Automated Rescue Vehicle
(A.R.V)

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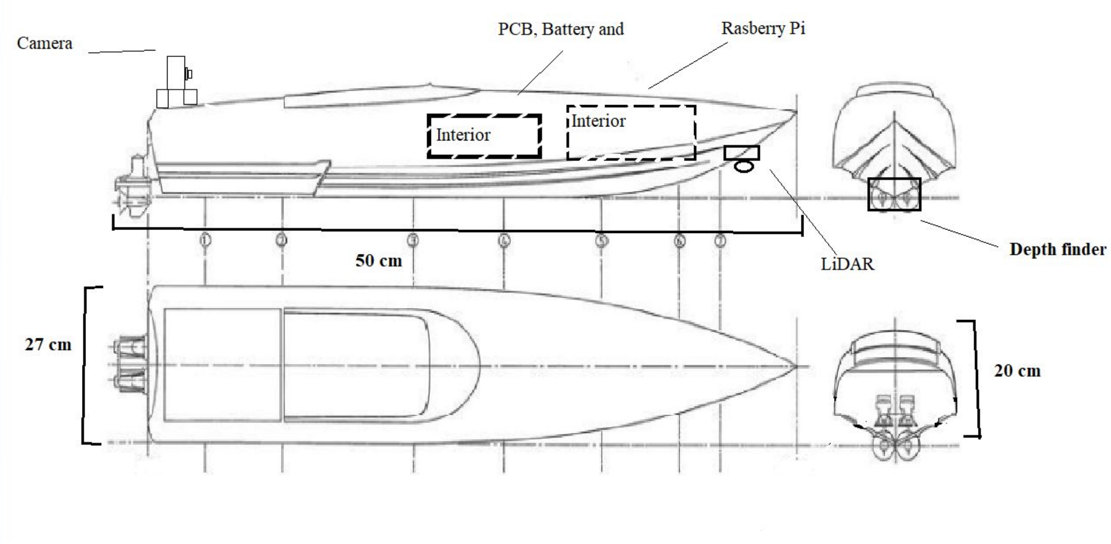
Motivation

- The increasing capabilities, but constant risks in ocean exploration
- Human dependence on large water sources
- Provide an independent device to assist in ocean search and rescue, following shipwrecks or passengers overboard
- The enormous difficulty in finding survivors or wreckage amid rapidly changing conditions
- Autonomous operation to allow for the operator to remain contributing to the search efforts, alongside the A.R.V.

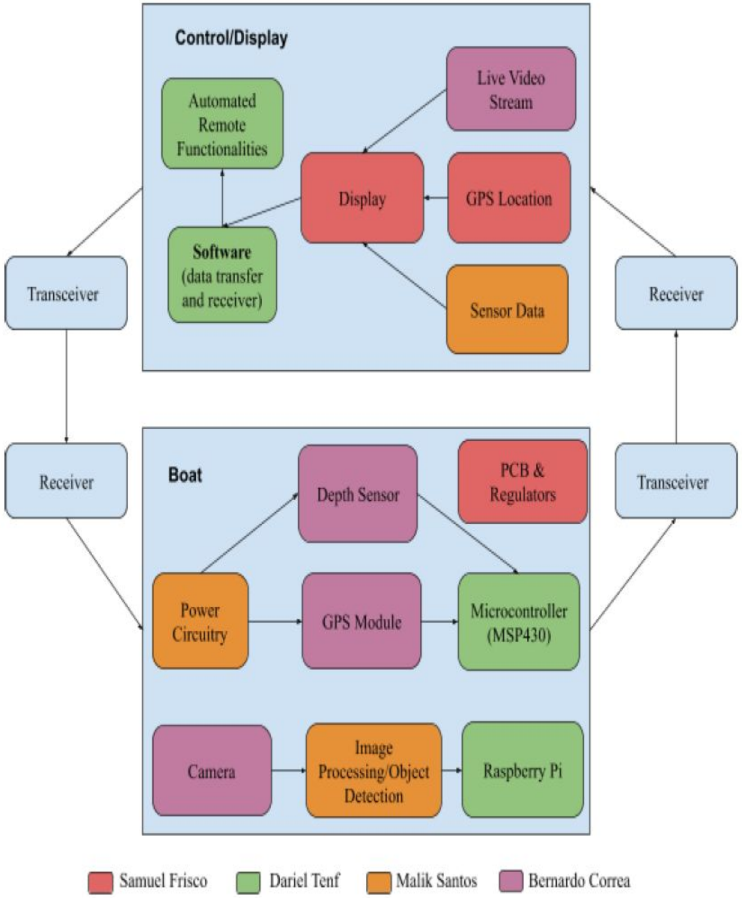
Goals and Objectives

- Provide an additional set of eyes in search and rescue, while minimizing human intervention, but allowing it when circumstances demand it
- Report a degree of certainty that the A.R.V. is in fact sees a person or wreckage
- Differentiate between people and debris, rocks, marine life, buoys, etc
- Once a specified degree of certainty is met, travel to the detected survivor autonomously
- Transmit a constantly updating GPS signal for the operator and rescue team to track

Prototype Illustration



Complete Block Diagram



Requirements

Requirement	Value
Object Detection for a Person	70% assurance
GPS Location Update	<5 seconds
Communication Range	>10 meters
System Runtime	>30 minutes
Speed	<6 miles per hour
Battery Lifetime	>30 minutes
Low Battery Alert	<= 6V

_____: Demonstrable

Specifications

Power Specifications	Tolerance
7.4V 5200mAh Battery Power	±2V
3.3V DC-DC Converter	5V-12V input range
	± 0.1V
3.3V GPS Chip (Locator)	1 - 3%
3.3V Wifi Chip for Wireless Data Transmission	1 - 3%
Dual Motor and H-Bridge	5V -12V Input range
Raspberry Pi & Camera (Image Processing)	5V, 2A - 10% Tolerance

The Boat: Flytec 2011-5

- Lightweight, yet durable ABS plastic construction
- 2-24hour run time, 10-12 hour charge time, 500 meter control distance
- Large size: 50x27x20 cm (height accounting for antenna)
- Ample internal space for additional components
- Sturdy 4 ½ lb weight, yet capable of 3.4 mph (2.95 knots)

Microcontroller Selection

- **MSP430 - sensing, monitoring, GPS**
  - ADC, UART
  - Ultra low power consumption
  - Detailed in PCB section
- **Raspberry Pi 4, Model B - image processing**
  - Object detection via TensorFlow library
  - WiFi communication
  - Implemented in machine learning
  - User friendly, proprietary OS and camera
- **STM32 ARM Cortex M4 - considered for image processing**
  - High power, low RAM (relative to Pi)
  - Fast memory access times (proximity)
  - Less support

Specification	TI MSP430 (Sensor Use)	Raspberry Pi 4 (Image Processing)	STM32
Operating Voltage	1.8-3.6V	5.1V	3.3V
Current Consumption	12.5mA	640mA	117mA
Chip		Cortex A-72 ARMv8	ARM Cortex M4
Clock Frequency		1.5 Ghz	84 -180 MHz
Memory	0.5-512 KB	SD card/external	128KB - 2056KB
RAM	0.125-66KB	2-8GB	32KB - 384KB
I/O Pins	4-100	40	114
Architecture	16-bit	64-bit	32-bit
Dimensions	1.75x1.85 in	2.2x3.35 in	3.27x2.26 in
Weight	0.7 oz	1.5 oz	----

Raspberry Pi 4

- **Raspberry Pi 4, Model B - image processing**
  - Powered via 3.7V LiPo add on battery for portable power
  - Internal protection from battery circuit board
  - Proprietary camera optimized to work with the board
  - Video transmission over WiFi

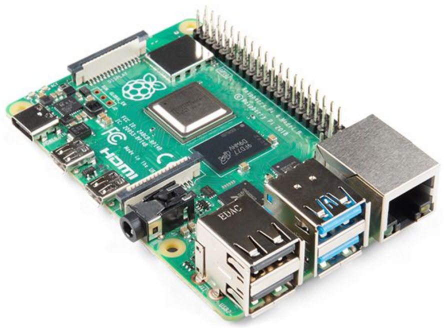
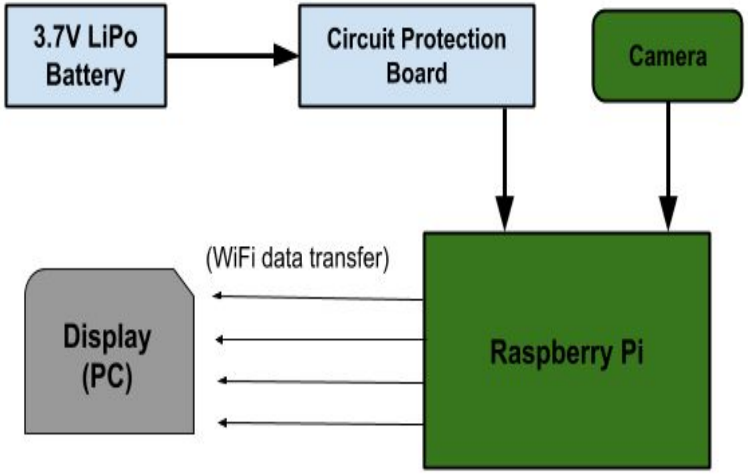


Figure 31: Raspberry Pi Interface Design Block Diagram



Raspberry Pi Camera

- Camera Module V2
  - Maximum 1080p
  - OpenCV and TensorFLow capable
  - Wired connection, easy installation

Feature/Specification	Camera Module v2
Operating Voltage	Regulated by Raspberry Pi Board
Resolution	1080p/1080TVL (high-definition)
Pixel	8 megapixel 3280 x 2464
Weight	3g
Data Transmission	Wired
Connector Type	CSI/Flex Cable
Power/Current Rating	Regulated by Raspberry Pi Board
Cost	$29.95

Battery Selection: Boat Power

- Technologies: LiPo vs NiMH
  - NiMH cheaper, easier to use, longer life
  - LiPo higher maintenance, lighter, more efficient,
- Factory Lithium Ion Polymer battery for the Flytec 2011-5
  - 7.4V 5200mAh, 4 cell
  - Reduction required for ADC implementation (see voltage monitoring)
  - Up to 12 hours run time powering the boat each (24hr total)

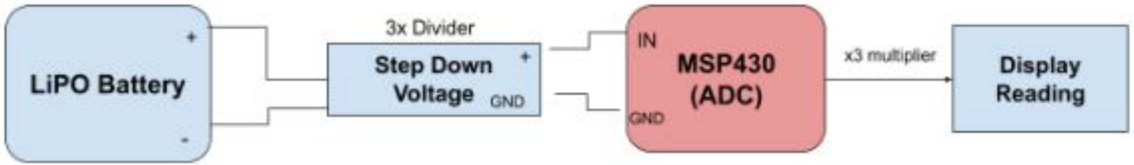
	Nickel-Metal Hydride	Lithium Ion Polymer
Specific Energy	60-120 W*h/kg	100-265 W*h/kg
Energy Density	140-300 W*h/l	250-730 W*h/l
(Charge) Cycle Durability	180 - 2000 cycles	300-500 cycles
Cell Voltage Rating	1.2 V	3.0 V

Battery Selection: Pi Power

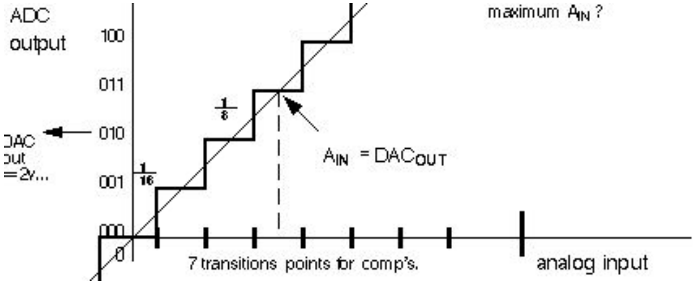
- Makerfocus Raspberry Pi Battery Pack, selected
  - LiPo, 3.7V, 3800mAh
  - Up to 9 hours run time powering the Raspberry Pi
  - Integrated under and overvoltage, and overcharge protection, charge level indication,
- PiJuice HAT, considered
  - Proven, but expensive
  - Doubles as a UPS, protects from data loss
  - Built in RTC
- MakerHawk RPi UPS HAT, considered
  - Replaceable battery option
  - Lacks support

Specifications	PiJuice HAT	MakerFocus RPi Batt Pack	MakerHawk RPi UPS HAT
Capacity	1820 mAh	3800 mAh	3600-7000 mAh
Battery Voltage	3.3-5V	3.7 V	2.5-4.2 Volts
Cost	$88.95	$20.99	$21.99
Runtime	4-6 hours	9 hours	>8 hours
Dimensions	4.33 x 4.92 x 1.38 inches	3.35 x 2.17 x 0.79 inches	3.82 x 2.24 x 0.39 inches

Battery Voltage Monitor



- Voltage is monitored using ADC (Analog to Digital Conversion)
    - MSP430 Analog Pinout has a 3.5V limit
- Voltage is stepped down for microcontroller input
- ADC Resolution is 10 bits
    - Digital Output will be converted to appropriate voltage reading
- Voltage reading is multiplied by 3 and sent to display



Battery Voltage Monitor Requirements and Limitations

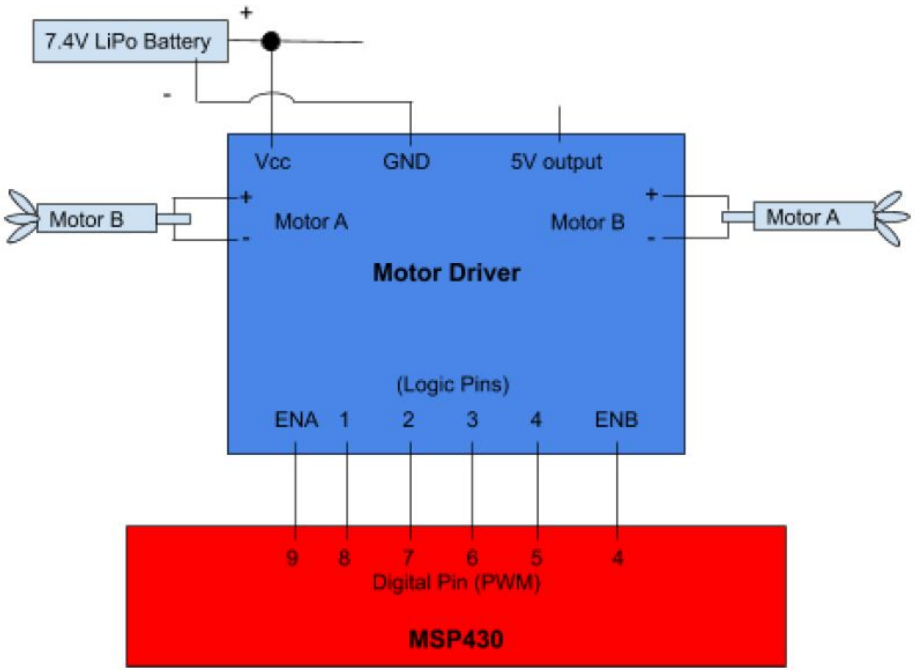
Using ADC to Monitor Battery Life

Voltage Monitor Requirement	Send Battery Voltage 10% Tolerance
Reference Voltage	2.5V or 2.0V
ADC Resolution	10 Bits
Analog Pin Limitation	3.5V Max

Progress Report:

Initial Prototype Testing - In Progress
PCB Implementation - Not Completed
Total Subsystem Progress: 60%

Dual Motor Interface for Automation



- H-Bridge Motor Driver: Used to drive motor either forwards or backwards
- Input voltage: System Requirements is 7.4V but motors can run at >5V

Two Enable Pins and 4 Logic pins

- **Enable Pins** : PWM (Pulse Width Modulation) Controls Speed
- **Logic Pins** : Controls Forward and Backward Movement of each motor.

Motor Driver Functionalities

Motor Driver Parts/PinOuts	Function
VCC	5V - 12V Operating Voltage Range
MOTOR A/B (+ -)	Positive and Negative Terminals for both motors. Internal connection to H-Bridge
5V output pin	Internal 5V regulator that outputs 5V
ENA, ENB	Logic Pin for Speed Control using Pulse Width Modulation
Pins 1,2,3,4	Logic Pins for Forward/ Backwards Motion
H-Bridge	Internal Chip to drive motors Forward and Backwards.

Dual Motor Driver Design Decisions and Difficulties

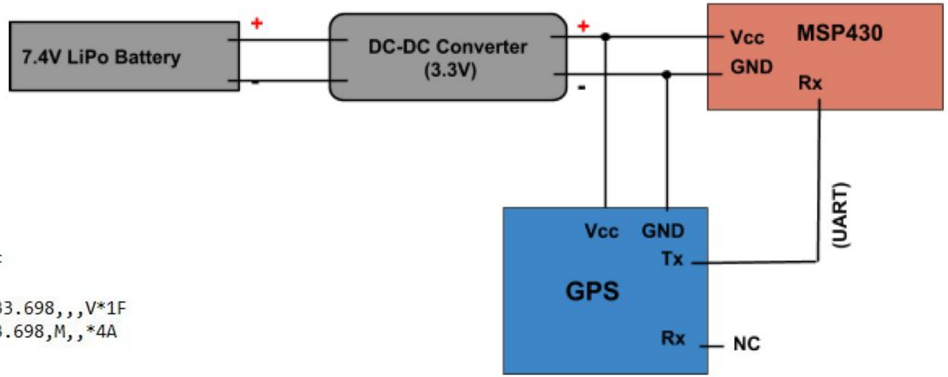
- Autonomous movements using GPS Interface or predetermined location ?
  - Dependent on scale of system
    - Small Scale Prototype: Predetermined Location
    - Large Scale Product: GPS Interface for autonomous movements
- Dual Motor Driver and H-Bridge is critical for design completion
  - Allows for speed control on 2 motors simultaneously

Progress Report:

Initial Prototype Testing - Completed
Full Autonomous Test using Predetermined route - Not Completed
Total Subsystem Progress: 60%

GPS Locator Chip Diagram

- 3.3V Input Requirement
- UART Communication @9600 Baud Rate
- GPS Chip Sends NMEA Sentences (National Marine Electronics Association)

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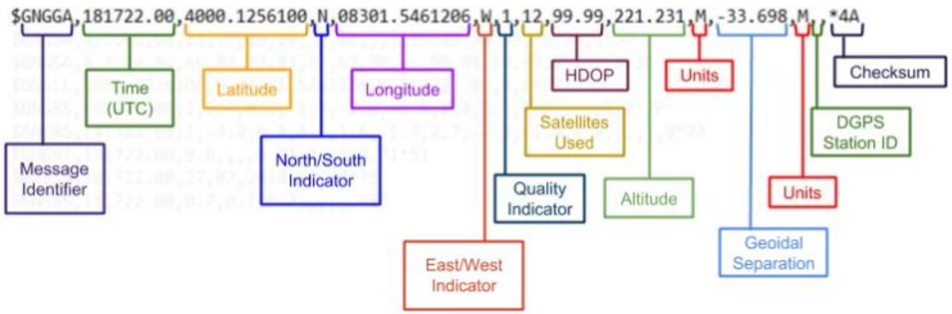
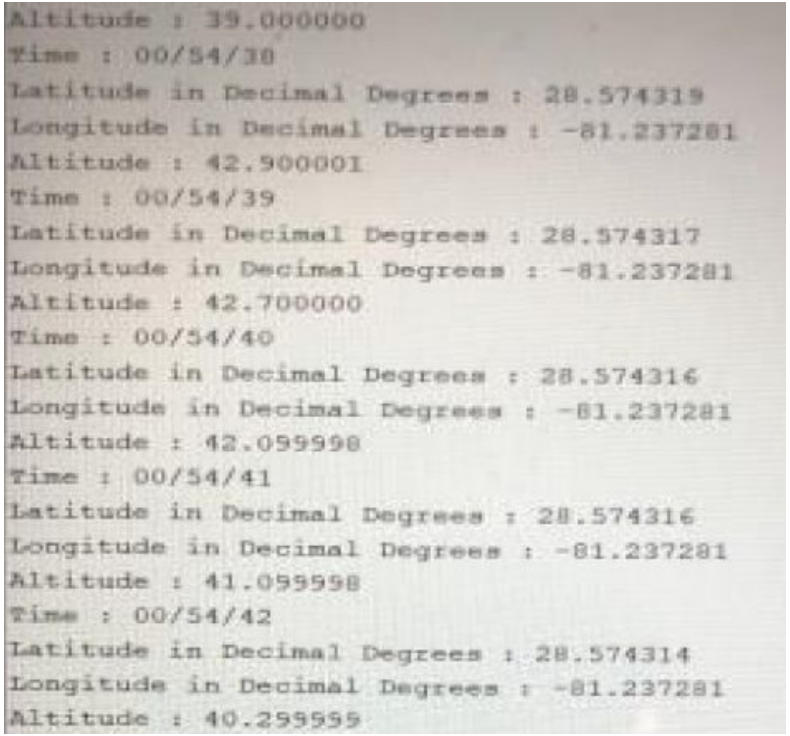
Coordinates Sent to Receiver

- NMEA Sentences are decoded, sorted and organized.
- Display Shows Latitude, Longitude, and Altitude.
- Time Interval is confirmed at 1 Second Update Time





GPS Selection Progress Discussion

- NEO 6m Selection
  - Operating Voltage contains 3.3V
  - Data Transfer Rate (constant update)
  - Fast Start Up
  - Cost effective

Specifications	NEO 6m Module (selected)	Pharos 360 Module	Particle Boron LTE
Operating Voltage	2.7V - 3.6V	3V	3.7V
UART Interface	Yes	Yes	Yes
Receiver	50 Channel	12 Channel	-
Wireless	No	No	Yes
Data Transfer Rate	1 Hz	1 Hz	-
Location Start-Up Time	27 Seconds	60 seconds	<1 second
Cost	$21.95	$18.50	$59.99

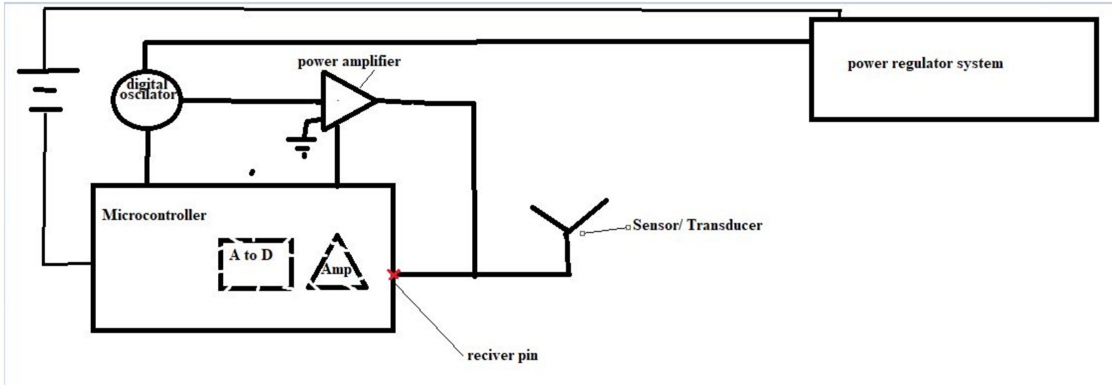
Progress Report:

Initial Prototype Testing - Completed
PCB Implementation - In Progress

Total Subsystem Progress: 80%

The Sensor: SM11 Transducer

- Micro sized 6.35mm x 0.7mm
- Duplexed; signal received from the oscillator and power supply, then reflected off the ocean floor
- Fast, repeated cycles, 215 Khz resonant frequency (±5 KHz)
- Operated via vibrations induced by current, combined with an oscillating signal



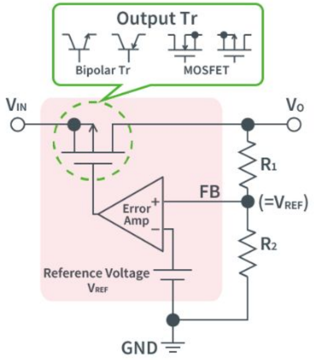
Necessity of the SM111 Sensor

- The ability to read and send the depth of the water around the rescue point is imperative when sending the rescue party

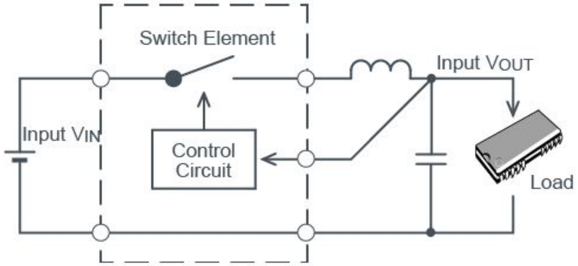
- This technology can also be taken past the prototype to also include the ability to map the bottom of the water floor giving even more insight for the rescue team moving in to be concise and quick.

DC-DC Converter, Technology Comparison

- Switching Regulator
  - Buck, boost, buck-boost, and flyback types
  - Switching element used to convert power from supply to pulsed voltage, then smoothed by L’s & C’s
  - Constant switching allows for heat dissipation
- Linear Regulator
  - Simpler, cheaper designs
  - One configuration - the step down converter (buck)



Linear

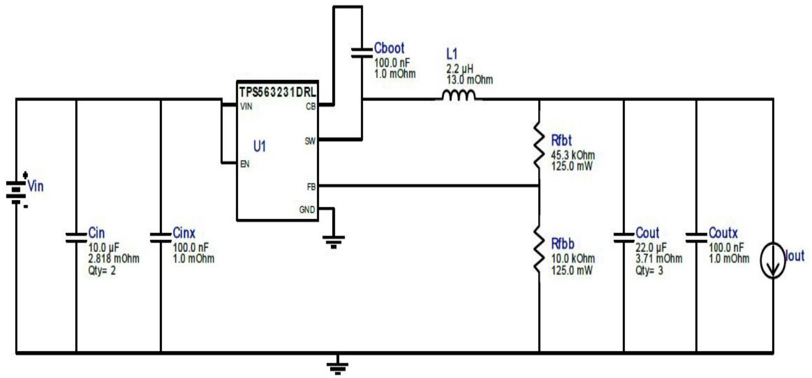


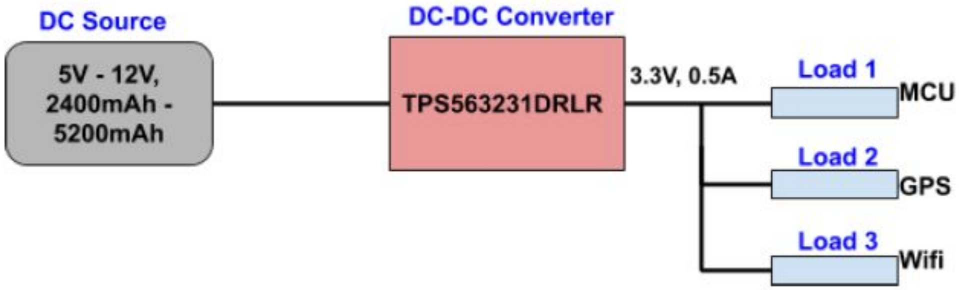
Switching

Specifications	Linear Regulator	Switching Regulator
Noise	Low	High
Efficiency	Low	High
Heat Generation	High	Low
Circuit Complexity	Low	High
Operations	Buck (Step-up)	Buck, Boost, Negative

DC-DC Converter

- **Buck Converter**
  - Input range: 5V-12V
  - Output: 3.3V
- Critical for multiple subsystems
  - Microcontroller
  - GPS
  - WiFi
  - Depth Sensor (Oscillator)

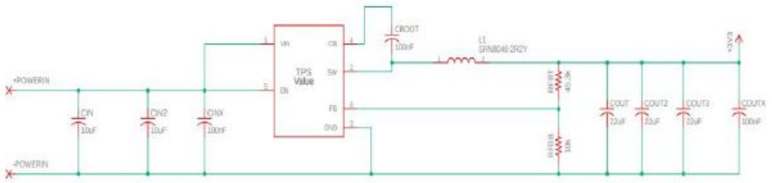


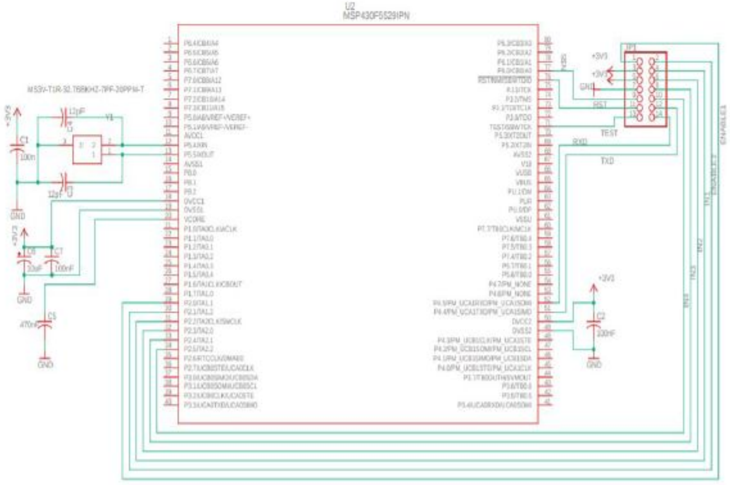


Progress Report - 75%

Regulator Output Testing on PCB - Not Completed
PCB Design Layout - Completed

PCB Schematic





Schematic Diagram for Prototype PCB

- MSP430F5529
- 14 pin connector
    - GPS
    - Dual Motor Driver
    - Wifi Module
    - Code Upload
- Buck Converter
- Depth Sensor

Design Progress : 85% completed

PCB Design

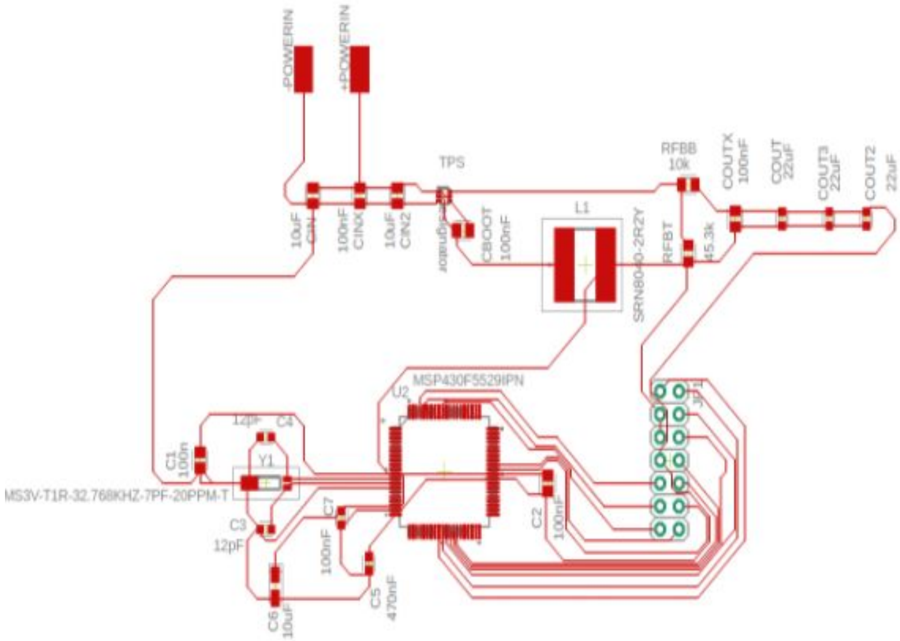
- PCB will be used for all system functions

- Image Processing is solely done on the

  Raspberry Pi

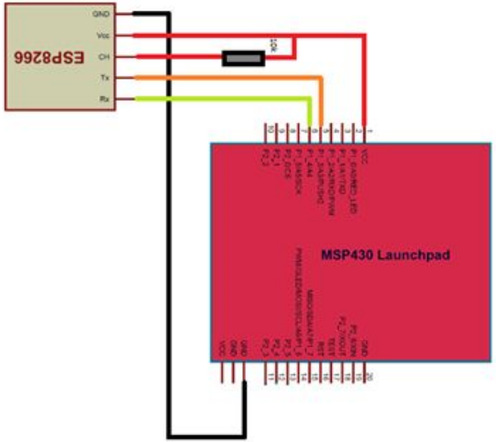
PCB Progress: 85%

Final adjustments and corrections need to be made based on testing.



Communicating with the MSP430

- MSP430’s typically do not come with a WiFi adapter.
- To compensate, we will be using a ESP8266 WiFi module.

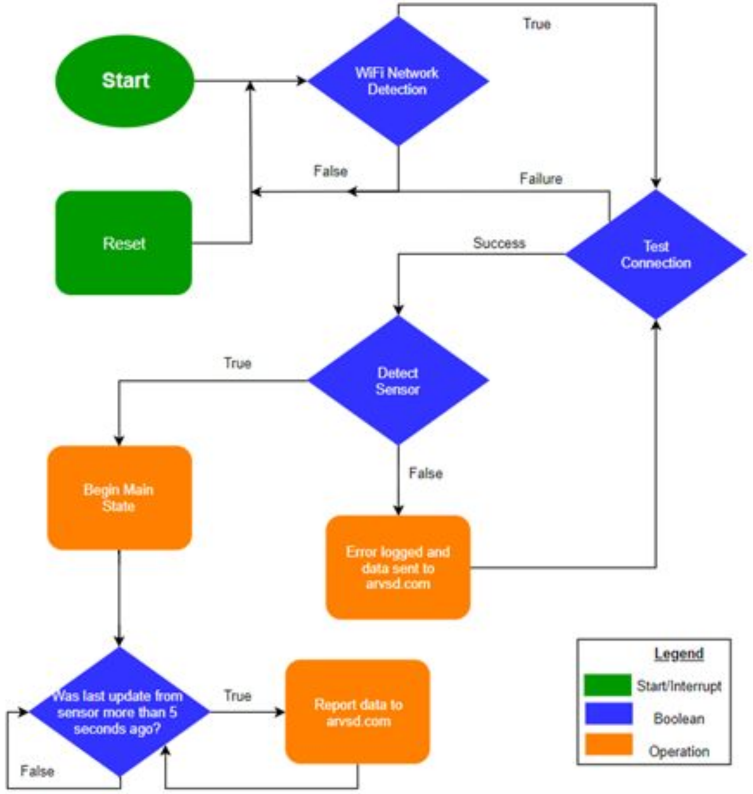


Development Process

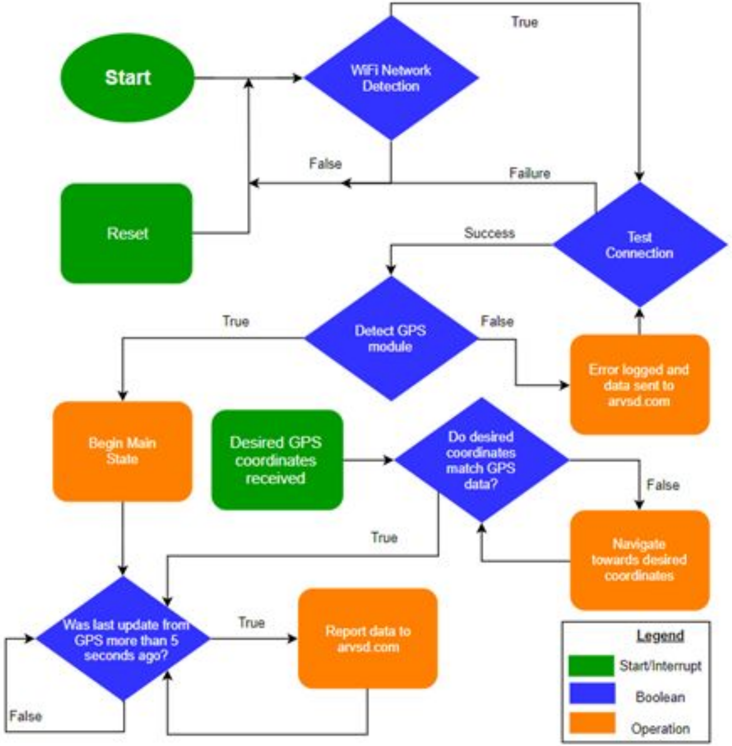
For the production stage of the A.R.V., we've decided to utilize the Agile software development technique to optimize the pace at which we can accomplish the project. We've split the production stage into four sprints which are listed as follows:

Sprints	**Product**
1^{st} Sprint	RC boat built (manual operation functional)
2^{nd} Sprint	Automation implemented
3^{rd} Sprint	Camera streaming implemented
4^{th} Sprint	Image processing implemented

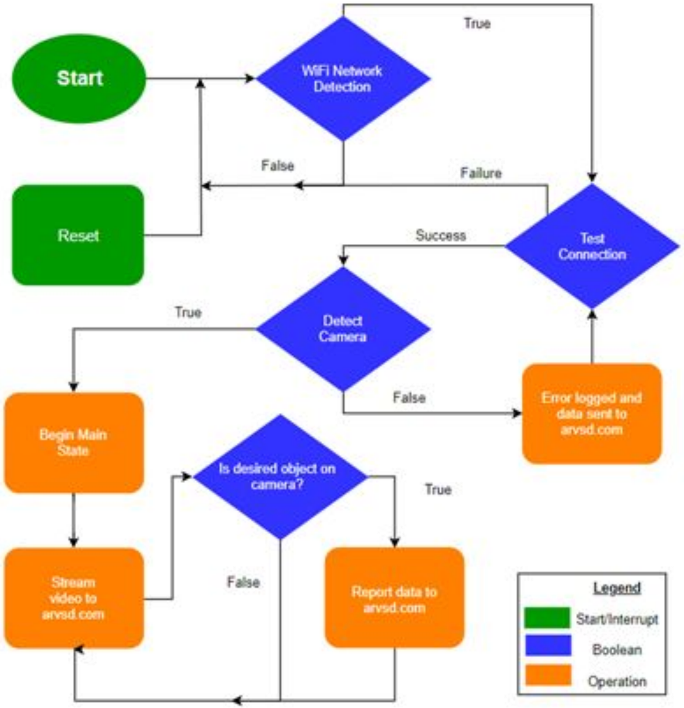
Sensor Software



GPS Software

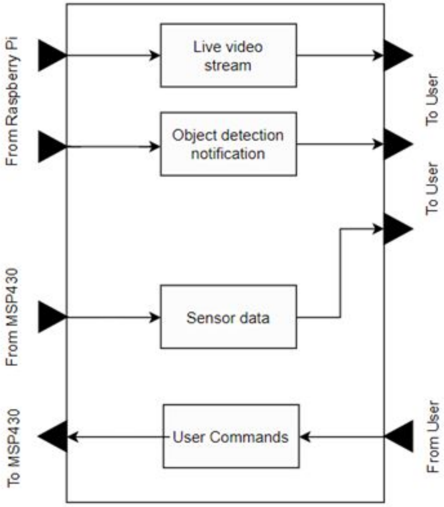


Camera Software



User Interface

- The user will interface through a website, and will only interface with the MSP430.



Testing

- The final product is put through 9 distinct levels of testing
- Each one is used to test a different complexity of this product
- Level one is the initial testing of the equipment alienated from their counterparts
- Each level is is more complex than the next until the end of the product
- Level nine is the final test of a fully integrated product in the terrain it was meant for

Standards and Constraints

<u>1679.1 Lithium Based Batteries Standard - Design Impact</u>

- Over discharge for a prolonged time causes critical voltage values.
  - Possibility of shorts and failures
- For safety, the solution is to constantly monitor the batteries voltage

<u>Ethical, Health and Safety Constraints</u>

- LiPo Battery is placed in secure location in the design
  - Decreases safety hazards that can be caused by water damage or heavy vibrations
- Tightened Specifications and requirements for system due to constraints
  - Delays in data or inaccurate data can result in failure of system functions

Difficulties and Successes

Difficulties

- Image Processing
- Using Wifi to transfer data from MSP430 to Display
- Depth Sensing will require a lot of testing for accurate results

Successes

- GPS is fully functional and meets requirements of <5 second update time
- Motor driver testing was successful and functional. Awaiting for autonomous testing
- ADC for battery monitoring was successful and displayed accurate results

Current progress

- Image Processing with Raspberry Pi - 10%
- Autonomous Motor Control using Motor Driver - 85%
- GPS - 90%
- Voltage Monitor - 60%
- Wifi (for wireless transfer of sensor data) - 15%
- Depth Sensor - 10%
- PCB/Schematic - 85%

Timeline For Completion

- GPS module and camera module powered and tested during SD1
- Motors fully functional and automated September, 21st
- PCB ordered and tested September, 21st - October 2
- Image processing software completed October, 28th
- Depth sensor using SM111 November, 5th
- Final integration of all software and hardware November, 20th
- Final product completion going into final testing November, 22nd
- Final video and presentation recorded before November, 28th

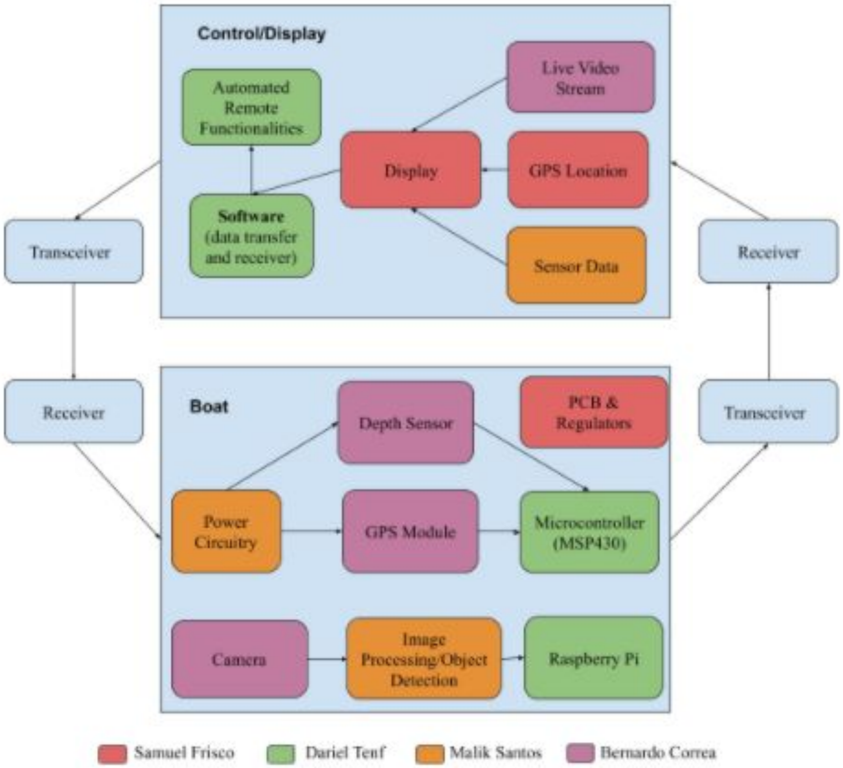
Estimated Budgeting

- Total Estimated Expenses $423

- **Large Expenses**
- Flytec HQ2011 $125
- Voltage Amplifier $88
- Raspberry Pi Camera Module $28

Item	Cost
Voltage amplifier	$88.00
Flytec HQ2011 RC boat (and remote)	$125.00
Raspberry Pi Battery pack	$25.00
Inductors x50	$36.00
VytaFlex 20	$28.35
Raspberry Pi Camera Module V2-8	$27.01
Pcb Assembly	$23.90
NEO-6M GPS Receiver Module	$11.99
Resistors x100	$10.00
SM111	$9.95
Capacitors x50	$8.50
Jumpers	$7.49
RF 433MHz Module	$4.95
Transmitter and Receiver	$4.95
Oscillator	$2.95
Transmitter and Receiver	$4.95
Battery pack	$2.00
Wifi Module	$10.00
Total	

Work Distribution



Thank You

Any Questions?