Conceptualization of a Surveillance Drone for Aquatic Expeditions

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Abstract: The age of technology has paved the way for technological advancements and inventions, one of which are Unmanned Underwater Vehicles (UUV) which are deployed in marine ecosystems for various purposes. This technology displays the potential of safer and more efficient monitoring methods for marine surveillance. However, in the Philippines, numerous leading marine organizations still use traditional methods such as the use of divers to collect data for research purposes. Thus, it is the study's general objective to conceptualize a UUV model that may be adapted in the Philippines for marine surveillance operations. The study undergoes a 4-step-process in fulfilling the general objective, this involves: (1) the Consultation of Marine Organizations and Personnel, (2) the finding of the Electrical Hardware Components, (3) the Simulation of the Conceptualized Drone Shapes, and (4) the Analysis of the Simulation Results. Through this systematic approach, the study conceptualized 3 drone shapes namely: the Disc Shape, the Torpedo Shape, and the Anomalous Shape. These conceptualized shapes were modeled and simulated through SolidWorks, where the ideal water conditions of the Philippines were set to accurately test the efficiency of these drone shapes. The obtained results suggest that the torpedo shape is the most ideal shape to utilize in Philippine marine surveillance application.

Key Words: unmanned underwater vehicle; conceptualize; SolidWorks; marine surveillance; drone shapes

1. INTRODUCTION

The UUV industry has introduced the viability of UUVs for marine surveillance. The integration of this drone technology underwater can be crucial in aiding long-term inexpensive, more task efficient, and safer practices in conducting underwater expeditions (The Explorer, n.d.). An example would be Irobot's Seaglider, a UUV specifically for surveillance purposes, that displayed the potential of UUVs for a safer and more efficient oceanic monitoring. However, given the diversities in the conditions of the world's bodies of waters, it is necessary to appropriate the drone design with regards to its own environmental challenges. As such, there is a surplus of different UUV designs in the market such as the spherical, torpedo, and anomalous each having their own sets of advantages and disadvantages (Chen & Liu, 2011).

The objective of this study is to conceptualize UUV models that may be adapted in the Philippines for surveillance purposes. The following steps were performed to accomplish the said objective:

1. To consult with various marine related organizations and personnel regarding various information needed for an ideal UUV.
2. To find the different electrical hardware components of the drone.
3. To simulate the hydrodynamics effects of different drone shapes through SolidWorks Flow Simulation.
4. To analyze the results of the simulation and identify the ideal drone shape to use in the Philippines.

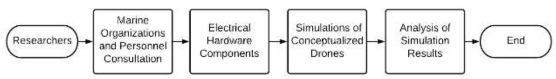
The study aims to help various organizations in the Philippines that advocate towards the preservation of marine wildlife and coral reefs as the study conceptualizes UUV models that can be integrated in the Philippines. Furthermore, the study extends knowledge in the field of underwater drones as the study provides comparative data between different shapes of UUVs through the parameters coefficient of drag and drag force.

The primary focus of this study revolves around the effectiveness of various UUV shapes in Philippine oceans. The design aspect of the conceptualized drones relies on the incorporation of the various electrical components specialized for marine surveillance into the different hull shapes. Certain external procedures such as the programming of the electrical components, actual fabrication of the drones, and post processing of gathered data by the drone is not included in the study. A total of 3 drone shapes were done in SolidWorks: spherical shape, torpedo shape, and manta ray shape. These designs were then tested through SolidWorks Flow simulation to identify their coefficient of drag and drag force.

2. METHODOLOGY

Figure 1

Flow of Methodology



Note. This figure shows the flow of which the objectives were done in sequence.

2.1 Marine Organizations and Personnel Consultation

Following the process seen in figure 1, proper guidance was imperative in setting the groundwork for the study to build upon. A survey was made through Google forms and was administered to various organizations and personnel in the field of marine biology. Personnel from marine organizations such as DLSU SHORE, Coral Guardian, Marine Conservation Ph, and National Oceanic and Atmospheric Administration (NOAA) took part in the survey; which includes inquiries about the ideal specs of an effective UUV while also including questions regarding the respondents' preferred drone shape based on the researchers' 3 initial drafts; the disc, the torpedo, and the manta ray (see Appendix A).

2.2 Electrical Hardware Components

The types of electrical components for the internal and external parts of the drone were selected to accommodate the compiled responses from the survey. The components to be included were centered around features, compatibility, and market availability. The various components were then compiled together in a table presenting their function, weight, quantity, and price (see Appendix B).

2.3 Simulations of Conceptualized Drone

2.3.1 Design Model

The 3 shapes in this subsection were modeled in SolidWorks by the researchers themselves. Every shape consists of the same components in quantity and quality but differs in its placement for each drone. Therefore, the shapes have been designed based on being compact with regards to the volume of the internal components. All of the designs were uniformly made out of 6061 aluminum alloy due to its reliability in UUV applications. This material is popular in underwater applications as it is corrosive resistant and precipitation hardened (Metal Supermarkets, 2017). A tether was also integrated into the designs since radio waves cannot travel too well through water.

Table 1

Compiled Drone Models

Disc	Manta Ray	Torpedo
		

Note. This table presents the processed models through the use of SolidWorks Visualize for a more presentable look. This however does not change the overall shape and performance of the drones.

To model the disc shape seen in table 1, it was divided into two areas: the main component area and the outer ring area. To achieve this disc shape, 4 thrusters were mounted vertically along the x-axis of the outer ring area at an equal distance from one another. The concept behind the positioning of these thrusters is based on the thrusters of quadcopters. The outer ring area is connected to the main component area through the use of watertight enclosures that also functions as a means for the wiring of the thrusters to be safely connected to the main component area. The main component area comprises the electrical components necessary for the drone to function. Located on the side of the main component area is the pH sensor while below it is the mounted camera, temperature sensor, and depth pressure sensor. The 2 Subsea lights are located separately; one is located directly at the top of the main component area, while the other is located directly below the main component area.

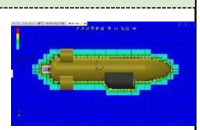
Now for the modeling of the manta ray shape in table 1, the position of the thrusters is as follows: 2 thrusters mounted vertically for upward and downward motions, and 2 thrusters mounted horizontally for propelling the drone forward. Although the thrusters are mounted at different orientations, the thrusters were however aligned at the same axis with each other for them to function as intended. This is done in order for the drone to have stability while thrusting the drone forward. However, due to the 2 thrusters positioned at the back, a hollow passage was implemented in order for them to have access to water flow. For the other external components of the drone, the water quality sensors are allocated on a chin compartment below the hull; While the internal components, the camera, and the two subsea lights are located inside the hull.

For the last design in table 1, the torpedo shape, there are 4 thrusters that are all positioned equidistant to each other located at the back of the drone where it can propel the drone forward. The other external components of the drone such as the water quality sensors and tether are also positioned in the back, while the camera and the subsea lights are allocated inside a chin compartment below the craft so that graphical recording is directed frontside of the drone's axis.

2.3.2 Actual Simulations

To set up the simulation environment, the following options were selected from the wizard command: external analysis excluding all cavities and internal spaces for the analysis type, water with a density of 1,023.6 kg/m^3 for the fluid to be considered, and default for the wall conditions. According to Sea temperature (n.d.), the lowest recorded water temperature in Manila for the past years is 25°C with a corresponding density of 1,023.6 kg/m^3. Due to the inverse proportion of temperature and density, using this temperature is tantamount to simulating the drones at the highest density. Now for the initial velocity condition, this was set to 1.5 m/s and 2.0 m/s derived from other drones that were considered (see Appendix C). However, due to the disc shape's design, two (2) assumptions were made in terms of how the initial velocity condition should be directed based on how it should be moving. First, if the thrusters can tilt, then the drone's movement should be parallel to the x-axis. Second, if the thrusters are fixed in its orientation, then the drone's movement should be approximately around 45° from the x-axis. The mesh settings used in the simulations can be seen in table 2 wherein these were set to: initial mesh level of 4, refining fluid cells level of 3, and refining cells at fluid/solid boundary level of 4.

Table 2
Mesh of the Drone Models

Disc	Manta Ray	Torpedo
		

2.4 Analysis of Simulation Results

The effectiveness of each UUV shape was based on the parameters: coefficient of drag and drag force. Thus, it was imperative to analyze the said parameters in conjunction to the pressure contours and velocity flows. The analysis of the parameters was done via comparison and transparency checking with regards to present-day data. Important concepts such as the reference area and streamlined bodies were also considered in the analysis.

3. RESULTS AND DISCUSSION

3.1 MARINE ORGANIZATIONS AND PERSONNEL CONSULTATION

Table 3
Responses from the Consultation

Marine Organization/ Personnel	Recommended Electrical Hardware	Recommended Battery Duration	Recommended Operational Depth	Preferred Drone Shape
Director of DLSU Shore	Temperature Sensor	2 to 3 hours	50 meters	Spherical
Marine Ecologist of NOAA	Alkalinity Sensor Temperature Sensor	3 to 4 hours	30 to 50 meters	Torpedo
Marine Conservation Ph	pH Sensor Temperature Sensor	2 to 3 hours	40 or 150 meters	Torpedo
Coral Guardian	pH Sensor Temperature Sensor	2 to 3 hours	Purpose Dependent	Spherical

Note. Presented in this table are the summarized responses that were considered by the researchers in conceptualizing the disc, torpedo, and manta ray shapes.

3.2 Conceptualized Drone Simulations

Table 4
Compiled Simulation Results

Simulation Results at 1.5 m/s		
Drone Shape	**Coefficient of Drag**	**Drag Force**
Disc at 0°	-0.5585	-36.05
Disc at 45°	-0.1318	-49.31
Manta Ray	-0.4576	-27.63
Torpedo	-0.7927	-16.49
Simulation Results at 2.0 m/s		
Disc at 0°	-0.5596	-64.20
Disc at 45°	-0.1273	-84.69
Manta Ray	-0.4790	-51.42
Torpedo	-0.7928	-29.33

Figure 2
Coefficient of Drag vs Velocity

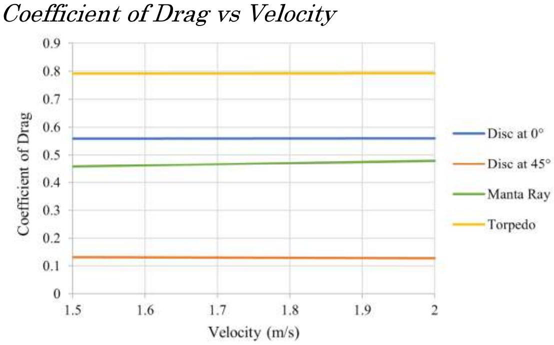


Figure 3
Drag Force vs Velocity

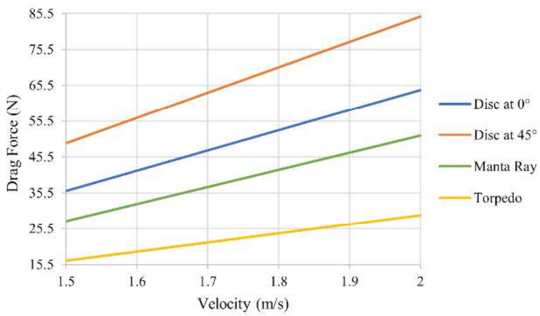
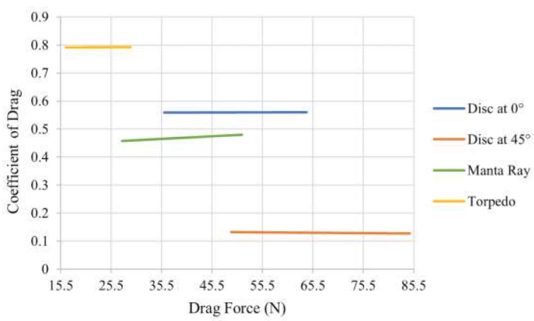


Figure 4
Coefficient of Drag vs Drag Force



As presented in figure 2, it can be noticed that among the 3 shapes, the disc shape at its second assumption, when it is angled at 45° from the x-axis, had the lowest coefficient of drag. An explanation to this is that among the factors that affect the drag equation, the reference area has an inverse relationship to the coefficient of drag (NASA, n.d). This means that as the reference area increases, the coefficient of drag should decrease. Consequently, the disc at its second assumption had the least coefficient of drag while having the largest reference area among the other shapes as seen in table 5. This is consistent with the result obtained from the torpedo wherein the torpedo shape, which has the smallest reference area, had the highest coefficient of drag.

However, the coefficient of drag is not the sole determinant in the drag equation. According to Restarts (n.d.), drag force, the force obtained in the drag equation, is dependent on numerous other variables such as density, velocity, and shape. This explains the data seen on figure 3 wherein the disc at its second assumption yielded the highest drag force despite it having the lowest coefficient of drag. The reason behind its high drag force attributes to the flow of fluid with regards to its shape. Referring to table 6, it can be observed that heavy turbulence is experienced at the rear of the drone. In contrast to this, the torpedo shape experienced a more streamline flow of fluid that correlates to less agitation or turbulence of fluid particles as it moves through a body (Swan, 2011). This resulted in a lower drag force despite its higher coefficient of drag.

Table 5
Compiled Pressure Contour

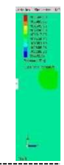
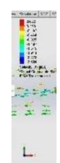
Disc at 0°	Disc at 45°	Manta Ray	Torpedo
			

Table 6
Compiled Velocity Flow

Disc at 0°	Disc at 45°	Manta Ray	Torpedo
			

4. CONCLUSION

This study, which aims to develop UUV models that can be adapted in the Philippines, has found out that based on the survey conducted, an ideal UUV should have 3 hours operational time and a depth rating of at least 30 meters. Moreover, the disc and torpedo shapes are preferred drone shape amongst the survey respondents. Now referring to the results seen in table 3, it can be inferred that based on the discussion in section 3, the ideal drone shape for the Philippines would be the torpedo. There were 2 bases for this interference. First, despite the torpedo's coefficient of drag being the highest, it was the closest one to the acceptable coefficient of drag value for underwater purposes. The coefficient of drag for most vehicles based on the cross-sectional area ranges from 0.8 to 1 (Marine Technology Society, 2017). Furthermore, the torpedo shape obtained the lowest drag force amongst the other drone designs. A similar observation was made in the thesis of Shah (2008) wherein he stated that torpedo shapes experience less drag compared to that of non-torpedo shapes.

For the proceeding studies to be conducted, a possible area of improvement for this research would be to consider upward and downward motions as well to investigate the lift force of the shapes. Moreover, simulation software that uses tetrahedral meshes such as Ansys could also be used to further improve the study as the SolidWorks Flow Simulation was only limited to cuboid meshes. Lastly, a significant rendition of this study would be to fabricate the drones for actual experimentations.

5. ACKNOWLEDGEMENTS

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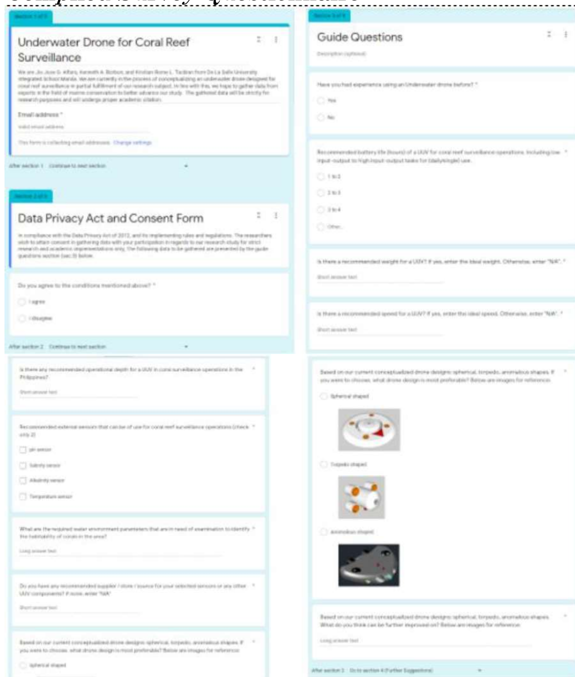
7. APPENDICES

Appendix A
Survey Questionnaire

Figure A1
Compiled Survey Questionnaire



Appendix B
Electrical Hardware Components
Table B1
Internal Electrical Hardware Components

Component	Function	Weight	Quantity	Total Price
Pixhawk Autopilot	An advanced autopilot/command center through which each command is taken and translated to the other components of the drone	33.3 grams	1	$170.00
ZTW 40A Brushless ESC	A non-physical controller that indicates the speed of the thrusters' speed.	36 grams	4	$72.00
BlueRobotic Power Sense Module	A module that provides current and voltage sensing to the Pixhawk autopilot	Not indicated	1	$31.00
Fathom-x Tether Interface Board Set	A tether interface board that Enables HD video and high-bandwidth data over 300m+ tether lengths.	N/A	2	$338.00
Raspberry Pi 3 Model B+	A credit-card sized computer with a 1.4GHz 64-bit quad-core processor, dual-	45 grams	1	$48.00

	band wireless LAN, Bluetooth 4.2/BLE, faster Ethernet, and Power-over-Ethernet support			
BlueRobotic 16 GB SD card preloaded with Raspian for ArduSub	A micro SD card preloaded with the Rasparian Linux Operating system and is preloaded with the software needed for ArduSub	Not indicated	1	$16.00
BlueRobotic Left-Angle Micro USB Cable for Raspberry Pi to Pixhawk	A cable capable of connecting a Micro-USB to USB-A cable which can be connected to the Raspberry Pi computer and Pixhawk autopilot	23 grams	1	$10.00
BlueRobotic 5V 6A Power Supply	A simple voltage regulator that provides a steady 5V at up to 6A for Raspberry Pi and Pixhawk servo rail.	Not indicated	1	$22.00
HiLetgo MPU9250 Gyroscope, accelerator, magnetometer sensor	A powerful inertial measurement unit (IMU) for Raspberry Pi 2/3/4 that adds X, Y, Z axis-functions for determining acceleration, and magnetometer sensor.	2.72 grams	1	$8.99
Battery	A custom-made battery-pack that accommodates the required electrical output of the 4 thrusters and other components	Not indicated	1	

Table B2
External Electrical Hardware Components

Component	Function	Weight	Quantity	Price
GAOHAU pH 0-14	An underwater pH sensor with a pH range of 0-14 pH and <= 1 minute.	136.078 grams	1	$40.99
BlueRobotics Celsius Fast-Response, ±0.1°C Temperature Sensor (I2C)	An underwater temperature sensor has an accurate sensor of down to tenths-celsius and a fast response/reading time of (0.5 m/s flow).	Not indicated	1	$60.00
BlueRobotics Bar30 High-Resolution 300m Depth/Pressure Sensor	An underwater pressure sensor for 300m depth operating capacity and depth resolution of 2mm.	Not indicated	1	$72.00
BlueRobotics Low-light HD USB Camera	An underwater camera based on the Sony IMX322 with a 1/2.9" sensor and a 2MP-1080p pixel count; to attain maximum light sensitivity.	Not indicated	1	$99.00
BlueRobotics Lumen Subsea Light	An underwater observation light with a fully dimmable PWM and has a light efficiency output of 1500 lumens at 15 watts. Its beam is rated with a 135° coverage and 6200k color temperature.	Not indicated	1	$115.00
Hawk Hobby Underwater Thrusters	An underwater reversible thruster with 860 RPM and rated at 300W max power.	163 grams	1	$49.99
Camera Mount	A custom-built 3D CAD camera mount for the BlueRobotic Low-light HD USB Camera	Not indicated	1	Not applicable
Fathom ROV Tether	A 70-meter polyurethane jacketed tether connected to the drone's tether interface board which connects the drone to the topside computer.	Not indicated	1	$350.00
Microsoft Xbox One Controller	A wired/wireless gamepad controller is compatible with Windows 10 or Linux operating systems.	281 grams	1	$59.99
Topside Computer	A topside Windows 10 os operating device with 8GB ram, i5 processor, and	Not indicated	1	649$

	solid-state drive (SSD).			

Appendix C
Research and Commercial Drone Specifications
Table C1
Available Drone Specifications

Disc Drones				
Drone	Max Speed	Battery Duration	Battery Capacity	Max Depth
Kiro Developed Drone	2.1 m/s	Not indicated	Not indicated	Not indicated
Underwater Disk Robot	2.57 m/s	Not indicated	3000W	Not indicated
Spherical Auv	Not indicated	Not indicated	8kWh	150 meters
Four Rotor Dish Drone	Not indicated	Not indicated	Not indicated	Not indicated
Torpedo Drones				
Bluefin-21	2.3 m/s	Not indicated	13.5 kWh	4500 meters
SPURV	1.95 m/s	5 hours	Not indicated	3650 meters
REMUS-100	2.6 m/s	Not indicated	1.5 kWh	100 meters
Anomalous/Commercial Drones				
PowerDolphin	4.5 m/s	2.0 hours	5,800 mAh	Not indicated
iBubble	1.5 m/s	1.5 hours	Not indicated	60 meters
Fifish V6	1.5m/s	4 hours	9000 mAh	100 meters
Gladius Mini	2.0 m/s	2 hours	5000 mAh	100 meters
Blueye Pioneer	1.5m/s	2 hours	96 Wh	150 meters