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Research on Search and Rescue by Coast Guard Vessel Based on the OODA Loop Theory

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Abstract. In view of the problems existing in search and rescue at sea by Coast Guard, this paper, with the OODA Loop theory as the framework, analyzes the four critical elements of search and rescue at sea, namely Observation, Orientation, Decision and Action, to build a command system model for search and rescue at sea. Combined with the distress alarm information, the search and rescue operation monitoring network is constructed to obtain timely and comprehensive observation information elements. It is developed to search and rescue simulation according to the search and rescue action plan, tested and verified for the search and rescue plan, and verified for the command process. In order to improve the efficiency of maritime search and rescue, some measures should be taken such as to improve the performance of search equipment and build professional rescue forces. This research can serve as significant reference for improving the efficiency of the search and rescue at sea.

Keywords: OODA loop, search and rescue, coast guard vessel

1. Introduction

In accordance with the relevant provisions in the *Coast Guard Law of the People's Republic of China*, search and rescue at sea is one of the duties the Coast Guard shall perform [1]. In practice, the emergency rescue at sea accounts for a large proportion in responding to the alerts at sea, which demands more for the rescue equipment, rescue forces, rescue technologies, etc. At present, compared with the professional search and rescue forces [2], there is still a big gap in rescue vessels and equipment of the Coast Guard, and its action preparing, plan making, emergency command process, etc., when conducting rescue tasks, need to be improved. Therefore, for the Coast Guard, it is necessary to further optimize the command process, strengthen coordination with other rescue departments, and improve the efficiency of rescue equipment.

2. OODA Loop

Developed by the United States Air Force Colonel John Boyd in the mid-1950s, the OODA Loop theory was successfully applied to the development of sophisticated weapons in the Gulf War and the C4ISR, an information-based combat command

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system [3]. In recent years, the OODA Loop theory and Grey Fuzzy theory has been combined and applied to evaluate the capacities of the Coast Guard vessels in rights and interests protection and law enforcement, providing effective theoretical reference for the Coast Guard Vessels in future development of equipment and allocation of competence indicators, etc.

The search and rescue at sea operational process can be regarded as a complex system, while the OODA Loop is a process carried out in a dynamic and complex environment, which will constantly recycle, update and implement through four links: Observation-Orientation-Decision- Action. As the rescue environment may change at any time during the operation, the feedback information in decision and action stages must be transmitted to the observation stage in a timely and effective manner to restart the OODA Loop, so as to transform "advantages in information" to "advantages in action" [4].

3. Command System of Search and Rescue at Sea Based on the OODA Loop

According to the analysis of the OODA Loop process above, the processes of search for target to be rescued, determination on rescue method, decision on rescue plan and rescue action during the operation are quite compatible with the four basic elements of the OODA Loop. Therefore, the OODA Loop theory can be introduced and applied to the Coast Guard command system of search and rescue at sea so as to deal with the complex and volatile task, improve the efficiency of the entire emergency command process, and shorten the rescue time. The search and rescue at sea based on OODA Loop is shown in figure 1.

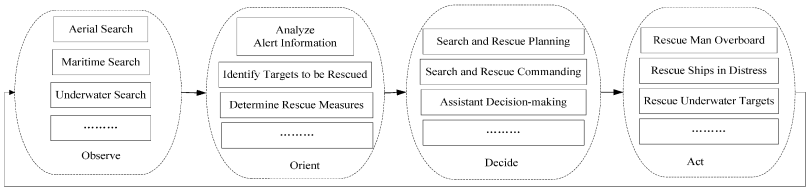

Figure 1. Search and Rescue at Sea Based on OODA Loop.

3.1. Observe

After receiving a maritime distress alert call through 95110, the Coast Guard detachment will conduct aerial search by helicopters or drones, maritime search by Coast Guard Vessels with radar, photoelectric and night vision equipment, and underwater search by specialized equipment. In addition to the on-spot observation mentioned above, the Coast Guard agency can also monitor the vessels sailing in the waters under its jurisdiction through monitoring network in the command center to, e.g. gather information such as vessel's course, speed and encounter state to evaluate the probability of ship accident; conduct big data analysis based on the integral information collected by satellites about navigation and communication of vessels, hydrometeorological condition, etc., so as to forecast and assess the collision risk and give real-time early warning to the vessel crew, ensuring the safety of the vessel. The search and rescue monitoring network is shown in figure 2.

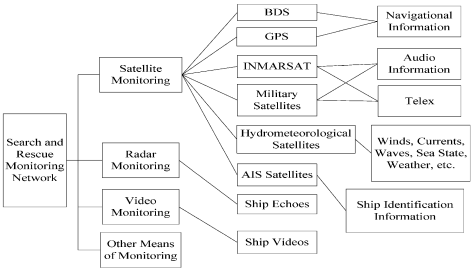

Figure 2. Search and Rescue Monitoring Network.

3.2. Orient

After receiving an alert, the Coast Guard agency should first analyze and determine the object in distress and the type of distress. If with a man overboard situation, it is necessary to determine whether to send a rescue helicopter for aerial rescue; if it is a ship in distress, the agency should determine the type of distress first. That's because the coping methods, rescue equipment needed and rescue approaches for different distresses, e.g. fire on ship, collision, grounding, sinking, explosion and other dangerous situations, are quite different, which need to be analyzed in detail. In addition, it is also necessary to make sure whether the target in distress is located in the area under its jurisdiction, if not, then consider to transfer the alert to the agency having jurisdiction for higher rescue efficiency.

According to previous statistics, the ship grounding accidents happen in high frequency, only second to collision, which will directly lead to grounding distress [5]. Sometimes, due to the meteorological conditions or improper operation, the ship grounds on the shoal or rocks, losing the ability to refloat by herself, so the rescue force's assistance is needed. When performing rescue in this situation, the priority is to guide the crew to refloat the ship on their own, and conduct rescue only when the measures taken are in vain. The rescue force should determine the rescue plan and measures and conduct the rescue based on the state of the grounded ship, the surroundings, the hydrologic and meteorological conditions around, and the information about the grounded ship.

Man overboard is one of the most dangerous situations for people in distress. In this case, all or part of the human body directly exposes to the water without protection, which will cause great danger. The risks such as drowning and suffering from wave attack, accompanied by reducing body temperature, are most likely to occur in this situation [6].

Generally speaking, man overboard can be regarded as the target of unpowered drift at sea. Without considering the vertical movement, man overboard will drift horizontally at sea under the combined influence of wind, wave and current [7]. For man overboard, the drift speed is mainly affected by two aspects, namely, the wind drift of the body part exposed to the sea and the velocity drift of the body part in the sea, so the drift speed of the target is:

$$V = V_{L} + V_{C} \tag{1}$$

Where, V_L is the wind drift velocity of the target, V_C is the velocity of surface current, and according to the force analysis of the target, the drift motion equation of the target is:

$$x(t+\Delta t)-x(t)=\int_{t}^{t+\Delta t}V(t')dt'=\int_{t}^{t+\Delta t}\left[V_L+V_C\right]dt' \tag{2}$$

3.3. Decide

According to the results from observation and orientation, a command team will be formed to carry out the search and rescue task. The team will formulate an operation plan based on the real-time feedback from the site and the expert opinions, and make assistant decisions and command decisions depending on the equipment of the Coast Guard vessels, the sea conditions on scene, the development of the situation and other relevant elements, so as to approach the target in distress safely, preventing secondary accidents such as collision with the targets in distress or crushing people overboard. This paper suggests to add the assistant decision-making system module to the search and rescue command system, so that the team will be able to make a comprehensive operation plan by taking advantage of the plan base and the expert advice.

The operation plan should include the search and rescue coordination procedure and action, personnel responsibilities, equipment needed, communication methods, requirements on organization, equipment, personnel and tools and other elements. It is necessary to constantly revise and review the plan based on the feedback information. With different types of distress, it's supposed to launch corresponding rescue plan for the predictable and unpredictable search and rescue ranges, which requires the emergency coordination of various departments [4]. When making the contingency plan for man overboard, two sets of plans, i.e., peacetime plan and wartime plan, should be formulated. In wartime, the probability of man overboard is relatively higher and there are rules to follow [8]. The operation plan should also focus on organizing and deploying rescue forces reasonably according to the characteristics and rules of the distress, clarifying the time and space of the rescue forces at all levels responsible for, coordinating all personnel under various circumstances, and making specification on operational command, communication and liaison, navigational safety, guarding and medical and logistics support.

3.4. Act

The agency conducts search and rescue at sea in accordance with the operation plan made in the decision stage. The process of maritime search and rescue command system is shown in figure 7.

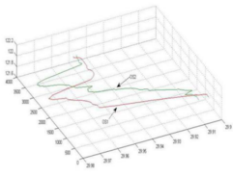

Figure 3. The Sailing Track of OS1, OS2.

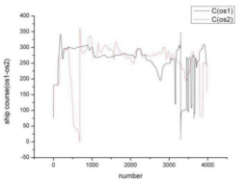

Figure 4. The Course Changes of OS1, OS2.

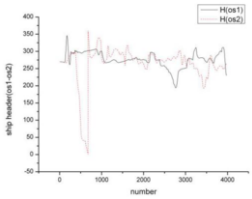

Figure 5. The Heading Changes of OS1 and OS2.

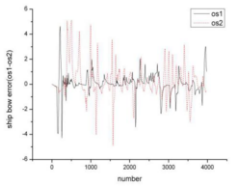

Figure 6. The Bow Error Changes of OS1 and OS2.

There are corresponding rescue methods for different situations which mainly are man overboard, ship in distress and underwater target in distress. In the operation, the equipment needed, the search and rescue capability, the professional ability of the personnel, the cooperative level of the rescued target and the coordination with other rescue forces are also the factors needed to be considered. In the process of coping with the distress, it is necessary to constantly transfer the information back to the emergency command team, so that the team can reasonably predict and evaluate the development of distress, and promptly adjust and optimize the plan.

In order to test the search and rescue operation, two ships were simulated and tested for OS1 and OS2 respectively. The sailing track of the two ships is shown in figure 3, the course changes of OS1 and OS2 are shown in figure 4, the heading changes of OS1 and OS2 are shown in figure 5, and the bow error changes of OS1 and OS2 are shown in figure 6.

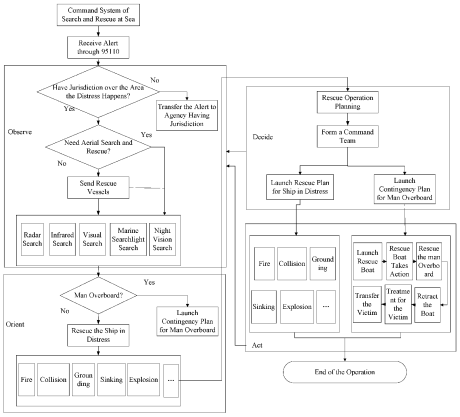

Figure 7. Command System of Search and Rescue at Sea.

4. Measures to Increase the Efficiency of Search and Rescue by Coast Guard

Each of the four basic elements of the search and rescue is critical. The timeliness is the key to a successful operation, no matter rescuing the ship in distress or the man overboard.

4.1. Effectively Improve the Performance of Search Equipment in the Coast Guard Vessels to Gain Time for the Operation

If the distress alarm call received through 95110 provides clear time and location, the search and rescue will be easier for the rescue vessels. However, if the location is

uncertain or the distress happened long ago, the search will be more difficult, which demands greater performance for the search equipment. In this case, the traditional methods such as parallel search and fan-shaped search conducted by rescue vessels are inefficient, and it is better to use Unmanned Aerial Vehicles (UAVs) for aerial search, or even to carry and put life-saving device into the distress area in advance. Additionally, the rescue vessels should be equipped with far-sighting, night vision, thermal imaging and microwave imaging facilities to ensure timely detection of targets in various environmental and climatic conditions. The satellite telephone should be updated to optimize the communication quality, so as to ensure command communication and liaison during remote search.

4.2. Promote Professional Search and Rescue Capabilities to Increase the Operation Efficiency

Since the main duty of the Coast Guard is maritime rights and interests protection and law enforcement, its capabilities on search and rescue at sea are relatively weak, resulting in inefficient search and rescue. In order to fulfill the complex search and rescue tasks, it is necessary to build professional search and rescue forces to perform the duties effectively. It's feasible for the Coast Guard to learn from the Navy, for example, to set up full-time emergency rescue brigades and squadrons equipped with various rescue vessels in all maritime areas to undertake the main tasks, and to equip the joint service system and form the maritime tactical units for participation in the operation as needed so as to improve the efficiency [8].

5. Conclusion

This paper takes the search and rescue by Coast Guard vessels as the object to, based on the OODA Loop theory, analyze the four key elements of the operation, which are closely related to each other, forming a closed loop. And the paper also develops a command system on the basis of the alarm information flows, which provides reference for the Coast Guard search and rescue command and operations, making great contribution to the efficient and successful operations.

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