Roboboat 2023: Nala Proteus' Technical Design Report Barunastra ITS Roboboat Team

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Abstract— This report will discuss competition strategy, latest design, and performance of Barunastra ITS' latest ASV competing in International RoboBoat Competition (IRC 2023) called Nala Proteus. Nala Proteus champions a new modular system concept which supports stability, velocity, and accuracy of the ASV. Each system present within Nala Proteus had been tried out upon simulation software and afterwards, under real conditions in the field. Based on the results of these trials, we can posit that the ASV is adaptable towards the various missions given.

Keywords—Adaptable, ASV, Modular Shipbuilding, Performance, Vision

I. Competition Strategy

Barunastra ITS Roboboat Team strives to produce ASVs with high performance and efficiency in each of our competitions. As our commitment, Nala Proteus is constructed. Nala Proteus is a refinement of Nala Theseus, our previous ASV.

A. General Strategy

Events held in distant proximities from our workspace mandate us to manufacture easily transportable ASV without reducing their capability to complete existing missions. Improvements to its modular system are done with a change in frame material. The resulting system is more robust, durable, and flexible; thereby providing the greatest of ease in altering the ASV's dimensions, mission completion, as well as disassembly-and-reassembly for transportation purposes.

To maintain the security of onboard electrical components, we increased the freeboard levels. Consequently, the ASV's centre of gravity is slightly elevated, thereby reducing its stability. To overcome that, the load is arranged to be more equally distributed. Therefore, Nala Proteus was designed to possess an extensive breadth and deck; minimizing pitching and rolling motions.

Additionally, the elevated freeboard protects onboard electrical systems from waves produced both by internal and external forces. Due to the wide array of components required to support Nala Proteus' performance, the increased dimension also increases displacement. As the weight increases, higher thrust is required; for which a pair of T500 motor thrusters and an additional pair of T200 bow motor thrusters are used.

B. Course Strategy

Computer systems onboard the ASV play a major role throughout the required missions. Navigating the Panama Canal, Magellan's Route, Inspecting Turtle Nests, Northern Passage Challenge, and Ocean Clean-up, all require the use of computer visions. To Navigate the Panama Canal, computer vision is used to detect gaps between gate buoys through which the ASV could surge through. Magellan's Route and Northern Passage employs a similar strategy, wherein the ASV would surge through pathways and circumnavigate around obstacles detected by the computer vision. Therefore, the 36.8 cm diameter gate buoys must be detectable by the computer vision algorithm from 30.48 m or 100 ft away [1].

Furthermore, through a combination of camera visions and data provided by a distance sensor, Nala Proteus can detect placards and orientation of the dock. Still, computer vision is used to detect the location and balls required to be 'cleaned up' in Ocean Clean-up. Moreover, waypoints are also employed as global control in the event when the vision can not detect any task. Additional components are also in play during Ocean Clean-up; a pool rake-like contraption is used to scoop up "debris". Beaching task algorithm is required to dock while Feeding the Fish; while sensors detecting ball inside the water tank determines the amount of water is necessary to complete Ponce de Leon [1].

II. Design Creativity

A. *Hull and Frame Design*

Various assortment of missions alongside unpredicted climate conditions requires ASV to be ready in any water condition. Therefore, ASVs need to possess high stability and maneuverability. As such, Nala Proteus was developed to remain stable despite high amplitudes and long wavelengths. With a comparatively higher beam-length ratio to previous ASV models, effects of rolling and pitching motions on Nala Proteus are kept at a minimum to ensure stability during operation [2].

TABLE I. Beam-Overlength Ratio

Beam-Overlength Ratio	
Proteus	0.866
Theseus	0.784

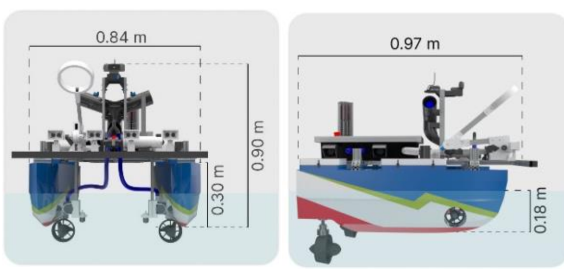

Figure 1. Principal Dimension

TABLE II. Principal Dimension

PRINCIPAL DIMENSION		
	Theseus	Proteus
Length	0.88 m	0.97 m
Beam	0.69 m	0.84 m
Height Overall	0.78 m	0.9 m
Height	0.21 m	0.3 m
Draft	0.14 m	0.18 m
Block Coeff.	0.57	0.544
Demi-hull	0.5 m	0.64 m
Displacement	25.46 kg	37.76 kg

Previous models' imprecise form and dimension while in production, lead to unfulfilled displacement. For this reason, Nala Proteus was produced using fiberglass, utilizing negative molding and glass method to obtain precise and durable results that can be used in subsequent developments.

In anticipation of changes in components with varying size and mass, a frame possessing alterable dimensions through adjustments in its center of gravity to maintain stability is required. Hence, our frame was constructed using aluminum extrusion and sliding nuts with alterable dimensions.

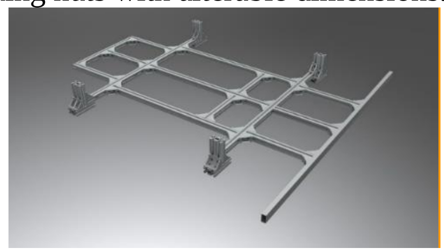

Figure 2. New Modular System's Frame

B. *Propulsion and Control System*

Nala Proteus' four thrusters, two each on both stern and bow, are further developments from Nala Theseus' existing propulsion systems [3]. The choice of T500 thrusters and an additional bow thruster is done to maintain ASV maneuverability and velocity along with an increase of resistance, dimension, and load. Accordingly, the ASV can carry out three different types of movement namely holonomic movement, consist of pivoting and orientation-locked motion, and path following.

For our ASV to perform holonomic motion and orientation-locked motion, Nala Proteus optimizes the algorithm previously developed for 2022's Roboboat Competition. However, to properly commit path-following, the ASV improves the previous program by summing up its heading error and perpendicular distance to the path and are inputted to a PID controller by the algorithm. The provided input is developed into sufficient thrust value required to restore the ASV back to its original/desired position. Furthermore, two GPS with real-time kinematic (RTK) algorithm, each acting as base station and rover, are employed to increase the accuracy of our GPS-provided data.

C. *Launcher and Blaster Design Mechanism*

The Feed the Fish and Ponce de Leon both require a system which gives stability, accuracy, and precision. The launcher and blaster system are designed as one system to achieve construction efficiency while fulfilling the required value. Said system and a DC brushed motor acting as an actuator are integrated as one. An incremental encoder is installed upon the motor to assess both positioning and angle of discharge.

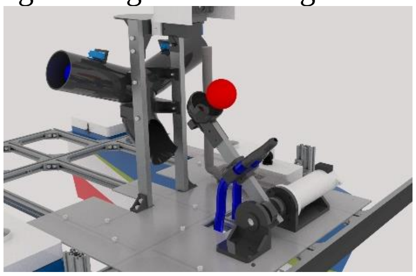

Figure 3. Nala Proteus' Launcher and Blaster

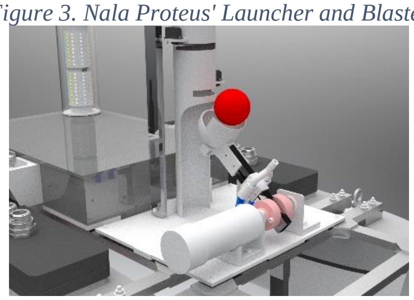

Figure 4. Nala Theseus' Launcher and Blaster

The accompanying problem that come with our previous model is the tube-shaped reload system which accelerated the servo’s gear breakdown due to the projectile load concentrating upon it. To mitigate damage done to the gear due to excess projectile load, we opted to fit a Y-shaped reload system, instead. Still, a similar system used by our previous ASV model is used to complete this mission.

D. *Scavenging Arm Mechanism*

Figure 5. Scavenging Arm Design

For the ocean clean up task, we attempt to approach this system as simple as possible from both its dimensions and mechanisms. Therefore, we tried to design a system flexible enough to be stored and bent when unused. It will protrude when operational, in the same way a rake supported by an elbow system would. The basic principle here is a pulley mechanism operated by motors and servos.

Our method of locating active underwater pingers matches how the human ear functions, making two H1A Aquarian Hydrophones equivalent to two human ears. Calculating the hydrophone's angular direction of reception is the key to determining the position of the acoustic signal. The position is then calculated using the total angular direction of all angular coordinates ASV [4]. Processing of acoustic signals are done in accordance to Figure 6.

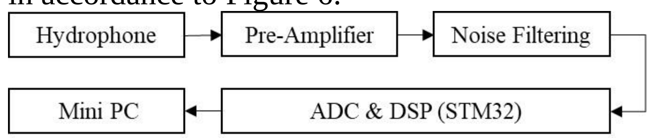

Figure 6. Hydrophone System-

Voltage noises produced by the propulsion and unclear signal received from the hydrophone poses a significant detriment to this method. As such, we utilized an arrangement of low noise op-amp. Thus, the level of the estimation filter certainty with the ASV's relative position will increase. With the implementation of STM32F4 arm-based CPU, which features an ADC and numerous supporting peripherals, signal processing and calculations are done individually [5].

E. *Power Safety Feature*

An issue affecting the previous model is the inaccuracy of ACS758ECB-200B sensors caused by imprecise calibration. Therefore, we intend to increase the functionality of our current sensors through the use of both ACS758ECB-200B and voltage dividers. A major consideration for this change is the insufficiency of voltage divider arrangement as the sole voltage sensor as a change in throttle will cause a voltage drop; preventing the aforementioned arrangement from being used as reference in monitoring the batteries’ condition. Further issue is found upon the ASV’s Holybro SiK Telemetry Radio Communication used for the wireless kill switch. Its relatively short range of communication, that is, better than 300 meters “out of the box” was found to be insufficient for our needs. Hence, it is switched out in favor of an SX1276 LoRa (long range) transceiver capable of communicating for up to 3 km “open communication". In addition, our current ASV employs NMOS to connect each actuator to its power source. The NMOS is also able to cut the current flow, triggerable by the kill switch arrangement through long range communication.

F. Software Architecture

Coming from the Nala Theseus' software architecture, we find that there are improvements to be made. Therefore, we added several new features which would maximize the already-existing program. Such features include a renewed user interface and real-time kinematic program to increase GPS accuracy.

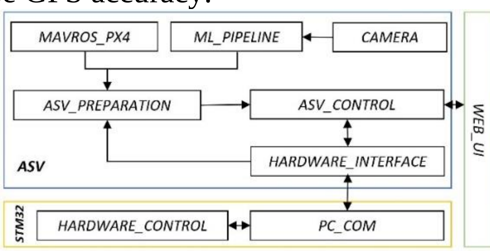

Figure 7. Software Architecture

G. Computer Vision

Nala Proteus is equipped with an Intel NUC PAHi7 Gen 11 as its onboard computing device. The reasoning behind this decision was due to the urgency to have a fast and accurate object detection algorithm in addition to the rarity of Jetson TX2 units. To comply with the on-board computer change, there are changes in the deep learning framework, from the TensorRT to the OpenVINO, which support the NUC's ability to run the computer vision model. The previous YOLOv4-Tiny-3L algorithm is reutilized for this year's model. Moreover, the addition of new tasks compels us to add new dataset as well as increasing their variations and amounts to produce more accurate detection results.

H. User Interface Control System

During the previous year, our Nala Theseus used RViz as the user interface. Unfortunately, RViz requires environment installation on a local computer to be accessed; reducing its portability. Thereby, in controlling the ASV, an accessible user interface is needed. Due to which, a web-based user interface is developed. This web enables real-time communications with high efficiency. It owes its higher efficiency to the great versatility of the web page. User-side, there is no need to set up a complex software environment to run the control system; the user can simply log in to carry out ASV operations.

Several features are present within this web interface. All missions to be carried out by Nala Proteus, and their respective control parameters are available. Additionally, 2 cameras equipped with coordinate lines and object detection features provide a view of Nala Proteus' waypoint. A virtual remote-control functioning as a manual control feature is also present. Moreover, the web could display Nala Proteus' condition for easier monitoring.

III. Experimental Result and Discussion

A. Simulation-Aided Mechanical Design

Performance and characteristics of Nala Proteus were analyzed through several methods. Compiled data was then compared with Nala Theseus', its predecessor.

1) Ansys Fluent and Structure: With the aim of improving mechanical design prior to production, Ansys Fluent was used to perform simulations in order to ascertain the ASV's resistance at 1.543 m/s or its equivalent at 3 knots. Below are comparisons of the collected data.

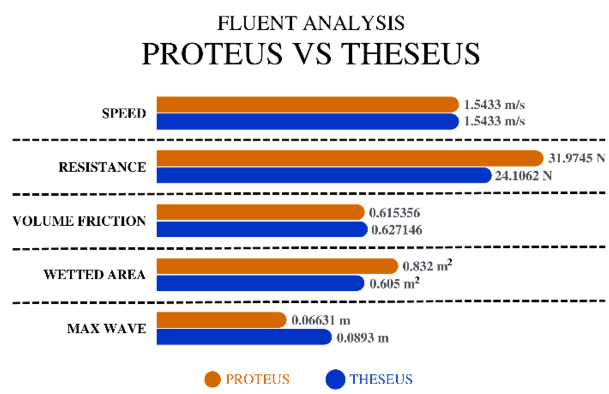

Figure 8. Fluent Analysis

Based on prior Roboboat 2022 experience, it is found that the lower freeboard height of Nala Theseus enables water to breach the deck. As is apparent, Nala Proteus commands a higher degree of resistance compared to Theseus. Larger dimensions allowing higher displacement values leading to larger load capacities may be a contributing factor to this matter. Additionally, the hull's shape reduces the maximum wave height; leading to higher freeboards for the safety of electrical components. Furthermore, this particular wave-height results in better wave-breaking for Nala Proteus.

Further analysis done towards the new modularity system's strength through Ansys Structure yields the following results.

TABLE III. EQUIVALENT STRESS ANALYSIS

Model	Material	Max. Equivalent Stress	Yield Strength
Proteus	Aluminum Extrusion	9.855e5 Pa	210 MPa
Theseus	Aluminum Hollow	2.2109e6 Pa	210 MPa

Results exhibit higher maximum equivalent stress of aluminium extrusion comparatively at the same yield strength. This indicates that the extrusion is more durable compared to hollow [6].

2) Maxsurf Motion Analysis: In addition to hull and frame analysis during maneuvering condition, further motion analysis on smooth waves were done to ascertain the ASV's response towards external forces, especially camera and distance sensor; both of which require high stability [7]. The results are shown below.

TABLE IV. RAO SIMULATION FOR CAMERA AND SRF

ASV Model	Parameter	m0	RMS	Significant Amplitudes
Untuk Nala Proteus	Abs. Vertical Motion	0.016 m^2	0.126 m	0.252 m
	Abs. Vertical Velocity	0.016 m^2/s^2	0.126 m/s	0.252 m/s
	Abs. Vertical Acceleration	0.094 m^2/s^4	0.307 m/s2	0.613 m/s^2
Nala Theseus	Abs. Vertical Motion	0.016 m^2	0.126 m	0.251 m
	Abs. Vertical Velocity	0.018 m^2/s^2	0.132 m/s	0.265 m/s
	Abs. Vertical Accel	0.128 m^2/s^4	0.358 m/s^2	0.715 m/s^2

Data collected from Response Amplitude Operator (RAO) concluded that Nala Proteus boasts higher degree of stability compared to Nala Theseus, indicated by the lower absolute vertical motion, velocity, and acceleration values [8].

B. Hull Production Method Analysis

Hull produced through plywood negative printing and glass is measured and had its accuracy compared to its predecessor, Theseus, which was produced through 3D printing. The measurements show the following results.

TABLE V. DESIGN-REAL COMPARISON

	Proteus (2023)		**Theseus (2022)**	
	Real	Design	Real	Design
Length	0.965 m	0.97 m	0.91 m	0.88 m
Breadth	0.2 m	0.2 m	0.186 m	0.178 m
Height	0.297 m	0.3 m	0.214 m	0.21 m
Avg. Error	0.505 %		3.269 %	

Through the data above, it is apparent that error rates in dimension between design and actual dimension values are 2.674 % higher in Theseus. This attest to Proteus' superior production methods.

C. Launcher and Blaster Mechanism

Firing trials are done in a lake with model arenas. The carried-out test is aimed to know the precision rate of the launcher and blaster. For the Feed the Fish, a ball shooter with four different elevation angles of 30°, 35°, 40° and 45° were tested, from 1.5 m distance, fifty trials each. Power adjustments from DC brushed motors were done based on battery voltage variations via a PID controller to keep the launch power's consistency. After multiple trials, it is found that the most effective elevation angle is 35° as seen on table vii.

TABLE VI. ELEVATION ANGLE TEST

	Launched (%)	Enter Square (%)	Enter Hole (%)
30°	95.5	88.5	79
35°	97	93.5	85.5
40°	94.5	93	70.5
45°	90	87.5	65

Ponce de Leon testing are done in the same environments as Feed the Fish. With an estimated distance of 1.5 meters between the ASV and its target, ten firing trials were done. This test is aimed to record the time needed for the ASV to finish the task. The firing angle is automatically adjusted based on the camera vision's detection system. Additionally, we have found that the ASV requires 16.53 seconds on average to fill the water blast's tank.

D. Computer Vision Performance

Several YOLOv4 models were compared on the on board computer Intel NUC PAHi7 Gen 11. Comparison results show that YOLOv4-tiny-3l has the best balance of speed and accuracy as required to compete in Roboboat 2023, among the various YOLOv4 models tested. During testing, we have found the maximum and minimum values of frames per second as listed underneath. These values are affected by mini PC temperature and battery condition.

TABLE VII. PERFORMANCE SEVERAL YOLOV4 MODELS

Model	Min. FPS	Max. FPS	Avg, FPS	mAP
YOLOv4	2.81	7.32	4.565	95.1
YOLOv4-tiny	13.17	30.72	18.41	89.9
YOLOv4-tiny-3l	14.52	30.92	18.82	92.2

Based on the table above, it is found that YOLOv4-tiny-31 provides the best result. We committed upon further testing using the model and determined that it could detect small objects, which are useful for several tasks. The result of which is shown in the picture below.

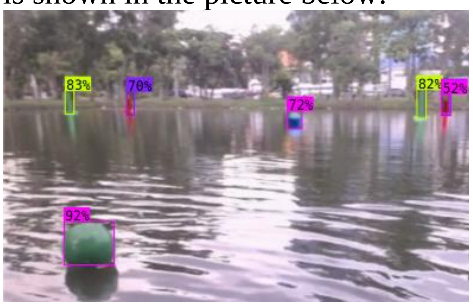

Figure 9. Object Detection

E. Endurance

The ASV requires battery endurance to complete all missions despite the worst case in which the ASV is going full throttle throughout the duration of the mission. Thus, two 6 cells 6200 mAh Li-Po batteries are used as the main power system and four 4 cells 7800 mAh Li-Po batteries are equipped to the motor. We did trials with a duration of 50 minutes each until the batteries reach their safe minimum voltage of 3.7 volts/cell. Further trial results are apparent in the following graph.

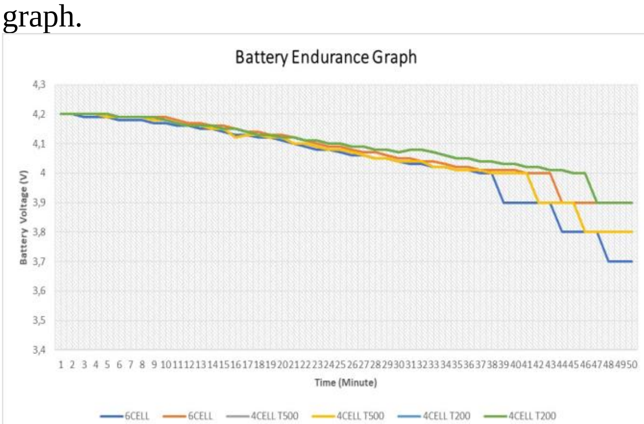

Figure 10. Battery Endurance Graph

F. On Water Testing

Testing was done by constructing the mission area in a lake within proximity to our workspace. Based on those trials, our ASV is capable of three different types of movement namely holonomic movement, consist of pivoting and orientation-locked motion, and path following. These behaviors were utilized to assist in completing missions. So far, our ASV is capable of successfully completing each mission apart from Ocean Clean-up as more time is required produce and try out a reliable system suitable for the task.

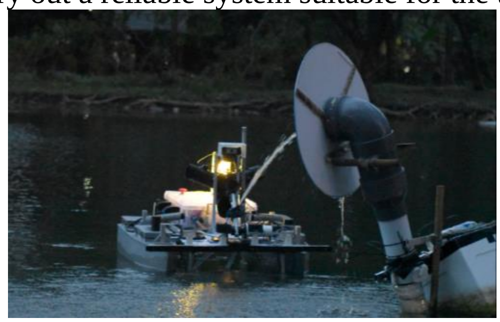

Figure 11. On-water Testing

IV. CONCLUSION

Nala Proteus is a refinement from its predecessor, Nala Theseus from RoboBoat 2022. Various improvements have been made both from a mechanical, electrical, and programming standpoint. Mechanically, Nala Proteus' displacement is 48.3% higher compared to its precursing model. In addition, it has lower wave-height comparatively to Nala Theseus; at approximately 34.7%. Furthermore, Proteus' frame strength exhibits lower equivalent strength making it 10 times stronger than Theseus' aluminum hollow frame. Electrically, this year, we opted for T500 thrusters and an additional bow thruster. While programming-wise, 11^{th} Gen Intel NUC replaces the role of Jetson TX2. An updated user interface involves a web-based, and the usage of real-time kinematics. While our software architecture focuses on optimizing the otherwise adequate architecture of our previous iteration. Coming from our testing result, Nala Proteus is expected to be able to finish all courses for the RoboBoat 2023.

ACKNOWLEDGMENT

Barunastra ITS's research and achievement would not be possible without the help from various parties. The team would like to express their deepest gratitude to our sponsors and supporting personnel (Appendix D)

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APPENDIX A: COMPONENT SPECIFICATION

Component	Vendor	Model/ Type	Specs	Custom/ Purcashed	Cost	Year of Purchase
ASV Hull	Barunastra ITS	Catamaran Hull	Fiber Glass with LOA = 96.5 cm, Breadth (Hull only) = 20 cm, Height (Hull only) = 29.7 cm. Draft = 18 cm, Displacement = 37.76 kg.	Custom	$428.00	2023
Platform	Barunastra ITS	V SLOT Extrusion	Aluminium Profile 20 x 20 V SLOT SILVER	Custom	$61.00	2023
Waterproof Connectors	-	-	3P 20mm waterprof aviation connector	Purchased	$6	2023
Propulsion	Blue Robotics	T200	T200 Thruster: ROV thruster for marine robotics propulsion (bluerobotics.com)	Purchased	$200.00	2023
Propulsion	Blue Robotics	T500	T500 Thruster for High-Power ROVs, USVs, AUVs, and marine robotics (bluerobotics.com)	Purchased	$690.00	2023
Propulsion (Mover)	Savox	SB-2290SG	Monster Torque, Black Edition Brushless Servo – Savox USA	Purchased	$182.44	2023
Propulsion (reload)	EMAX	ES08MAII	EMAX ES08MA II 12g Mini Metal Gear Analog Servo for RC Model&Robot PWM | Emax (emaxmodel.com)	Purchased	$7.75	2023
Propultion (arm)	Savox	SW-0231MG	WATERPROOF STD DIGITAL SERVO .15/208 – Savox USA	Purchased	$54.99	2023
Power System	Onbo	-	2x Tattu 22.2V 30C 6S 10000mAh Lipo Battery	Purchased	$129.00	2023
Power System	Onbo	-	4x Tattu 14.8V 25C 4S 10000mAh Lipo Battery	Purchased	$68.00	2020
Motor Controls	Blue Robotics	Basic ESC	Basic ESC (Electronic Speed Controller) for Thrusters and Brushless Motors (bluerobotics.com)	Purchased	$27.00	2021
CPU	Intel	NUCi7	-	Purchased	$1122.00	2022
Teleoperation	Radiolink	AT9sProR 9DS	AT9S PRO 12 channels transmitter for racing drone, fixed wing, helicopter, glider, cars and boats (radiolink.com)	Purchased	$170.00	2021
Localization and Mapping	Sparkfun	GPS ZED F9P	https://www.sparkfun.com/products/17751	Purchased	$281.25	2023
Camera	Logitech	C930e	Logitech C930e 1080p Business Webcam with Wide Angle Lens	Purchased	$103.00	2020
LED Indicator(s)	Adafruit	NeoPixel	https://www.digikey.com/catalog/en/partgroup/flexible-8x8-neopixel-rgb-led-matrix/73472#datasheets	Purchased	$6.00	2022
Water Pump(s)	-	-	DC 12V Water Pump 8W	Purchased	$5.00	2022

Hydrophone	Aquarian	H1A	[H1a Hydrophone (aquarianaudio.com)]	Purchased	$149.00	2020
Algorithms	Barunastra ITS	-	-	-	-	-
Inertial Measurement Unit (IMU)	Cubepilot	Cube Orange	CubePilot | Autopilot-on-Module | Blue Manufactured in USA | Blue Assembled in USA | Pixhawk Original Team	Purchased	$328.00	2023
Vision	OpenCV	-	YoloV4 Tiny 3L	Custom	-	2023
Open-Source Software	ROS	-	Noetic	Custom	-	2023
Compass	Cubepilot	Cube Orange	CubePilot | Autopilot-on-Module | Blue Manufactured in USA | Blue Assembled in USA | Pixhawk Original Team	Purchased	$328.00	2023
Doppler Velocity Logger (DVL)	Cubepilot	Cube Orange	CubePilot | Autopilot-on-Module | Blue Manufactured in USA | Blue Assembled in USA | Pixhawk Original Team	Purchased	$328.00	2023
Autonomy	BARUNASTRA ITS	-	-	Custom	-	2023

APPENDIX B.1: TEST PLAN AND RESULT - ANSYS FLUENT

a. Scope : Calculating resistance, volume friction, and max wave-height values experienced by the ship operating at its service speed.

b. Schedule : 15^{th} to18^{th} of January 2023

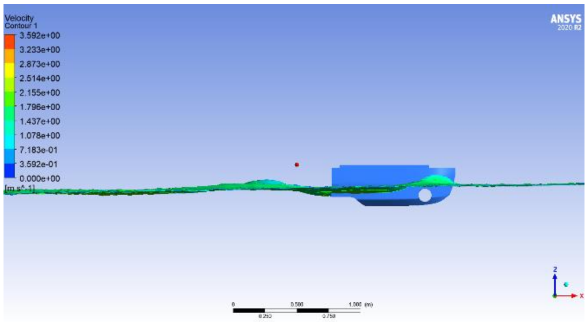
c. Resource and Tools : Ansys Fluent 2020 R2

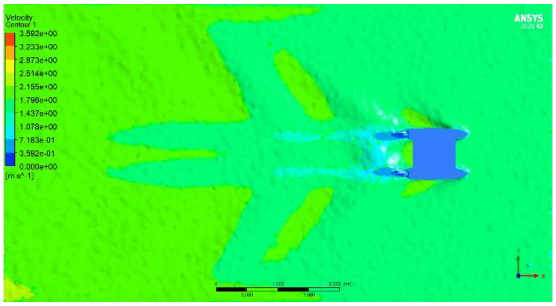
d. Environment : Tests are conducted at a service speed of 3 knots or equivalent to 1.5433 m/s, gravitational acceleration of 9.81 m/s^2, meshing on the hull 2 mm, meshing on test area 5 mm.

e. Risk Management : Should the Ansys Fluent test not be conducted, the ship's resistance values at its service speed would not be accurately determined, resulting in the propulsion system producing insufficient system to overcome the ship's resistance. Whilst maximum wave-height was analyzed to ascertain the wave height produced by the ship, thereby anticipating and minimizing the chances of electrical components coming into contact with water.

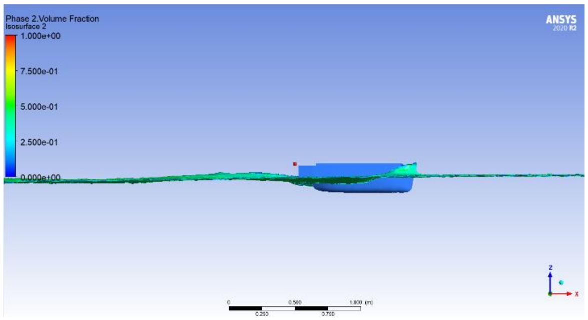
f. Results :

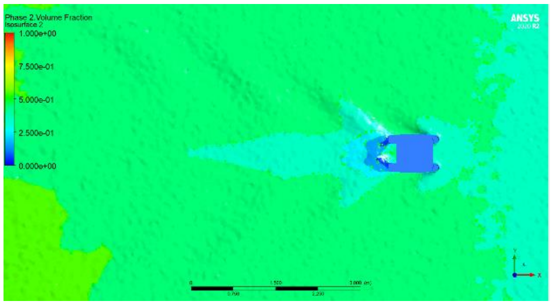
Nala Proteus





Nala Theseus

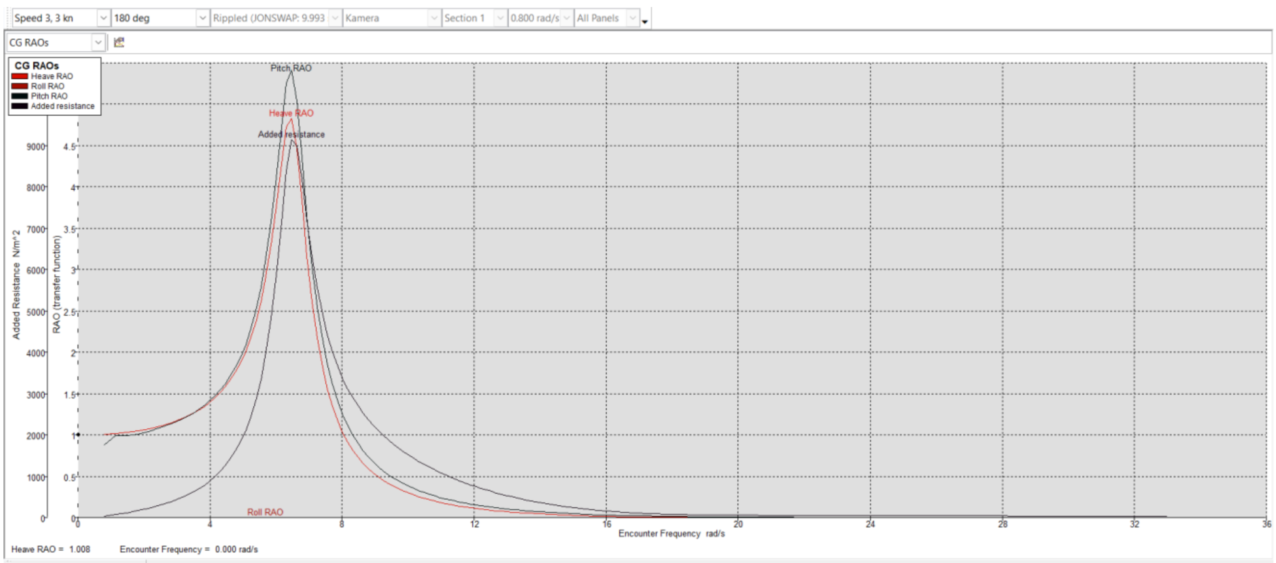




Model	**Proteus**	**Theseus**
Speed	1.5433 m/s	1.5433 m/s
Resistance	31.9745 N	24.1062 N
Volume Friction	0.615356	0.627146
Max Wave Height	0.06631 m	0.0893 m

APPENDIX B.2: TEST PLAN AND RESULT - MAXSURF MOTION ANALYSIS

a. Scope : Maxsurf motion analysis is conducted to analyze the ship's Response Amplitude Operator when affected by external forces under stationary conditions.
b. Schedule : 19th and 20th January 2023
c. Resource and Tools : Maxsurf Motion Advanced
d. Environment : Speed of 3 knots 180 degrees, and smooth-type waves.
e. Risk Management : The test is conducted to minimize the risk of rolling or pitching motions that can affect the stability of the camera and SRF's stability. Should their stability be affected, vision and sensor results are disrupted for the operation's duration.
f. Results :



(gambar di kecepatan 3 knot, keadaan 180 degree, kapal Nala Proteus)

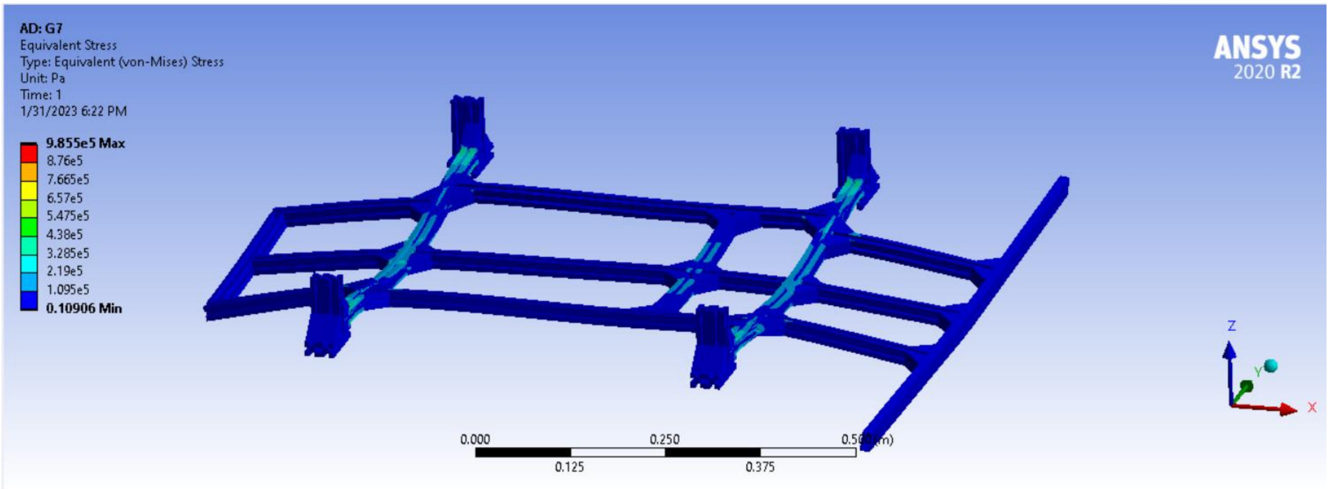
Ship Model	location	Parameter	m0	Unit	RMS	Unit	Significant Amplitudo	Unit
Nala Proteus	Kamera	Abs. Vertical Motion	0.016	m^2	0.126	m	0.252	m
		Abs. Vertical Velocity	0.016	m^2/s^2	0.126	m/s	0.252	m/s
		Abs. Vertical Acceleration	0.094	m^2/s^4	0.307	m/s^2	0.613	m/s^2
	SRF	Abs. Vertical Motion	0.016	m^2	0.125	m	0.251	m
		Abs. Vertical Velocity	0.016	m^2/s^2	0.128	m/s	0.255	m/s
		Abs. Vertical Acceleration	0.111	m^2/s^4	0.333	m/s^2	0.667	m/s^2
Nala Theseus	Kamera	Abs. Vertical Motion	0.016	m^2	0.126	m	0.251	m

		Abs. Vertical Velocity	0.018	m^2/s^2	0.132	m/s	0.265	m/s
		Abs. Vertical Accel	0.128	m^2/s^4	0.358	m/s^2	0.715	m/s^2
	SRF	Abs. Vertical Motion	0.015	m^2	0.124	m	0.249	m
		Abs. Vertical Velocity	0.017	m^2/s^2	0.131	m/s	0.262	m/s
		Abs. Vertical Accel	0.126	m^2/s^2	0.355	m/s^2	0.710	m/s^2

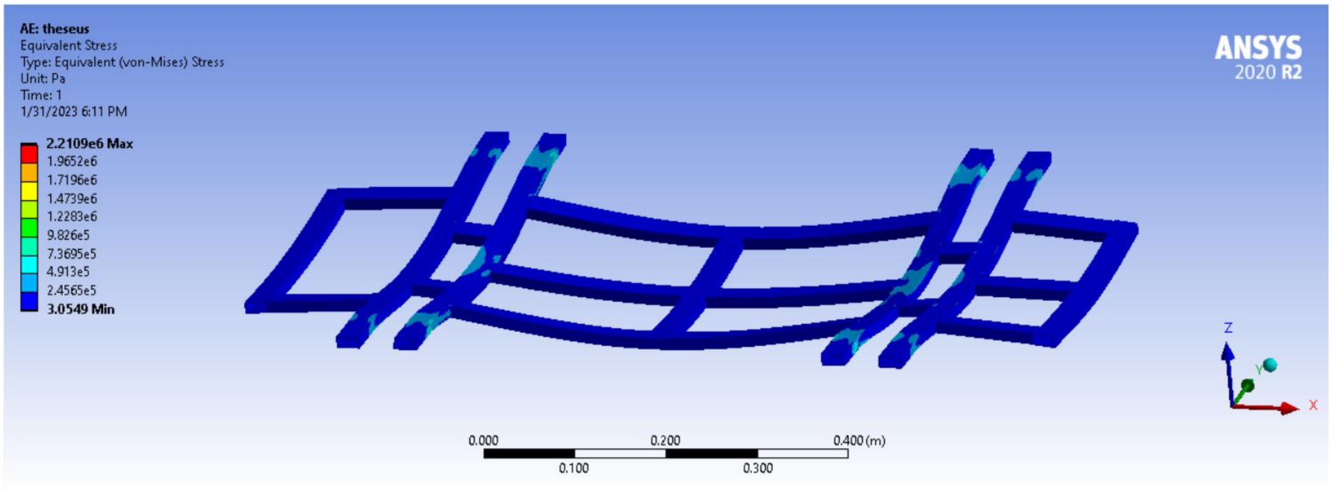
APPENDIX B.3: TEST PLAN AND RESULT - ANSYS STRUCTURE ANALYSIS

a. Scope : Simulation is done to analyze the maximum reliability and strength of the frame used in the ASV
b. Schedule : 31st of January 2023
c. Resource and Tools : Ansys Static Structure 2020 R2
d. Environment : Under 15 Newtons worth of stress
e. Risk Management : The simulation is done to ascertain the maximum weight limit that the frame could withstand. Should the weight surpass its limit; the frame will bend.
f. Results : Detailed outcomes of test cases

Nala Proteus



Nala Theseus



Model	Material	Maximum Exerted Pressure
Proteus	Aluminum Extrusion	9.8550e5 Pa
Theseus	Aluminum Hollow	2.2109e6 Pa

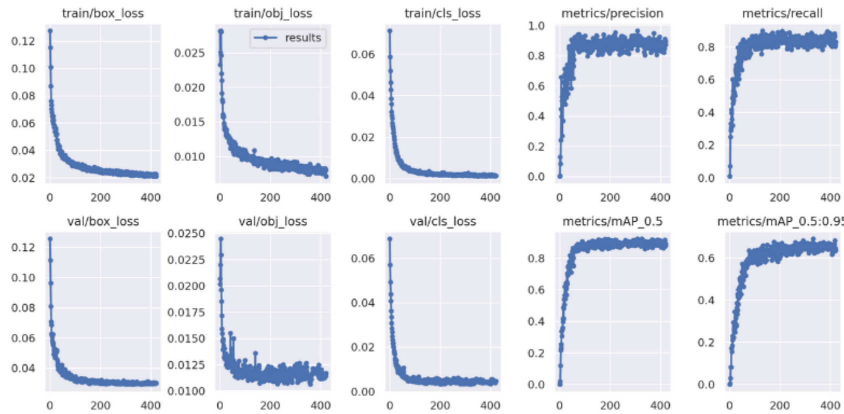
APPENDIX B.4: ON-WATER TEST PLAN AND RESULT

Date	Duration /day	Scope of Testing	Environment	Risk Management	Result
January 25-28, 2023	90 min.	PROPULSION TEST - First test using Thruster + ESC T500 with azimuth gear ratio of 0.67 and bow thruster	Overcast, calm waters	The retaining ring was unable to be fastened onto the shaft, thereby risking disconnection of the propulsion arrangement.	PROPULSION - ship is able to surge, yaw, and sway well. - change of gear ratio from 1:1 to 0.67 increased the ship's sensitivity and by extension its difficulty to turn smoothly.
		STABILITY TEST - Ship ran with varying movements (straight, turning, zigzag, holonomic)	Overcast, calm waters	An iteration utilizing new aluminum extrusion frame and connecting method risks detachment of frame construction from ship hull.	
		SPEED TEST - Ship is operated at full speed moving in a straight line to assess the resulting wave and its velocity	Overcast, calm waters	Due to the high velocity, water may breach onboard and ESC is in risk of overheating due to using the highest level of PWM.	- Ship is able to move in accordance to F4ansys fluent analysis and produce suitable waves, with a velocity of 1.5m/s - Ship experienced trim at high velocities due to great stern thruster torsion.
January 29, 2023	120 min.	Autonomus Trial New Board	Overcast, calm waters	Electrical board short-circuiting	- Ship can move following predetermined GPS waypoint. Poor object detection due to dim lighting caused by the weather. Left hind thruster value is 0 due to disconnected solder.
January 30, 2023	90 min.	Adjustable Camera Angle Path following	Heavy rain	Camera is in risk of falling into water since its only fasten using tape. Additionally, electronical arrangements are in risk of malfunctioning due to exposed to the heavy rain.	- Adjusted camera angle thanks to the addition of servo underneath; camera is fixed firmly to the servo despite coming into contact with water - Path following unable to be done because bad weather disturbed the signal received by the ship. - The ship's hull experienced leakage due to great shaft tolerance.

February 1-5, 2023	150 min.	Completing the task using path following and object detection	Slight drizzle, overcast, and calm waters	Potential of malfunction due to electronical arrangements exposed to rain; loss of control.	- Ship is capable of Navigating the Panama Canal, Northern Passage Challenge, and Magellan Routes. - Ship could not connect to landbound laptop due to malfunction in the receiver's antennae.
February 6, 2023	120 min.	Tuning control and adjustable camera angle Task Ponce de Leon	Clear skies, calm waters	Electrical components in risk of short-circuiting should they come in contact with water from the blaster. Ship operating under unstable conditions with inaccurate tuning.	- Ship is successfully tuned to complete 3 tasks. - Ship can complete the Ponce de Leon - Malfunction occurred on the water pump, which was left on for a while, due to a mistake in the microcontroller's program.

APPENDIX B.5: TEST PLAN AND RESULT - COMPUTER VISION DATASHEET ADDITION

a. Scope : Adding and testing computer vision utilized for IRC 2023 with a new datasheet.
b. Schedule : 1st – 5th of February 2023
c. Resource and Tools : Camera and PC
d. Environment : Data is taken in arenas replicated from the official competition’s arena.
e. Risk Management : Object is undetectable.
f. Results : YOLOv4-Tiny-3L is found to be the best model with 92.2% mAP, 83.7% precision, and 87.5 recall as well as maximum and minimum FPS respectively, 30.92 dan 14.52 FPS and an average of 18.82 FPS.



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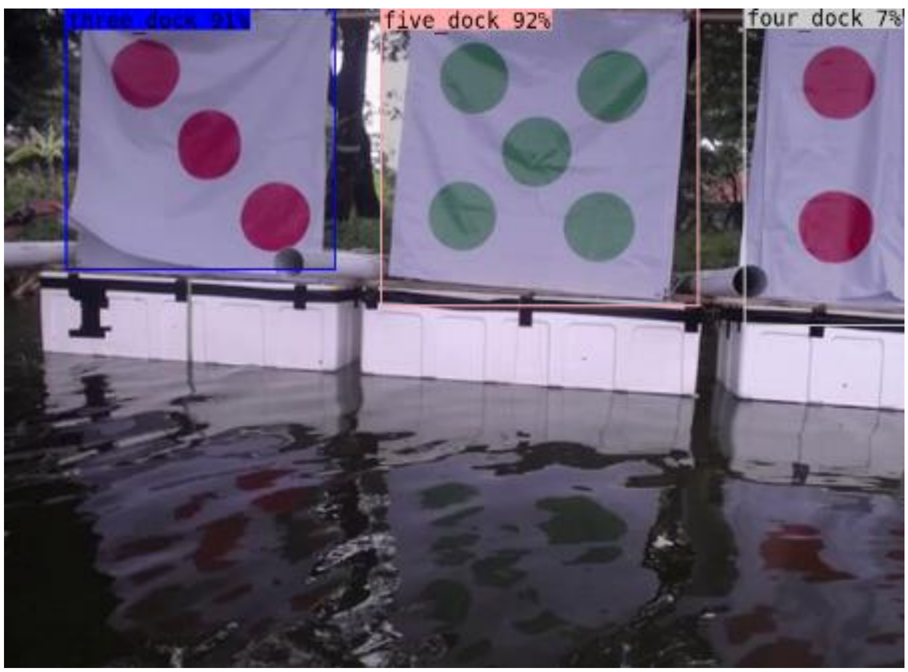


APPENDIX B.6: TEST PLAN AND RESULT - BEHAVIOUR TEST

a. Scope : Test Pivoting, Orientation Lock Motion, and Holonomic Motion
b. Schedule : 6th of February 2023
c. Resource and Tools : ASV with Basic Moving System
d. Environment : Test is done in a lake with clear weather.
e. Risk Management : ASV is incapable of performing basic movements properly; by extension, incapable of completing assigned missions.
f. Results : An effective setting is found for each behaviour test.

APPENDIX B.7: TEST PLAN AND RESULT - PATH FOLLOWER TEST

a. Scope : Tests the ASV’s ability to move in accordance to given waypoints.

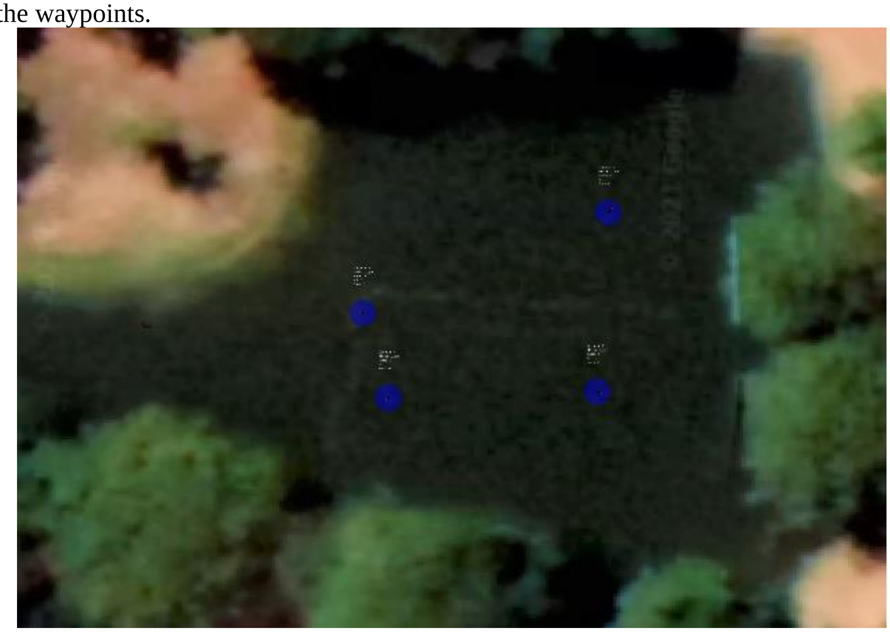
b. Schedule : 1^{st} – 5^{th} February of 2023

c. Resource and Tools : Camera and PC

d. Environment : ASV with Navigation System

e. Risk Management : ASV incapable of following given waypoints thereby incapable of completing autonomy challenges.

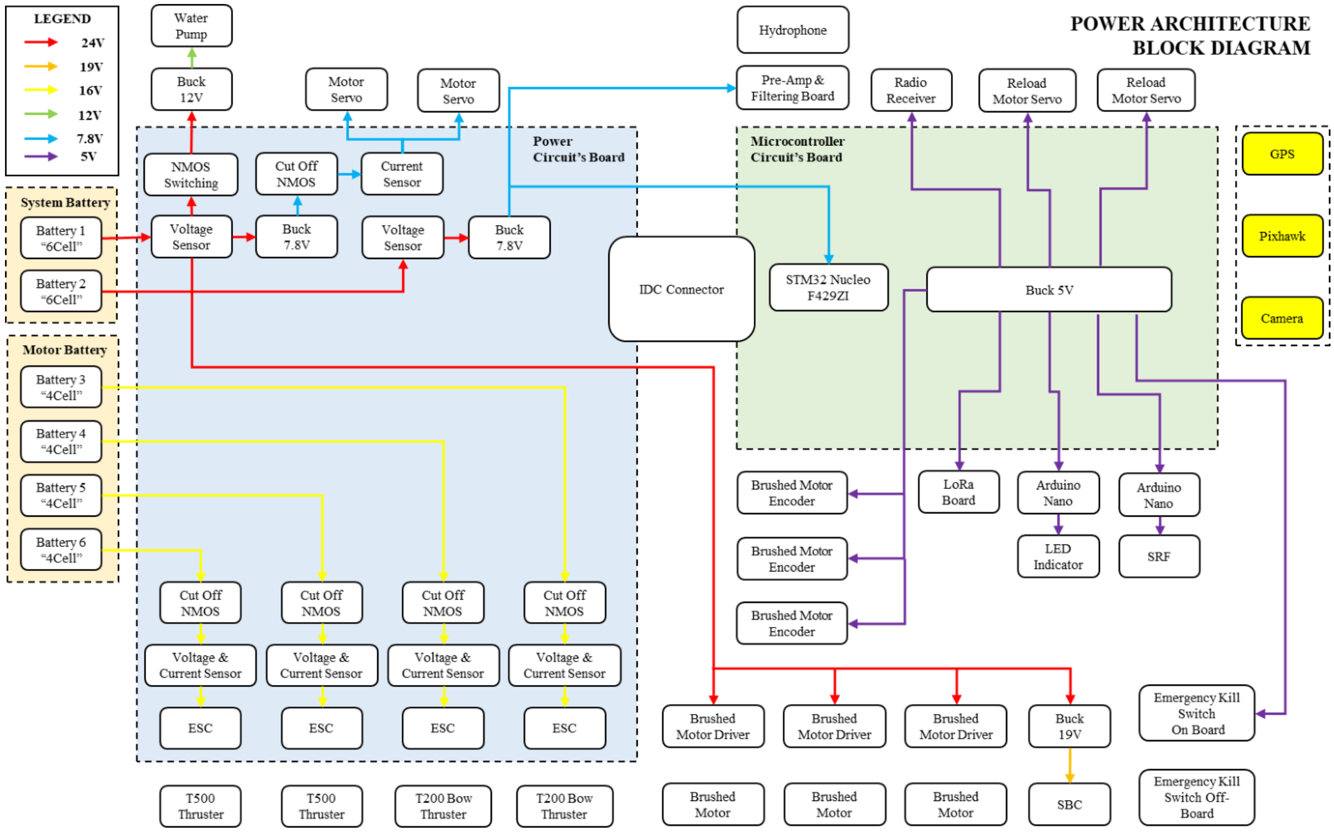
f. Results : Responsive, effective setting is found such that the ASV is proven to be competent in following the waypoints.

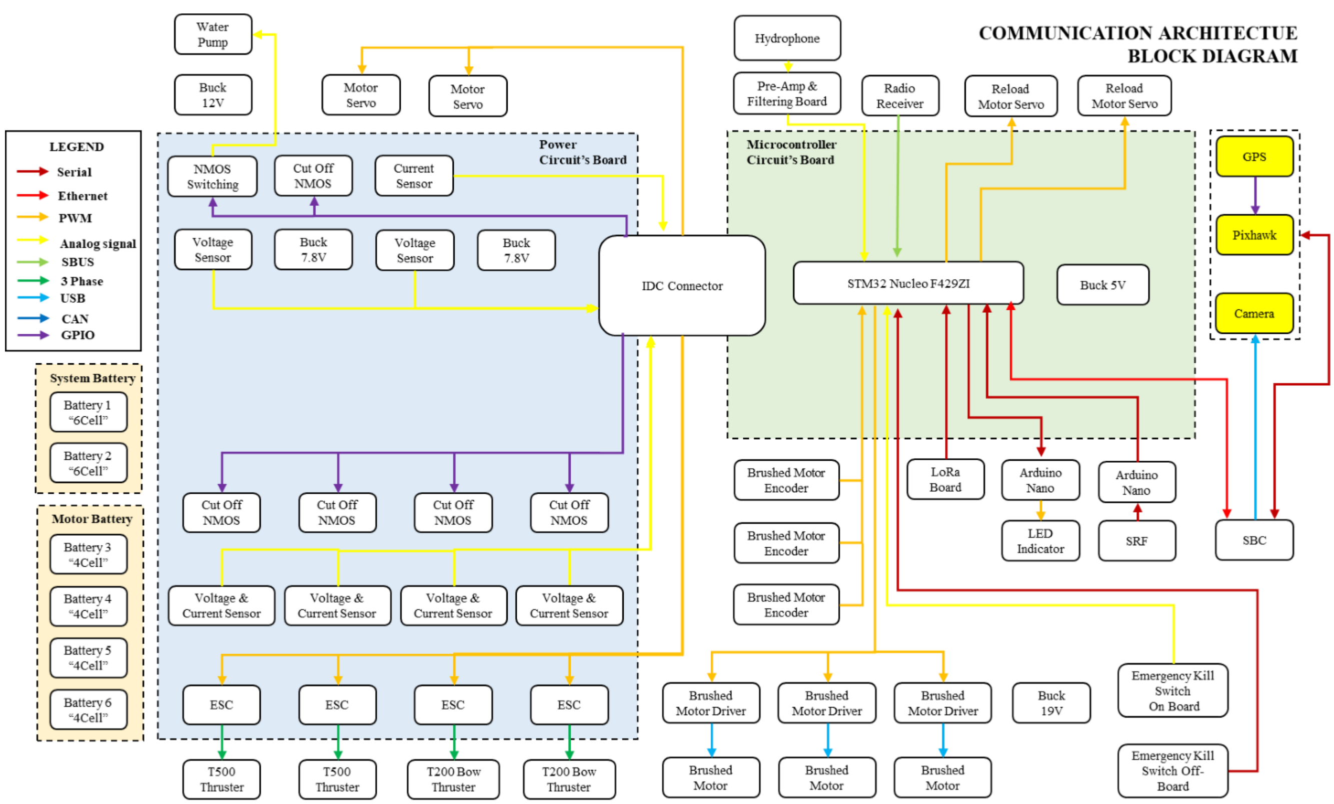


APPENDIX B.8: TEST PLAN AND RESULT - MISSION TEST

g. Scope : Testing for Panama Canal Navigation, Magellan's Route, and Northern Passage Challenges in replicated arenas.
h. Schedule :
i. Resource and Tools : ASV and arenas designed to look like the real thing.
j. Environment :
k. Risk Management : ASV incapable of completing autonomy challenges.
l. Results : ASV could Navigate the Panama Canal, Magellan's Route, and Northern Challenges well.

APPENDIX C: ELECTRICAL ARCHITECTURE





APPENDIX D: SPONSORS AND SUPPORTING PERSONNEL

1. Institut Teknologi Sepuluh Nopember — For their funding support, equipment procurement, and academic support in our research.
2. ITS Robotics — For their facilities and technical guidance in our research.
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