

**Evaluation Form – Technical Background Review**

**Student Name:** \_\_\_\_\_

**Project Advisor:** \_\_\_\_\_

**Team Name:** \_\_\_\_\_

**Team Members:** \_\_\_\_\_

\_\_\_\_\_ / 30      **Technical Content**

- Current state-of-the-art and commercial products
- Underlying technology
- Implementation of the technology
- Overall quality of the technical summary

\_\_\_\_\_ / 30      **Use of Technical Reference Sources**

- Appropriate number of sources (at least six)
- Sufficient number of source types (at least four)
- Quality of the sources
- Appropriate citations in body of text
- Reference list in proper format

\_\_\_\_\_ / 40      **Effectiveness of Writing, Organization, and Development of Content**

- Introductory paragraph
- Clear flow of information
- Organization
- Grammar, spelling, punctuation
- Style, readability, audience appropriateness, conformance to standards

\_\_\_\_\_ / 100      **Total - Technical Review Paper**

## **Energy supply of Unmanned Autonomous Sailing Boat**

### **Introduction**

Unmanned autonomous sailing boats are considered promising in several fields including intelligent sensor buoys, sea rescue, supply vessel and surveillance of borders. A long term mission requires highly-efficient energy utilization. Sailing boats contain units like sensors, microprocessor, communication system, and control system. Rudder control and propulsive force consume the most energy. This technical review briefly summaries some commercially available unmanned surface vehicles (USV) which take the advantages of different kinds of natural resources, explains functionality and improvements in the technology, and provides approaches of implementations.

### **Commercial Applications of Unmanned Autonomous Sailing Boat**

Due to the growing demand of ocean sampling and marine mammal research, a self-sufficient movable data gathering buoys is needed. A sailing boat which operates with DC motors, telecommunication module, and sensors is the most popular solution [1]. Operation duration is limited because the motors are energy consuming. At the top of this kind is C-Enduro which is offered by Autonomous Surface Vehicles (ASV), Ltd [2]. Its ancestors like C-Cat 2 and C-Cat 5 cannot run more than 12 hours. C-Enduro which can utilize solar, wind and diesel simultaneously has duration up to 90 days [3, 4]. USV with DC motors can have speed up to 7 knots but the drawback is its limited operation duration.

Another kind of product is Wave Glider which is designed by Liquid Robotics, Inc. Wave Glider is not dependent on motors or wind power. Its propulsive force only comes from the potential energy of the wave which is transformed by the crafts of the gliders under seven meters below the sea surface [5, 6]. Using energy only for gathering and processing data, Wave Glider can sustain for one year without maintenance. Liquid Robotics also claims that the Wave Glider is able to swim across the Pacific Ocean and to endure 105 mph wind. The Wave Glider does not rely on sails which generates wind propulsion force, so its maximum speed is only about 1.5 knots [5]. The Wave Gliders are used mostly in research area, as they are marketed at \$200,000 which is an unaffordable price for most common customers [7, 8].

### **Technology of Unmanned Autonomous Sailing Boat**

#### *Functionality*

Solar energy is the most commonly used resource of unmanned sailing boat. Above the ocean surface, sailing boats can obtain solar energy efficiently because there are no obstacles between sun and the boat. It can store the energy in the battery for later use [9]. However, solar energy is limited by the size of solar panels and sunshine duration. Moreover, frequently recharging battery result in battery and solar panels degradation. Using only solar energy is not reliable for a long term mission. Because there are no obstacles on the sea, wind power is more stable than solar power. Wind turbines can be placed

on the deck and generate more reliable power. Wind power can also be used for propulsion. Sails provides consistent propulsion force for sailing boat. Besides wind turbines and sails, Anemometer and wind direction sensors can be used to find an optimum angle between the sailing boat and direction of the wind which maximizes the speed of the boat [10, 11]. Wave gliders are another kind of energy supply for propulsion. Surface waves pull the submerged glider up. The glider's crafts convert the potential energy of the wave proportionally to the propulsive energy of the boat [12]. Sea water can also be another kind of energy supply. Sea water battery takes the active metal such as magnesium or aluminum alloy as the anode and the sea water as the electrolyte to generate power. Most sea water battery is utilized in unmanned underwater vehicles (UUV), but it is still promising to implement it in unmanned sailing boat [12, 13].

### *Improvements*

In order to be as self-sufficient as possible, a hybrid energy supply system can be used for sailing boats. Relying on a single energy supply is unreliable due to the unstable environment. Sails and gliders can generate propulsive force for the boat while solar panels, wind turbines and sea water battery can restore energy for the use of data processing and rudder control. Another improvement can be the placement of solar panels. Solar panels can be placed all over the sails instead of only on the deck. Therefore, some solar panels can also get direct sunshine which results in higher power generation even not at noon [14].

### **Implementation of Unmanned Autonomous Sailing Boat**

Implementations of unmanned autonomous sailing boat can be complicated, as it has numerous units to combine and each unit has its own functionality. Because gliders can maintain an average speed, propulsive force from sails can be a tradeoff as battery level drops. The microprocessor can stop calculating the optimum angle for higher speed and it will only maintain a long term path instead of short term course [10]. Some other units like sensor fusion functions can provide more reliable data and generate power more efficiently [15]. The sailing boat can have multiple sets of sea water batteries suspended below the sea surface. The number of sea water battery is based on duration and difficulty of the mission. Hybrid energy supply system can also be reconstructed based on different environmental conditions [2, 16]. When the boat operates inshore for short term mission, sails and gliders can be replaced with DC motors and diesel [2]. When it needs to operate in a typhoon, sails can be removed for safety consideration [14].

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