ARBWCI

ME 476C – Sec 001

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3/1/2026

NAU NORTHERN ARIZONA UNIVERSITY
Steve Sanghi College of Engineering

Introduction

The goal is to create a boat that can scan the bottom of canals and detect things like objects, cracks, and buildup. As of right now, SRP has to completely drain the canals to manually inspect the floors and walls of the canals. With our autonomous robot boat for water canal inspections, we will be able to prevent SRP from draining an 8-mile canal section of water every year.

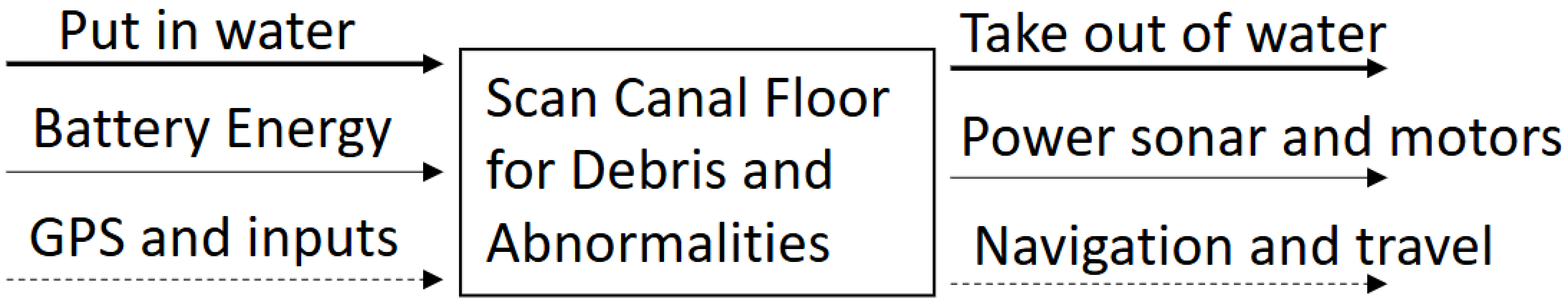
Client 1:
Dr. Reza Sharif Razavian

SRP

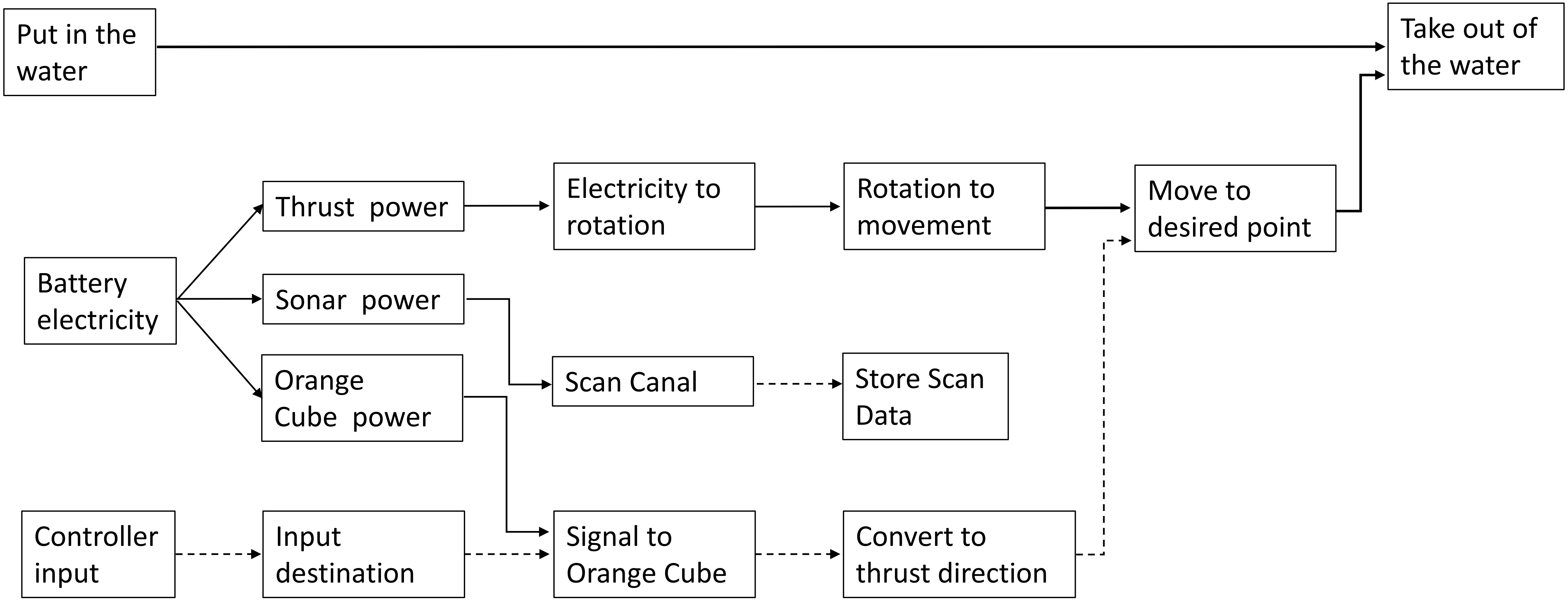
Client 2:
SRP

Christian

Functional Model



Functional Model

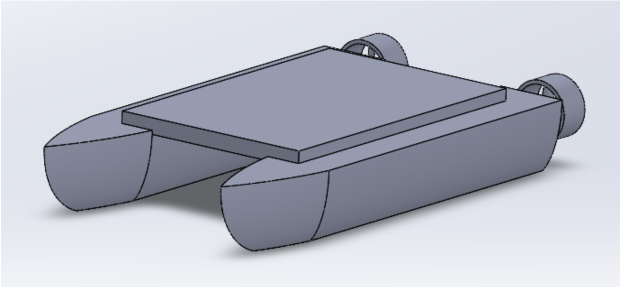


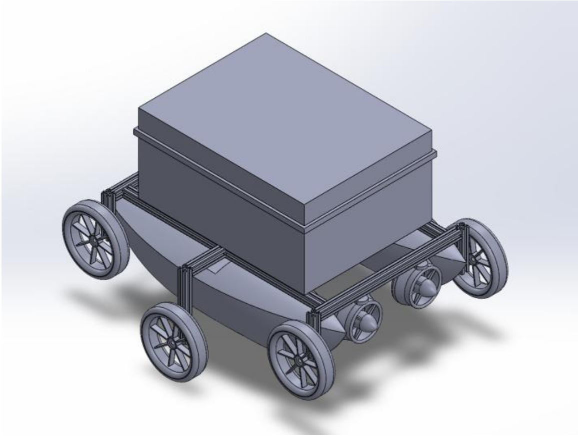
Alex

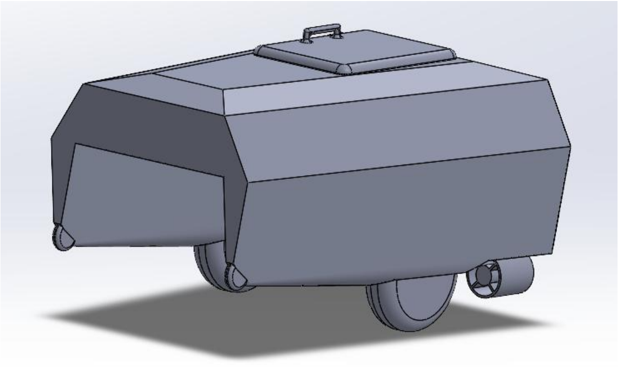
Concept Generation

We discussed many ways we could fix the issue that the current boat model has.

- To add better thrusters/more of them
- Wheels to the boat itself
- Make the control box be on top of the frame instead of inside
- Use one control box instead of two
- Different hydrodynamic design
- Lateral Thruster for side-to-side movement

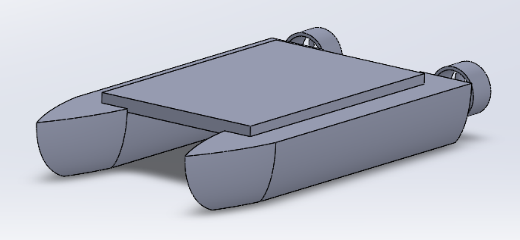






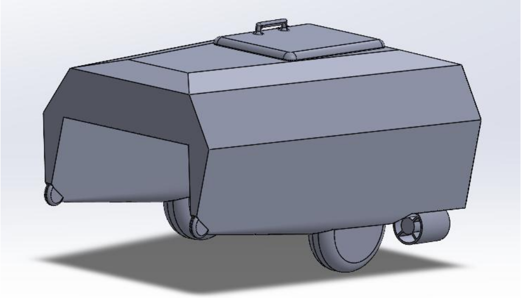
Rikki

Concept Generation



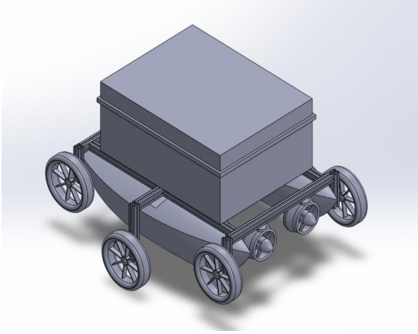
Advantages:
- Precise Control
- Hydrodynamic
- Light

Disadvantages:
- No Lateral Movement
- Needs Framing
- Hard Recovery



Advantages:
- Hydrodynamic
- One Piece
- More Room/No need for Electrical Box
- Easy Recovery

Disadvantages:
- Hard to Construct
- Heavy



Advantages:
- Precise Control
- Lateral Movement
- Easy Recovery

Disadvantages:
- Less Hydrodynamic
- Heavy

Advantages:
- Simple
- Light
- Energy Efficient

Disadvantages:
- Not Stable

Rikki

Customer and Engineering Requirements

Customer Requirements:

- Deploy & Recover quickly / safely
- Operate in a current
- Accurate autonomous navigation
- Long operation per charge
- Remote operation
- Rugged / Waterproof while withstanding heat
- Fail-safe recovery
- Easy sensor data logging + transfer
- System fit in an SUV

Engineering Requirements:

- Deployment / Recovery time : < 5 mins.
- Launch angle: ~ 60 deg.
- Current tolerance: 2 m/s
- Nav accuracy: midline < 0.5 m error
- Range: 3-5 km
- Size Under Water: < 3 ft. depth
- Weight / Material: ~ 50 lbs.

Christian

QFD

Engineering requirements

- Safe & Fast Deployment & Recovery
  - Time it take to deploy and recover it safely
- Ship Design
  - How well it can work under the canal conditions
- Sensor and Data Logging
  - How well the sensor can see and log the data

System QFD — Date: 3/1/2026

#	Technical Requirement	1	2	3	4	5	6
1	Deployment & Recovery time						
2	Launch angle	9					
3	Tolerance	3	1				
4	Nav accuracy	1		1			
5	Range				9		
6	Size	3	1	9	3	9	
7	/Material	1	1	9	3	9	3

Legend
- A Modified RC Boat
- B Our Design
- C Previous Design

#	Customer Needs	Customer Weights	Deployment & Recovery time	Launch angle	Tolerance	Nav accuracy	Range	Size	Material	1 Poor	2	3 Acceptable	4	5 Excellent
1	Quick Deployment & Recovery	5	9	9	3			3	1		C		AB	
2	Safe Deployment & Recovery	5	9	9	3			3	1	C		A		B
	Deploy & Recover on 60 degree canal walls	5	9	9	1			3	1	C			B	A
	Float Upstream	3			9	9	3	3	1		C		A	B
3	Accurate autonomous navigation	4			3	9	3	1	1	A	C		B	
4	Long operation per usage	3			3	1	9		1					ABC
5	Hands off operation	2				3	9				A			BC
6	Waterproof	4			3			3	9		A		BC	
7	Withstand Phoenix Weather	3					1	1	9			A		BC
8	Fail-safe recovery	1				3	1			C	A		B	
9	Easy data logging & transfer	3				3	1					A		BC
10	Portable	2						9	9					ABC
11	Technical Requirement Units		Minutes	Degrees	m/s	m	km	m	kg					
	Technical Requirement Targets		5	60	2	0.5	2	0.5	15					

Technical Requirements / Customer Opinion Survey

Figure 1 System QFD

William

Engineering Calculations of Buoyancy

1) Convert volume

$$V_p = 395\ \text{in}^3 \left(\frac{0.0254\ \text{m}}{1\ \text{in}}\right)^3 = 6.47 \times 10^{-3}\ \text{m}^3$$

2) Buoyant force

$$F_{b,p} = \rho g V_p = (1000)(9.81)(6.47 \times 10^{-3}) = 63.5\ \text{N}$$

3) Total buoyant force

$$F_{b,\text{total}} = 2F_{b,p} = 127\ \text{N}$$

4) Max supported mass

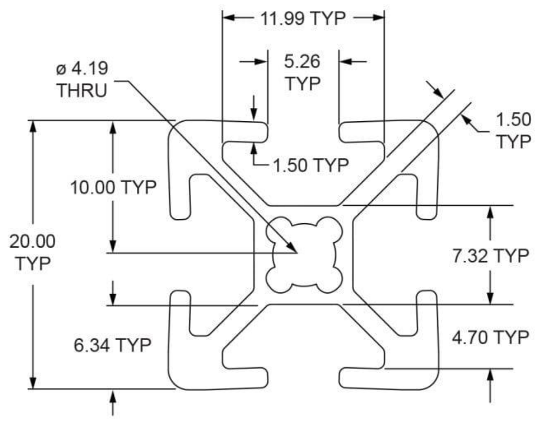
$$m_{\max} = \frac{F_{b,\text{total}}}{g} = \frac{127}{9.81} = 12.95\ \text{kg} \approx 28.5\ \text{lb}$$

Christian

Engineering Calculations of Materials

[20-2020 | 20mm X 20mm T-Slotted Profile - Four Open T-Slots]

For the framing of the boat, we looked at three different types of materials to see which one would be the best to use for what we are trying to accomplish.



Aluminum Density: 2700 kg/(m^3): ($9.00)
Steel Density: 7850 kg/(m^3): ($43.00)
HDPE Density: 950 kg/(m^3): ($24.00)
V = A * L: 20 mm * 20 mm * 0.508 m = 0.0002032 m^3

Aluminum mass = 2700 kg/(m^3) * 0.0002032 m^3 = 0.55 kg
Steel mass = 7850 kg/(m^3) * 0.0002032 m^3 = 1.6 kg
HPDE mass = 950 kg/(m^3) * 0.0002032 m^3 = 0.19 kg

Aluminum = A very good balance between cost and support.
Steel = A little overkill unless the weight is drastically heavy.
HDPE = The lightest but has the least amount of support.

William

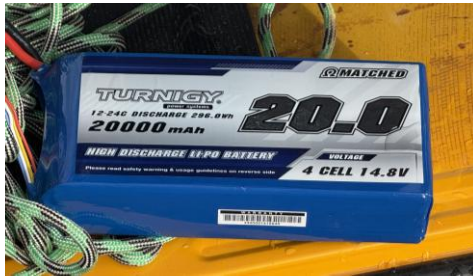
Engineering Calculations of Battery

As for battery consumption and runtime we have to take into account these different components

- HDS7 Sonar transducer
- CubePilot Orange Cube +
- 3 T200 thrusters
    - 2 thrusters @ 60% power
    - 1 thruster at 20% for minimal time

$$V = 3.7 * N_s$$

$$N_s = Number\ of\ cells\ in\ series\ [4S, 6S, 8S]$$



V = 3.7 * 4S

V = 14.8 V

This lead us to the Turnigy 4S 14.8V 20,000 mAh battery pack

$$E_{battery} = V * C$$

$$E = Battery\ energy\ [Wh]$$
$$V = Voltage\ [V]$$
$$C = Battery\ Capacity\ [Ah]$$

E = 14.8V * 20Ah

E = 296 Wh

$$t = \frac{E_{usable}}{P}$$

$$t = Runtime\ [h]$$
$$P = Power\ Consumption\ [W]$$

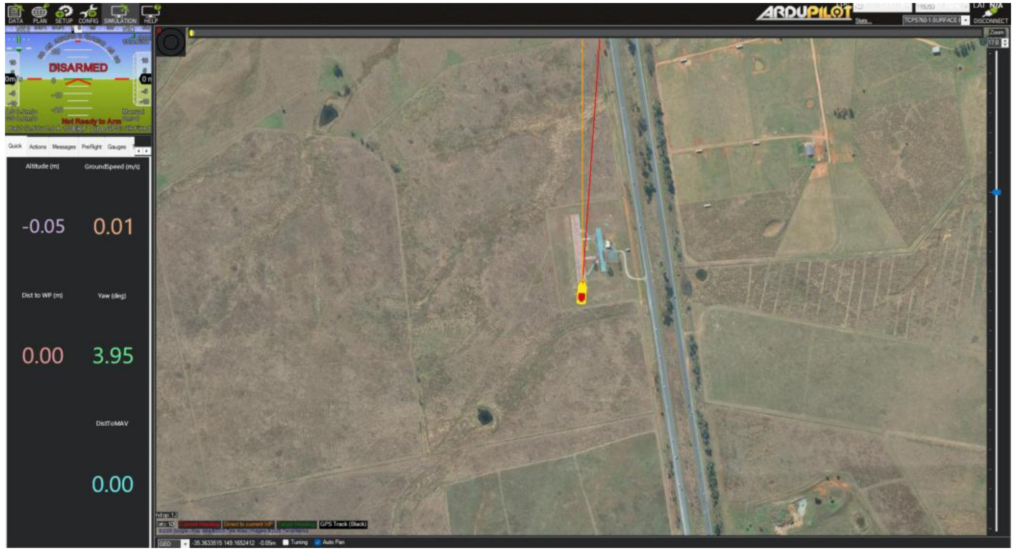
t= 296Wh / 514.5W

t= 0.575 hr.

t= 34.5 min.

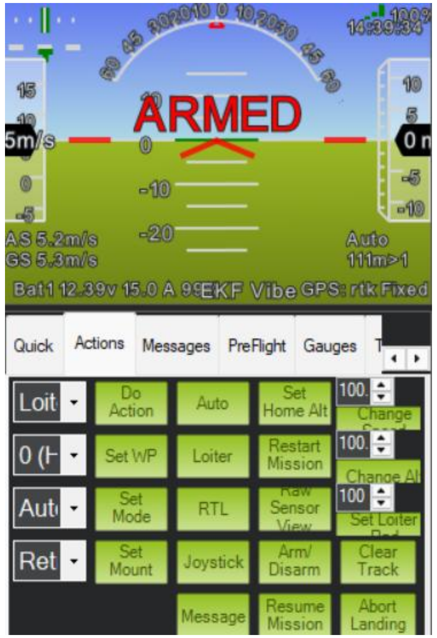
Rikki

Engineering Analysis of ArduPilot



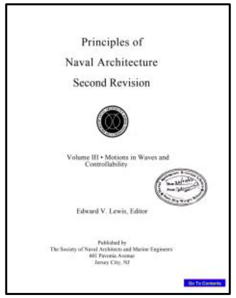
Name	Value	Default	Units	Options	Desc
FRAME_CLASS	2	1		Boat (Undefined, Rover, Boat, BalanceBot)	Frame Class
FRAME_TYPE	0	0			Frame Type

Name	Value	Default	Units	Options	Desc	Fav
SERVO1_FUNCTION	26	26		-1:GPIO 0:Disabled	Function assigned to this servo. Setting this to Disabled(0) will setup this output for control by auto missions or MAVLink servo set commands. any other value will enable the corresponding function	
SERVO1_MAX	2000	2000	PWM	800 2200	maximum PWM pulse width in microseconds. Typically 1000 is lower limit, 1500 is neutral and 2000 is upper limit.	
SERVO1_MIN	1000	1000	PWM	800 2200	minimum PWM pulse width in microseconds. Typically 1000 is lower limit, 1500 is neutral and 2000 is upper limit.	
SERVO1_REVERSED	0	0		0:Normal 1:Reversed	Reverse servo operation. Set to 0 for normal operation. Set to 1 to reverse this output channel.	
SERVO1_TRIM	1500	1500	PWM	800 2200	Trim PWM pulse width in microseconds. Typically 1000 is lower limit, 1500 is neutral and 2000 is upper limit.	



Alexander

Engineering Calculations of Differential Thrust

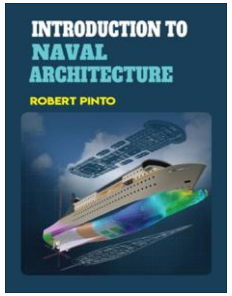


		Thrust		
Voltage	Combo	Right	Left	M_z (N*m)
32 V	Nominal	51.45	-39.2	7.19534375
40 V	Max	65.66	-49.49	9.14003125
16 V	Half Nominal	51.45	0	4.08384375
20 V	Half Max	65.66	0	5.2117625

	Forward	Backward
Nominal kgf	5.25	4
Max kgf	6.7	5.05
Nominal N	51.45	39.2
Max N	65.66	49.49

$$M_z = (T_R - T_L)\frac{b}{2}$$

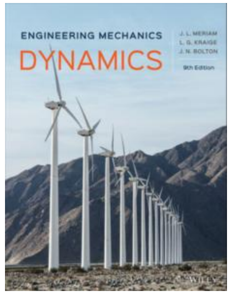
distance (b)	
in	6.25
m	0.15875



mass distibution	(k)	I_z (kg*m^2)
center	0.6	0.343
even	0.8	0.457
outside	1	0.572

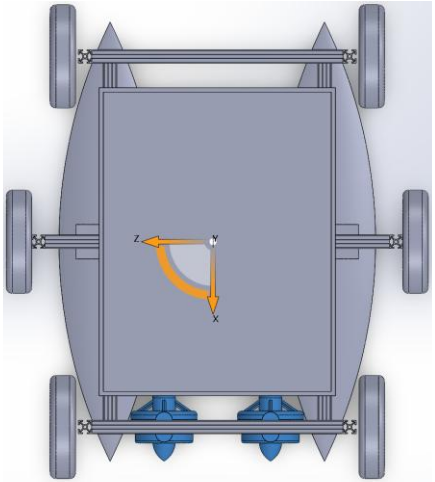
$$I_z = km\left(\frac{b}{2}\right)^2$$

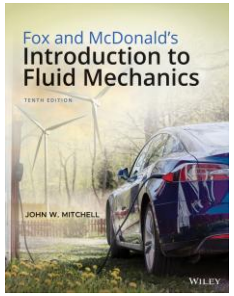
	distance (b)		mass
in	12.5	lbs	50
m	0.3175	kg	22.6796



angular acceleration (rad/s^2)					
M_z	I_z=.343	M_z	I_z=.457	M_z	I_z=.572
7.195	2.468	7.195	3.290	7.195	4.113
9.140	3.134	9.140	4.179	9.140	5.224
4.084	1.401	4.084	1.867	4.084	2.334
5.212	1.787	5.212	2.383	5.212	2.979

$$\alpha = \frac{M_z}{I_z}$$



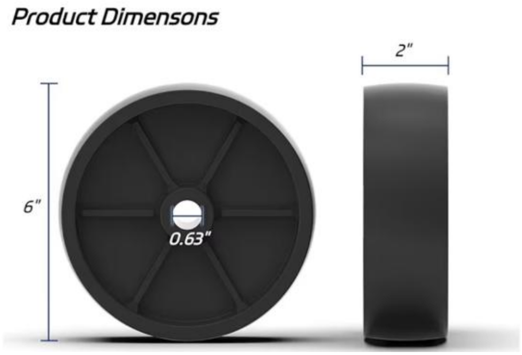


$$D = \frac{1}{2}\rho C_d A U^2$$

Alexander

Engineering Analysis of Wheels

One major issue with the current model is how it's launched into the canal. The boat sits on a separate cart and must be pulled into position with a long hook to latch onto the cart. This process is difficult and once led to the hook snagging an electrical plug, flooding the electronics and causing about $300 in damage.
Our design improves this by attaching wheels directly to the boat, eliminating the need for a separate cart system. The external wheels will also act as a buffer, hitting the canal walls first and protecting the boat from damage.



$$V_o = \frac{\pi h\,(D^2 - d^2)}{4} = 9.032 in^3$$

$$V_i = \frac{\pi h_i({D_i}^2 - {d_i}^2)}{4} = 11.723 in^3$$

$$V_o + V_i = 20.755 in^3$$

$$B = \rho V = 0.749 lbf$$

$h = 2\ in$

$D = 6\ in$

$d = D_i = 5.5\ in$

$h_i = 0.5\ in$

$d_i = 0.63$

$\rho = 0.03613\ lb/in^3$

TOWKING 1200lbs 6inch Boat Trailer Jack Wheel, Wheel Replacement for Jack https://a.co/d/01Too7mY

Norah

Concept Evaluation – Pugh Chart

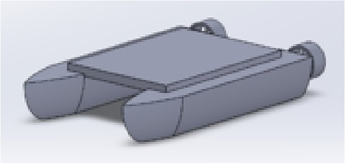
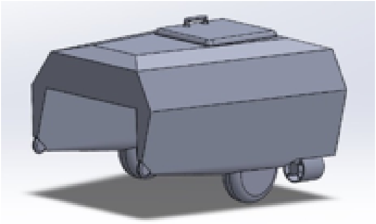
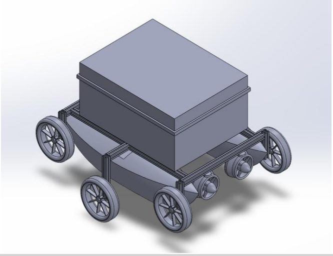
Criteria					
Deployment	-	s	Datum	-	+
Recovery	-	s	Datum	-	+
Navigation	-	-	Datum	+	S
Waterproof	+	+	Datum	-	+
Battery Life	S	-	Datum	+	-
Data Logging	S	S	Datum	+	S
Size	+	-	Datum	+	S
Total +	2	1	Datum	3	3
Total -	3	3	Datum	3	1
Total Same	2	3	Datum	0	3

Figure 2: Pugh Chart

Norah

Concept Evaluation - Decision Matrix

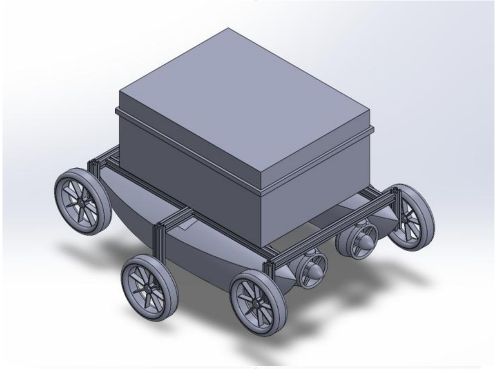
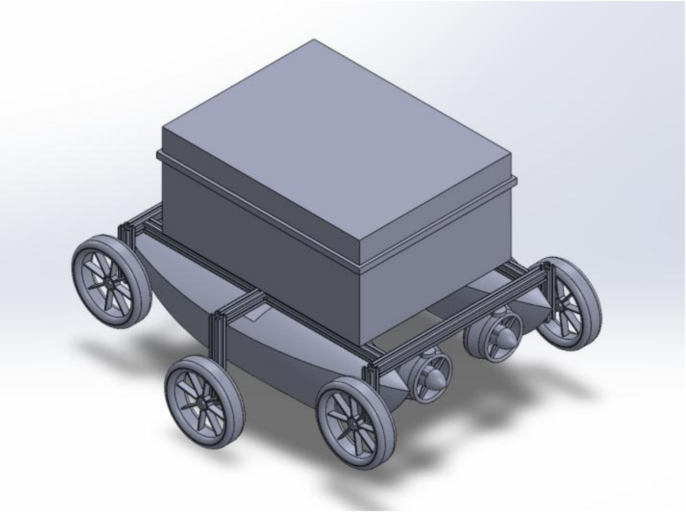
Criteria	Weight						
		Unweighted:	Weighted:	Unweighted:	Weighted:	Unweighted:	Weighted:
Deployment	0.25	90	22.5	50	12.5	80	20
Recovery	0.25	90	22.5	50	12.5	80	20
Navigation	0.15	85	12.75	85	12.75	85	12.75
Waterproof	0.1	100	10	85	8.5	90	9
Battery Life	0.1	75	7.5	90	9	75	7.5
Data Logging	0.1	80	8	80	8	80	8
Size	0.05	90	4.5	90	4.5	90	4.5
Total	1	Sum:	87.75	Sum:	67.75	Sum:	81.75

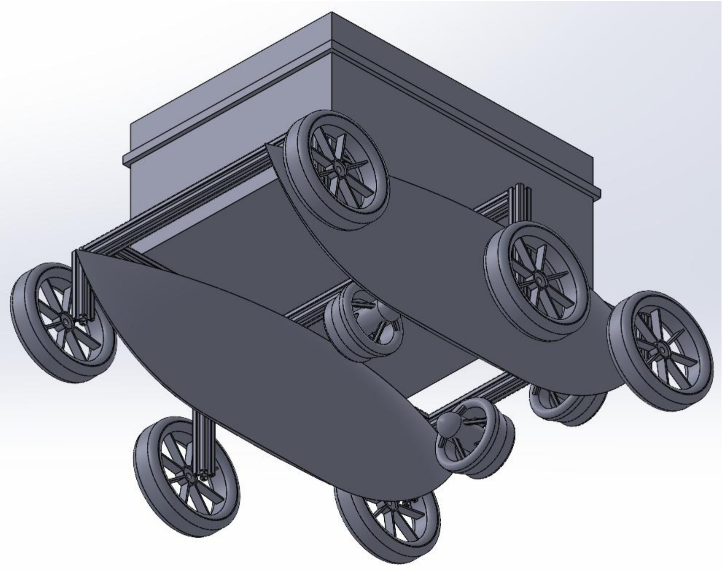
Figure 3: Decision Matrix

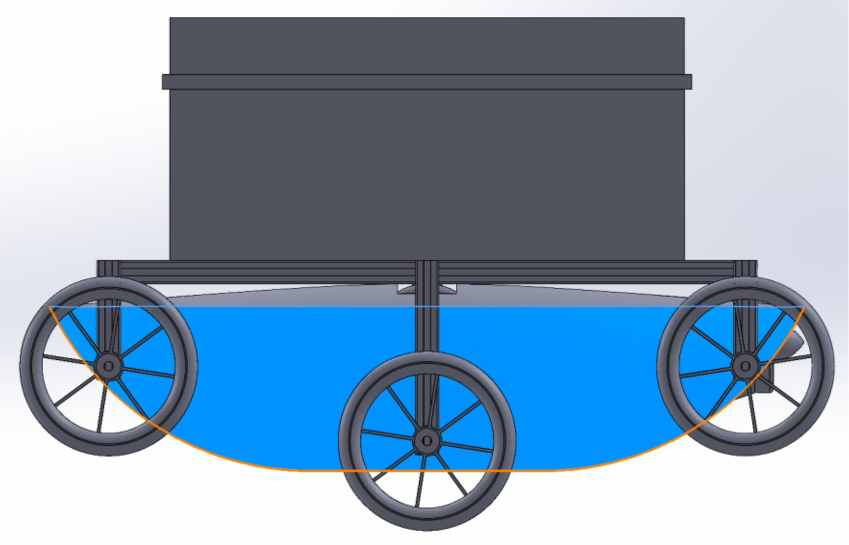
William

Concept Evaluation – Chosen Design

This is our current final design. It uses aluminum extrusions for the frame, an electric box to hold all the electronics and controls, kayak stabilizers for buoyancy, wheels for easier transportation and deployment, thrusters of different power capacities, and the sonar sensor.





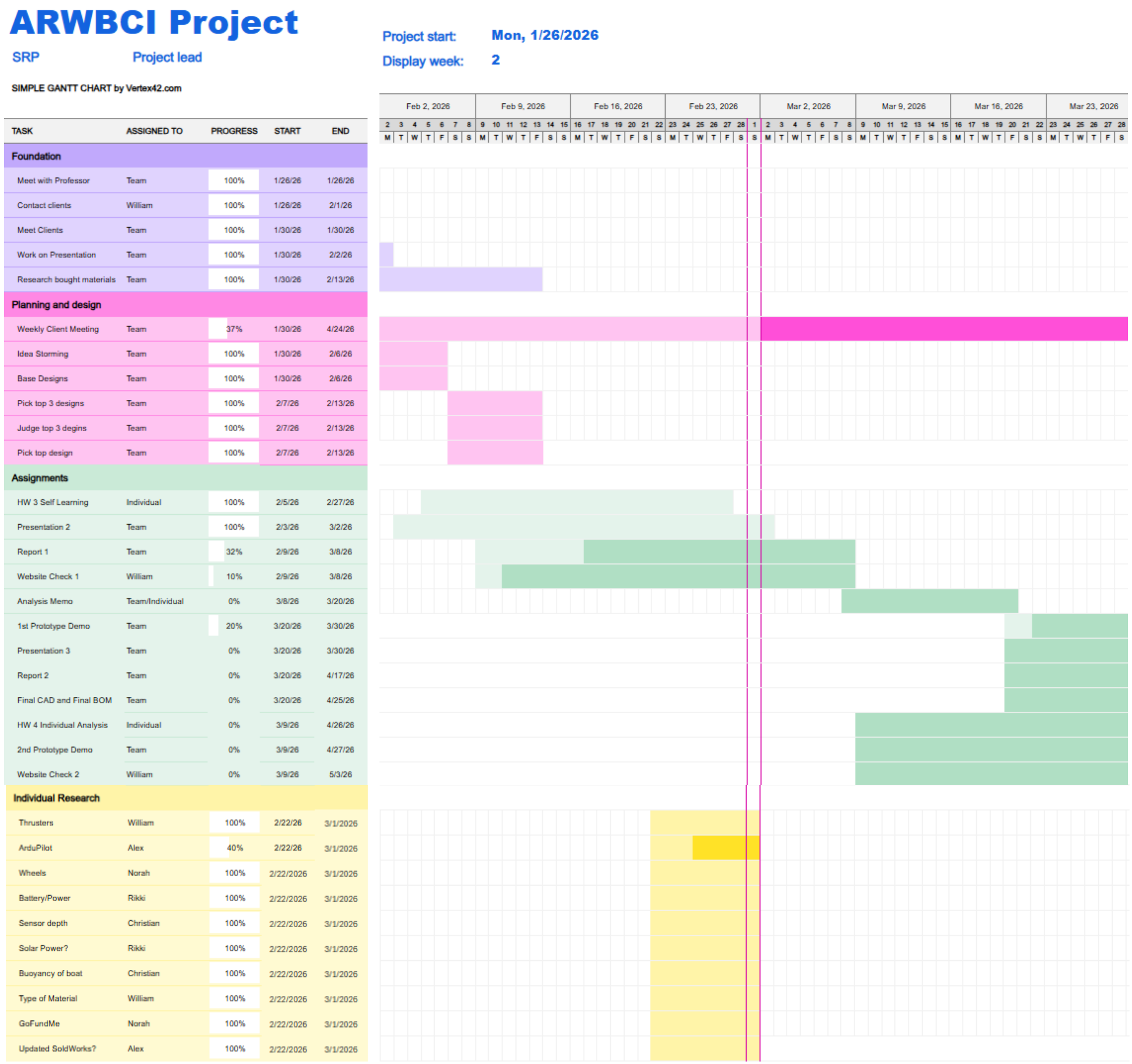


28 inches long
25 inches wide
18 inches tall

Alex

Gantt Schedule:

As we are on week 8 of the project some of our most pressing milestones are making the website, the first prototype demo, and the first report of our capstone.



TASK	ASSIGNED TO	PROGRESS	START	END
Foundation				
Meet with Professor	Team	100%	1/26/26	1/26/26
Contact clients	William	100%	1/26/26	2/1/26
Meet Clients	Team	100%	1/30/26	1/30/26
Work on Presentation	Team	100%	1/30/26	2/2/26
Research bought materials	Team	100%	1/30/26	2/13/26
Planning and design				
Weekly Client Meeting	Team	37%	1/30/26	4/24/26
Idea Storming	Team	100%	1/30/26	2/6/26
Base Designs	Team	100%	1/30/26	2/6/26
Pick top 3 designs	Team	100%	2/7/26	2/13/26
Judge top 3 degins	Team	100%	2/7/26	2/13/26
Pick top design	Team	100%	2/7/26	2/13/26
Assignments				
HW 3 Self Learning	Individual	100%	2/5/26	2/27/26
Presentation 2	Team	100%	2/3/26	3/2/26
Report 1	Team	32%	2/9/26	3/8/26
Website Check 1	William	10%	2/9/26	3/8/26
Analysis Memo	Team/Individual	0%	3/8/26	3/20/26
1st Prototype Demo	Team	20%	3/20/26	3/30/26
Presentation 3	Team	0%	3/20/26	3/30/26
Report 2	Team	0%	3/20/26	4/17/26
Final CAD and Final BOM	Team	0%	3/20/26	4/25/26
HW 4 Individual Analysis	Individual	0%	3/9/26	4/26/26
2nd Prototype Demo	Team	0%	3/9/26	4/27/26
Website Check 2	William	0%	3/9/26	5/3/26
Individual Research				
Thrusters	William	100%	2/22/26	3/1/2026
ArduPilot	Alex	40%	2/22/26	3/1/2026
Wheels	Norah	100%	2/22/2026	3/1/2026
Battery/Power	Rikki	100%	2/22/2026	3/1/2026
Sensor depth	Christian	100%	2/22/2026	3/1/2026
Solar Power?	Rikki	100%	2/22/2026	3/1/2026
Buoyancy of boat	Christian	100%	2/22/2026	3/1/2026
Type of Material	William	100%	2/22/2026	3/1/2026
GoFundMe	Norah	100%	2/22/2026	3/1/2026
Updated SoldWorks?	Alex	100%	2/22/2026	3/1/2026

Figure 4: Gantt

Norah

Bill of Materials:

To the right is our current bill of materials but we are prepared to expand it as we move along in the project.

Since we are planning to spend around $1,800, we need to fundraise around $500 along with our budget of $1500 for a total of $2000.

To raise the required $500 we have created a GoFundMe page which will make it easily accessible for others to donate.

BOM Level	Components	Unit Cost	Quantity	Total Cost
1	Kayak Stablizers	$215.99	1	$215.99
1	T200 Thruster	$270.00	2	$540.00
1	Apisqueen	$42.00	1	$42.00
2	Aluminum Extrusions (4 pack)	$40.64	2	$81.28
3	Kore Carrier Board	$300.00	1	$300.00
3	Cube Orange +	$226.00	1	$226.00
2	Waterproof Electrical Junction Box	$114.99	1	$114.99
2	Wheels (4 pack)	$26.99	2	$53.98
3	Screws	$20	1	$20.00
3	Batteries	$116.99	1	$116.99
3	Wires	$16.00	1	$16.00
	Herelink Controller	$1529.62	1	$1529.62
Sum:	Without Controller	$1727.23	With Controller	$3256.85

References

[1] "Zhao, C., Thies, P., Lars, J., & Cowles, J. (2021). ROV launch and recovery from an unmanned autonomous surface vessel – Hydrodynamic modelling and system integration. *Ocean Engineering*, *232*, 109019. https://doi.org/10.1016/j.oceaneng.2021.109019
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[5]"Tuning Navigation — Rover documentation," Ardupilot.org, 2024. https://ardupilot.org/rover/docs/rover-tuning-navigation.html (accessed Feb. 02, 2026).
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THANK YOU

Questions?