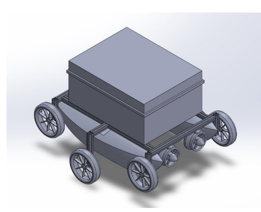
[ARBWCI]

Initial Design Report

William Britt [Project Lead and Mechanical Platform]
Norah Cooley [Treasurer and Recovery]
Alexander Davis [CAD and Navigation Specialist]
Rikki Mendoza [Manufacturing Engineer and Propulsion]
Christian Mpoyo [Test Engineer and Data Logging]

Spring 2026 - Fall 2026



Project Sponsor: SRP
Faculty Advisor: Dr. Razavian

DISCLAIMER

This report was prepared by students as part of a university course requirement. While considerable effort has been put into the project, it is not the work of licensed engineers and has not undergone the extensive verification that is common in the profession. The information, data, conclusions, and content of this report should not be relied on or utilized without thorough, independent testing and verification. University faculty members may have been associated with this project as advisors, sponsors, or course instructors, but as such they are not responsible for the accuracy of results or conclusions.

EXECUTIVE SUMMARY

The ARBWCI project stands for “Autonomous Robotic Boat for Water Canal Inspection”. The whole goal of the project is to design and build a boat that will be used to find breaks and cracks in the saltwater canals down in Phoenix. Due to the amount of dirt in these canals, they are unable to see anything through the water to detect damage. The only other option would be to drain and clean the canals, which is out of the realm of possibility for them. Over the course of about two months, the group has come up with a design that we believe will be able to do the main goal of sensing breaks in the canals while accomplishing its design goals set in fourth by the instructor. The current design is around 28 inches by 25 inches by 18 inches in height. It has two pontoons on both sides of it with 3 wheels attached into both sides to allow the deployment of to be easier. Undeneath the frame there will be two thrusters in the back and one thruster in the middle to give it side to side movement. The sensor we have chosen will also be underneath the frame. On top there will be a waterproof box with all the electronics for the sensor and battery for the power to consolidate everything. Finally, there will be a GoPro at the very top of the frame to give a live feed to the drone controller if needed. At the current point we have not started building the robot as everything has been through math and CAD modeling. The major breakthroughs we have currently had in the project are that we have a final design with a CAD model for reference as well as some finalized calculations. As you read through the rest of this report, you will see everything talked about here in more detail with reference images and sources to show the progress we have made over the last two months.

TABLE OF CONTENTS

Contents

DISCLAIMER 1
EXECUTIVE SUMMARY 2
TABLE OF CONTENTS 3
1 BACKGROUND 1
1.1 Project Description 1
1.2 Deliverables 1
1.3 Success Metrics 1
2 REQUIREMENTS 3
2.1 Customer Requirements (CRs) 3
2.2 Engineering Requirements (ERs) 4
2.3 House of Quality (HoQ) 4
3 Research Within Your Design Space 6
3.1 Benchmarking 6
3.2 Literature Review 6
3.3 Mathematical Modeling 9
4 Design Concepts 12
4.1 Functional Decomposition 12
4.2 Concept Generation 12
4.3 Selection Criteria 13
4.4 Concept Selection 13
5 CONCLUSIONS 15
6 REFERENCES 16
7 APPENDICES .... **Error! Bookmark not defined.**
7.1 Appendix A: Descriptive Title .... **Error! Bookmark not defined.**
7.2 Appendix B: Descriptive Title .... **Error! Bookmark not defined.**

1 BACKGROUND

This chapter of the report will be going over the history and goals of the project and how we plan to measure the success of it. Firstly, there will be a brief description about what are project is and why it is important as well as the budget of it. Next, the major deliverables of the project will be discussed that our course professor and client have tasked us with. Lastly, how our project will be considered "successful" will be discussed and how we can measure it when the time comes.

1.1 Project Description

The ARWBCI project is to create a small portable boat that can be driven in the waters of the Phoenix saltwater canals to allow for it to scan them to look for any damages or cracks that may be unable to be seen. The boat needs to be small enough to be portable into the back of an SUV as well as have enough thrust to be able to go up stream in the canal. When in the water there also needs to be some sort of sensor that is powerful enough to detect broken parts in the canal over a long stretch of the canal. The budget we were given for this project was $1,000 which can go up to $1,500 with reasoning to our advisor if requested. The drone controller needed for this project will possibly be funded by our advisor if requested and if we do need one. Beyond that we are looking to spend $2,000 to create this boat which requires at least $500 which we plan to do through a GoFundMe and then local food fundraiser if needed. The reason why this project is so important is due to the safety of the canals that house all of this water. With how dirty the water is to check the canals would need for them to be drained which would take immense time and money where our boat will be able to do the same thing both cheaper and faster.

1.2 Deliverables

From our client we do not have time-specific deliverables as we are able to deliver our results at the same time, we need to deliver them for the course. The only deliverable we have is to have a working boat with a scanner by the end of the capstone period in December. For the course, around half of the deliverables have been passed by and completed. One of the first major deliverables was to present a introduction presentation in week 4 regarding what our project is and how we plan to complete it. A month later we gave a second presentation showing what work we have done up to this point and how far we have gotten with the project. By March 15th we will need to have our website up and running showcasing all of our prototype models, papers, and other work that has been done on the project. Then by March 30th we will present our third presentation building off the second one and show off our first prototype which can be about any metric of the project. Finally, during the week of April 20th to the 27th we will need to show off a second prototype of the project and have our final Cad model of the boat and its subsystems. Once we get to ME-486C, we will have more finalized deliverables but for 476C these will be our milestones for the rest of the semester.

1.3 Success Metrics

Due to there already being a working boat done by a different team of graduate students for our project to be a success we need for our boat to be better. While their boat is working, there are still some small issues and kinks that are built into its design. With our we are designing those problems in mind and will see it as a success if we are able to fix them and run better. On a smaller scale of course if our boat is just able to work and scan the same as the graduate student boat, we will see it as a success but for us to be the happiest about our success we want it to surpass theirs by and large.

2 REQUIREMENTS

In this chapter of the report will be going over the customer requirements, engineering requirements, and the House of Quality for this project. The customer requirements for our project are what the people who assigned this project to us want us to accomplish with the finished project. The engineering requirements are then taking those requirements given to us a putting them into a way we can measure and work on. Finally, all the requirements will be put into a House of Quality to show how the two sections of requirements correlate with each other and how they are viewed on importance and feasibility.

2.1 Customer Requirements (CRs)

2.2 **Deploy & Recover quickly / safely:** Due to the canals having a 60-degree angle we will need to figure out a way to both deploy and recover the boat without damaging it.

2.3 **Operate in a current:** At points the canal could be affected by wind which can create a current which means we need to have strong enough thrusters for this.

2.4 **Accurate autonomous navigation:** We need to be able to have the boat drive itself without any human input which requires it to have a good GPS.

2.5 **Long operation per charge:** The boat will need to have a strong battery life to allow it to be in there for a decent amount of time.

2.6 **Remote operation:** We need to have the boat operate on it’s own once in the water with no human input

2.7 **Rugged / Waterproof while withstanding heat:** With the canals being in Phoenix it will need to survive in hot weather.

2.8 **Fail-safe recovery:** We need to make sure the boat will not be broken in the canal so the recovery can be without problems.

2.9 **Easy sensor data logging + transfer:** Whatever sensor we use for the boat needs to be recording data easy and easy for us to take.

2.10 **System fit in an SUV:** The boat needs to be compact enough to fit in the truck of a SUV.

2.11 Engineering Requirements (ERs)

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

2.19 House of Quality (HoQ)

System QFD — **Date:** 3/1/2026

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	Technical Requirements: Deployment & Recovery time	Launch angle	Tolerance	Nav accuracy	Range	Size	Material	Customer Opinion Survey: 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					

Figure 1: House of Quality

3 Research Within Your Design Space

3.1 Benchmarking

[Describe System-level benchmarking identifying at least three systems that you consider state-of-the-art. Describe all other sub-system-level benchmarking. Cite each benchmarked system/sub-system per IEEE citation style.] ***SOTA slide from presentation 1***

For the project we looked at three systems regarding it that we consider state-of-the-art. The first one is regarding the launch and recovery of a similar type of project that we used in our design project. The second one is a whole textbook about sensors and how they sense which we used to pick the sensor for our boat. The final source was a YouTube video showing a similar boat to the one we were tasked with making which we used to determine the navigation system for our boat.

[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

[2] HANDBOOK OF MODERN SENSORS cited. [Online]. Available: https://uodiyala.edu.iq/uploads/PDF%20ELIBRARY%20UODIYALA/EL95/Handbook%20of%20Modern%20Sensors%20%20Physics,%20Designs,%20and%20Applicatio.pdf

[3] Teledyne Oceanscience. (2015, March 30). *Teledyne Oceanscience Z Boat with eBee Drone Surveying - Newfields LLC* [Video]. YouTube. https://www.youtube.com/watch?v=3FoXxacB6Ro

3.2 Literature Review

Each person was tasked with finding multiple sources based on their specific subsystem that they would be able to use while researching their portion. The list of 37 sources below is a combined list of all the sources we used for this project. Each source is important as a piece of each one was used to get us to the point we are today in the project. Alexander looked at navigation sources, Rikki looked at propulsion sources, William looked at material sources, Norah looked at deployment and recovery sources, and finally Christian looked at sources about the sensor.

[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

[2] HANDBOOK OF MODERN SENSORS cited. [Online]. Available: https://uodiyala.edu.iq/uploads/PDF%20ELIBRARY%20UODIYALA/EL95/Handbook%20of%20Modern%20Sensors%20%20Physics,%20Designs,%20and%20Applicatio.pdf

[3] Teledyne Oceanscience. (2015, March 30). *Teledyne Oceanscience Z Boat with eBee Drone Surveying - Newfields LLC* [Video]. YouTube. https://www.youtube.com/watch?v=3FoXxacB6Ro

Alexander's Sources:
[4]"Planning a Mission with Waypoints and Events — Copter documentation," Ardupilot.org, 2024. https://ardupilot.org/copter/docs/common-planning-a-mission-with-waypoints-and-events.html (accessed Feb. 02, 2026).
[5]"Tuning Navigation — Rover documentation," Ardupilot.org, 2024. https://ardupilot.org/rover/docs/rover-tuning-navigation.html (accessed Feb. 02, 2026).
[6]A. Lekkas and T. Fossen, "Minimization of Cross-track and Along-track Errors for Path Tracking of Marine Underactuated Vehicles."
[7]A. Lekkas and T. Fossen, "Line-of-Sight Guidance for Path Following of Marine Vehicles."
[8]X. Yan, X. Yang, and Z. Xiang, "A Compensated Line-of-Sight Guidance Law for Unmanned Surface Vehicles Based on Dual-Mode Compensation Architecture," IFAC-PapersOnLine, vol. 59, no. 22, pp. 824–829, 2025, doi: https://doi.org/10.1016/j.ifacol.2025.11.737.
[9]H. Zheng and C. Liu, Towards Unmanned Surface Vehicles. CRC Press, 2025.
[10]T. I. Fossen, Handbook of Marine Craft Hydrodynamics and Motion Control. John Wiley & Sons, 2021.

Rikki's Sources:
[11] U.S. Navy employment options for unmanned surface vehicles (usvs) on JSTOR, https://www.jstor.org/stable/10.7249/j.ctt5vjw3v (accessed Feb. 2, 2026).
[12] J. T. Warner, *The Handbook of Lithium-Ion Battery Pack Design*. 2024.
[13] Energy Storage Structural Composites with integrated lithium-Ion Batteries: A review - galos - 2021 - advanced materials technologies - wiley online library, https://advanced.onlinelibrary.wiley.com/doi/10.1002/admt.202001059 (accessed Feb. 2, 2026).
[14] Modeling, identification, and control of an unmanned surface vehicle ..., http://onlinelibrary.wiley.com/doi/10.1002/rob.21452/abstract?deniedAccessCustomisedMessage=&userIsAuthenticated=false (accessed Feb. 2, 2026).
[15] W. Wang *et al.*, "USVs-Sim: A general simulation platform for unmanned surface vessels autonomous learning," *Concurrency and Computation: Practice and Experience*, vol. 34, no. 3, Sep. 2021. doi:10.1002/cpe.6567
[16] "USV hull," USV Hull -, https://oceangreenbay.com/usv-hull/ (accessed Feb. 1, 2026).
[17] Grava Hydro, "Photo Gallery," Grava Hydro, https://gravahydro.com/media#afdbc16e-d7fa-4e63-9e13-d08fe7731ded (accessed Feb. 1, 2026).

William's Sources:
[18] G. Rublein, "The Stability of Boats: A Science, Technology, Engineering, and Mathematics (STEM) Exercise," *VCU Scholars Compass*, 2019. https://doi.org/10.25891/5y1p-p659 (accessed Feb. 02, 2026).
[19] R. Holmes, T. McDougall, P. Barker, R. Pawlowicz, S. Griffies, and P. Durack, "The interpretation of temperature and salinity variables in numerical ocean model output and the calculation of heat fluxes and heat content - ACCESS-CM2 data and code," *Zenodo (CERN European Organization for Nuclear Research)*, Oct. 2021, doi: https://doi.org/10.5281/zenodo.5580343.
[20] A. S. Ghasseminia and A. Faraji, "Storm Resistant Boat Designing Based on the Geometry and Movement of Water Strider," *Journal of Bionic Engineering*, vol. 5, pp. 87–90, Sep. 2008, doi:

https://doi.org/10.1016/s1672-6529(08)60077-3.
[21] V. Mihai and L. Rusu, "An Overview of the Ship Ventilation Systems and Measures to Avoid the Spread of Diseases," *Inventions*, vol. 6, no. 3, p. 55, Jul. 2021, doi: https://doi.org/10.3390/inventions6030055.
[22] E. Bormashenko, "Surface tension supported floating of heavy objects: Why elongated bodies float better?," *Journal of Colloid and Interface Science*, vol. 463, pp. 8–12, Feb. 2016, doi: https://doi.org/10.1016/j.jcis.2015.10.031.

Norah's Sources:
[23] C. Zhao, P. Thies, J. Lars, and J. Cowles, "ROV launch andrecovery from an unmanned autonomous surface vessel –Hydrodynamic modelling and system integration," *OceanEngineering*, vol. 232, p. 109019, Jul. 2021, doi:https://doi.org/10.1016/j.oceaneng.2021.109019.
[24] "Winch calculation," *Emce.com*, 2020.https://emce.com/about-winches/winch%20calculation
[25] J. Li, J. Chavez-Galaviz, and N. Mahmoudian, "Vision driventrailer loading for autonomous surface vehicles in dynamicenvironments," *Frontiers in Robotics and AI*, vol. 12, Sep.2025, doi: https://doi.org/10.3389/frobt.2025.1607676.
[26] E. Sarda and M. Dhanak, "A USV-Based Automated Launchand Recovery System for AUVs," Sep. 2016.https://www.researchgate.net/publication/309055907_A_USV-Based_Automated_Launch_and_Recovery_System_for_AUVs
[27] L. Lord, *Naval Architecture of Planing Hulls*. 1954.

Christian's Sources:
[28] A. C. Bovik, Ed., *Handbook of Image and Video Processing*. Burlington, MA, USA: Elsevier Science, 2010.
[29] D. R. Yoerger *et al*., "Autonomous underwater vehicle data collection systems," *IEEE Robotics & Automation Magazine*, accessed Feb. 2, 2026. [Online]. Available: https://ieeexplore.ieee.org
[30] N. Fairfield, G. Kantor, and D. Wettergreen, "Real-time sensor fusion for autonomous navigation," *The International Journal of Robotics Research*, accessed Feb. 2, 2026. [Online]. Available: https://journals.sagepub.com
[31] N. E. Saadi and Z. Istenes, "Benchmarking data logging strategies in ROS-integrated multi-sensor robots under network constraints," in *Proc. Int. Conf. Formal Methods and Foundations of Artificial Intelligence*, 2025, pp. 188–200, doi: 10.17048/fmfai.2025.188.

Universal Sources:
[32]A. Dominguez, "SRP begins draining, clean-up as part of maintenance on canals in Mesa," *https://www.azfamily.com*, Nov. 21, 2024. https://www.azfamily.com/2024/11/21/srp-begins-draining-clean-up-part-maintenance-canals-mesa/
[33]S. O'Sullivan, "Around 8 miles of Scottsdale canals to be dried, worked on," *KTAR.com*, Jan. 06, 2026. https://ktar.com/arizona-water-news/canals-dry-up-maintenance-2026/5802217/
[34]E. V. Lewis, Ed., *Principles of Naval Architecture*, 3rd ed. Jersey City, NJ, USA: Society of Naval Architects and Marine Engineers (SNAME), 1988.
[35] E. C. Tupper, *Introduction to Naval Architecture*, 5th ed. Oxford, U.K.: Butterworth-Heinemann,

2013.
[36] R. C. Hibbeler, *Engineering Mechanics: Dynamics*, 14th ed. Upper Saddle River, NJ, USA: Pearson, 2016
[37] P. J. Pritchard and J. W. Mitchell, *Fox and McDonald's Introduction to Fluid Mechanics*, 9th ed. Hoboken, NJ, USA: Wiley, 2016

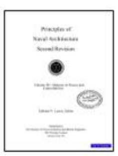
3.3 Mathematical Modeling

Each member of the project did their own research into their own sub-system of the project. Their math and reasoning for what they did and accomplished is shown in each image of their section of the report shown below.

3.3.1 Alexander's Modeling - Thrust:

As seen below, Alexander did calculations on the thrust based on the weight and where the thrusters were located. The textbooks he used for these equations are shown next to their respective sections.

Engineering Calculations of Differential Thrust



		Thrust							
Voltage	Combo	Right	Left	M_z (N*m)		Forward	Backward		
32 V	Nominal	51.45	-39.2	7.19534375	Nominal kgf	5.25	4		
40 V	Max	65.66	-49.49	9.14003125	Max kgf	6.7	5.05	distance (b)	
16 V	Half Nominal	51.45	0	4.08384375	Nominal N	51.45	39.2	in	6.25
20 V	Half Max	65.66	0	5.2117625	Max N	65.66	49.49	m	0.15875

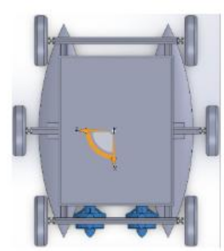
$$M_z = (T_R - T_L)\frac{b}{2}$$

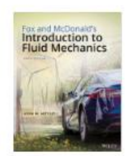
mass distibution	(k)	I_z (kg*m^2)		distance (b)		mass
center	0.6	0.343				
even	0.8	0.457	in	12.5	lbs	50
outside	1	0.572	m	0.3175	kg	22.6796

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

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

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





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

Figure 2: Alexander's Modeling

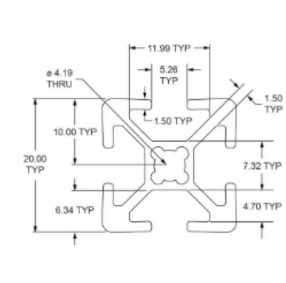
3.3.2 William's Modeling - Materials:

As seen below, William did calculations on what material should be used for the framing of the entire boat. He got his numbers off industry websites that were selling the rods at 20 mm by 20 mm by 20 inches, which is the size we are looking to use. His conclusion was that aluminum rods would be the best ones to use.

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

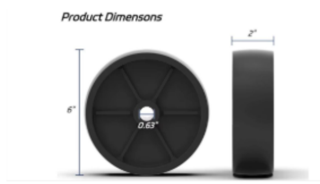


Aluminum = A very good balance between cost and support.
Steel = A little overkill unless the weight is drastically heavy.
HDPE = The lightest but has the least amount of support.

Figure 3: William's Modeling

3.3.3 Norah's Modeling – Deployment and Recovery:

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.



$$V_o = \frac{\pi h\,(D^2 - d^2)}{4} = 9.032 in^3$$
$$V_i = \frac{\pi h_i (D_i{}^2 - d_i{}^2)}{4} = 11.723 in^3$$
$$V_o + V_i = 20.755 in^3$$
$$B = \rho V = 0.749 lbf$$

$$h = 2\ in$$
$$D = 6\ in$$
$$d = D_i = 5.5\ in$$
$$h_i = 0.5\ in$$
$$d_i = 0.63$$
$$\rho = 0.03613\ lb/in^3$$

Figure 4: Norah's Modeling

3.3.4 Rikki's Modeling - 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.

Figure 5: Rikki's Modeling

3.3.5 Christian's Modeling - Buoyancy:

As seen below, Christian did calculations to figure out how buoyant our pontoons holding everything up will be and how many lbs. they can hold. He got the equations from his sources and all the numbers from what we believe will be the final area for our boat. He concluded that each pontoon will be able to hold around 28.5 lbs. of force each.

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

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

Figure 6: Christian's Modeling

4 Design Concepts

4.1 Functional Decomposition

The chart shown below is a decomposition chart which shows all of the important functions the project must accomplish. The chart highlights some major ones like the function of the controller, the power supplied by the batteries, and how it will interpret everything. The chart is important due to it being an easy and fast way to look at what specific tasks are required by other tasks and what still needs to be done before we get to that task. For example, we are unable to start on how we will store the data until we figure out the power situation as shown in the chart.

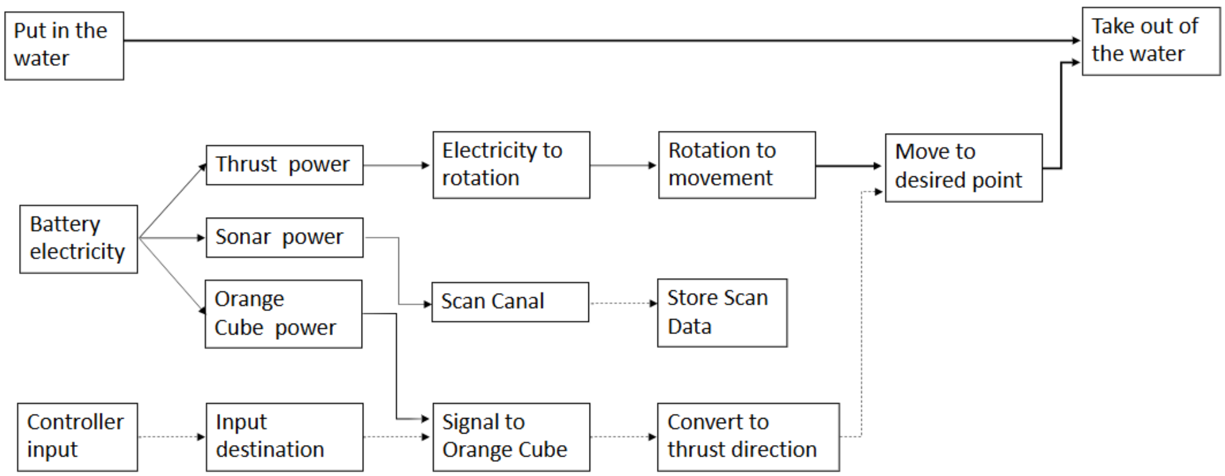
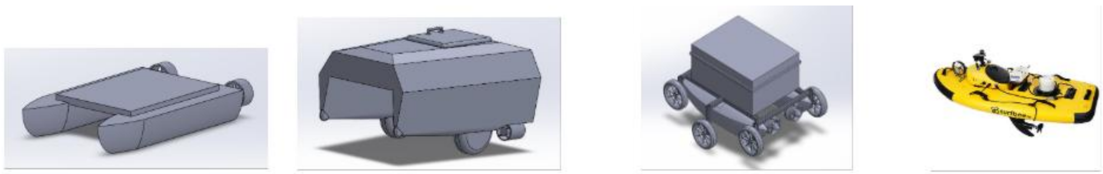


Figure 7: Function Chart

4.2 Concept Generation

The four designs that we used during the design process are shown below in the image with the pros and cons for each. Early in the design process we had many different designs that we believed all would be equally good. We filtered out design four first as all the electronics were more in the way, and it had the least amount of stability. Design two was next as the hull was too complicated, and the 3D printing technology we wanted to use would not be feasible for it. Design three was the last to be counted out as similar to design one; it was not very stable in windy circumstances. That left us with design one as the design we went with.



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

Figure 8: Concepts

4.3 Selection Criteria

As stated above for why the designs weren't picked, the selection criteria were based off boat feasibility and how they would interact with the engineering requirements. The most important requirements that knocked out most of the designs were that it was heavy or would be hard to recover. The heaviness stems from how big the design would be required to be while the hard recovery comes from how it was designed to begin with. This led us to go with the most reasonable design number three.

4.4 Concept Selection

Shown below are 3 different figures showing the decision matrix, pugh chart, and final CAD. The other sections above went into detail on what concept was chosen with those being represented in the Pugh chart and decision matrix below. The image of the CAD model is currently what we are working with and calculating for our project. We believe it is close to what we need visually and hope that it will hold up mathematically.

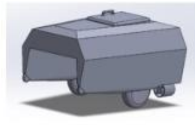
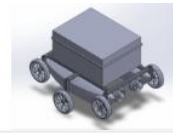
Criteria					
Deployment	-	s	Datum	-	+
Recovery	-	s	Datum	-	+
Navigation	-	-	Datum	+	S
Waterproof	+	+	Datum	-	+
Battery Life	S	-	Datum	+	-
Data Logging	S	S	Datum	+	S
Size	+	-	Datum	+	S
Total +	2	1	Datum	3	3
Total -	3	3	Datum	3	1
Total Same	2	3	Datum	0	3

Figure 9: Pugh Chart

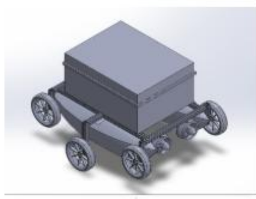
Criteria	Weight						
		Unweighted:	Weighted:	Unweighted:	Weighted:	Unweighted:	Weighted:
Deployment	0.25	90	22.5	50	12.5	80	20
Recovery	0.25	90	22.5	50	12.5	80	20
Navigation	0.15	85	12.75	85	12.75	85	12.75
Waterproof	0.1	100	10	85	8.5	90	9
Battery Life	0.1	75	7.5	90	9	75	7.5
Data Logging	0.1	80	8	80	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 10: Decision Matrix

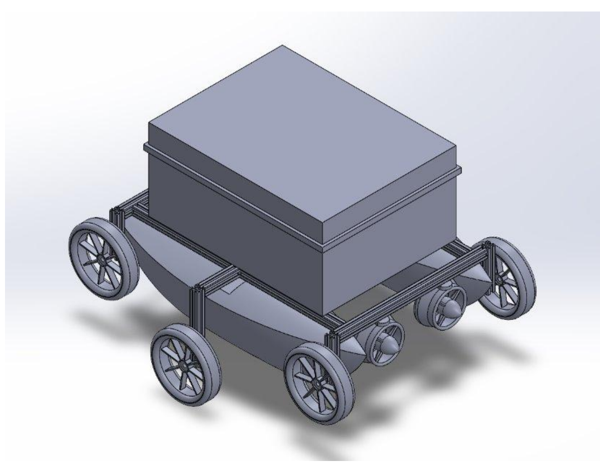


Figure 11: Current Cad Model

CONCLUSIONS

Overall, throughout this report you should have gotten a decent understanding of what the project is, what our goals are, the current progress done on the project, and what we will be doing with the future. The ARWBCI project believes that it will be able to create something to analyze these dirty canals to the best of its ability and what is being asked of it. With its sensor and its thrusters, it will be able to find the cracks and traverse through the water with relative ease. With the current CAD model shown earlier being our hopeful final design we believe that will be the final solution for our design and will be exactly what is built for those saltwater canals down in Phoenix.

5 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
[2] HANDBOOK OF MODERN SENSORS cited. [Online]. Available: https://uodiyala.edu.iq/uploads/PDF%20ELIBRARY%20UODIYALA/EL95/Handbook%20of%20Modern%20Sensors%20%20Physics,%20Designs,%20and%20Applicatio.pdf
[3] Teledyne Oceanscience. (2015, March 30). *Teledyne Oceanscience Z Boat with eBee Drone Surveying - Newfields LLC* [Video]. YouTube. https://www.youtube.com/watch?v=3FoXxacB6Ro

Alexander's Sources:
[4]"Planning a Mission with Waypoints and Events — Copter documentation," Ardupilot.org, 2024. https://ardupilot.org/copter/docs/common-planning-a-mission-with-waypoints-and-events.html (accessed Feb. 02, 2026).
[5]"Tuning Navigation — Rover documentation," Ardupilot.org, 2024. https://ardupilot.org/rover/docs/rover-tuning-navigation.html (accessed Feb. 02, 2026).
[6]A. Lekkas and T. Fossen, "Minimization of Cross-track and Along-track Errors for Path Tracking of Marine Underactuated Vehicles."
[7]A. Lekkas and T. Fossen, "Line-of-Sight Guidance for Path Following of Marine Vehicles."
[8]X. Yan, X. Yang, and Z. Xiang, "A Compensated Line-of-Sight Guidance Law for Unmanned Surface Vehicles Based on Dual-Mode Compensation Architecture," IFAC-PapersOnLine, vol. 59, no. 22, pp. 824–829, 2025, doi: https://doi.org/10.1016/j.ifacol.2025.11.737.
[9]H. Zheng and C. Liu, Towards Unmanned Surface Vehicles. CRC Press, 2025.
[10]T. I. Fossen, Handbook of Marine Craft Hydrodynamics and Motion Control. John Wiley & Sons, 2021.
[11] U.S. Navy employment options for unmanned surface vehicles (usvs) on JSTOR, https://www.jstor.org/stable/10.7249/j.ctt5vjw3v (accessed Feb. 2, 2026).
[12] J. T. Warner, *The Handbook of Lithium-Ion Battery Pack Design*. 2024.
[13] Energy Storage Structural Composites with integrated lithium-Ion Batteries: A review - galos - 2021 - advanced materials technologies - wiley online library, https://advanced.onlinelibrary.wiley.com/doi/10.1002/admt.202001059 (accessed Feb. 2, 2026).
[14] Modeling, identification, and control of an unmanned surface vehicle ..., http://onlinelibrary.wiley.com/doi/10.1002/rob.21452/abstract?deniedAccessCustomisedMessage=&userIsAuthenticated=false (accessed Feb. 2, 2026).
[15] W. Wang *et al.*, "USVs-Sim: A general simulation platform for unmanned surface vessels autonomous learning," *Concurrency and Computation: Practice and Experience*, vol. 34, no. 3, Sep. 2021. doi:10.1002/cpe.6567
[16] "USV hull," USV Hull -, https://oceangreenbay.com/usv-hull/ (accessed Feb. 1, 2026).
[17] Grava Hydro, "Photo Gallery," Grava Hydro, https://gravahydro.com/media#afdbc16e-d7fa-4e63-9e13-d08fe7731ded (accessed Feb. 1, 2026).
[18] G. Rublein, "The Stability of Boats: A Science, Technology, Engineering, and Mathematics (STEM)

Exercise," *VCU Scholars Compass*, 2019. https://doi.org/10.25891/5y1p-p659 (accessed Feb. 02, 2026).
[19] R. Holmes, T. McDougall, P. Barker, R. Pawlowicz, S. Griffies, and P. Durack, "The interpretation of temperature and salinity variables in numerical ocean model output and the calculation of heat fluxes and heat content - ACCESS-CM2 data and code," *Zenodo (CERN European Organization for Nuclear Research)*, Oct. 2021, doi: https://doi.org/10.5281/zenodo.5580343.
[20] A. S. Ghasseminia and A. Faraji, "Storm Resistant Boat Designing Based on the Geometry and Movement of Water Strider," *Journal of Bionic Engineering*, vol. 5, pp. 87–90, Sep. 2008, doi: https://doi.org/10.1016/s1672-6529(08)60077-3.
[21] V. Mihai and L. Rusu, "An Overview of the Ship Ventilation Systems and Measures to Avoid the Spread of Diseases," *Inventions*, vol. 6, no. 3, p. 55, Jul. 2021, doi: https://doi.org/10.3390/inventions6030055.
[22] E. Bormashenko, "Surface tension supported floating of heavy objects: Why elongated bodies float better?," *Journal of Colloid and Interface Science*, vol. 463, pp. 8–12, Feb. 2016, doi: https://doi.org/10.1016/j.jcis.2015.10.031.
[23] C. Zhao, P. Thies, J. Lars, and J. Cowles, "ROV launch andrecovery from an unmanned autonomous surface vessel –Hydrodynamic modelling and system integration," *OceanEngineering*, vol. 232, p. 109019, Jul. 2021, doi:https://doi.org/10.1016/j.oceaneng.2021.109019.
[24] "Winch calculation," *Emce.com*, 2020.https://emce.com/about-winches/winch%20calculation
[25] J. Li, J. Chavez-Galaviz, and N. Mahmoudian, "Vision driventrailer loading for autonomous surface vehicles in dynamicenvironments," *Frontiers in Robotics and AI*, vol. 12, Sep.2025, doi: https://doi.org/10.3389/frobt.2025.1607676.
[26] E. Sarda and M. Dhanak, "A USV-Based Automated Launchand Recovery System for AUVs," Sep. 2016.https://www.researchgate.net/publication/309055907_A_USV-Based_Automated_Launch_and_Recovery_System_for_AUVs
[27] L. Lord, *Naval Architecture of Planing Hulls*. 1954.
[28] A. C. Bovik, Ed., *Handbook of Image and Video Processing*. Burlington, MA, USA: Elsevier Science, 2010.
[29] D. R. Yoerger *et al*., "Autonomous underwater vehicle data collection systems," *IEEE Robotics & Automation Magazine*, accessed Feb. 2, 2026. [Online]. Available: https://ieeexplore.ieee.org
[30] N. Fairfield, G. Kantor, and D. Wettergreen, "Real-time sensor fusion for autonomous navigation," *The International Journal of Robotics Research*, accessed Feb. 2, 2026. [Online]. Available: https://journals.sagepub.com
[31] N. E. Saadi and Z. Istenes, "Benchmarking data logging strategies in ROS-integrated multi-sensor robots under network constraints," in *Proc. Int. Conf. Formal Methods and Foundations of Artificial Intelligence*, 2025, pp. 188–200, doi: 10.17048/fmfai.2025.188.
[32]A. Dominguez, "SRP begins draining, clean-up as part of maintenance on canals in Mesa," *https://www.azfamily.com*, Nov. 21, 2024. https://www.azfamily.com/2024/11/21/srp-begins-draining-clean-up-part-maintenance-canals-mesa/
[33]S. O'Sullivan, "Around 8 miles of Scottsdale canals to be dried, worked on," *KTAR.com*, Jan. 06, 2026. https://ktar.com/arizona-water-news/canals-dry-up-maintenance-2026/5802217/
[34]E. V. Lewis, Ed., *Principles of Naval Architecture*, 3rd ed. Jersey City, NJ, USA: Society of Naval Architects and Marine Engineers (SNAME), 1988.

[35] E. C. Tupper, *Introduction to Naval Architecture*, 5th ed. Oxford, U.K.: Butterworth-Heinemann, 2013.
[36] R. C. Hibbeler, *Engineering Mechanics: Dynamics*, 14th ed. Upper Saddle River, NJ, USA: Pearson, 2016
[37] P. J. Pritchard and J. W. Mitchell, *Fox and McDonald's Introduction to Fluid Mechanics*, 9th ed. Hoboken, NJ, USA: Wiley, 2016