ARBWCI

ME 476C – Sec 001

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3/30/2026

NAU NORTHERN ARIZONA UNIVERSITY
Steve Sanghi College of Engineering

Introduction

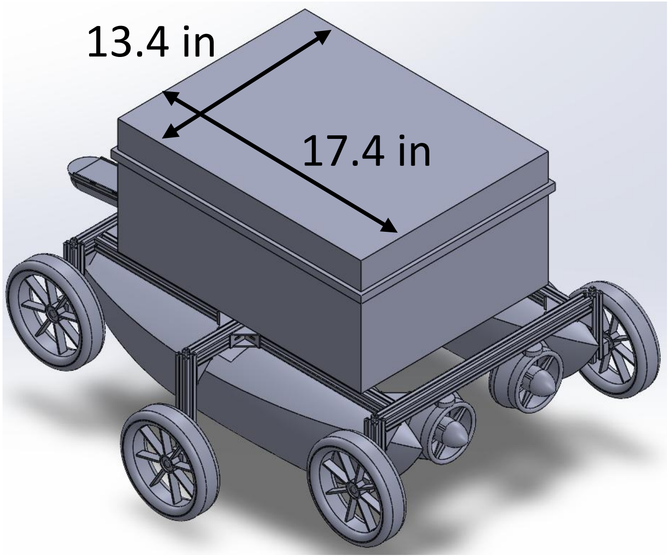
There are about 211 kilometers of canals in Arizona that require regular inspections. Currently, sections are being drained for inspection, but they may not be checked again for five to ten years. Our main goal is to design an autonomous boat that can not only inspect the canals without draining them, but also make the process faster and more efficient. Our design improves on a previous version with better deployment, recovery, reliability, and navigation.

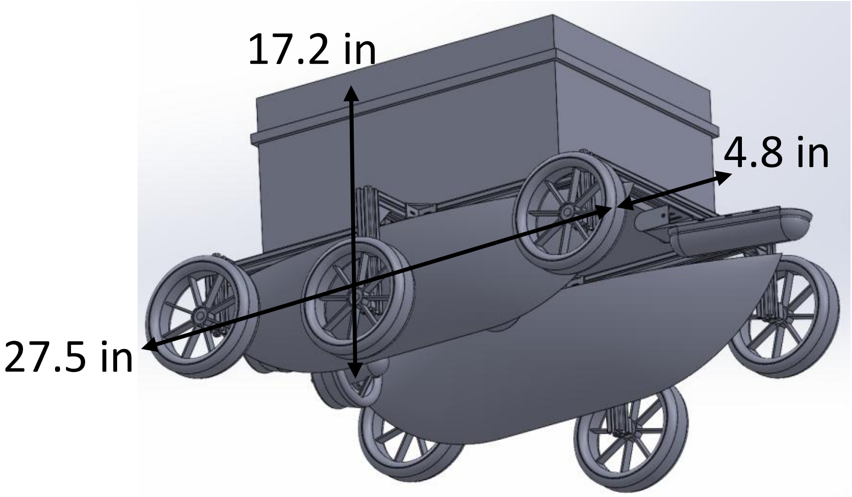
Client 1:
Dr. Reza Sharif Razavian

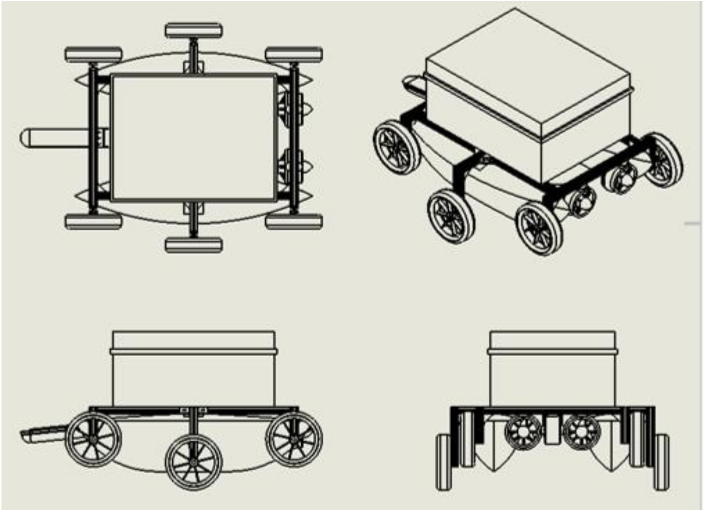
Client 2:
SRP

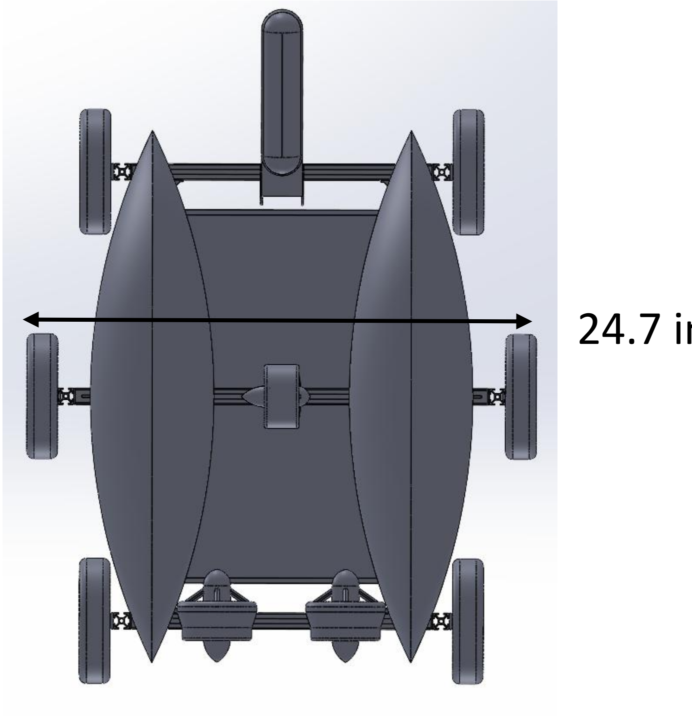
Christian

Design Description Dimensions





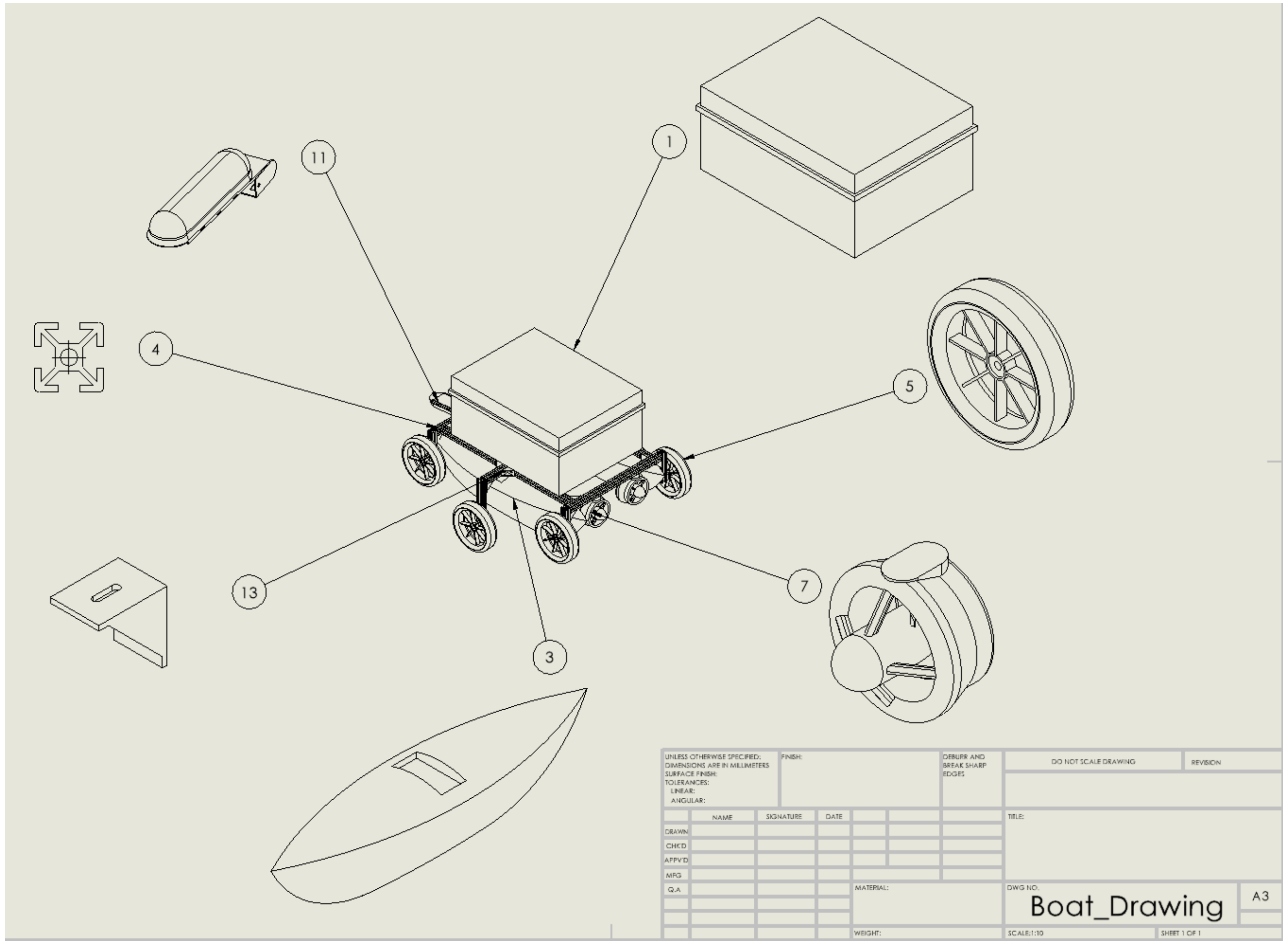




Alex

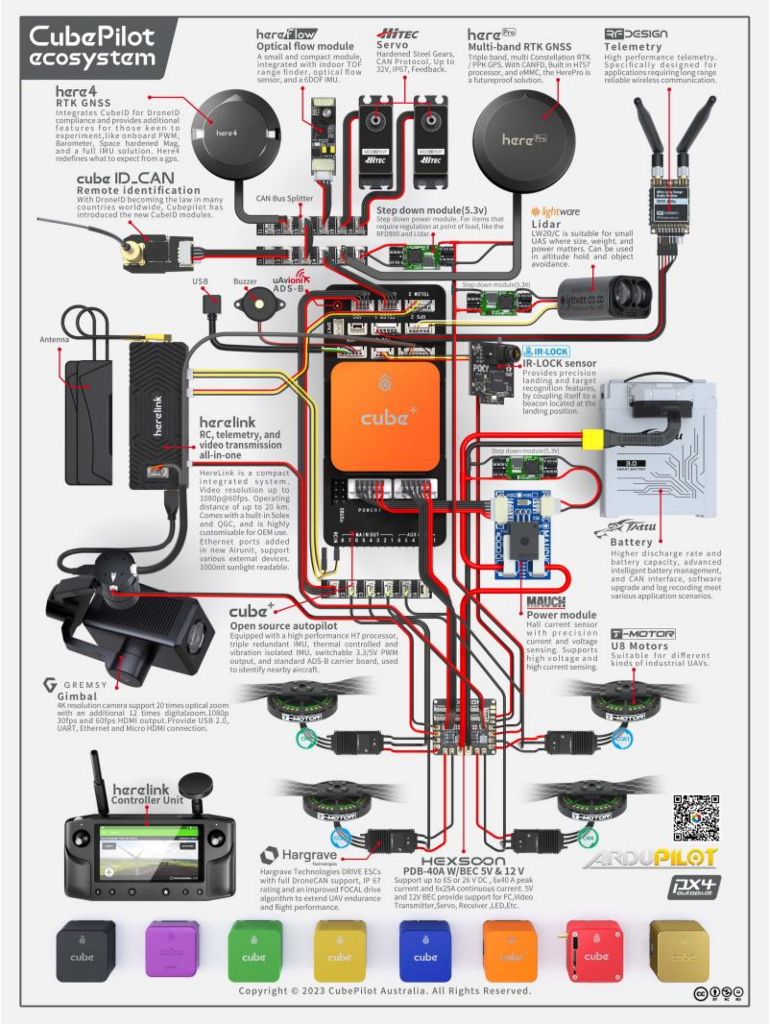
Design Description Drawing

ITEM NO.	PART NUMBER	DESCRIPTION	QTY.
1	Case	Electrical box that holds all hardware	1
2	2020_Aluminum_Extention_20.7126	Framing of different sizes	2
3	BroCraft_Pontoon	The current sized pontoons	2
4	2020_Aluminum_Extention_14.75	Framing of different sizes	2
5	Wheel	Generic sized wheel for CAD	6
6	2020_Aluminum_Extention_20.2	Framing of different sizes	1
7	Thruster	Two T200 main forward thrusters	2
8	2020_Aluminum_Extention_4	Framing of different sizes	4
9	2020_Aluminum_Extention_6.5	Framing of different sizes	2
10	Apis_Queen	Small lateral correction thruster	1
11	3-in-1	Transducer Sonar for scanning	1
12	Wheel_bearing	Generic wheel bearinng attachment	6
13	2020_Bracket	Commercial connection for 2020 extrusions	18



Alex

Design Description Hardware



Alex

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.
- 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

Updated QFD

Project:	ARBWCI
Date:	3/30/2026

Office on the web Frame

	Deployment & Recovery time	Overheating	Scan Speed	Turning Speed	Float ablility	Nav accuracy	Range	Size
Deployment & Recovery time								
Overheating	1							
Scan Speed	1	3						
Turning Speed	3	9	1					
Float ablility	3			3				
Nav accuracy	1		9	3	3			
Range		9	3	9	3	1		
Size	9	3		9	9	3	9	
Material	3	3		3	9		3	9

Legend

A	Modified RC Boat
B	Our Design
C	Previous Design

		Technical Requirements									Customer Opinion Survey				
Customer Needs	Customer Weights	Deployment & Recovery time - Wheels	Overheating - Heat Transfer	Scan Speed - Relative speed	Turning speed - Differential thrust	Float ability - Buoyancy	Nav accuracy - Cross track error	Range - Power consumption	Size - Pontoon dimensions	Material - Framing	1 Poor	2	3 Acceptable	4	5 Excellent
Quick Deployment & Recovery	5	9		1					3	1		C		AB	
Safe Deployment & Recovery	5	9		1	1	3			3	3	C		A		B
Deploy & Recover on 60 degree canal walls	5	9		1	3	3			3	3	C			B	A
Float Upstream	3			1	3	9	3	9	3	1		C		A	B
Accurate autonomous navigation	4			3	3		9	3	1	1	A	C		B	
Long operation per usage	3		3	3			1	9	1	1					ABC
Hands off operation	2				3		9	3				A			BC
Waterproof	4					3			3	9		A		BC	
Withstand Phoenix Weather	3		9			1			1	9			A		BC
Fail-safe recovery	1	3			3	3	3	1		1	C	A		B	
Easy data logging & transfer	3			3			3	1					A		BC
Portable	2	9				3			9	3					ABC
Technical Requirement Units		Minutes	Degrees - C	m/s	rad/s^2	lbs	m	km	m	kg					
Technical Requirement Targets		5	20	3	1	60	0.5	2	0.5	15					
Absolute Technical Importance		156	36	48	50	81	78	76	94	115					
Relative Technical Importance		1	9	8	7	4	5	6	3	2					

Figure 1 System QFD

Rikki

Engineering Calculations of Buoyancy

Buoyancy of Pontoons

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

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

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

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

Maximum Power Requirement

2 × T200 thrusters ≈ **700 W**

1 × ApisQueen thruster ≈ **100 W**

Cube Orange+ ≈ **5 W**

Here3 GPS ≈ **2 W**

SiK telemetry radio ≈ **2 W**

Lowrance HDS-7 ≈ **35 W**

Lowrance 3-in-1 transducer ≈ **25 W**

ESC / system losses ≈ **80 W**

$$P_{total,max} \approx 700 + 100 + 5 + 2 + 2 + 35 + 25 + 80$$

$$P_{total,max} \approx 949\ \text{W}$$

Christian

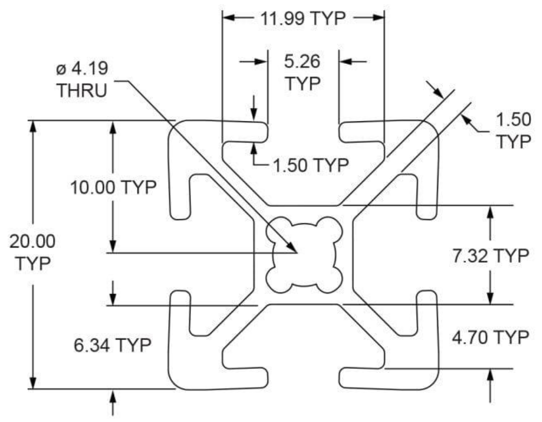
Engineering Calculations of Materials

[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 Heat

With the amount of electronics, we are expecting to put into a singular box with the Phoenix sun blaring down, we needed to see if there was a chance of the electronics inside the box overheating with our design as this was also happening with the grad student's design.

Electronics in the box:

- Orange Cube (autopilot): 4W
- Here3 GPS: 1.5W
- 1 SiK telemetry radio 0.5W
- 3 ESCs: 2W
- Lowrance 3-in-1 transducer: 17W
- Lowrance HDS-7 display: 5W

Q = 30 Watts

Calculations:

- Box = 0.5 m * 0.4 m * 0.2 m
- A = 0.84 m^2

Plastic Thermal Resistance

- U = 5 W/*m^2*K)

Internal Temperature:

- Delta_T = Q/(U * A)
- Delta_T = 30/(5 * 0.84) = 7.1 C

Outside Temperature of Phoenix in June: 100 C
Inside Temperature = 107 C
Range: 95 C – 115 C

William

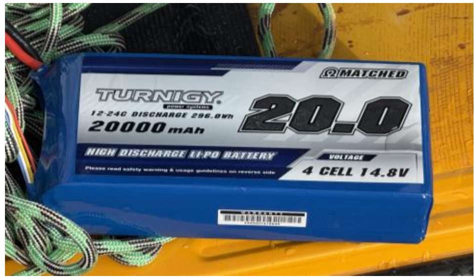
Engineering Calculations of Battery

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

$$V = 3.7 * N_s$$

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



V = 3.7 * 4S

V = 14.8 V

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

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

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

E = 14.8V * 20Ah

E = 296 Wh

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

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

t= 296Wh / 514.5W

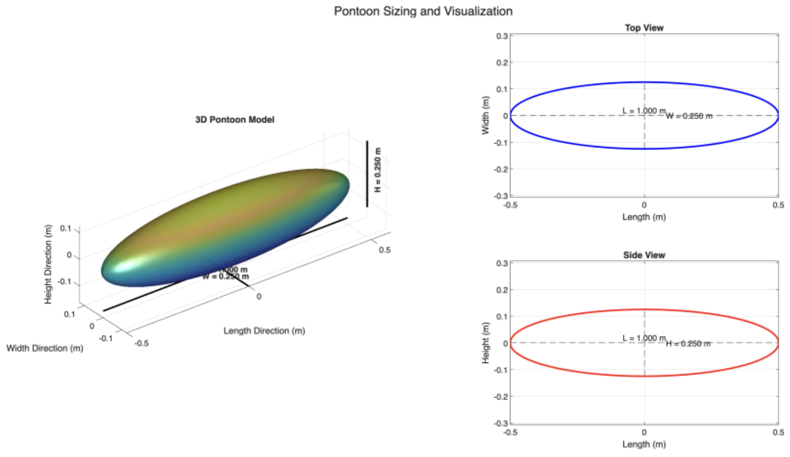
t= 0.575 hr.

t= 34.5 min.

Rikki

Engineering Calculations Pontoon Generator

```
clc; clear; close all;


%  Pontoon size generator
%  Inputs: Length, Width, Height
%  Output: Dimensions, volume, buoyancy, and visual

% Desired Dimensions
L = input('Enter pontoon length (m): ');
W = input('Enter pontoon width  (m): ');
H = input('Enter pontoon height (m): ');


if L <= 0 || W <= 0 || H <= 0
    error('All dimensions must be greater than zero.');
end

a = L/2;   % semi-length
b = W/2;   % semi-width
c = H/2;   % semi-height

% Calculations
volume = (4/3) * pi * a * b * c;      % m^3
rho_water = 1000;                     % kg/m^3
g = 9.81;                             % m/s^2
max_buoyant_force = rho_water * g * volume;% N
max_supported_mass = rho_water * volume;% kg

% Results
fprintf('\n===== PONTOON DIMENSIONS =====\n');
fprintf('Length  = %.4f m\n', L);
fprintf('Width   = %.4f m\n', W);
fprintf('Height  = %.4f m\n', H);

fprintf('\n===== CALCULATED PROPERTIES =====\n');
fprintf('Volume              = %.6f m^3\n', volume);
fprintf('Max buoyant force   = %.2f N\n', max_buoyant_force);
fprintf('Max supported mass  = %.2f kg\n', max_supported_mass);
```



Command Window

```
Length   = 1.0000 m
Width    = 0.2500 m
Height   = 0.2500 m

===== CALCULATED PROPERTIES =====
Volume              = 0.032725 m^3
Max buoyant force   = 321.03 N
Max supported mass  = 32.72 kg
```

$$L = 1m,\ W = 0.25m,\ H = 0.25m$$

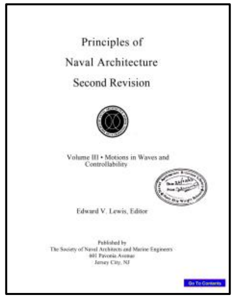
$$a = 0.5,\ b = 0.125,\ c = 0.125$$

$$V = 4/3\,\pi\, abc = 4/3\,\pi\,(0.5)(0.125)(0.125) = 0.0327m^3$$

$$m = \rho V = (1000)(0.0327) = 32.7kg = 72.1\ lb$$

Rikki

Engineering Calculations of Differential Thrust

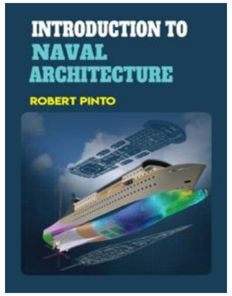


		Thrust		
Voltage	Combo	Right	Left	M_z (N*m)
32 V	Nominal	51.45	-39.2	7.19534375
40 V	Max	65.66	-49.49	9.14003125
16 V	Half Nominal	51.45	0	4.08384375
20 V	Half Max	65.66	0	5.2117625

	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

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

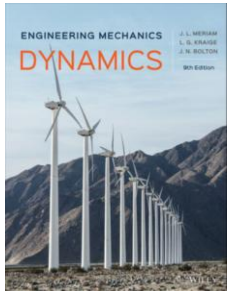
distance (b)	
in	6.25
m	0.15875



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

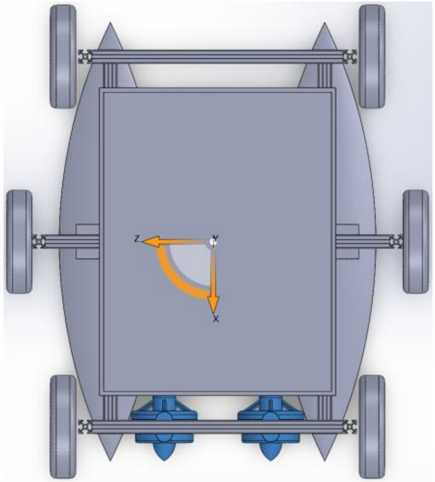
$$I_z = km\left(\frac{b}{2}\right)^2$$

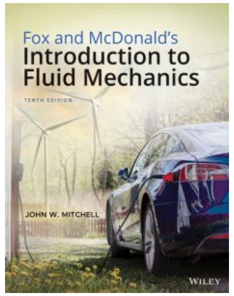
	distance (b)		mass
in	12.5	lbs	50
m	0.3175	kg	22.6796



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

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

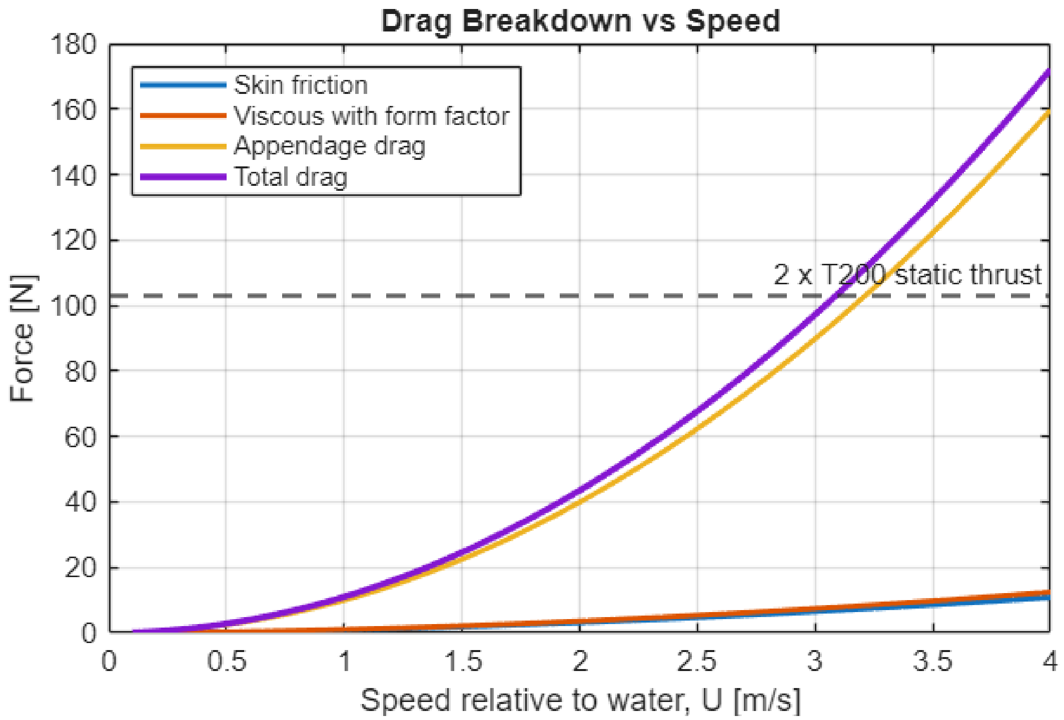




$$D = \frac{1}{2}\rho C_d A U^2$$

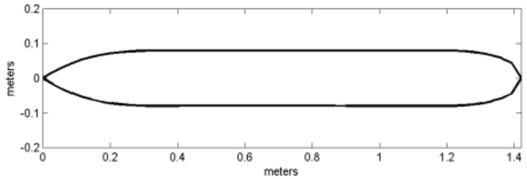
Alexander

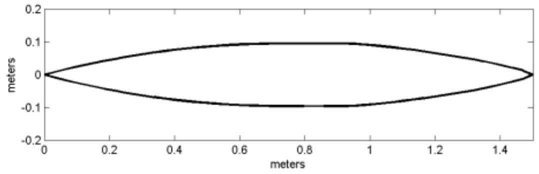
Engineering Calculations of Hydrodynamics



$$F_D = \frac{1}{2}\rho C_D A V^2$$

```
===== GEOMETRY RESULTS =====
Pontoon length                   = 0.647 m
Pontoon width                    = 0.152 m
Pontoon height                   = 0.159 m
Center spacing                   = 0.319 m
Estimated draft                  = 0.1209 m
Submerged area per pontoon       = 0.01549 m^2
Estimated wetted area per pontoon  = 0.17565 m^2
Estimated total wetted area      = 0.35130 m^2
Estimated total frontal area     = 0.05098 m^2
```





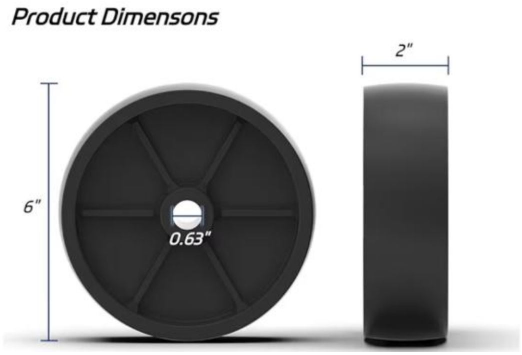
72% resistance reduction

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.



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

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

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

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

$h = 2\ in$

$D = 6\ in$

$d = D_i = 5.5\ in$

$h_i = 0.5\ in$

$d_i = 0.63$

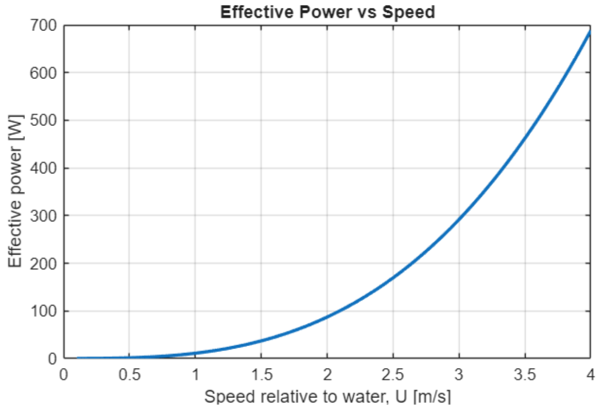
$\rho = 0.03613\ lb/in^3$

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

Norah

Engineering Analysis of Thruster Power

The original boat had issues with having enough power with completing a section and going back upstream. This analysis will see if the thrusters we plan on using will be enough to meet our requirements.




```
Estimated max water-relative speed with 2 x T200 = 3.05 m/s
Estimated upstream ground speed there            = 1.05 m/s
```

```
--- At U = 1.01 m/s ---
Re                 = 6.509e+05
Fn                 = 0.399
Total drag          = 11.15 N
Effective power     = 11.22 W
Thrust per motor    = 5.58 N
Upstream speed      = -0.99 m/s
Boat would not make upstream progress at this speed.
2 x T200 appears sufficient, margin = 91.85 N
--- At U = 1.52 m/s ---
Re                 = 9.823e+05
Fn                 = 0.603
Total drag          = 25.19 N
Effective power     = 38.24 W
Thrust per motor    = 12.59 N
Upstream speed      = -0.48 m/s
Boat would not make upstream progress at this speed.
2 x T200 appears sufficient, margin = 77.81 N
--- At U = 1.99 m/s ---
Re                 = 1.288e+06
Fn                 = 0.790
Total drag          = 43.11 N
Effective power     = 85.82 W
Thrust per motor    = 21.55 N
Upstream speed      = -0.01 m/s
Boat would not make upstream progress at this speed.
2 x T200 appears sufficient, margin = 59.89 N
```

```
--- At U = 2.50 m/s ---
Re                 = 1.619e+06
Fn                 = 0.994
Total drag          = 67.87 N
Effective power     = 169.89 W
Thrust per motor    = 33.94 N
Upstream speed      = 0.50 m/s
1 km upstream time = 33.1 min
2 km upstream time = 66.3 min
2 x T200 appears sufficient, margin = 35.13 N
--- At U = 3.02 m/s ---
Re                 = 1.951e+06
Fn                 = 1.197
Total drag          = 98.20 N
Effective power     = 296.08 W
Thrust per motor    = 49.10 N
Upstream speed      = 1.02 m/s
1 km upstream time = 16.4 min
2 km upstream time = 32.8 min
2 x T200 appears sufficient, margin = 4.80 N
```

$$V = V_c + V_g$$
$$T_s = kgf(g)$$
$$T_{avail} = N(T_s)$$

FMEA

Product Name: Canal Boat		Development Team: ARBWCI				Page No 1 of 1		
System Name						FMEA Number: 1		
Subsystem Name						Date: 3/30/26		
Component Name								
Part # and Functions	Potential Failure Mode	Potential Effect(s) of Failure	Severity (S)	Potential Causes and Mechanisms of Failure	Occurance (O)	Current Design Controls Test	Detection (D)	RPN
Electrical Box	Water leakage	Damage all electronics and lose control	10	Bad seal, leaking cable connector, damag	3	Seal inspection	3	90
Rear Thrusters	Lose power/breaks/fails	Unable to move/control boat	8	Motor burnout, loose wiring, collision	3	Pre-run thrust check	3	72
Lateral Thrusters	Lose power/fails	Boat won't be able to adjust for drift	5	Motor burnout, loose wiring	3	Pre-run thrust check	3	45
GPS	GPS has the wrong locatio	Autopilot could send the boat into a wall	4	GPS having a bad read on the data from t	4	Double Check GPS before testing	3	48
Battery	Power depletion	Loss control of thrusters,sensor, data loggin	9	Not fully charged,stronger current	5	Check charge level, charge before	3	135
Controller	Loss of Signal	The boat would not be able to be controlled	6	The chartplotter would stop sending signal	3	When testing see if/when the cont	3	54
Sonar	Data Tracking Fails	Whatever we are testing would not have dat	10	Bad connection between sensor and chart	4	Make sure there's no loss in data	3	120

William

2nd Semester Testing

As we progress into our project and go into the next semester building our design, we have to first test some things.

- Use ponds in Flagstaff to test the motors
- Use a pool to continue testing on the sensor and buoyancy of the boat
- Test whole build in the canals in Phoenix

Norah

Gantt Schedule:

As the semester is starting to be close to finished, we have started to look ahead to next semester and have created a hopeful schedule for the first period of the semester (8/25/26 - 9/22/26).

ARWBCI Project

SRP   Project lead

Project start: **Tue, 8/25/2026**

Display week: **2**

SIMPLE GANTT CHART by Vertex42.com

TASK	ASSIGNED TO	PROGRESS	START	END
Client Meetings				
Meet with Professor	Team	0%	8/25/26	11/10/26
Building				
33% Build	Team	0%	8/25/26	9/22/26
67% Build	Team	0%	8/25/26	10/13/26
100% Build	Team	0%	8/25/26	11/3/26
Assignments				
HW 00	Individual	0%	5/8/26	8/25/26
Project Management	Team	0%	5/8/26	8/25/26
Self Learning or Individual An	Individual	0%	8/25/26	9/1/26
Engineering Calculations	Team	0%	8/25/26	9/1/26
Peer Eval 1	Individual	0%	8/25/26	9/22/26
Peer Eval 2	Individual	0%	9/22/26	10/20/26
Peer Eval 3	Individual	0%	10/20/26	11/10/26
Peer Eval 4	Individual	0%	11/10/26	12/8/26
Website Check #1	Team	0%	8/25/26	10/6/26
Draft Poster	Team	0%	10/20/26	10/27/26
Final Poster & PTT	Team	0%	10/27/26	11/10/26
Final CAD Packet	Team	0%	8/25/26	11/17/26
Final Report& Website	Team	0%	8/25/26	11/24/26
Testing				
Make Testing Plan	Team	0%	10/13/26	10/27/2026
Present Testing Results	Team	0%	10/13/26	11/17/2026

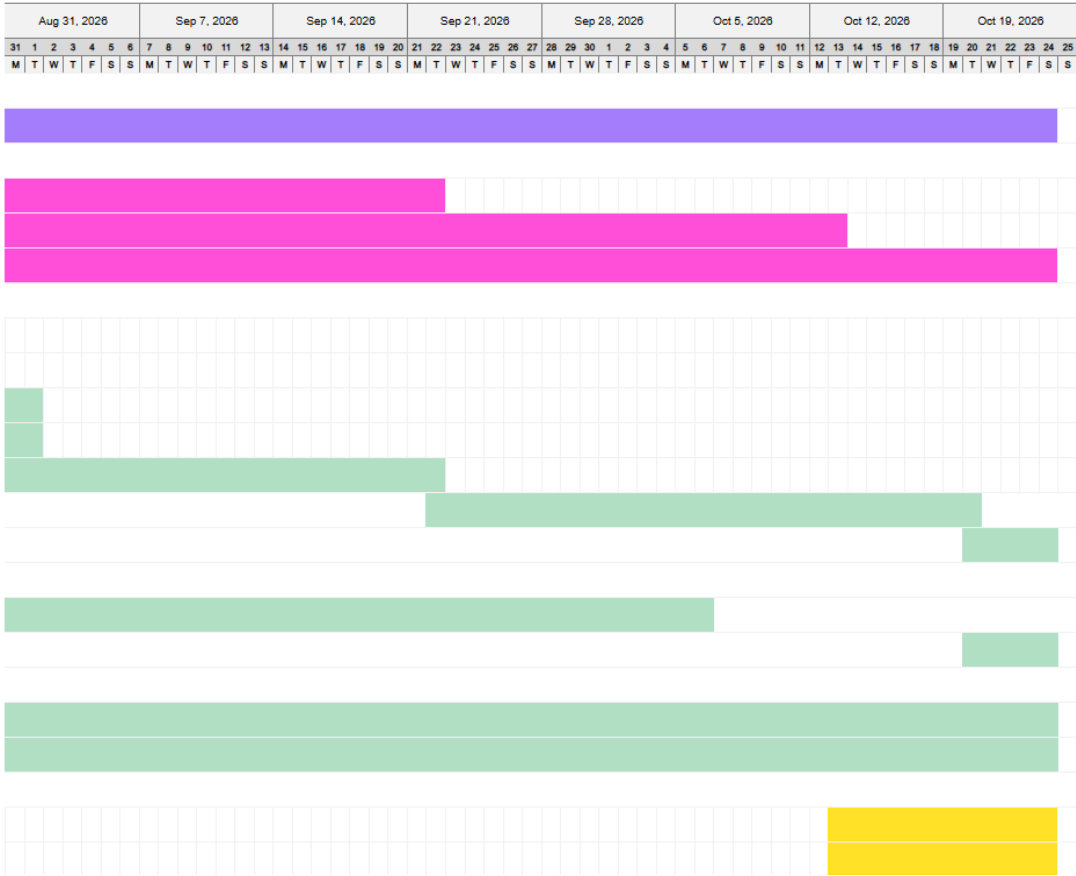


Figure 4: Gantt

Norah

Bill of Materials:

To the right is our current bill of materials which has had some changes.

Since the amount we expect to spend is around $2000, we need to fundraise over the required $500 so when our budget of $1500 is added we will have more than $2000.

To raise the money 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	Here3	$225.00	1	$225.00
3	SiK Telemetry Radio	$58.99	1	$58.99
3	Basic ESC	$40.00	1	$40.00
3	Cube Orange + Standard Set	$400.00	1	$400.00
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
3	Herelink Controller	$1529.62	1	$1529.62
Sum:	Without Controller	$2005.22	With Controller	$3534.84

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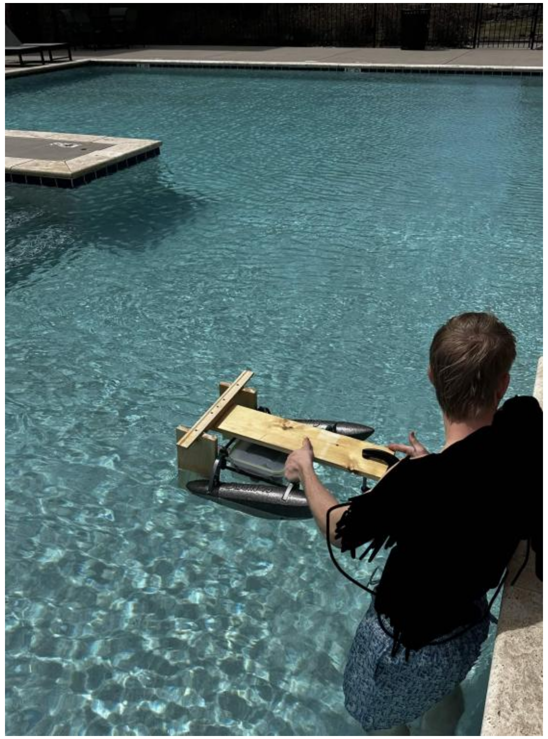
THANK YOU

Questions?

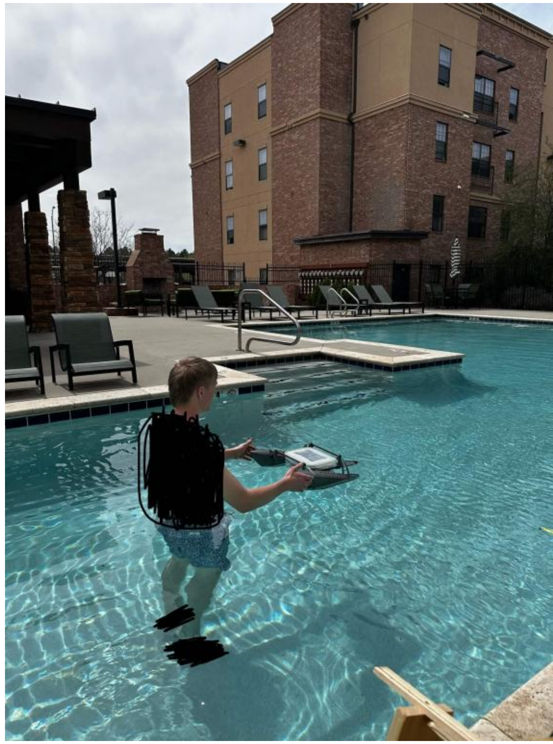
Testing Physical: Photos

Built Wood Rig



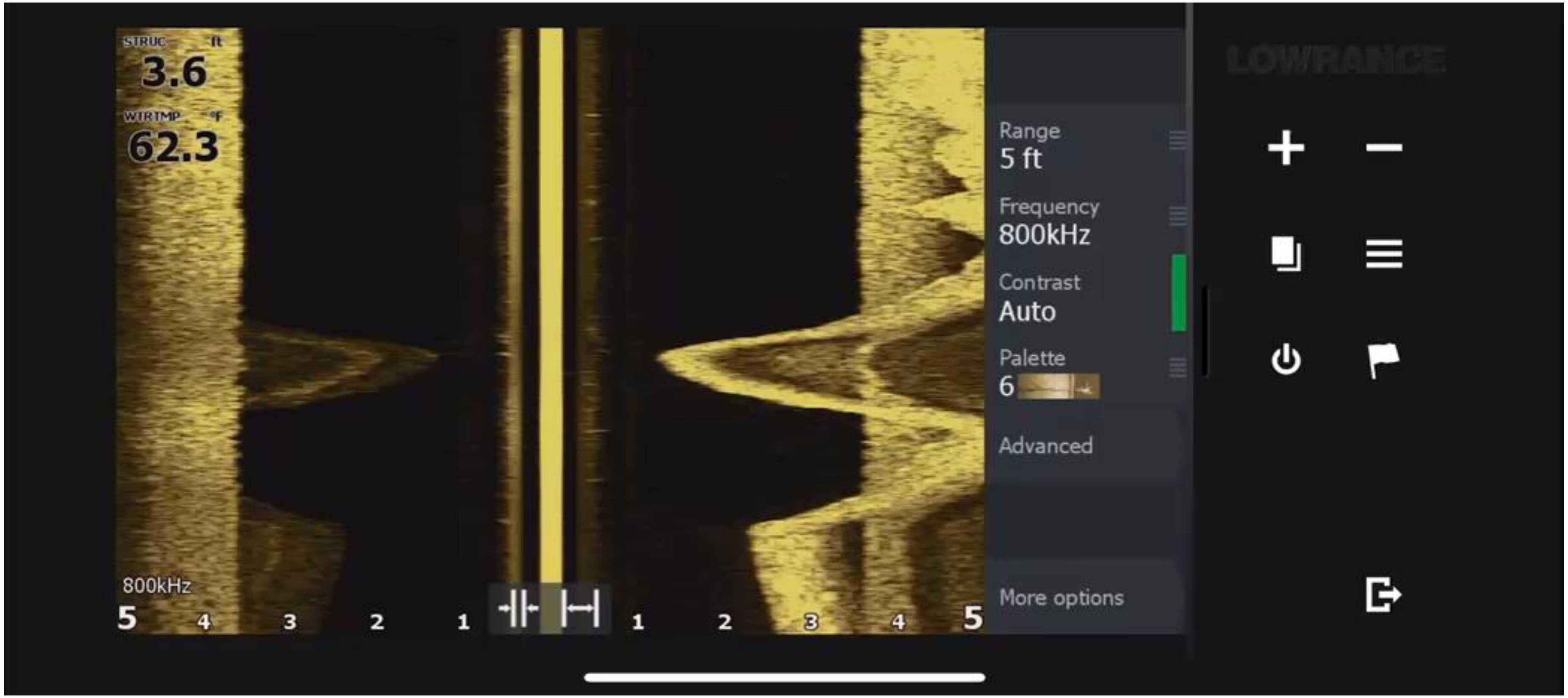
Testing with Rig

Testing Sonar Angle



Testing Wall Interference

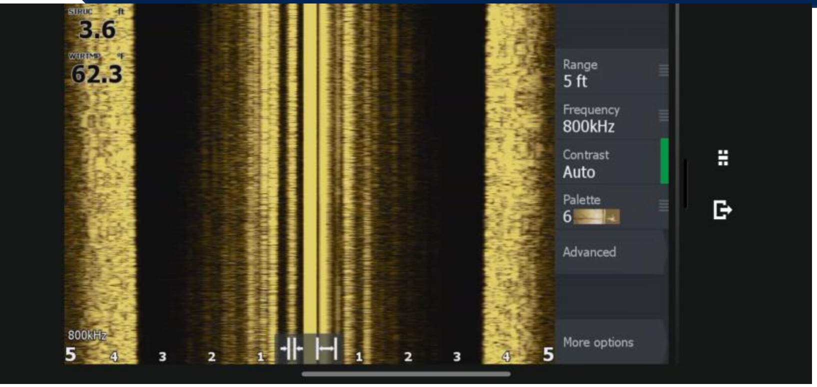
Testing Physical: Video



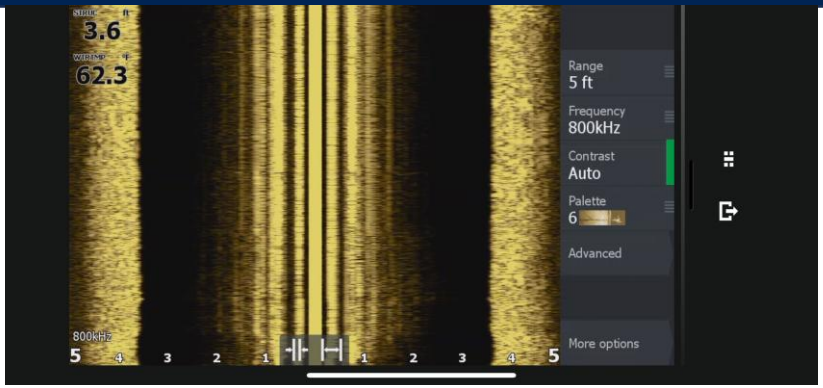
Test Video

William

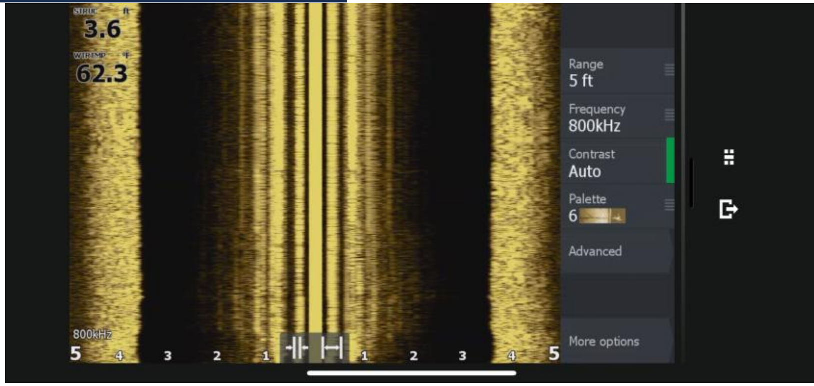
Testing Physical



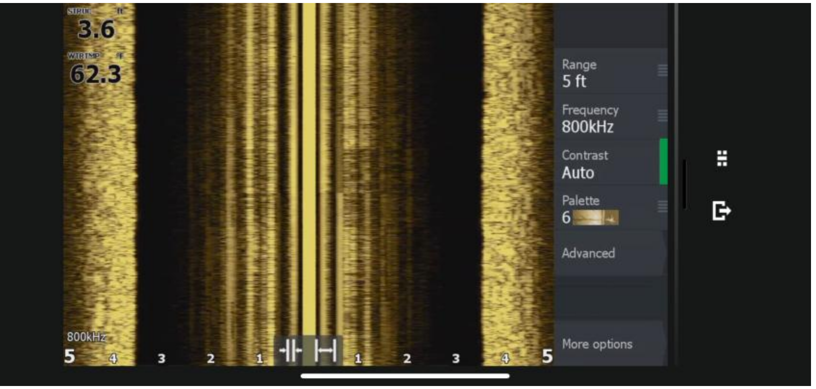
Test 1



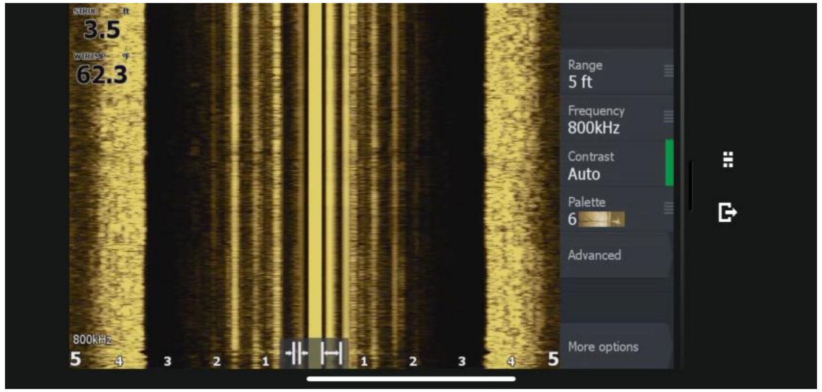
Test 2



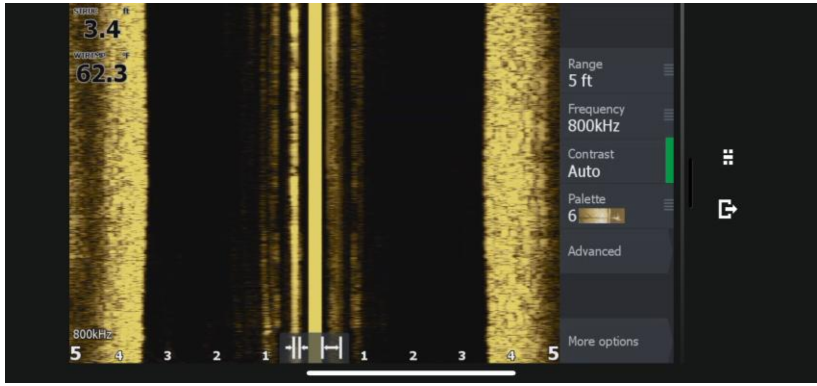
Test 3



Test 4



Test 5



Test 6

William

Testing Virtual

```lua
-- canal_centering.lua

local LATERAL_FUNC = 94                                  --
function 94 is "Script 1"
local PWM_CENTER   = 1500                                --
1500 is no output
local PWM_RANGE    = 400                                 --
+/- thrust range 1900 to 1100

local UPDATE_MS    = 100                                 --
runs every 100ms
local KP = 0.25                                          --
proportional gain (speed up speed)
local KD = 0.10                                          --
derivative gain (don't overshoot)
local MAX_NORM = 0.7                                     --
thruster % limit

local last_xtrack = 0.0                                  --
stores previous crosstrack data
local last_ms = millis():tofloat()                       --
stores previous time data

local function clamp(x, lo, hi)
  if x < lo then return lo end
  if x > hi then return hi end
  return x
end
```

```lua
local function mission_item_to_loc(i)
  local m = mission:get_item(i)                          --
asks for waypoint "i"
  if not m then return nil end
  local loc = Location()
  loc:lat(m:x())                                         --
latitude output
  loc:lng(m:y())                                         --
longitude output
  loc:relative_alt(true)
  loc:alt(math.floor(m:z() * 100))                       --
altitude output
  return loc
end


local function cross_track_m(curr_loc, prev_loc, next_loc)
  local v_path = prev_loc:get_distance_NED(next_loc)     --
gets the vector between waypoints
  local v_curr = prev_loc:get_distance_NED(curr_loc)     --
gets the vector from previous waypoint to current location
  local px, py = v_path:x(), v_path:y()                  --
assigns x and y variables
  local cx, cy = v_curr:x(), v_curr:y()                  --
for both vectors
  local path_len = math.sqrt(px*px + py*py)              --
calculates the length of the path
  if path_len < 0.5 then return 0.0 end               -- if
the path is too short, return 0
  local cross = (cx * py - cy * px) / path_len           --
calculates the cross track error
  return cross / path_len
end


local function set_lateral_norm(norm)
  norm = clamp(norm, -MAX_NORM, MAX_NORM)                --
clamp the norm to the maximum allowed
  local pwm = math.floor(PWM_CENTER + PWM_RANGE * norm)  --
calculate the PWM signal based on the norm
  SRV_Channels:set_output_pwm(LATERAL_FUNC, pwm)
```

```lua
end


local function update()
  local idx = mission:get_current_nav_index()            --
gets the current waypoint index
  local curr = ahrs:get_location()                       --
gets the current location of the vehicle

  if not idx or idx < 2 or not curr then
    set_lateral_norm(0.0)                             -- if
we don't have enough waypoints or location data, set lateral norm to 0
    return update, UPDATE_MS
  end

  local prev_wp = mission_item_to_loc(idx - 1)           --
gets the previous waypoint location
  local next_wp = mission_item_to_loc(idx)               --
gets the next waypoint location

  if not prev_wp or not next_wp then
    set_lateral_norm(0.0)                             -- if
we can't get the waypoint locations, set lateral norm to 0
    return update, UPDATE_MS
  end

  local xtrack = cross_track_m(curr, prev_wp, next_wp)   --
calculates the cross track error
  local now_ms = millis():tofloat()                      --
gets the current time in milliseconds
  local dt = (now_ms - last_ms) * 0.001                  --
calculates the time difference in seconds
  if dt < 0.02 then dt = 0.02 end                        --
prevent division by very small dt
  local dx = (xtrack - last_xtrack) / dt                 --
calculates the derivative of the cross track error
  local cmd = -(KP * xtrack + KD * dx)                   --
calculates the control command using PD control
  set_lateral_norm(cmd)                                  --
sets the lateral norm based on the control command

  if math.floor(now_ms) % 1000 < UPDATE_MS then
```

```lua
    gcs:send_text(6, string.format("xtrack=%.2f m cmd=%.2f", xtrack, cmd))  --
sends telemetry to GCS every second
  end

  last_xtrack = xtrack                                   --
updates the last cross track error
  last_ms = now_ms                                       --
updates the last time
  return update, UPDATE_MS                               --
schedules the next update
end


return update()
```

William

Testing Virtual

```
xtrack=-0.08 m cmd=0.02
xtrack=-0.08 m cmd=0.02
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xtrack=-0.11 m cmd=0.03
xtrack=-0.11 m cmd=0.03
```

```
SERVO_OUTPUT_RAW (2.0 Hz, #36) 44Bps
  port            0
  servo1_raw   1868
  servo10_raw     0
  servo11_raw     0
  servo12_raw     0
  servo13_raw     0
  servo14_raw     0
  servo15_raw     0
  servo16_raw     0
  servo2_raw   1504
  servo3_raw   1868
```

William