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The Impact of Covid-19 on Human Rescue Operations: A Review on Past Unmanned - Water Rescue Boats (U-Wrb) and Adopting Them to The New Norm

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***Abstract* — Recently, the drowning cases of human beings are at an alarming rate. The current work presents a dedicated review on U-WRB for human rescue operations subjected to drowning. The review from year 1996 to 2018 highlights the key factors such as advantages and limitations of the developed U-WRB's. Having completed the review, the work further proposes new research pathways that could be beneficial to the scientific community living in the new norm; COVID-19 where minimal contact between humans are of concern when it comes to human rescue operations. Possible new research pathways include but not limited to the type of sensors used, material selection, incorporation of state-of-the-art attachments to the U-WRB and customizable attachments to the main unit based on a given real time rescue operation are proposed.**

Keywords—Drowning, COVID-19, flood, natural fibre composites, unmanned rescue boats

I. INTRODUCTION

In December 2021, Malaysia had been hit with the worst flood ever. Most of the low-level residential areas had been completely submerged with water of more than 10 feet high. Many victims were stranded in their homes and vehicles resulting in loss of lives due to the lack of rescue teams deployed. In conjunction to this, it has been countlessly reported that the number of drowning cases in Malaysia had been increasing over the years. For an instance, in year 2018 itself, News Straits Times [1] reported that there were 700 reports on drowning cases throughout Malaysia. This staggering figure indicates that Malaysia records a total of 1.6 cases of drowning daily. Additionally, the World Health Organisation (WHO)'s report showed that about 40 people drowned worldwide in every hour which summed up to 372,000 drowned victims every year [2]. In Malaysia, majority of the drowned victims were children found swimming by the rivers or canals [3]. Based on the National Water Activity Safety Council (WASC) in Malaysia [1, 4], it was revealed that there is lack of public awareness and back dated state-of-the-art rescue facilities on drowning cases in Malaysia. Concurrent to this, there were also cases reported where the rescue team itself lost their lives during saving the drowning victims. This is because on the unpredictable water conditions, unsteady water current, large and rough waves, panic attacks incurred during rescuer and many more. Having said so, with the recent spike of cases related to COVID-19 pandemic outbreak, it had somehow impacted the perception of humans not to be in close contact with others by maintaining a strict social distance rule. Indirectly, it had contributed to the fear in rescuing a drowning victim with the perception that the victim could be a possible contributor to the COVID-19 virus. To overcome the afore said claims, a feasible immediate proposal is to introduce a state-of-the-art Unmanned - Water Rescue Boat (U-WRB) to save victims from drowning.

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Over the past decade, researchers had labelled the current research era to be a 'cellulosic century' [5] namely due to the enormous amount of attention paid on natural fibres reinforced polymeric composite (NFRPC) subjected to various types of testing and real time applications. Among them are the mechanical and tribological properties of NFRPC, water absorption test, interfacial adhesion of natural fibres against different matrices subjected to different fibre treatment test, aging characterises of the composite subjected to various solutions / lubricants, abrasiveness of the fibre to processing equipment's and etc. Surprisingly, majority of the reported works are in agreement that NFRPC's exhibited competitive and improved properties as compared to synthetic fibre composites; i.e. glass fibre composites. In conjunction to this, NFRPC had been used in the automotive industries, construction sectors and in the armed force sectors.

On the other point of view, Malaysia which is geographically located at the equatorial region, is blessed with its high amount of agricultural output throughout the year. According to IndexMundi [6], Malaysia is the second largest oil palm producer in the world after Indonesia. It was reported that 199 million ton of oil palm was produced in year 2020. As a result to this, a huge amount of oil palm fibre husks are being abundant from the cultivation of ripen oil palm fruits [7 - 10]. This puts a huge amount of oil palm fibres to waste causing serious environmental problems such as greenhouse effect and forest devastation which can lead to physical disturbance of the ecological behaviour of an ecosystem. Similarly, various types of other non-useful bioproducts such as kenaf fibres, corn stalks, sugarcane bagasse, pineapple leaves, banana leaves, bamboo trees, betelnut husks and coir husks are produced in bulk quantity each day as a result of harvesting their useful bioproduct [11]. From the literature [5, 12, 13], it is learned that the quickest way to dispose the harvested agricultural product is to burn them in a proper manner. Sadly, in the rural areas in Malaysia, the harvested fibres are often used as an insect repellent when they are burnt openly into the atmosphere [14]. This causes serious health problems, high readings of Air Pollution Index (API) and a major destruction to the flora and fauna ecosystem.

From the claims made above, it can be summarized that there is an urgency to tackle the alarming drowning cases reported in Malaysia. Coupled with the global COVID-19 pandemic attack, there is a need to minimize close contact among human beings. This motivates of developing a U-WRB using home grown readily available resources. Having said that, the current work is a dedicated review on the developments of U-WRB for human rescue operations. The review will focus on the applicability, features and limitation of the design. Following to this, necessary judgements will be taken into consideration in proposing a state-of-the-art U-WRB. This review will be beneficial to others as it proposes new research pathways involving human rescue operations.

II. REVIEW OF PREVIOUS WORKS

Figure 1 shows the five subsequent phases of the human drowning process [15]. It is to be noted here that most of the developed U-WRB's are based of saving victims in mode '1' (in Fig. 1). Hence, once the drowning victim progresses to mode '2' onwards, it is impossible for the U-WRB to safe the drowning victim. This is because the rescue boat is intended to work at the surface of the water. Having said that, the following below presents past reported works on the types of developed U-WRB and its features involved for human rescue works.

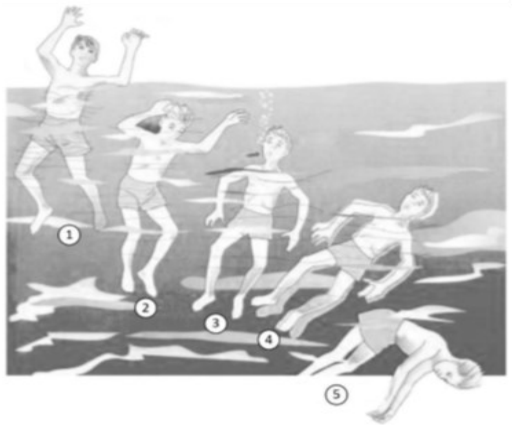


Fig. 1. The five different stages of the human drowning process.

A. *Artemis*

Artemis is the first Autonomous Unmanned Surface Vehicle (USV) that was developed by MIT Sea Grant College Program in 1993. Artemis design is like the vessel and the design is towards to the scale replica of a fishing trawler as the platform as shown in Fig. 2. In 1996, Artemis is used to collect simple bathymetry data in the Charles River in Boston, MA [15]. ARTEMIS is equipped with a microcomputer for autonomous guidance, a GPS system for navigation, a depth sounder for bathymetric-data collection, and a radio modem for data transmission in real-time. However, its overall hull design is bulky making transportation from land to water challenging when manual human labour is involved.

Fig. 2. Artemis.

In year 1997, 'Autocat' was introduced based on the design improvement from Artemis. Since Artemis platform is small, it adapted the kayak platform instead of fishing trawler as shown in Fig. 3. Besides that, Autocat has significantly improved in mechanical system such as hull structure, steering system and power motor compared with Artemis. However, the model was only intended for use in hydrographic survey where it had successfully completed the first survey in Boston Harbor in December 1997. Similar to Artemis model, Autocat design was way too bulky if one was to use it for unmanned human rescue applications. Although the hull was fabricated using composite material, it needed four manpower to lift the entire unit when transporting it from land to water and vice versa.

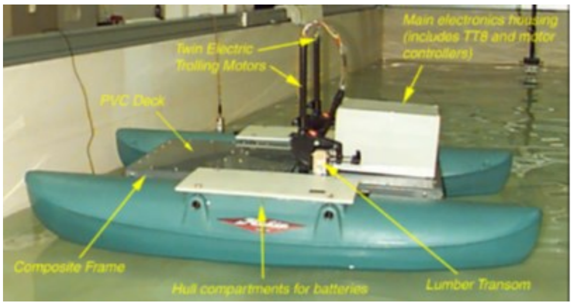


Fig. 3. Autocat [16].

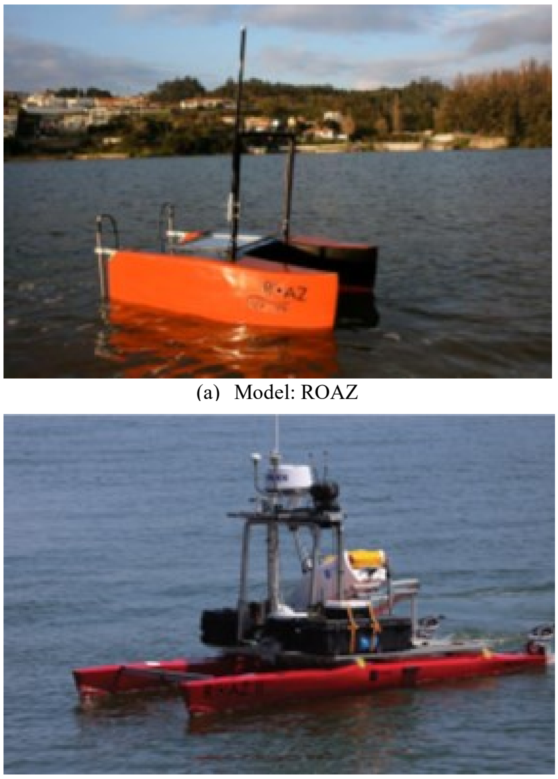
B. *ROAZ and ROAZ II USV*

These systems were developed at Autonomous Systems Lab, ISEP/IPP – Instituto Superior de Engenharia do Porto under a research program in marine robotics in 2007. With multiple applications either in river and estuarine environments or in the sea, the system applications in search and rescue operations are addressed and were taken in consideration for the overall system design. The design of ROAZ is more compact and suitable to use in the river as shown in Fig. 4(a). The material for the platform is made from fibre glass. ROAZ II is bigger than ROAZ and suitable to use in open sea as shown in Fig. 4(b). The material for the platform is from density polyethylene (HDPE). Table I shows the specification of ROAZ II.

Table I. Technical Specification of ROAZ II.

Boat Type	Autonomous ROAZ II
Length	4.2 m
Weight	200 – 400 kg (depending on battery and payload
Propulsion	Two independent electric thrusters
Maximum speed	10 knots
Control range	Up to 1 nm

ROAZ and ROAZ II are equipped with conventional cameras (both for on board image processing and for video transmission). ROAZ II system is equipped with a thermographic infrared camera capable of resolution up to 0.1ºC of temperature difference as shown in Fig. 5. Their capability of autonomous operation in extended periods of time, night operation and autonomous search can be exploited to augment current marine rescue human and technical infrastructure. Besides that, ROAZ II is equipped with GPS system and it allows the operator to remotely control from a base station. Further work is still necessary to throughout validate the approach under stronger varying light and wave conditions [17].



(a) Model: ROAZ

(b) Model: ROAZ II

Fig. 4. Different models of the ROAZ's design.

Fig. 5. ROAZ II Visible and infrared camera [17].

C. *U-Ranger USV*

U-Ranger was developed by company Calzoni S.r.l in 2009. U-Ranger is a remotely controlled or autonomous Unmanned Surface Vehicle for Maritime security with a wide possibility to be configured for a variety of mission due to its flexible concept. The Command-and-Control system can operate the vehicle's motion manually or to plan and execute pre-programmed tracks [18]. The boat can do search and rescue in ocean and can be remotely controlled from the base station. The boat is equipped with basic navigation sensor such as compass, GPS system, navigation camera, sonar sensor and vehicle control radio link as shown in Fig. 6. Table II shows the detail specification of U-Ranger boat. Despite having many advance features equipped, the design and development of the boat is justified to be too bulky as it would occupy a large space for storage and transportation. However, having a large design structure for its purpose is acceptable as this boat was designed for Maritime Security missions where it would require extensive operations. Another drawback is the difficulty in detecting fast objects or making detections during sharp turns.

Fig. 6. Allocation of sensor in U-Ranger [18].

The advantages of U-Ranger compared to ROAZ II are:

a) The payload of the U-Ranger is 4 times bigger than ROAZ II, enabling the U-Ranger to carry loads up to 1800 kg.

b) The U-Ranger is made from aluminium but ROAZ II is made from fiberglass. In terms of durability in the ocean, U-Ranger is stronger and more stable to face the wave of the ocean.

c) U-Ranger has the maximum speed 40 knots while the ROAZ II has a maximum speed of 10 knots. In terms of ratio, the U-Ranger can reach the search and rescue areas 4 times faster than ROAZ II.

Table II. Technical Specification of U-Ranger.

Boat Type	**U-Ranger**
Length	7 m
Weight	1400 – 1800 kg (depending on battery and payload
Propulsion	Two independent electric thrusters
Maximum speed	40 knots
Control range	Up to 5 nm

D. Unmanned Capsule Deployment System (UCAP)

The project of Unmanned capsule deployment system (UCAP) was started in 2013 and the first researcher to publish it was Matos *et al*. [19]. The capsule was able to be operated remotely by the operator or autonomously. Besides that, the capsule was originally used for Integrated Components for Assisted Rescue and Unmanned Search Operations (ICARUS) project where the capsule is transported and deployed by a larger USV into a determined disaster area and is used to carry a life raft and inflate it close to survivors in large-scale maritime disasters. The goal of this development is to endow search and rescue teams with tools that extend their operational capabilities in scenarios with adverse atmospheric or maritime conditions. Figure 7 shows few variations of the first prototype of UCAP. The hull of the UCAP is made from fibre glass and is covered with wooden deck. Figure 7(a) depicts the first designed prototype of the UCAP that was tested in open water. Its ability to carry large weight was tested out by carrying a life raft on the UCAP as shown in Fig. 7(b). Since it is design to be fitted on different USV, the UCAP was fitted on the ROAD USV and tested out by deploying it at sea to test its effectiveness. Figure 7(c) and 7(d) illustrates the testing being done on the ROAD USV.

(a) First prototype UCAP.

(b) Life Raft deployment system with the life raft.

(c) UCAP Deployment system installed on ROAZ USV.

(d) UCAP deployment from ROAZ USV.

Fig. 7. Variations of the first prototype of UCAP [19].

The first prototype of UCAP was 30 kg and the weight of raft was about 25 kg. The carrying capacity by UCAP inclusive of its own weight is summed up to 90 kg. The life raft can carry 4 people in a rescue mission. The life raft also consists of two inflatable buoyancy tube, a first aid kid and signalling equipment. The requirement that was required to fulfil the design and development of the UCAP for the ICARUS project are as follows:

a) UCAP should be easily transport and carried by larger USV.

b) UCAP should be able to carry and deploy up to 4 people in a single life raft.

c) UCAP range should be at least 0.6 nautical miles, capable of navigating under sea state 3 (wave height up to 1.25 m – Douglas Sea Scale) and wind conditions 6 (wind speed of 22 to 27 Knots - Beaufort).

d) UCAP should be able to navigate on water at a minimum speed of 2 knots.

In 2017, Matos *et al.* [20] published a review paper regarding the next prototype of UCAP. The prototype is shown in Fig. 8 where it is single hull vessel, with a lower rear deck to accommodate the uninflated life raft as well as the corresponding compressed gas bottle. The hull was fabricated using a custom-made mould of fibre glass [21]. The UCAP's dimensions was 1.45 m in length, 0.52 m in width and 0.42 m in maximum height. Its weight is 22 kg, a reduced of 8 kg in comparison to its first designed prototype. The weight of life raft has significantly been reduced from 25 kg in first prototype to 8 kg (raft + full inflation bottle) as shown in Fig. 9. A brushless DC motor with the water jet propeller was used to accelerate the UCAP to a maximum speed of 3 knots.

Fig. 8. Unmanned capsule [20].

Fig. 9. Inflated life raft [20].

The UCAP was equipped with the intelligent control system together with and integrated Wi-Fi module, GPS system, life raft deployment system and on-board camera system. Figure 10 depicts the UCAP which was mounted to a U-Ranger USV during a search and rescue operation. During deployment of the UCAP from the U-Ranger USV platform, the unmanned capsule deployment system was introduced as shown in Fig. 11. Matos *et al.* [20] described the design and the hardware equipment for unmanned capsule deployment.

Fig. 10. Two UCAPs mounted on the deployment system installed on the U-RANGER [20].

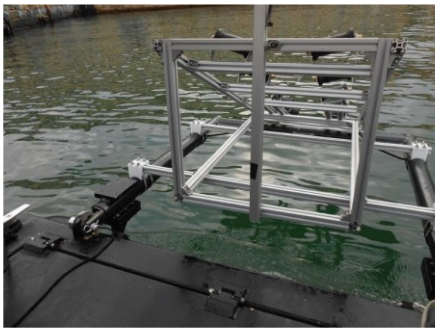


Fig. 11. Deployment system installed on the U-RANGER USV [20].

The design and development of the UCAP was motivated to be a good USV but its design structure was too complex and not easily designed. It encompasses many features which deem to be useful during a rescue mission that other USV did not acquire and hence making it a bulky and heavy USV. Transportation and maintenance would also be difficult as the UCAP was heavy since it had a life raft of about 8 kg.

E. EMILY

EMILY (Emergency Integrated Lifesaving Lanyard) was created by Anthony Mulligan and Robert Lautrup in 2009. In conventional water rescue missions, rescue boats are operated by a captain onboard and carry victims to land. EMILY is operated using remote control and controlled by the operator or navigates automatically using GPS system or overhead visual. Besides that, EMILY is also able to save the drowning victim by serving as a buoy to rescue victims back to land. Figure 12 shows EMILY saving a drowning victim.

Table III shows the specification of EMILY which includes in a 11.8 kg weight and a 1.27 m long buoy body. EMILY is made from Kevlar and aircraft-grade composites which helps its structure to sustain the impact when it is thrown out from a helicopter, boat or bridge to the sea. EMILY has propulsions equivalent to a jet ski without propeller blades, reducing the chances to cause any injuries or allow anything to get tangled in it. It zips along at a brisk of 35 km/h. During rough conditions, EMILY is still durable to be operated as it can handle 30-waves and survive collisions with rocks. For remote controlling, EMILY is equipped with a 2.4 GHz transmitter controller where the operator can control EMILY with a maximum range of up to 1.6 km. For rescue mission, EMILY is equipped with life jackets, helmets and float cover. Its long bright reddish-orange flag ensures there is good visibility during a search and rescue operation. Figure 13 exemplifies all the above characteristics. The downside to employing EMILY as a search and rescue USV includes in the reduced saving capacity it provides. Due to its length and speed, it is only able to rescue 2 people in a single operation.

Fig. 12. EMILY acting as a buoy to save victims [22].

Fig. 13. Rescue and safety equipment in EMILY [22].

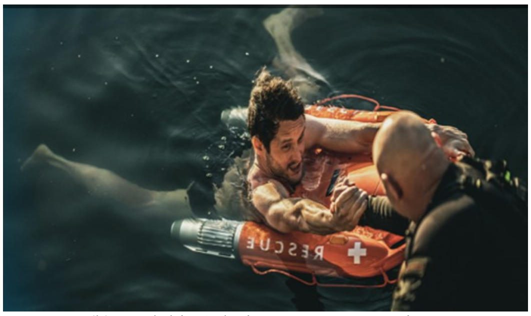
Table III. Technical Specification of EMILY.

Boat Type	**EMILY**
Height x Width x Length	0.35 m x 0.35 m x 1.27 m
Weight	11.8 kg
Propulsion	Steerable jet pump with inlet grate
Maximum speed	35 km/h
Radio Frequency Range	Up to 1.6 km

F. Dolphin 1

Dolphin 1 was developed in 2018 by OceanAlpha company as shown in Fig. 14 which started from conventional lifebuoy. The Dolphin 1 is built with two propellers which are encased inside separate housings to avoid undesired accidents as shown in Fig. 14(a). Figure 14(b) illustrates the functionality of the Dolphin 1 during a rescue operation. There is also a bumper built around the blades with soft rubber for protection to avoid the Dolphin 1 from grinding on rocks or being sucked by water underneath it. *Chan et al.* [23] described the remote control lifebuoy was designed to equip lifeguards to save people from drowning. The hull material of Dolphin 1 is made from density polyethylene (HDPE) plastic. Detailed specifications of the Dolphin 1 USV is further tabulated in Table IV. The weight of Dolphin 1 is 13 kg and it has the buoyancy equivalent to two regular buoys, enabling it to carry two people in a single time. By using the remote control, the operator will be able to control the Dolphin 1 up to a maximum range of 500 m. The maximum speed of Dolphin 1 is capped at 12 km/h and can do a rescue mission in a maximum duration 30 minutes. Dolphin 1 has one main disadvantage which includes in a short range of search and rescue operation. Due to its communication range being limited to only 500 m, Dolphin 1 is not able to perform search and rescue operations at larger radius from the shore.

(a) Dolphin 1 design.



(b) Dolphin 1 during a rescue operation.

Fig. 14. Ocean Alpha's Dolphin 1 [24].

Table IV. Technical Specification of Dolphin 1.

Boat Type	**Dolphin 1**
Height x Width x Length	0.21 m x 0.83 m x 1.15 m
Weight	13 kg
Propulsion	Two electric water-jet propulsion
Maximum speed	12 km/h
Radio Frequency Range	500 m

G. Hover Ark H3

The Hover Ark H3 has a similar appearance to the Dolphin 1 as shown in Fig. 15(a). It is equipped with two propellers that are enclosed in a shell and has a U-shape body that can rescue up to 4 people during a single operation as described in Fig. 15(b) [25, 26]. It is an intelligent water rescue USV which is in between of a lifeboat and traditional life buoy. Hover Ark H3 was developed to cope with complex and harsh water conditions. It can operate longer in comparison with the Dolphin 1. It can accommodate a maximum of 3 people during each rescue operation. Another positive trait of the Hover Ark H3 is its ability to return to the shore whenever the communication signal is lost for over 15 seconds. In addition to that, it has a one-key return button to be utilized whenever necessary which sends a signal to it to directly return to the shore. Its radius of search and rescue operation can span up to 800 m with a maximum load speed of 7 km/h. Due to its symmetrical design, the Hover Ark H3 is able to operate on both sides of it. The GPS on-board it has an accuracy of 2 m during operation and the design structure of the Hover Ark H3 is made up of density polyethylene (HDPE) plastic which is human skin friendly. Its operation time is elongated by an extra of 10 minutes in comparison with the Dolphin 1. The disadvantages of the Hover Ark H3 includes in absence of high penetration light on it which describes it to be inoperable during bad or dark weather. Table V illustrates the operational specifications for the Hover Ark H3.

(a) Hover Ark H3 design.

(b) Hover Ark H3 accommodating up to 4 people in a rescue operation.

Fig. 15. Hover Ark H3 [26].

Table V. Technical Specification of Hover Ark H3 [25].

Boat Type	**Hover Ark H3**
Height x Width x Length	0.20 m x 0.63 m x 1.03 m
Weight	13.8 kg
Propulsion	Two electric water-jet propulsion
Maximum speed	7 km/h
Radio Frequency Range	800 m

III. SUMMARY OF REVIEWED WORKS

From the review works done, it is understood that the designed of U – WRB must be durable, light weight, reliable and equipped with adequate sensors to be utilized during a search and rescue mission. Table 6 summarizes six USVs and their aspects amped accordingly. Artemis is not included to be compared because it was only a prototype that has not been commercialise in the market, hence the information obtained is too little to deduce any outcomes.

The comparison of the six USV's was carried out and the following observed:

a) Design structure of the USV must be adequate to accommodate at least a minimum of 3 people during a single rescue operation.

b) The chassis of the USV must be of a hard material which is not easily deform but at the same time lightweight to reduce the total weight of the USV.

c) Employing a USV with adequate speed is crucial in reaching to the victim who needs to be rescued.

d) The operating range is also vital as this would further help the USV to be operated at greater distance, hence enabling a wider radius of search and rescue operations.

e) The propulsion system employed in the USV should be durable, able to operate for long hours and enclosed well to avoid any other accidents.

f) Vital auxiliary equipment like cameras, collision sensors, GPS system, alarm, lighting system, communication radio system and compass system should be equipped in the USV, hence making it independent and reliable during search and rescue missions.

These are the identified parameters that should be paid close attention when developing a U – WRB. Overlooking these factors / parameters may result in a poorly design U-WRB which may 'add burden' to the human rescue activities carried out.

IV. PROPOSED NEW RESEARCH PATHWAYS

There are several areas of improvements that can be carried out on an existing Unmanned Surface Vehicle (USV) for search and rescue operations. These areas which have prospects of being improve would boost the accuracy and efficiency of rescue operations, which is the key point and obstacle in the field of search and rescue. Components which are vital to be inclusive during the design and development of the USV includes but not limited to the following:

a) High accuracy of sonar sensors and compass

b) High accuracy real time GPS navigation system

c) Waterproof alarms, strobe lights and microphone accessories

d) Waterproof day and night vision high resolution camera

e) Reliable microcontroller system to store the customized program for the operation of the USV

f) Long lasting power supply with backup power to power the entire USV and its accessories with an onboard solar charger

g) Material used to fabricate the USV must be light weight, durable and strength-full which can withstand rough waves and shock resistance in the event of colliding with hard surfaces; i.e., rocks

h) The interest of using home grown natural fibres to produce composite materials should be explored further since they do possess enhanced composite strength as compared to conventional composites namely glass fibre composites.

i) The USV has self-righting features which is able to return to is normal position in the event of overturning caused by rough waves

j) Fail safe features – the USV is capable to return back to its origin in the case of loss of communication signal between the operator and the USV.

Table VI. Summary Comparison of Six USVs.

USV / Aspects	Roaz II	U-Ranger USV	Unmanned Capsule Deployment System (UCAP)	EMILY	Dolphin 1	Hover Ark H3
Dimension, m (Length × Width × Height)	4.50 × 2.20 × 0.50	7 × 2.50 × 0.60	1.45 × 0.52 × 0.42	1.27 × 0.35 × 0.35	1.15 × 0.83 × 0.21	1.03 × 0.63 × 0.20
Total Weight, kg	200 – 400	1400 – 1800	30	11.8	13	13.8
Type of Material	Fibre glass	Aluminium	Fibre glass	Kevlar and aircraft-grade composites	Polyethylene, PE plastic	Polyethylene, PE plastic
Maximum Speed, km/h	18.52	74.08	5.6	35	12	7
Maximum Operating Range, m	100	500	1000	1600	500	800
Capacity of People	2	Minimum of 6	4	6	2	3
Propulsion System	Two electric thrusters	Two electric thrusters	Two Seabotix BTD150 thrusters	Steerable jet pump with inlet grate	Two electric waterjets propulsion	Two electric waterjets propulsion
Full Battery Operation, minutes	600	480	25	14	30	40
Additional Sensors	Thermal camera, radar sensor, GPS system, sonar sensor	Thermal camera, GPS system, compass, sonar sensor, radio link sensor	Camera and GPS system	Sonar sensor, microphone, GPS system	Camera, GPS system, sonar sensor	Camera, GPS system

V. CONCLUSION

With the review works carried out on USV's, there are certainly limitations in the design elements which could be improved further namely to increase the efficiency of human rescue operations subjected to drowning. In a nutshell, the key factors of improvement had been presented in detail where it could open up future research pathways. Having said that, it is hoped that this work had provided sensible piece of information which could benefit the scientific community in the subject of interest.

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