Bengawan UV Roboboat Team: Mandakini Neo

Ahmad Ramadhan Yusfianda[1], Angga Sifta Pratama[1], Aurora Halmahera Noor Hidayah[2],
Awdy Paramadan Tashadini[3], Fahri Setyo Utomo[4], Flavia Salsabila[5], Hafidz Dhani Wicaksono[6],
Hananta Diatmaja[1], Hanandya Maya Shafira[7], Handy Prabowo[8], Imaduddin Faqih[1],
Mohammad Inggi Hilmawan[1], Muhammad Azharuddin Asyrofi[1], Muhammad Hasya Nurfaizi[7],
Mukhammad Afit Lutfi[1], Nadia Alfi Nur Farikha[9], Noviana Dwi Murtiastuti[9], Pradana Ricardo[10],
Tri Rahmaji[1]

[1] Department of Mechanical Engineering, Universitas Sebelas Maret, Surakarta 57126, Indonesia
[2] Department of Biology Education, Universitas Sebelas Maret, Surakarta 57126, Indonesia
[3] Department of Indonesian Language Education, Universitas Sebelas Maret, Surakarta 57126, Indonesia
[4] Department of Region Literature, Universitas Sebelas Maret, Surakarta 57126, Indonesia
[5] Department of Chemistry Education, Universitas Sebelas Maret, Surakarta 57126, Indonesia
[6] Department of Chemical Engineering, Universitas Sebelas Maret, Surakarta 57126, Indonesia
[7] Department of Electrical Engineering, Universitas Sebelas Maret, Surakarta 57126, Indonesia
[8] Department of Mechanical Engineering Education, Universitas Sebelas Maret, Surakarta 57126, Indonesia
[9] Department of Industrial Engineering, Universitas Sebelas Maret, Surakarta 57126, Indonesia
[10] Department of Indonesian Literature, Universitas Sebelas Maret, Surakarta 57126, Indonesia

Abstract—**Mandakini Neo is an autonomous vehicle that was designed and built by the students of the Universitas Sebelas Maret, which was included in the Bengawan Unmanned Vehicle (UV) Roboboat Team to compete in the annual international Roboboat competition of 2021. This competition requires participants to complete several missions; one of the main missions is to move through two gates made from four poles using full automatic navigation, in order to continue on with the other missions. To complete the course, we used Pixhawk and GPS to allow the ship to run automatically, while minimizing the ship's movement tolerance. The use of Mission Planner software for monitoring, and also for color and shape image processing to help with the reading of objects, along with a sensor fitted on the ship, allowed the mission to be completed. Mandakini Neo was made with the capacity, speed, and comfort of the ship in mind, as well as the ship's hydrodynamic performance, stability, volume, structural integrity, and construction cost. Following its development we conducted tests of stability, maneuverability, and seakeeping in order to achieve the smallest possible resistance rate; for this purpose, we used the Savitsky method. The manufacture of the ship also required the choosing of the material, the use of the sensor, and also selection of an appropriate system. Finally, the design that we developed was a ship with a catamaran hull type, for which the dimensions had already been calculated, and the proper materials decided, and simple electrical components were able to be obtained for the sensor and the system.**

Keywords—Mandakini Neo, Autonomous Surface Vehicle, Bengawan UV Roboboat Team, Hull Design, Savitsky Formula, Sensor and System

I. INTRODUCTION

Mandakini Neo is an autonomous vehicle that was designed and built by the students of Universitas Sebelas Maret that was included in the Bengawan Unmanned Vehicle (UV) Roboboat Team to compete in the annual international Roboboat competition of 2021. This was the first international competition for the Bengawan UV Team, which had only been competing at the national level in Indonesia prior to this. This competition was expected to be a way to develop our team, requiring more advanced research on autonomous vehicles in order to complete the missions provided by the committee of the competition. Figs. 1 and 2, following, are the ship design and an image of the actual Mandakini Neo ship.

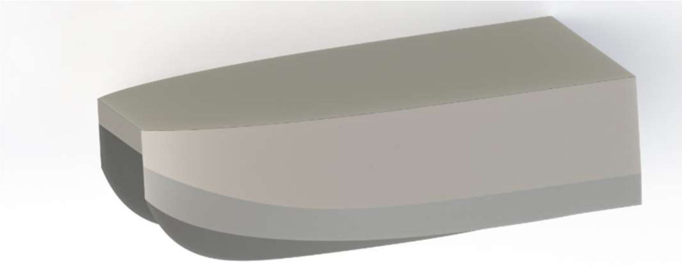

Fig. 1. Design of the Mandakini Neo Ship.

Fig. 2. The actual Mandakini Neo ship.

II. COMPETITION STRATEGY

In this year's Roboboat competition, we only maximized the completion of the main mission, which was mandatory, plus one additional mission—the speed gate mission. As seen in the flowchart below, the competition strategy starts with completing the mandatory mission. After the ship completes the mandatory mission, checks are carried out on the mission results; if the mandatory mission has been completed properly and in accordance with the regulations, the ship can continue with the next mission, which is the speed gate mission. However, if the ship is deemed to have failed or imperfectly completed the mandatory mission, the ship must restart the competition strategy from the beginning, or start over from the starting point. The systematics for completing the speed gate mission are the same as the systematics for completing the mandatory mission. When the ship is deemed to have failed or imperfectly completed the speed gate mission, the ship must restart the competition strategy from the beginning, or start again from the starting point. However, if the speed gate mission is carried out properly and according to the regulations, the ship will return to the starting point, and the entire mission will be considered complete. The following is the mission flow chart of the Mandakini Neo ship (Fig. 3).

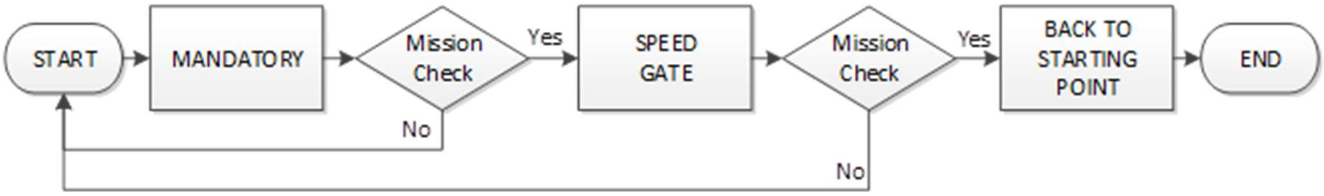

Fig. 3. Mission flow chart of the Mandakini Neo ship.

A. Mandatory Navigation

The first mission of the competition was the mandatory navigation. In this first mission, two gates consisting of four poles of two different colors (red and green) were positioned 25 m apart. In order to complete this mission, the ship was required to cruise between two of the poles, set at a 3 m distance from each other (the first gate), and then continue to the end gate, which was the same size as the first gate. We used a Pixhawk and GPS, fitted to the upper part of the ship, to determine three waypoints between the starting line, after passing the first gate, and onto the finish line located after the second gate. The purpose of adding the waypoints was to make sure that the ship could run on its course automatically, and allow it to be monitored by the mission planner software. The GPS fitted to the ship had the function of minimizing the tolerance of the ship's movement to ± 2-4 m during the course of the mission. Another way to complete the mission could be by using color and shape image processing to detect the poles in the mission's course. On completing the first mission, the GPS component can then be used to report the correct radius, and to determine the position of the ship in order to avoid mistakes.

B. Speed Gate

The second mission for the Mandakini Neo was the speed challenge. This mission utilizes logic, and similar procedures to the mandatory autonomous navigation challenge. Several waypoints were determined for the course of the ship. When the ship moves near to the poles, the output servo is controlled by image processing, and it circles the ball with the blue color. An ultrasonic sensor on the ship was fitted so the ship would not hit the balls with the blue color on the left side, allowing the ship to circle the balls smoothly.

III. DESIGN CREATIVITY

A. Hull Design

The selection of the type of hull that will be used must be adjusted to the ship's function, and the needs of the missions. This ship was required to maneuver well and have high ship stability. Therefore, we decided on an asymmetric catamaran hull, as the catamaran hull was able meet all the needs of the ship for carrying out its missions. Another reason for choosing this type of hull is that it has a large enough space to place complex electronic components. The ship had the main dimensions of LOA 0.97 m, beam 0.5 m, and depth 0.3 m.

Several other aspects needed to be considered when determining the hull shape and main design too; namely, the capacity, speed, and comfort of the ship. Furthermore, several factors determined the main dimensions (LOA, depth, beam) of the ship's hull; the ship's hydrodynamic performance (resistance and propulsion, seakeeping, and maneuverability), stability, sufficient load volume, structural strength, and construction costs.

Stability affects the ship's balance, wherein the ship's ability to return to its original position (ship's equilibrium point) after tilt occurs due to external forces. This ship required good stability, meeting the prescribed standards, because stability will affect the ship's performance in the water when exposed to external forces when completing the missions. Stability was also needed to support the ship in maneuvering and maintaining the balance of the components inside the ship. On the Mandakini Neo, the best stability was obtained with a righting lever (GZ) value of 0.1417 m and an angle of vanishing stability of 30°, which already met IMO standards. Hence, the ship was safe to use for missions.

Maneuverability affects the ship's ability to maintain its position under the control of the ship operator. Maneuverability testing helps determine the level of safety in ship maneuvering due to various factors, such as the magnitude of water flow waves and ship shipping in narrow areas like rivers, lakes, and ports. Ships with good maneuvering will be able to avoid accidents or collisions with objects around them. There are six types of floating body movements included in the six degrees of freedom: heaving, pitching, rolling, swaying, surging, and yawing. There are only three types of motion that are affected by acceleration and deceleration, which is known as added mass: heaving, pitching, and rolling. Swaying, surging, and yawing movements can occur if the acceleration is close to zero, however for this analysis the ship is under acceleration.

Before carrying out the maneuvering test, it is necessary to know the ship's characteristics, because the level of maneuverability of the ship is also influenced by the shape of the hull, according to the International Maritime Organization (IMO). The characteristic values of the Mandakini Neo prototype are presented in Table 1. Figs. 4 and 5 present images of the rotary motion trajectory, to further clarify the five outputs in the maneuvering test.

TABLE I. SHIP CHARACTERISTIC VALUES.

LWL (m)	**B (m)**	**TF (m)**	**C_b**	**LCG (m)**
0.941	0.50	0.08	0.262	0.39

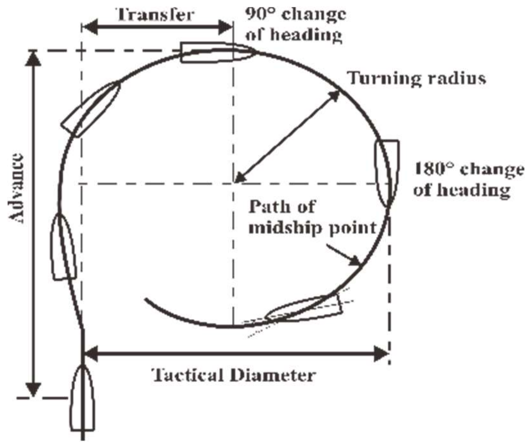

Fig. 4. Rotary motion trajectory.

Fig. 5. Rotary motion of the Mandakini Neo.

In the maneuvering test, the ability of the Mandakini Neo prototype ship at each steering angle (10°, 15°, 20°, 25°, 30°, and 35°) was predicted. This test was intended to determine the characteristics of the ship prototype from the rotation at each steering angle. Table II and Figs. 6 to 9 present the data and graphical images of the Mandakini Neo prototype maneuvering test results.

TABLE II. TEST RESULT DATA ON MANEUVERING OF THE PROTOTYPE MANDAKINI NEO SHIP.

Data Output	**Turning Angle**					
	10°	***15°***	***20°***	***25°***	***30°***	***35°***
Steady Turning Diameter (m)	1.0	0.9	0.8	0.8	0.7	0.7
Tactical Diameter (m)	1.3	1.0	1.0	0.9	0.8	0.8
Advance (m)	1.2	1.1	0.9	0.7	0.7	0.6
Transfer (m)	0.7	0.7	0.6	0.5	0.4	0.4
Steady Speed in Turn (m/s)	2.1	1.9	1.8	1.6	1.4	1.2

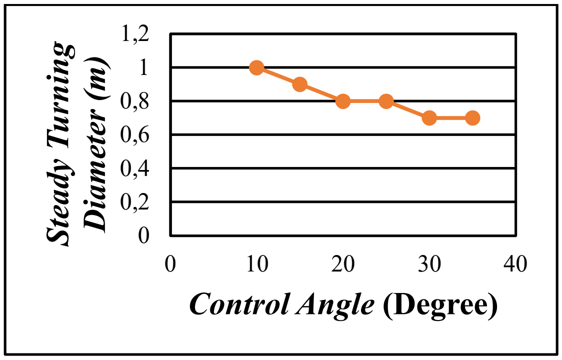

Fig. 6. Steady turning diameter.

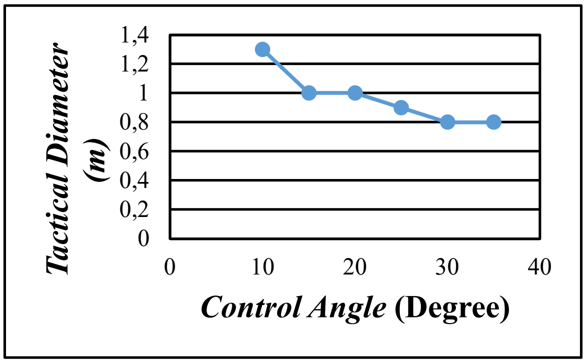

Fig. 7. Tactical diameter.

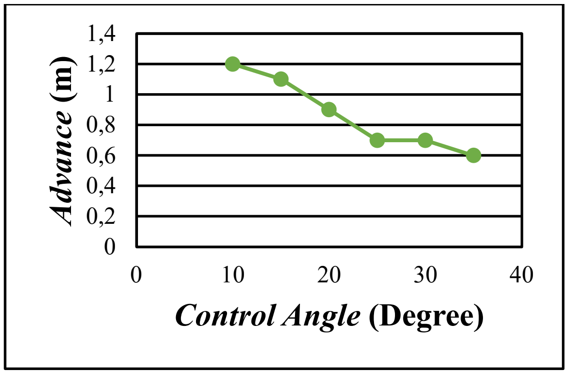

Fig. 8. Advance.

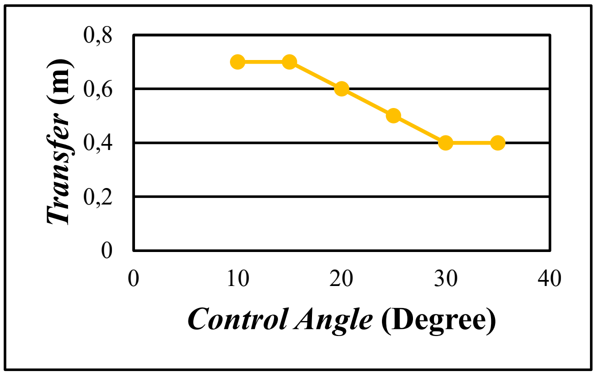

Fig. 9. Transfer.

From the results of the turning cycle of the prototype Mandakini Neo ship, a standard check was able to be carried out to evaluate the maneuverability, according to the International Maritime Organization (IMO), which is applicable to all ships. This states that the advance trajectory length rotating capability should not be more than 4.5 times the ship length, and the tactical diameter should not be more than five times the length of the ship. Below is the calculation for the advanced track length and tactical diameter.

- The length of ship (LOA) = 0.97 m
- Advance trajectory length at a steering angle of 35° = 0.6 m
- The length of the tactical diameter at a steering angle of 35° = 0.8 m
- The advance length according to IMO is 4.5 x ship length = 0.5 m
- The length of the tactical diameter according to IMO is 5 x the length of the ship = 0.7 m

In the experiment, the rotating capability of the Mandakini Neo ship prototype, according to the International Maritime Organization (IMO), meets the standards for both advance and diameter tactical maneuvers, so that it is safe when maneuvering.

In the seakeeping test, this ship is required to have the ability to maintain its stability in choppy water conditions. This test is conducted to meet IMO standards that limit ships' movement due to waves, which can cause motion sickness. This test aims to maintain the position of the components attached to the ship, such as sensors, GPS, cameras, and other electrical components, so that there is no position movement which could lead to malfunctions in the prototype system and derail the mission trajectory due to the waves on the water surface. In this research, a seakeeping test was carried out at a speed of 5 knots and 10 knots. Tables III and IV present the data on the Mandakini Neo prototype maneuvering test results.

TABLE III. SEAKEEPING PERFORMANCE AT 5 KNOTS.

Item	Wave Heading	Motion	Velocity
Heave	90°	0.0096 m	0.0077 m/s
	135°	0.0096 m	0.0092 m/s
	180°	0.0096 m	0.0098 m/s
Roll	90°	0.24°	0.02245 rad/s
	135°	0.36°	0.06312 rad/s
	180°	0°	0 rad/s
Pitch	90°	0.039°	0.00073 rad/s
	135°	0.030°	0.00182 rad/s
	180°	0.042°	0.0028 rad/s

After conducting several tests on the Mandakini Neo ship design, we found that this ship design has a reasonably small resistance value. The advantage of ships with small values is that they can move forward and have good maneuverability. This makes it easier to complete missions. Obstacles are not only caused by external factors such as fluid and air, but also various other factors, such as the designer's ability to select and create a model to produce the slightest possible resistance.

TABLE IV. SEAKEEPING PERFORMANCE AT 10 KNOTS.

Item	Wave Heading	Motion	Velocity
Heave	90°	0.0096 m	0.0077 m/s
	135°	0.0096 m	0.0108 m/s
	180°	0.0096 m	0.0122 m/s
Roll	90°	0.24°	0.02245 rad/s
	135°	0.36°	0.06251 rad/s
	180°	0°	0 rad/s
Pitch	90°	0.021°	0.00040 rad/s
	135°	0.028°	0.00263 rad/s
	180°	0.46°	0.0048 rad/s

There are two ways to determine the value of ship resistance; the Savitsky method and the Holtrop method. Vessel resistance is one important factor that must be taken into account when wanting to build a hull. When the hull operates in the water, there will be resistance (resistance) from the fluid that passes through. These obstacles will be the primary influence on the performance of the ship [1]. The Savitsky method is used to estimate the resistance of the hull when in planning speed conditions. The planning condition is when the speed of the ship is 30 knots and the Froude number is more than 1.5, making it a fast ship. The Savitsky method takes into account the resistance at the trim angle with speed, whereas the Holtrop method does not take this resistance into account. Therefore, to measure the resistance of fast boats, it is better to use the Savitsky method. This research used the Savitsky method to calculate the value of ship resistance through Equations 1 and 2.

$$R_T = \Delta tan\tau + \frac{{}^{1}/_{2}\, \rho V^2 \lambda b^2 C_{FO}}{cos\tau \; cos\beta} \tag{1}$$

$$R = \Delta tan\tau + \frac{D_f}{cos\tau} \tag{2}$$

From these equations, the results obtained were 14.57 N at a speed of 5 knots and 36.66 N at a speed of 10 knots. In selecting the ship materials, we must pay attention to the structural strength of the ship. Therefore, we chose carbon fiber to manufacture the ship. This choice of material for the Mandakini Neo ship was a change from when the Bengawan UV Team participated in national competitions, which still use composites in the form of fiberglass. Therefore, the choice of carbon fiber could be compared to this earlier material, with the result that the carbon fiber is better than fiberglass. To prove this, we carried out several tests.

Specifically, to assess the performance of the carbon fiber, we considered the tensile modulus and tensile strength. Tensile modulus and tensile strength tests were carried out to determine the stiffness and strength of the materials. Fiberglass has both advantages and disadvantages in its use. The main benefits of are low cost, high tensile strength, and high chemical resistance. On the other hand, the disadvantages are a relatively low tensile modulus and relatively low fatigue resistance [2]. In addition, fiberglass has two types; E-glass and S-glass. The difference between the two is in the mechanical properties and fiber production costs; the E-type glass has a tensile modulus of 72.5 GPa and a tensile strength of 3500 MPa, while the S-glass has a tensile modulus of 85.5 GPa and a tensile strength of 4600 MPa.

Unlike fiberglass, carbon fiber is commonly used in the aerospace industry. This industry considers the density of materials to be more important than the cost of manufacture. The advantages of carbon fiber are its lower specific gravity than fiberglass, and high tensile and compressive strength. The disadvantage is its high conductivity, which can cause a short in an electric engine if it is not protected. In the tests carried out, carbon fiber had a tensile modulus mechanical property value of 276 GPa and a tensile strength of 5.413 MPa. In other words, carbon fiber has a higher tensile modulus and tensile strength than fiberglass. Therefore, carbon fiber has higher stiffness and strength than fiberglass.

B. Sensor

The Global Positioning System (GPS) is a global coordinate system that can determine the coordinates of objects. The output of a GPS receiver is latitude, longitude, and height in the World Geodetic System 1984 (WGS84) coordinate frame [3]. GPS is a fully operational coordinate system; the system provides accurate, continuous, worldwide, three-dimensional position and velocity information to users with the appropriate receiving equipment. GPS also disseminates a form of Coordinated Universal Time (UTC). The satellite constellation nominally consists of 24 satellites arranged in six orbital planes, with four satellites per plane [4]. The problem is that the number of satellites received by the GPS sensor constantly changes, depending on the weather and satellite factors. Given the changeable conditions, in this study, testing and implementation were needed to determine the effect on the GPS of the number of satellites available due to the vehicle's position, when carrying out autonomous navigation. By creating a navigation system that could read the values received by the GPS and then compare them with the intended location, the navigation system could be applied to the ship.

This research used the Ublox Neo M8N GPS sensor module on the Mandakini Neo ship. This sensor was controlled using the Pixhawks PX4 Set, with the Mission Planner software. Mission Planner was used to maintain the propulsion systems, to travel to the location determined by the GPS. To minimize problems from use of the GPS sensor, we tested the GPS sensor on the vehicle directly. The test was carried out automatically to give the accuracy of the GPS, so that the best test data could be obtained as a reference for its use on the mission.

In GPS testing, there is a tolerance for the accuracy of the location to be addressed. For this reason, image processing using a webcam was applied to the vehicle to determine the direction/destination. This was based on an object in the form of an obstacle that was adjusted for the mission. The detection of existing obstacles was based on three parameters: color, shape, and area. The color parameter was used as the existing obstacle had been given a striking color that differed according to its function. The color detection system was based on the Hue Saturation Value (HSV) color code. The HSV color space was used because it corresponds closely to the human color perception [5]. It has proven more accurate in distinguish shadows than the RGB space. Color detection is carried out in the open and in real-time, so additional parameters facilitated color detection; specifically, contrast and brightness. The area parameter was based on the extent of the area where the color was detected by the color parameter entered. Shape parameters were used to improve the systematics of object detection, improving the precision. Object detection systematics were based on the angle of the detected object. Furthermore, the object was classified based on the three parameters. After the object had been classified, the program provided the direction of the vehicle's destination, according to the mission and the detected object.

Because GPS sensors and webcams were insufficient on their own, an ultrasonic sensor (HC-SR04) was added as an object avoidance system. This sensor functioned so that the ship could avoid obstacles such as buoys, and other obstacles that could interfere with the ship's process of completing the mission. This ultrasonic sensor was controlled using an Arduino, with a servo motor angle output. This system also utilized a relay as a servo PWM input switch when the ultrasonic read an object at a certain distance. When the object was too close, the Arduino triggered the relay, and the servo signal input then came from the Arduino. When no nearby objects were detected, the Arduino did not trigger the relay, and the servo signal input came from the Pixhawk (GPS).

C. System

At the 2021 International Roboboat Competition, we used simple electronic components with low specifications due to limited funds and limited time to undertake research, even with simple component conditions. We relied on the creativity and intensity of the work as much as possible to produce the best results. This research used HC-SR04 and Ublox Neo M8N (GPS) components for the main sensor, assisted by image processing via the Logitech C922 webcam. The main electrical components used were the Arduino Due microcontroller, Servo, Pixhawk PX4, and a thruster for ship propulsion. This research used a USB cable to connect the Arduino and Pixhawk microcontrollers, allowing commands from the Personal Computer (PC) to drive the thruster and servo. Pixhawk was used to determine the starting point to the end point of the ship's movement in carrying out missions, with data from the GPS, using the Mission Planner software via the PC. The webcam output data, once processed via a PC and HC-SR04, was further processed by a microcontroller to drive the servo, with the help of a relay module to convert the input from Pixhawk into commands from the microcontroller.

For more powerful image processing, used a PC rather than a mini PC as a motherboard for; namely, an ACER SF314 with a Nvidia MX250 GPU, which was able to process color detectors, shapes, and sizes of bodies. This also meant that lightness did not overload the ship, minimizing the low thrust of the thruster. We used Tenda AC6 as the primary network system to connect the vehicle and the team base with the Team Viewer software. The circuit system is shown in the appendix.

IV. EXPERIMENTAL RESULTS

A. Hull Design

In selecting the material to build the ship, we carried out trials on the manufacturing method, and found some problems occurred when using carbon fiber composites. Overcoming these was a challenge in this research, and the first step in developing carbon fiber as the material for the ship. Previously, we used the hand lay-up fabrication method to work with fiberglass. For the carbon fiber, we chose vacuum bagging technology. Vacuum bagging is a method for making composite specimens by pressing with a vacuum bag to suppress lamination from the gelcoat, fiber, and other layers on the mold, until all the layers merge into a structural composite.

The vacuum bag method uses atmospheric pressure as a clamp to suppress the lamination coat through sealing the materials in an air bag with an even, equal pressure. These bagging techniques usually require a longer vacuum-hold time for adequate depletion of entrapped air, as the bag holds the laminates tightly through-out the cure cycle which leaves no or very minimal bag-laminate clearance [6]. The carbon fiber material produced with the vacuum bag method was then tested to find its tensile strength and modulus of elasticity. From the test results, we found out that using vacuum bag method led to an increase in the tensile strength by 29.41%, and in the modulus of elasticity by 19.30%, compared to the previous method (the hand lay-up fabrication method).

For the in-water testing, we ran the ship manually in the water without using the autonomous mode so the ship would experience the desired water draft. To test the the stability of the ship, we cruised the ship both in straight lines and around turns to check stability was maintained and that the ship did not tilt enough to cause a change in the components' positions, which could interfere with the ship's ability to complete the mission. According to this testing the ship was stable and not too tilted when turning, allowing every component to remain in its original position.

We also carried out cruising tests with waves occurring from the front and the sides of the ship, to assess the movement of the ship when it was impacted by a shock. From these tests, we confirmed the ship was able to maintain in its original position, and again the components on the ship also remained in their original position. Based on these findings, we expected the ship to be able to complete the missions.

B. System and Sensor

In this research we considered GPS M8N, image processing, and an ultrasonic sensor. The focus of the research was on the basic function of the sensor, and also the image processing. For the GPS sensor test, we set three parameters that could be regulated: the number of waypoints, waypoint radius, and speed. Determination of the waypoints was undertaken by placing the ship at the desired point. That point was then marked by a buoy, so later the ship could be directed to the buoy. When the ship stopped at the buoy, the Mission Planner then marked that location. After the point was marked by the software, the ship was able to run automatically by following the previously marked points. The next step involved changing and combining the three test parameter in order to achieve the best result in terms of the distance of the ship and the determined waypoint. The results of the GPS M8N sensor test of Mandakini Neo are listed in Table V.

TABLE V. GPS M8N SENSOR TESTING.

WP Para meter	**Speed (throttle)**	**WP Radius (m)**	**Distance from the *Buoy* (m)**					**Average**
			1st Test	***2nd Test***	***3rd Test***	***4th Test***	***5th Test***	
1 WP	50%	0	1.23	1.43	1.35	1.54	1.5	1.41
		1	2.06	2.38	2.5	2.14	2.29	2.274
	70%	0	1.52	1.72	1.37	1.48	1.6	1.538
		1	2.39	2.52	1.98	2.28	2.6	2.354
2 WP	50%	0	0.98	1.32	1.68	1.21	0.89	1.216
		1	1.89	2.55	2.17	2.01	2.18	2.16
	70%	0	1.01	1.45	1.22	1.63	1.12	1.286
		1	2.12	2.77	1.98	2.27	2.43	2.314

The GPS sensor test compared the use of parameter combinations to run the ship automatically. The best average after running the test was obtained with the use of the parameter 2 waypoint, with a 50% speed throttle and a 0 m waypoint radius, and 1.216 m for the determined waypoint range. The worst result was obtained with the use of the parameter 1 waypoint, with 70% speed throttle and a 1 m waypoint radius. From the earlier result, we can conclude that the more waypoints that are used, the more accurate the GPS is, because the course is much clearer with more waypoints. Additionally, the lower the speed and the smaller the waypoint radius, the greater the accuracy of the GPS, because a larger waypoint radius means a larger the range that can be reached by the GPS, so the waypoint distance determined by the ship will be greater. The best result from this test was applied to the missions.

The testing of the ultrasonic sensor HC-SR04 was undertaken using two ultrasonic sensors fitted at a 30° angle from the front of the ship. We used two ultrasonic sensors because the mission objectives were able to be met using only two sensors for object avoidance. The test compared two parameters: the turn angle of the servo, and the trigger distance carried out manually to move the ship towards the object. When the determined parameter was fulfilled, the ship was able to run while avoiding the object. The data from the ultrasonic sensor HC-SR04 test of Mandakini Neo are presented in Table VI, below.

TABLE VI. ULTRASONIC SENSOR TESTING HC-SR04.

***Speed* (throttle)**	**Turning Angle (°)**	**Trigger Distance (m)**	**Result**					**Percen tage of Success**
			1st Test	***2nd Test***	***3rd Test***	***4th Test***	***5th Test***	
70%	30	0.8	Succeed	Failed	Failed	Failed	Failed	40%
		1	Succeed	Succeed	Succeed	Succeed	Failed	80%
	45	0.8	Failed	Failed	Succeed	Succeed	Succeed	60%
		1	Succeed	Failed	Succeed	Succeed	Succeed	80%

First, we compared the ship's performance without using the ultrasonic sensors and then using the ultrasonic sensory. When using the ultrasonic sensors, the ship was able to avoid the object, and there was no collision. However, it was necessary to optimize the ultrasonic sensor to maximize the avoidance system performance. The success parameter of this test was if the ship could avoid an obstacle without touching or bumping into it. The test was conducted with 70% speed from maximum throttle. For the first test, we used a 30° turn angle and trigger distance of 0.8 m. For the second test, we used a 30° turn angle and 1 m trigger distance. In the third test, we used a turn angle of 45° and trigger distance of 0.8 m. For the fourth, we used a 45° turn angle and trigger distance of 1 m. Based on the tests conducted, two parameter settings had a success rate of 80%. We chose to use the parameters consisting of a 30° turn angle and trigger distance of 1 m, because the ship was more stable and more secure when avoiding obstacles with these parameters in place.

The test of the digital algorithm of image processing compared the use of a combination of shape and space as detection parameters, using a pole as the object. The test was conducted by comparing three programs: 1) A color detection program with a space parameter; 2) color detection program with a space parameter and the shape of four corner points; and 3) color detection program with a space parameter and the shape of 4 to 6 corner points. In the first test, the program detected too many objects, meaning the wrong signal was sent to the ship. For the second test, under several conditions, the color parameter was not detected in its entirety, and the shadow of the pole was also legible. This meant that the object could not be detected as having four corner points and categorized as a rectangle, as it should have been. For the second test, under several conditions, an object that was accidently read could be dismissed, and the pole was still read as an object even though the result from the color parameter was not perfect.

In this research, an intensive trial was carried out of the mandatory navigation mission, because it needed to be completed successfully in order to continue to the other mission. This intensive trial was an optimization and combination of the functions of the three sensors we used. Some difficulties occurred, but we attempted to minimize these. Based on our results, we are hopeful that the Mandakini Neo will be able to complete the missions.

V. ACKNOWLEDGMENTS

The Bengawan UV Roboboat Team would like to thank all those who participated in and supported this research for the 2021 Roboboat. In particular, our thanks go to our professor and supervisor, Dr. Eng. Aditya Rio Prabowo, who has guided and advised our team on both the technical and non-technical aspects of the research for this competition. We would also like to thank the Universitas Sebelas Maret, Lembaga Penelitian dan Pengabdian Masyarakat Universitas Sebelas Maret Surakarta (Sebelas Maret University of Surakarta, Institution of Research and Community Service), Computer and Design Laboratory, and Automation and Robotics Laboratory. Our gratitude goes also to our sponsors—Junko, Widya Robotics, Frogsid, PT. Global Welding, CV. Indigo Baru Biru, and Bank Jateng—who provided help to the Bengawan UV Team in this competition.

VI. REFERENCES

[1] R. I. Julianto, A. R. Prabowo, N. Muhayat, T. Putranto and R. Adiputra, "Investigation of Hull Design to Quantify Resistance Criteria Using Holtrop's Regression-Based Method and Savitsky's Mathematical Model: A Study Case of Fishing Vessels," *Journal of Engineering Science and Technology,* vol. 16, no. 2, pp. 1426-1443, 2021.

[2] P. Mallick, Fiber-Reinforced Composites: Materials, Manufacturing, And Design, London: CRC Press, 2007.

[3] S. P. Drake, "Converting GPS coordinates [phi, lambda, h] to navigation coordinates (ENU)," Vols. DSTO-TN, April 2002.

[4] E. D. Kaplan and C. Hegarty, Understanding GPS: Principles and Application, London: Artech House, 2005.

[5] N. Herodotou, K. Plataniotis and A. Venetsanopoulos, "A color segmentation scheme for object-based video coding," in *1998 IEEE Symposium on Advances in Digital Filtering and Signal Processing. Symposium Proceedings (Cat. No.98EX185)*, Victoria, IEEE, 1998, pp. 25-29.

[6] Y. Mujahid, N. Sallih, M. Z. Abdullah and M. Mustapha, "Effects of Processing Parameters for Vacuum-Bag-Only Method on Void Content and Mechanical Properties of Laminated Composites," *Polymer Composites,* 2020.

APPENDIX A: COMPONENTS SPESIFICATION

Component	**Vendor**	**Model/Type**	**Specs**	**Cost (USD)**	**Status**
ASV Hull form/platform	Handmade, Semi vacuum with *Carbon Fibre*	Catamaran Flat Side Inside	LOA = 0.97 m D = 0.3 m T = 0.15 m B = 0.5 m	568	New
Propulsion	Chenjuan	T60 Propulsion System	Each : Thrust 3-5 kgf,	106	New
CPU	Acer	SF314-56G	Intel Core i7-8565U8 GB DDR4 240 GB SSD + 1 TB HDD WiFi, Bluetooth, Webcam Nvidia GeForce MX250 2 GB 14.0-inch Full HD Windows 10 Home Fingerprint	600	Old
Teleoperation	TP-Link	CPE-510	15 km range, 100 mbps, 27 dBm, 5 GHz	75	New
Compass	Ublox	M8N	Receiver type 72-channel u-blox M8 engine GPS/QZSS L1 C/A, GLONASS L10F, BeiDou B1 SBAS L1 C/A: WAAS, EGNOS, MSAS Galileo-ready E1B/C (NEO-M8N)	20	New
Camera(s)	Logitech	C922	HD 1080	97	Old
Motor and propellers	Chenjuan	T60 Propulsion System	Each : Thrust 3-5 kgf,	106	New
Motor controls	Ardupilot	Pixhawk 2.4.8	32-bit ARM Cortex M4 core with FPU	100	New

CPU	Acer	SF314-56G	Intel Core i7-8565U8 GB DDR4 240 GB SSD + 1 TB HDD WiFi, Bluetooth, Webcam Nvidia GeForce MX250 2 GB 14.0-inch Full HD Windows 10 Home Fingerprint	600	Old
Camera(s)	Logitech	C922	HD 1080	97	New
Autopilot Algorithms	Ardupilot	Pixhawk 2.4.8	32-bit ARM Cortex M4 core with FPU	100	New
Vision	Logitech	C922	HD 1080	97	New
Localization and mapping	Ardupilot	Pixhawk 2.4.8	32-bit ARM Cortex M4 core with FPU	100	New
Autonomy Team Size (number of people)	N/A	N/A	N/A	N/A	19
Expertise ratio (hardware vs. software)	N/A	N/A	N/A	N/A	4 vs 3
Testing time: simulation	N/A	N/A	N/A	N/A	2 months
Testing time: in-water	N/A	N/A	N/A	N/A	3 weeks
Programming Language(s)	N/A	N/A	N/A	N/A	C/C++, Python