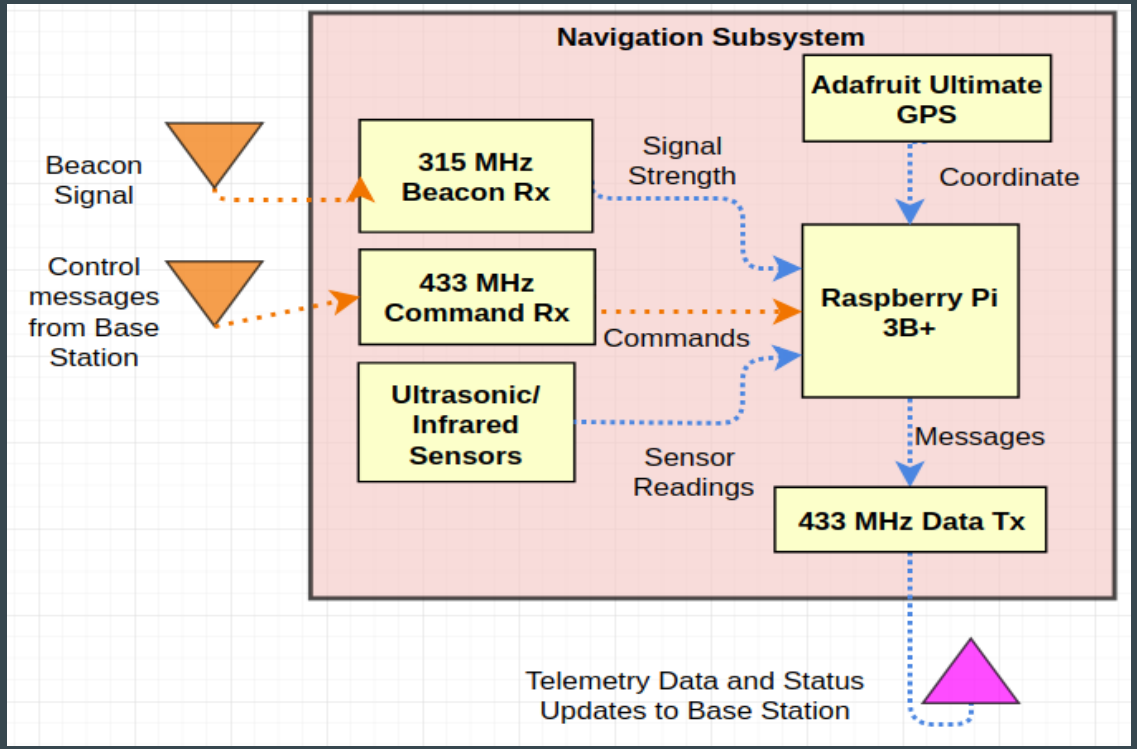
- Video feed transmits directly to base station

- Uses 1.2 GHz Transmitter



WCP09 ABLS Navigation Subsystem

- Obstacle avoidance
- Infrared for obstacles
- Ultrasonics for water
- Angle sensors to see holes and cliffs

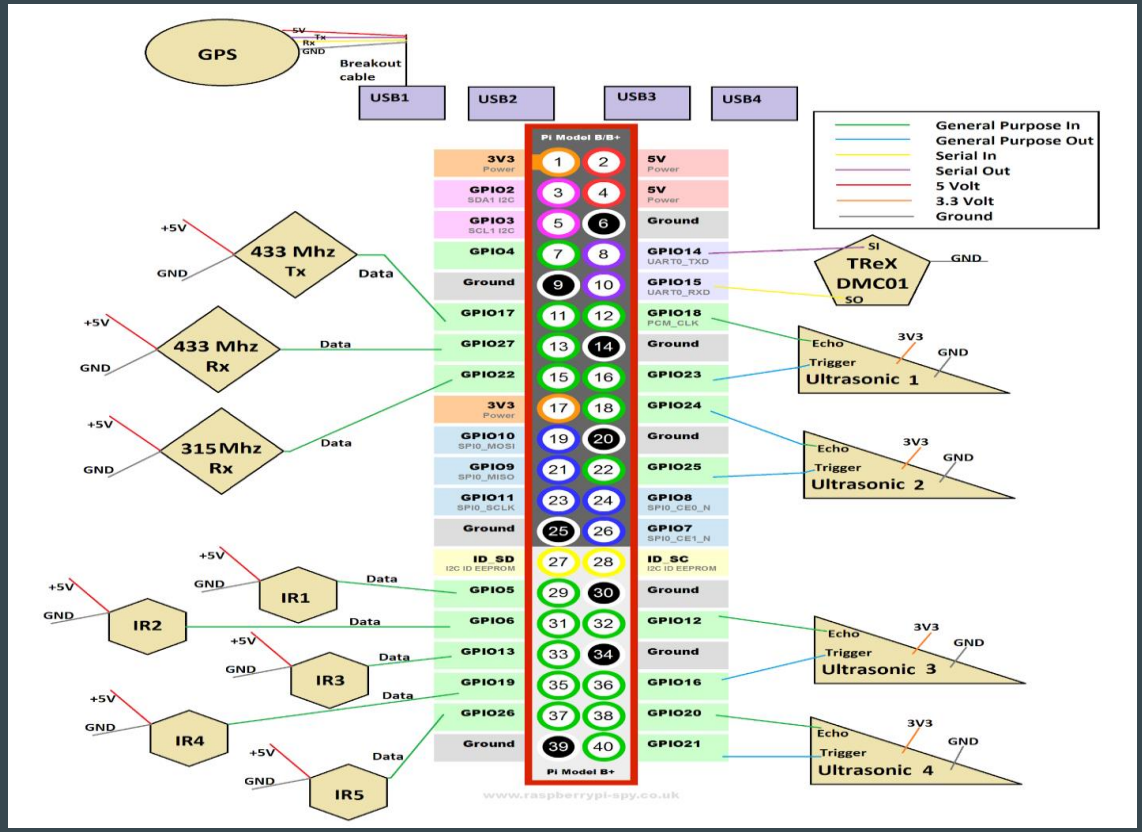


WCP09 ABLS Interface Matrix - Navigation

Communication	Navigation	Base Station	Power	Camera/ Video	Drive	Messages	Description	Type/Unit(?)	Value Range
X					X	Motor Command	According to the Motor Controller Instruction set, the motor command should be one byte in length.		
X		X				Beacon signal Strength	Signal Strength of the Beacon	Categorical	
X		X				Beacon Direction	Direction of the beacon relative to our vehicle	Categorical	to the east/ north east/south etc
X					X	Motor Speed	As specified in Motor Controller Instruction set		

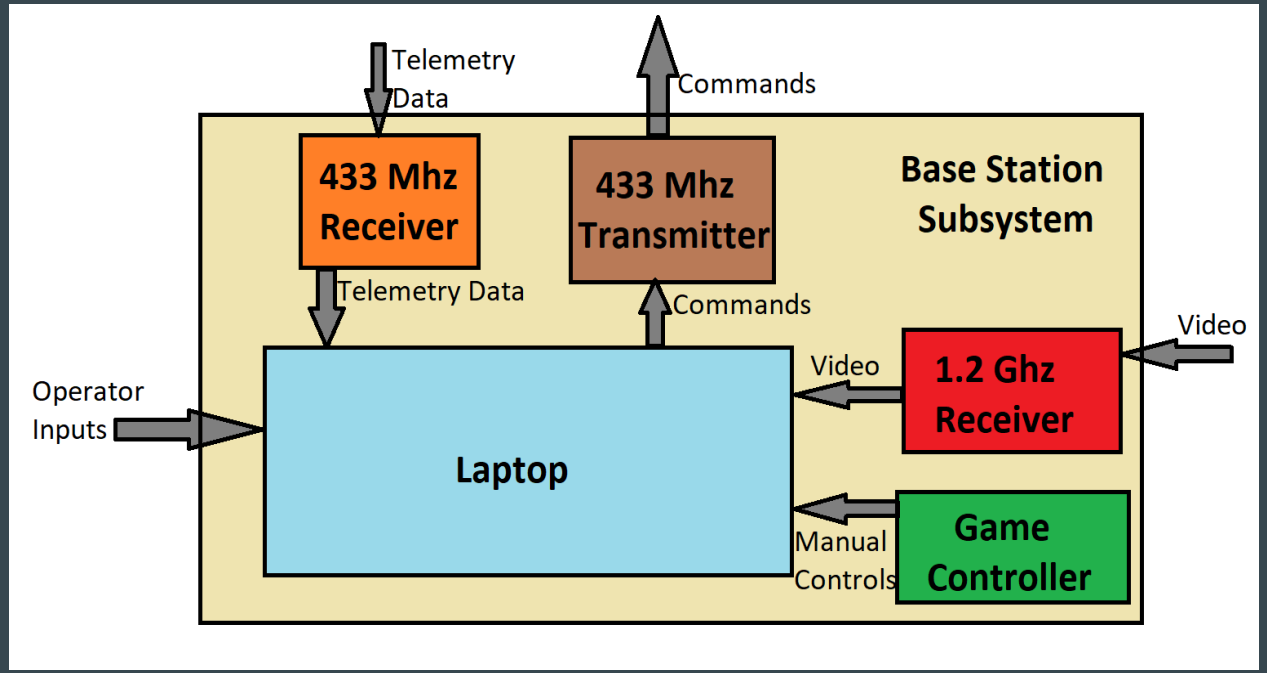
- Interface matrices created for other subsystems

WCP09 ABLS Raspberry Pi Connection Diagram

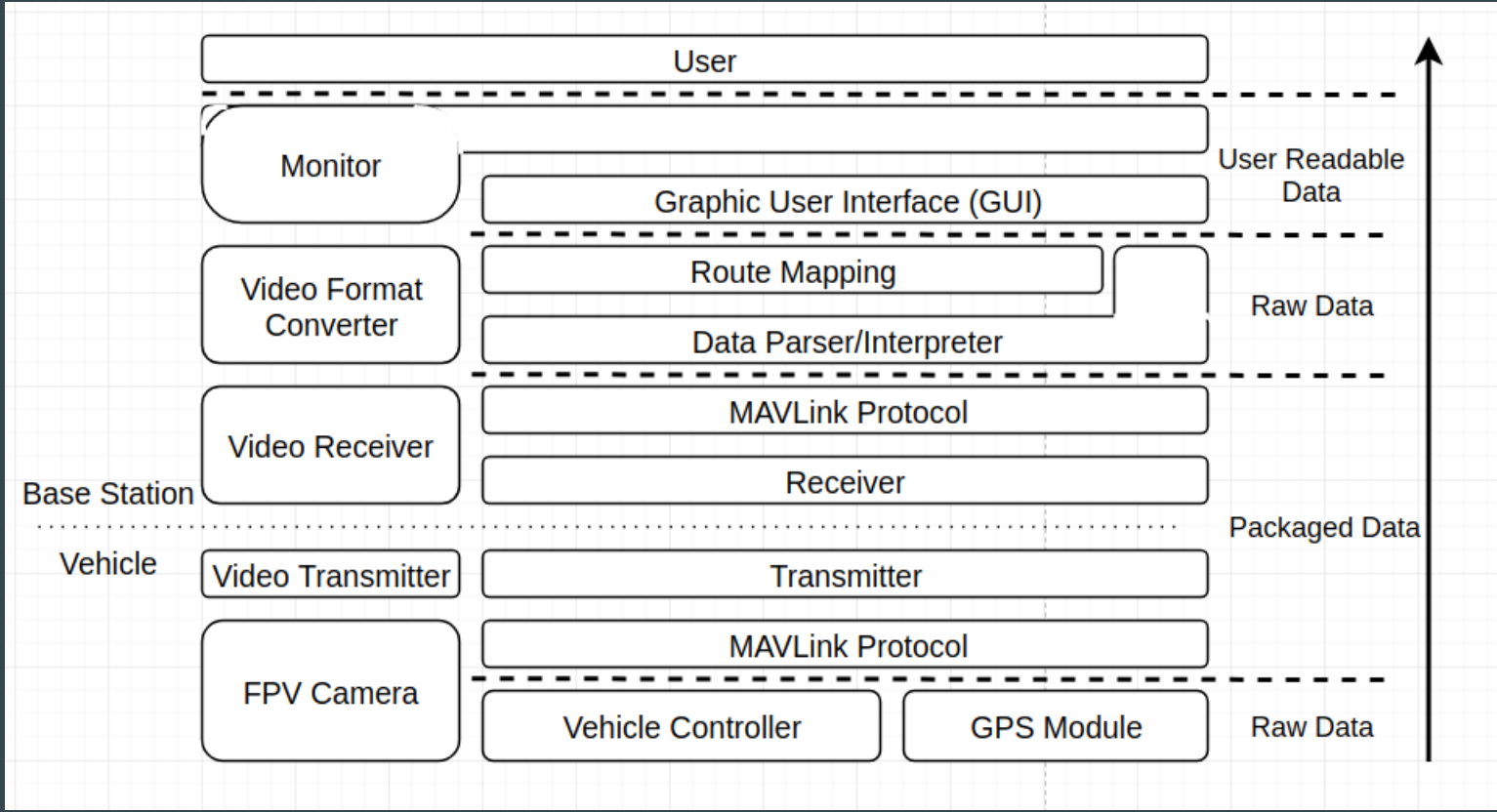


WCP09 Base Station System Diagram

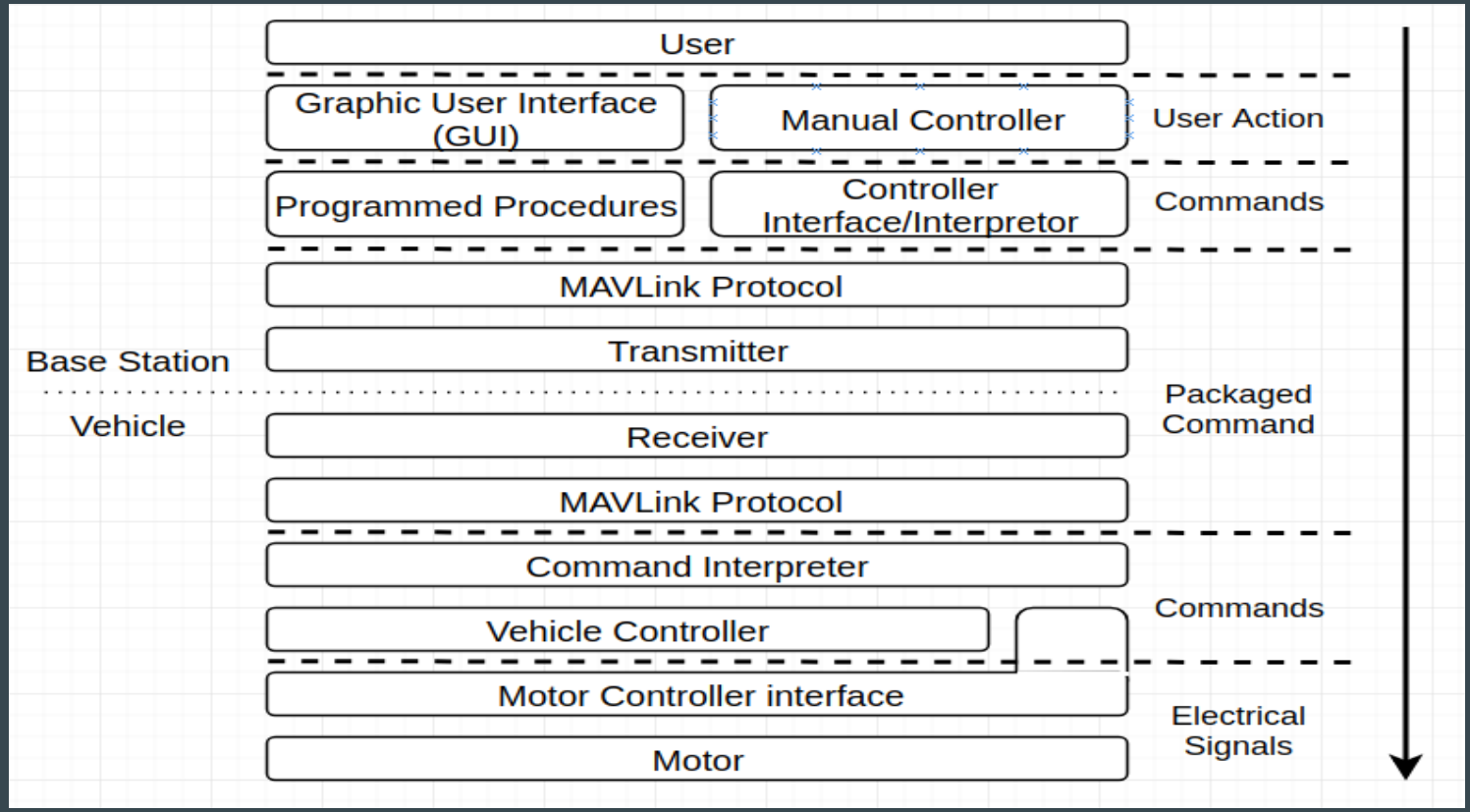
- Based off of Laptop
- 433 Mhz Receiver
- 433 Mhz Transmitter
- 1.2 Ghz Video Receiver
- Game Controller



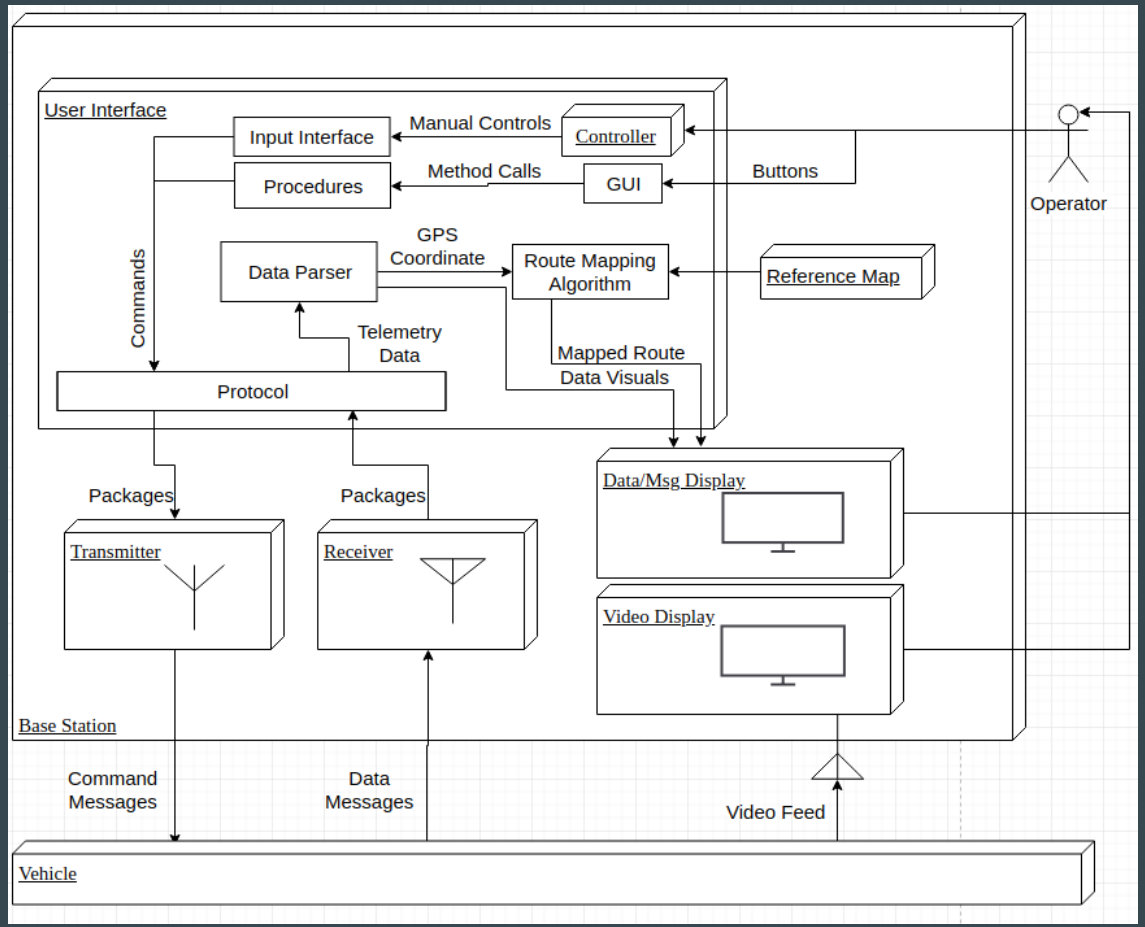
WCP09 ABLS Data Layers



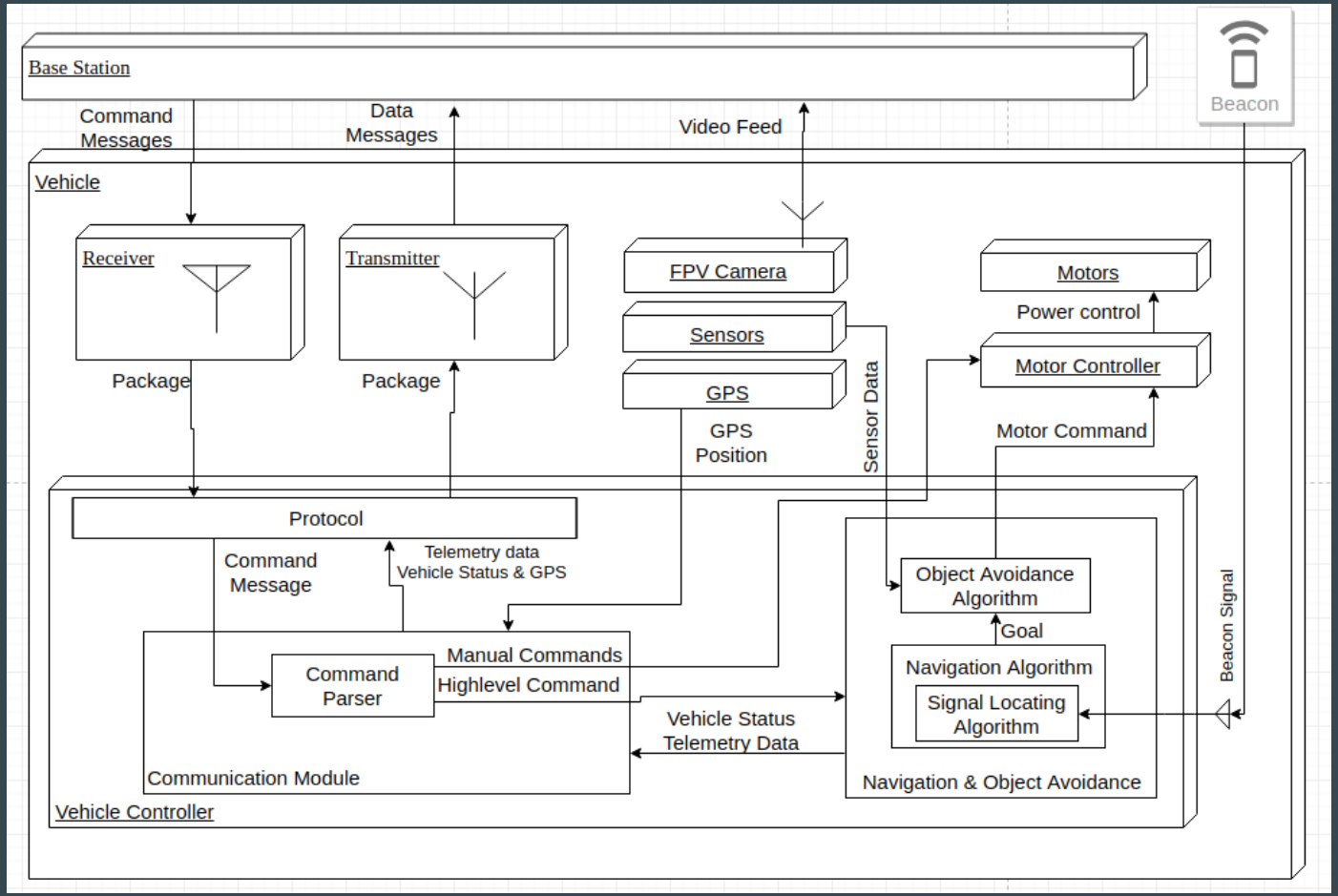
WCP09 ABLS Command Layer



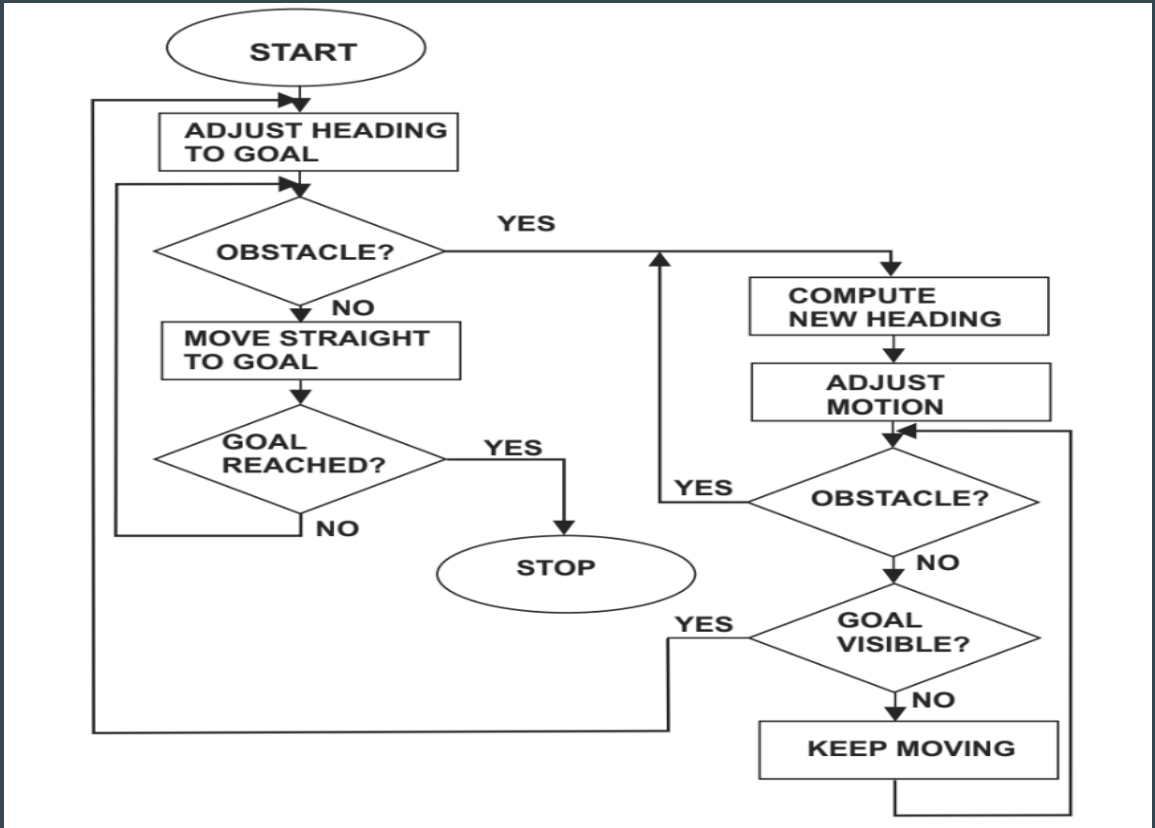
WCP09 ABLS Software Block Diagram



WCP09 ABLS Software Block Diagram cont.

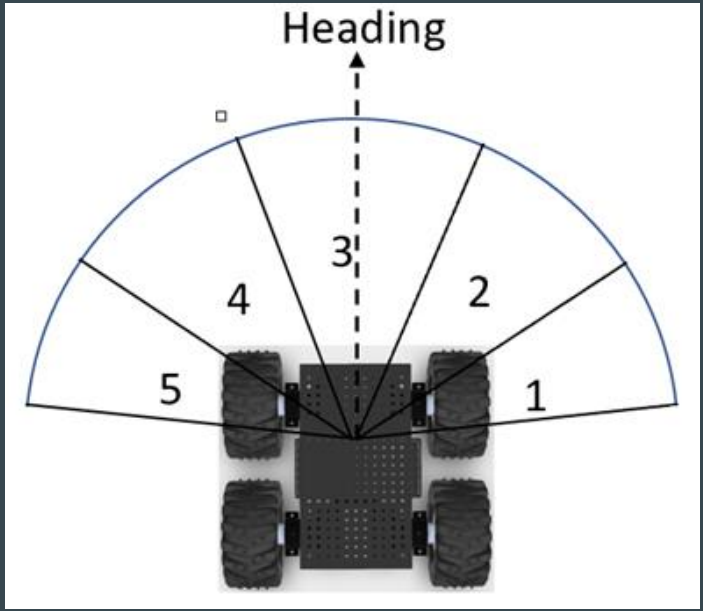


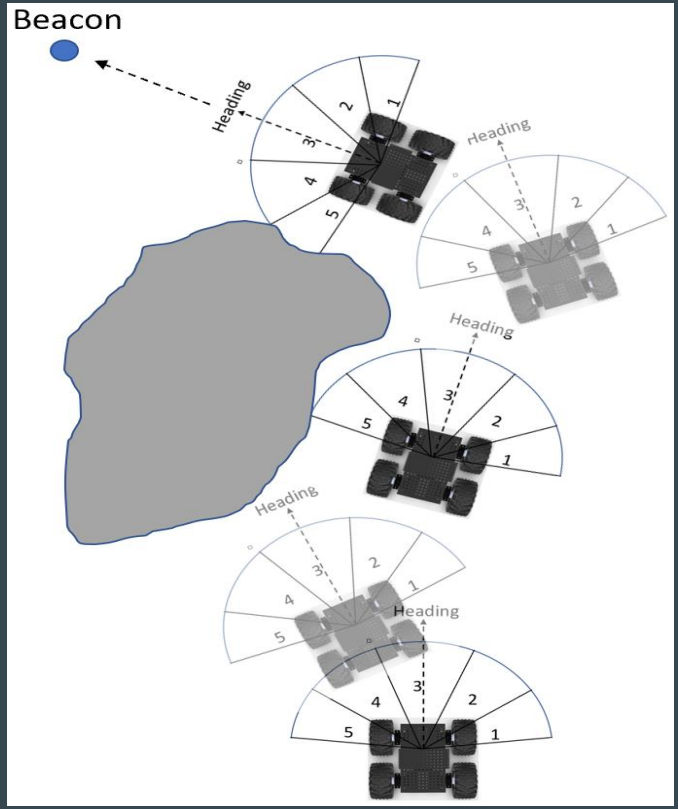
WCP09 ABLS Obstacle Avoidance Algorithm



https://pdfs.semanticscholar.org/519e/790c8477cfb1d1a176e220f010d5ec5b1481.pdf

WCP09 ABLS Obstacle Avoidance Algorithm





WCP09 ABLS Risk Analysis

Risk#:	Risk:	Impact:	Probability:	Reduction Strategy:
M-01	Weather makes vehicle difficult to operate	High	Medium	Test on different day, travel to other location
M-06	Detectors give inaccurate outliers	High	Medium	Detect running average
M-08	Inaccurate telemetry data reported	Very high	Medium	Ensure vehicle is calibrated, test in controlled environment
M-11	Vehicle loses connection with base station	Very high	Medium	Vehicle will stop when connection lost
M-12	Terrain makes vehicle difficult to operate	High	Medium	Choose different path

WCP09 ABLS Risk Analysis Matrix

Probability							
	90%	Very High					
	70%	High					
	50%	Medium		M-07	M-03,M-04,M-09, M-10,M-13	M-01, M-06, M-12	M-08,M-11
	30%	Low		P-01	M-02,P-03	M-14,P-02	
	10%	Very Low			M-05		
			Very Low	Low	Medium	High	Very High
			5%	10%	20%	40%	80%
			Impact (as % of Project)				

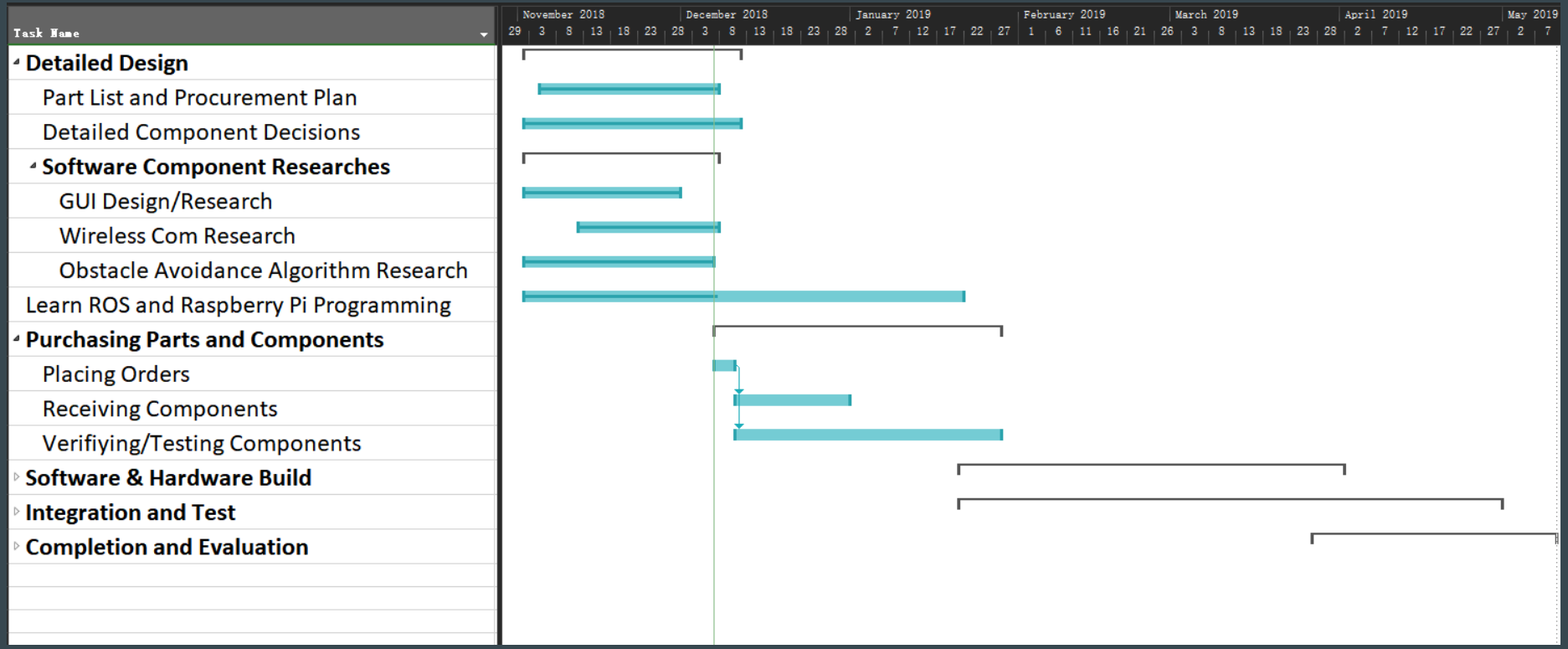
WCP09 ABLS Reduced Risk Analysis Matrix

Probability							
	90%	Very High					
	70%	High					
	50%	Medium			M-06		
	30%	Low		M-01, M-07,M-09, M-10,P-03	M-03,M-04, M-12, M-13, M-14	M-08	M-11
	10%	Very Low		P-01, M-02,M-05		P-02	
			Very Low	Low	Medium	High	Very High
			5%	10%	20%	40%	80%
			Impact (as % of Project)				

WCP09 ABLS Budget

Items	Original Estimate $	Actuals to Date $	Estimate to Completion $	Estimate at Completion $
Dagu Rover 4WD	175	0	175	175
FPV Camera	35	0	35	35
RF Tx and Rx	70	0	70	70
Raspberry Pi	40	0	40	40
GPS/Sensors	60	0	60	60
Motor Controller	100	0	100	100
Batteries	45	0	45	45
Amateur Radio License	30	0	30	30
Misc.	100	0	100	100
Subtotal:	**655**	**0**	**655**	**655**
Minimum Reserve:	95		Current Reserve:	95
Funding Limit:	750			750

WCP09 ABLS Schedule

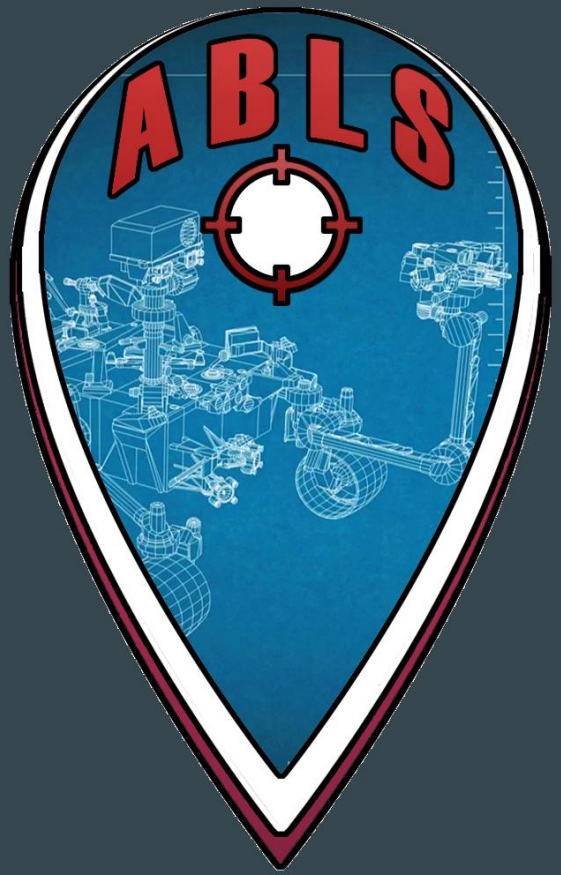


WCP09 ABLS Foreseen Challenges

- Obstacle Avoidance Algorithm
- Communications Protocols
- Outdoor Testing
- Beacon Design
- Assembly

WCP09 ABLS Summary

- Integration project
  - Few components to design and build
  - Research for trade studies
  - Integrate existing tested parts
    - Code libraries
    - Motor controller, transmitter and receiver circuits
  - Uniquely customize to fit customer needs
- Under budget and on schedule
- On track to meet all requirements


ABLS

WCP09 ABLS Bill of Materials

Part Desc.	Place of Purchase	Part Name:	Part #	Quantity:	Price:	Total Price:	Expected Order Date:	Expected Delivery Date:
Rover Chassis	pololu.com	Dagu Wild Thumper 4WD, 75:1	1566	1	$ 174.95	$ 174.95	12/7/18	1/7/19
Motor Controller	pololu.com	Pololu TReX Dual Motor Controller DMC01	777	1	$ 99.95	$ 99.95	12/7/18	1/7/19
Batteries	Hobbyking.com	Turnigy Stick Pack Sub-C 3000mAh 7.2v NiMH High	9440000002	2	$ 14.23	$ 28.46	12/7/18	1/7/19
Battery Charger	"	Turnigy B6 PRO 50W 6A Balance Charger	9070000041-0	1	$ 13.99	$ 13.99	12/7/18	1/7/19
Motors	N/A	comes with dagu	1566			$ -	12/7/18	1/7/19
Tires	N/A	comes with dagu	1566			$ -	12/7/18	1/7/19
ESC	N/A	comes with TReX motor controller	777			$ -	12/7/18	1/7/19
Radio Transmitter/Receiver(Beacon)	amazon.com	HiLetgo 315Mhz RF Transmitter and Receiver		1	$ 4.69	$ 4.69	12/7/18	1/7/19
Radio Transmitter/Receiver(Vehicle Co	amazon.com	WINGONEER 433Mhz RF Transmitter and Receiver		2	$ 5.99	$ 11.98	12/7/18	1/7/19
FPV Camera	amazon.com	Runcam Racer Micro		1	$ 36.75	$ 36.75	12/7/18	1/7/19
Raspberry pi cpu	amazon.com	Raspberry Pi 3b+		1	$ 38.90	$ 38.90	12/7/18	1/7/19
USB to TTL	amazon.com	HiLetgo USB to TTL Serial Cable		1	$ 5.19	$ 5.19	12/7/18	1/7/19
Antenna for Beacon	amazon.com	315Mhz-470Mhz Omnidirectional Antenna		1	$ 8.98	$ 8.98	12/7/18	1/7/19
Micro SD Card for Rasp PI	amazon.com	16 GB Micro SD card		1	$ 3.99	$ 3.99	12/7/18	1/7/19
FPV transmitter/receiver	aliexpress.com	1.2G TX1000 1W 1500mW 8CH Transmitter		1	$ 56.31	$ 56.31	12/7/18	1/7/19
IR Sensor	aliexpress.com	Infrared Obstacle Avoidance Sensor Module		10	$ 0.38	$ 3.80	12/7/18	1/7/19
GPS	adafruit.com	Adafruit Ultimate GPS Breakout	746	1	$ 39.95	$ 39.95	12/7/18	1/7/19
Ultrasonic Sensors	digikey.com	SparkFun Electronics Ultrasonic Sensor HC-SR04	SEN-13959	4	$ 3.95	$ 15.80	12/7/18	1/7/19
steel screw	mcmaster.com	18-8 Stainless Steel Socket Head Screw	92196A051	1	$ 6.73	$ 6.73	12/7/18	1/7/19
					Total Amount:	$ 550.42		

WCP09 ABLS Mission Risk Analysis

Risk#:	Mission Risk	Impact:	Probability:	Reduction Strategy:
M-01	Weather makes vehicle difficult to operate	High	Medium	Test on different day
M-02	Signal is intercepted	Medium	Low	Encrypt signal
M-03	Water seeps into vehicle	Medium	Medium	Cover all parts
M-04	Signal interference	Medium	Medium	Choose higher frequency
M-05	Animal interference	Medium	Very low	Operator override
M-06	Detectors give inaccurate outliers	High	Medium	Detect running average

WCP09 ABLS Mission Risk Analysis (cont.)

Risk#:	Mission Risk:	Impact:	Probability:	Reduction Strategy:
M-07	Vehicle gets stuck in algorithm	Low	Medium	Operator override
M-08	Inaccurate telemetry data reported	Very high	Medium	Ensure vehicle is calibrated
M-09	Requires too much operator input	Medium	Medium	Preliminary testing
M-10	Battery dies	Medium	Medium	Spare battery
M-11	Vehicle loses connection with base station	Very high	Medium	Vehicle will stop when connection lost
M-12	Terrain makes vehicle difficult to operate	High	Medium	Choose different path
M-13	Tires stuck in ground	Medium	Medium	Operator override
M-14	Tires lose air	High	Low	Spare tire

WCP09 ABLS Project Risk Analysis

Risk#:	Project Risk	Impact:	Probability:	Reduction Strategy:
P-01	Costs go over budget	Low	Low	Plan parts list before purchases
P-02	Takes place within 1 mile of FCC facility	High	Low	Research test location
P-03	Purchased Non-functional Component	Medium	Medium	Test component before integration

WCP09 ABLS Interface Matrix - Communication

Communication	Navigation	Base Station	Power	Camera/ Video	Drive	Messages	Description	Type/Unit(?)	Value Range
	X					Motor Override Command	According to the Motor Controller Instruction set, the motor command should be a byte in length.		
		X				Status Message	Status update of the rover, expected to include its operating mod, Vehicle status, etc		
		X				Operation Mode	Flag that indicates the mode of operation that the vehicle is currently in. Autonomous and Manual	Categorical	Autonomous Manual
		X				Vehicle status	A few bits that indicates the current status of the vehicle.	Categorical	Operating Immobilized Awaiting Instructions Suspended
		X				Battery status	Indicates the estimated battery life	Categorical	High, Medium, Low, Very Low

WCP09 ABLS Interface Matrix - Communication (cont.)

Communication	Navigation	Base Station	Power	Camera/ Video	Drive	Messages	Description	Type/Unit(?)	Value Range
		X				Vehicle Position	A GPS Coordinates indicates the location of the vehicle		
		X				Orientation	Orientation that the vehicle is facing	Categorical	N, NW, W, etc
		X				Beacon signal Strength	Signal Strength of the Beacon	Categorical	
		X				Beacon Direction	Direction of the beacon relative to our vehicle	Categorical	to the east/ north east/south etc
		X			X	Vehicle Speed	The speed of the vehicle based on the GPS postiion	Numeric	0 - 2 mph

WCP09 ABLS Interface Matrix - Camera/Video

Communication	Navigation	Base Station	Power	Camera/ Video	Drive	Messages	Description	Type/Unit	Value Range
		X				Video feed	FPV video feed	Analog	

WCP09 ABLS Interface Matrix - Drive

Communication	Navigation	Base Station	Power	Camera /Video	Drive	Messages	Description	Type/Unit	Value Range
X	X					Motor Command	According to the Motor Controller Instruction set, the drive system will return some specified information		

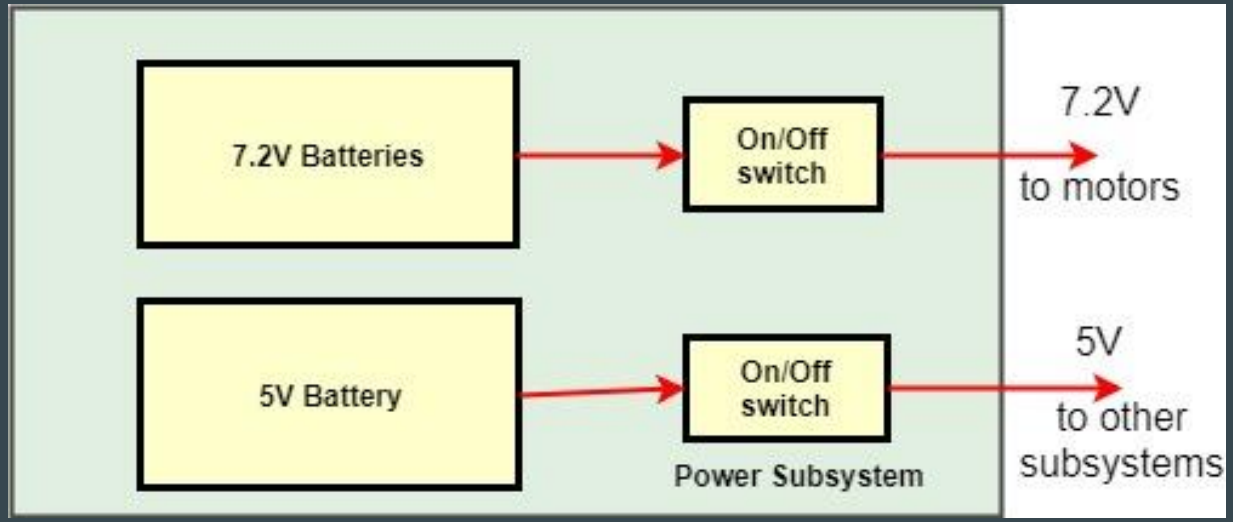
WCP09 ABLS Interface Matrix - Power

Communication	Navigation	Base Station	Power	Camera/Video	Drive	Messages	Description	Unit	Value Range
X	X					Battery Life	Percentage battery life remaining on the rover	Percentage	0%-100%
X	X			X	X	Voltage	Voltage needed to power devices	Volts	0 - 7.2

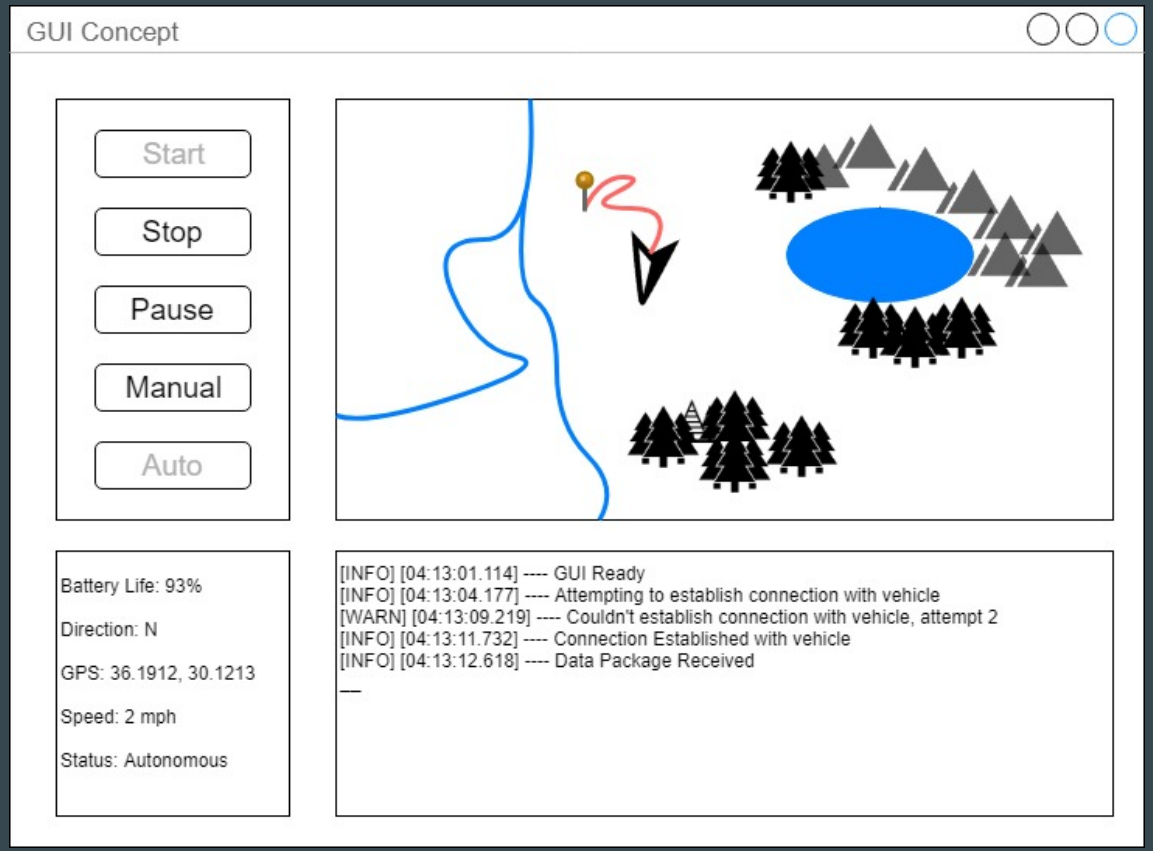
WCP09 ABLS Interface Matrix - Base Station

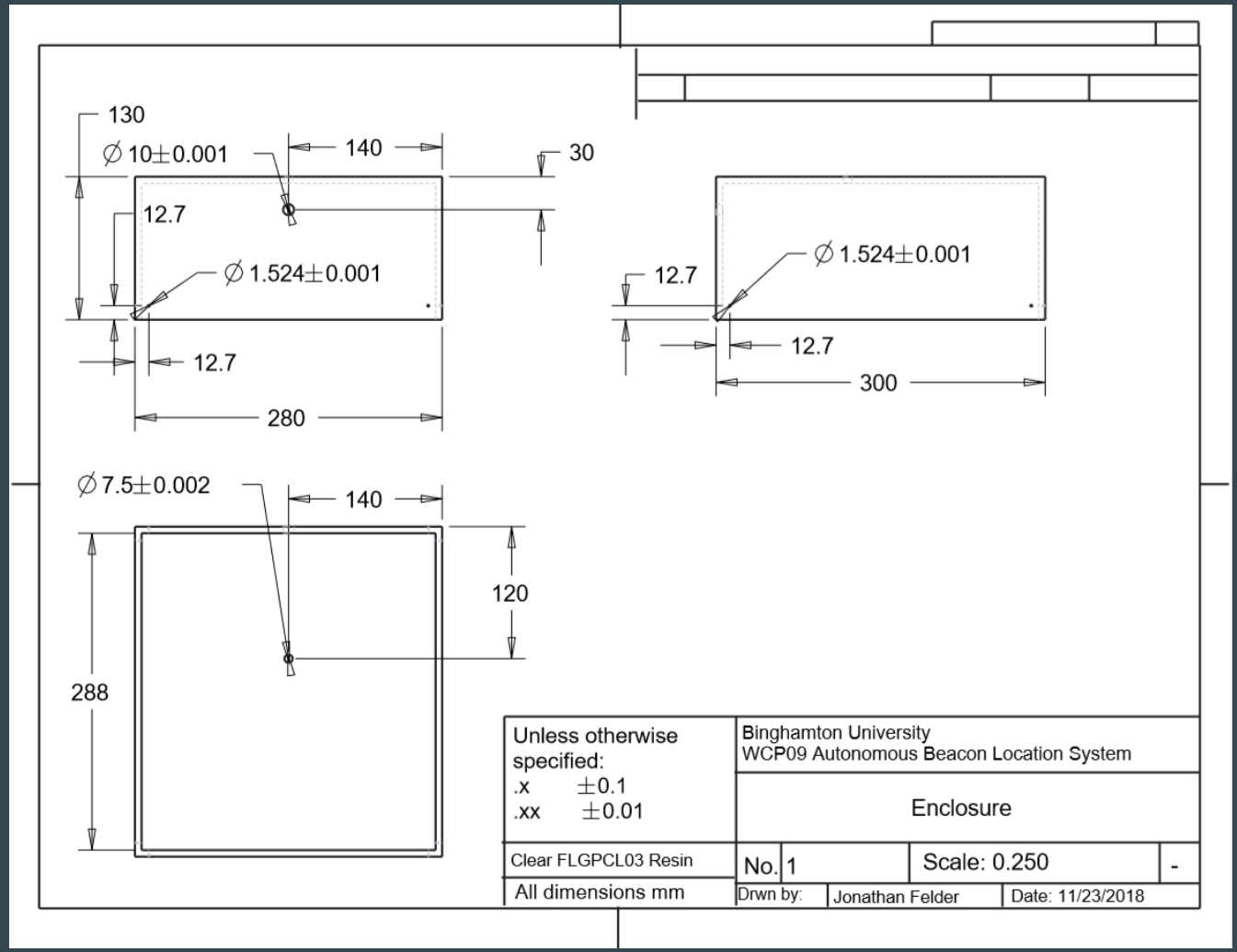
Communication	Navigation	Base Station	Power	Camera /Video	Drive	Messages	Description	Type/Unit	Value Range
X	X				X	Commands	High level commands sent to the vehicle controller	Categorical	Start Stop Autopilot mode Manual mode Shutdown
X	X				X	Controller input, throttle	Input from the Operator's controller indicating how fast the motor would run	Numeric	0.0 - 1.0
X	X				X	Controller input, Turns	Input from the Operator's controller indicating directions the vehicle will turn to	(direction of turning, duration of turn)	

WCP09 ABLS Power Subsystem



WCP09 ABLS GUI Concept

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∅10±0.001
140
30
12.7
∅1.524±0.001
12.7
280
12.7
∅1.524±0.001
12.7
300
∅7.5±0.002
140
120
288
Unless otherwise specified:
.x ±0.1
.xx ±0.01
Clear FLGPCL03 Resin
All dimensions mm
Binghamton University
WCP09 Autonomous Beacon Location System
Enclosure
No. 1
Scale: 0.250
-
Drwn by: Jonathan Felder
Date: 11/23/2018