ARBWCI

ME 476C – Sec 001

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Introduction

Our goal is to create an autonomous boat that can scan the bottom of canals and detect buildup, cracks, and objects. This project is sponsored by the Salt River Project (SRP), as we will be using the boat in their canals.

Client 1:

Client 2:

Christian

State-of-the-Art (SOTA)

To inspect canal beds more frequently we were tasked with creating an autonomous robotic boat with a sensor to gather the data from these salt water river canals.

ROV launch and recovery from an unmanned autonomous surface vessel, Journal Article [1]

- Example of a good recovery types.

HANDBOOK OF MODERN SENSORS, Handbook [2]

- Gives good context on how to use different kinds of sensors.

Teledyne Oceanscience Z Boat with eBee Drone Surveying - Newfields LLC [3]

- Full of linkages, control mechanisms, and mathematical relations core to our project

William

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.

Rikki

QFD

Engineering requirements

- Deployment / Recovery time & safety
  - Time it take to deploy and recover it safely
- Ship Design
  - How well it can work under the canal conditions
- Sensor and logging
  - How well the sensor can see and log the data

System QFD | **Date:** 1/30/2025

#	Technical Requirement	1	2	3	4	5	6
1	Deployment/Recovery time						
2	Launch angle	9					
3	Current tolerance	3	1				
4	Nav accuracy	1		1			
5	Range				9		
6	Size Under Water	3	1	9	3	9	
7	Weight/Material	1	1	9	3	9	3

Legend
- A Modified RC Boat
- B Custom Boat
- C Previous Custom Boat

#	Customer Needs	Customer Weights	Deployment/Recovery time	Launch angle	Current tolerance	Nav accuracy	Range	Size Under Water	Weight/Material	1 Poor	2	3 Acceptable	4	5 Excellent
			Technical Requirements							**Customer Opinion Survey**				
1	Deploy & Recover quickly	5	9	9	3			3	1		C		AB	
2	Deploy & Recover safely	5	9	9	3			3	1	C		A		B
	Deploy & Recover on steep canal walls	5	9	9	1			3	1	C			B	A
	Operate in current	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 charge	3			3	1	9		1					ABC
5	Remote operation	2				3	9				A			BC
6	Rugged/waterproof	4			3			3	9		A		BC	
7	Withstand Phoenix heat	3					1	1	9			A		BC
8	Fail-safe recovery	1				3	1			C	A		B	
9	Easy sensor data logging + transfer	3				3	1					A		BC
10	Portable: system fits in an SUV	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 System QFD

Alexander

Mathematical Modelling of Navigation

Based on the project requirement that the autonomous boat must maintain positioning accuracy along the canal midline with less than 0.5 m error, we define and analyze cross-track error and the guidance law used to correct it.

Using the perpendicular distance from the canal midline

$$|e_y| \leq .5m$$

To drive the boat toward the canal centerline,
a Line-of-Sight (LOS) guidance method is used

$$\psi_d = \psi_{path} + \arctan\left(\frac{-e_y}{\triangle}\right)$$

To ensure corrective steering is consistent, the lookahead distance is based on the allowable correction angle

$$\theta_{max} = \arctan\left(\frac{e_{max}}{\triangle}\right)$$

To solve for an appropriate lookahead distance

$$\triangle = \frac{e_{max}}{\tan(\theta_{max})}$$

We can use a heading correction of 15 degrees

$$\triangle = \frac{.5}{\tan(15)} = 1.87m$$

[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).

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Alexander

Mathematical Modelling of Propulsion + Power

Based on the earlier design, we know that the robot is going to need an increase of power and battery life in order to easily travel upstream and sustain the output of power.

Battery Energy

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

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

Operating Voltage (LiHV)

$$V = 3.7 * N_s$$

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

Runtime

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

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

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Rikki

Mathematical Modelling of Materials

Due to the nature of the canals the autonomous boat would need to both be designed out of a material that can both withstand salt water and the intense heat of Phoenix. With all the electronics and devices needed for the boat all areas they are attached to need to be both water and heat proof.

Temperature change of water

$$\Delta T = \frac{(1-0.1)\cdot S \cdot A \cdot t}{m \cdot c_p}$$

Heat Equation

$$Q = mC_p \, \Delta T$$

Buoyancy Equation

$$F_B = \rho g V$$

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William

Mathematical Modelling of Deployment

Using the weight of the boat and the flow of the canal we have to figure out the best way to launch and load the boat without the current sweeping it away. We also cannot rely on using the motors and power when trying to get the boat out of the water because we have to be prepared to load the boat when the batteries are dead.

$$W = mg$$

$$F_g = W \sin\theta$$

$$N = W \cos\theta$$

$$F_f = \mu N$$

$$F_d = \frac{1}{2}\rho C_d A v^2$$

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Norah

Mathematical Modelling of Sensors

The system collects data from sonar and cameras, stores it onboard, and sends key information to a ground station. This section evaluates data generation, storage needs, and wireless transmission to prevent data loss during missions.

Total Data Rate

$$R_{total} = R_{camera} + R_{sonar} + R_{telemetry}$$

Storage Requirements

$$S = \frac{R_{total} \cdot T}{8}$$

Communication Constraint

$$R_{link} < R_{total}$$

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Schedule and Budget:

We have a budget of $1000 but $1500 with proper justification. We plan on fundraising over $500 so after fundraising we will have a minimum budget of $1500. We plan on fundraising by having a fast food restaurant agree to give us a percentage of sales when customers mention our fundraising code.

Our supplies we will use for this project aren't completely decided but we plan on using a majority of our budget to go towards a controller, motors, and powerful batteries.

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	30%	1/30/26	2/13/26
Planning and design				
Weekly Client Meeting	Team	5%	1/30/26	4/24/26
Idea Storming	Team	60%	1/30/26	2/6/26
Base Designs	Team	60%	1/30/26	2/6/26
Pick top 3 designs	Team	0%	2/7/26	2/13/26
Judge top 3 degins	Team	0%	2/7/26	2/13/26
Pick top design	Team	0%	2/7/26	2/13/26

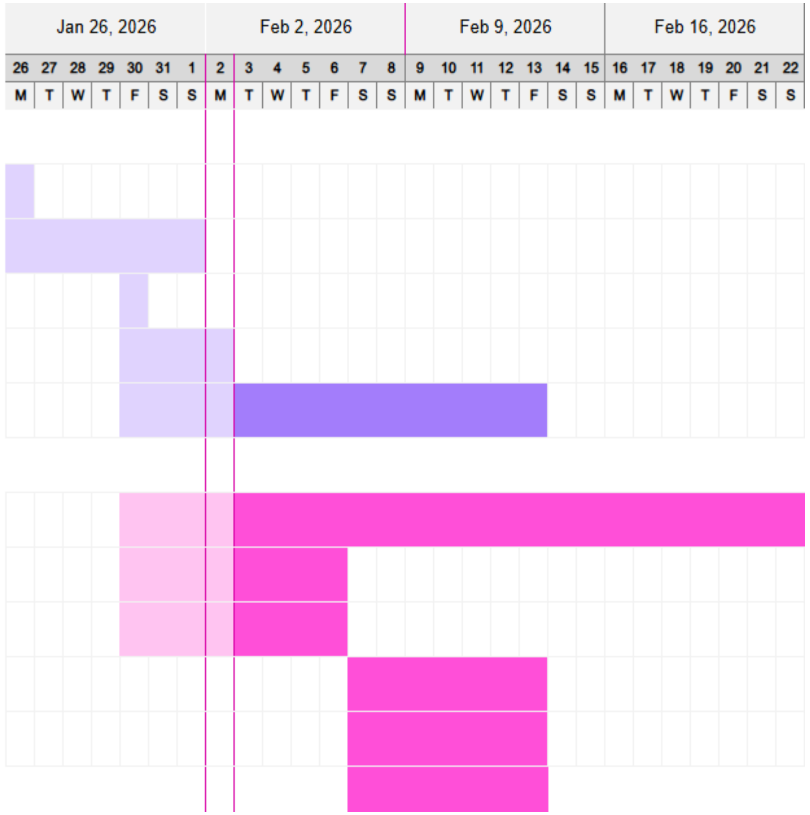

Figure 2: Gantt

Norah

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THANK YOU

Questions?