

The Recovery of Sunken Object from a Lake – Study Case

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ABSTRACT: The recovery of sunken objects from the sea, rivers and lakes is a complex and dynamic activity where actors meet up with numerous problems and challenges such as: unpredictability, quick response, unavailability of valid information, engagement huge number of subjects and a high risk of activity. The execution of such and similar tasks requires: multidisciplinary approach, adequate selection of personnel and resources, successful deployment of forces to inapproachable terrain, efficiency locating of sunken objects and original solutions. The primary aim of this paper is to highlight the key elements of search and rescue operation through the form of a case study which is based on detailed analysis event of the recovery of a sunken fighter jet from the "Gruža" Lake in the Republic of Serbia. The methods that will be applied in the preparation of this work will be based on fundamental scientific methods in order to provide valid and comprehensive data about the event. For instance, content analysis of command documents will provide key information such as: forces, resources, time of engagement, organization, etc., while the interview method will gather data from direct participants regarding to the problems, challenges and specific solutions which were applied in the field. The expected result of the research is that, through systematizing experience and learned lessons, generate paradigm of good practice which can be use like solution for solving future similar tasks.

1 INTRODUCTION

The potential spill of fuel and other harmful substances from the plane that sank into Lake Gružan could have caused a huge ecological disaster, jeopardizing the water supply of thousands of residents of the nearby towns. Solving the problem required a quick and efficient response, namely the engagement of highly trained personnel from various fields, but as well as the use of appropriate specific equipment. The case study describes a modular approach to crisis management and provides the original solutions that were applied during the deployment of Serbian Armed Forces units in resolving such a specific task

The second chapter of the paper presents the basic information about the event – when it occurred, the cause of the crash and a description of the location where the aircraft sank. The third chapter describes the operation planning, the preparation and organization of forces, the use of diving and pontoon units (Applying various techniques and procedures), as well as the process of disengagement from the operation zone. Finally, the fourth chapter and the conclusion provide a brief summary in the form of lessons learned, namely the positive and negative experiences gained during of this operation.

2 BASIC INFORMATION ABOUT THE INCIDENT

On June 3, 2010, at 11:17 hours, four J-22 Orao fighter jets (Figure 1) took off from the Lađevci Airport near Kraljevo. They were practicing low-altitude flight mission. The formation followed the route Lađevci–Paraćin–Ćuprija–Batočina–Knić–Lađevci. After completing the mission, during landing, the pilot was forced to eject due to the inability to deploy the landing gear. The landing gear was initially attempted to be deployed via the hydraulic system and then manually. As a final attempt the pilot even tried to lightly touch the runway with the other wheels in an attempt to use inertial forces to release the stuck wheel.



Figure 1. Fighter jet type J-22 „Eagle“

Due to a low amount of fuel, it was decided to fly to the nearby Gruža Lake and abandon the aircraft over it, in order to avoid potential casualties and damage on the ground. At around 12:00 hours, the pilot ejected from the aircraft at an altitude of 500 to 700 meters, and the aircraft crashed into the lake.

Gruža Lake (Figure 2), one of the largest reservoirs in central Serbia, supplies water to the city of Kragujevac and the municipality of Knić. This artificial lake was formed in 1983 by damming the Gruža River and is located in the municipality of Knić. With a capacity of 64.5 million cubic meters and an area of 900 hectares, the lake has an average depth of 6.5 meters at maximum water level, while the maximum depth reaches 35 meters [1]. In its northern part, the lake is between 1,000 and 2,000 meters wide, while in the southern part (toward the dam), it narrows to between 100 and 500 meters. At maximum water level, the shoreline is 42 kilometres long.



Figure 2. Gružansko lake

Based on the presented data about the lake, two basic conclusions can be drawn. First, it is a massive reservoir of drinking water that supplies a large number of residents in the surrounding areas. Second, due to the lake's large surface area, locating sunken objects presents a very challenging task. Therefore, besides the usual challenges typical of search and recovery operations (such as a large search area), participants also faced a potential crisis situation (contamination of drinking water). In order to prevent further problems caused by fuel and oil leakage, the speed of the intervention was of critical importance, which further complicated the search and recovery operation. In this context, interviewing eyewitnesses proved to be very important, although their statements about the crash site were contradictory. However, by cross-referencing all collected data, the search area was reduced from 900 to 92 hectares. This information later turned out to be crucial for the rapid recovery of the aircraft and for preventing chemical pollution of the reservoir.

3 OVERVIEW OF THE SEARCH AND RECOVERY OPERATION OF THE FIGHTER JET FROM THE LAKE

There are various criteria for classifying military operations. For example, based on the nature of the task to be performed, operations are divided into combat and non-combat operations. In combat operations, the primary goal is to impose one's will on the enemy through the use of armed force, unlike non-combat operations, where the desired end state is achieved through non-combat activities. However, regardless of the differences between combat and non-combat operations, every military operation consists of three basic phases: preparation, execution and stabilization or disengagement of forces [2].

The operation in question is classified as a non-combat operation, within which these three basic phases can also be identified.

3.1 Preparation Phase of the Operation

The preparation phase of the operation involves the activities of commands and units conducted immediately prior to the execution phase, with the main goal of building and maintaining a high level of operational capability required for the successful execution of the upcoming operation. Purposeful and timely preparations are intended to ensure the effective use of units in accordance with a unified plan and under unified command for the entire duration of the operation [3].

The conditions under which the preparation phase is carried out depend on many factors such as: the condition and availability of equipment, the amount of time available for preparation, availability and training level of personnel, as well as the quality of information available to the command during both preparation and execution phase of the operation.

To avoid or mitigate potential consequences caused by the aforementioned factors, the preparation phase typically includes key activities such as: operation planning, organization of forces, coordination, control,

reconnaissance, equipping, training, and other tasks carried out during the preparation process that are essential for achieving the capabilities required to accomplish assigned missions. During the search and recovery operation in question, similar activities were conducted, with emphasis placed primarily on operation planning, force organization, reconnaissance, and deployment of forces into the area of operation, i.e., their operational development.

The planning of the aircraft search and recovery operation was carried out by staff officers of the River Flotilla Command and the 1st River Detachment. Their primary task was to draft an operational order encompassing all elements of the operation, i.e., to define objectives, expected outcomes, methods for achieving them, and the intent and decisions of commanders. The planning process officially began upon receipt of the operation execution order from higher command on June 4, 2010, at 06:30 hour. Upon receiving the mission, the unit commander organized the decision-making process. The decision-making process was conducted in accordance with the "Interim Guidelines for Operational Planning and Command Work in the Serbian Armed Forces", and followed the prescribed seven-phase procedure [4]:

- Phase 1. Initiation
- Phase 2. Orientation
- Phase 3. Development of Courses of Action
- Phase 4. Analyses of Courses of Action (war games)
- Phase 5. Comparison of Courses of Action
- Phase 6. Approval of Courses of Action
- Phase 7. Development of Operational Documents

The greatest challenge faced by the command was how to best respond to the crisis, specifically, how to approach problem-solving using a modular principle, as required by the nature of the task. The solution was found in the combined use of diving and pontoon units, which, although very different in purpose and equipment, were highly complementary and effective for this mission. The planning process was completed by 09:30 hours on the same day and formed an integral part of the comprehensive preparations, primarily led by the Commander of the River Flotilla and his command, i.e., the Operational Planning Group (OPG).

The Organization of forces required an integrated approach involving various units of the Serbian Armed Forces, structured into command forces, task execution forces and logistical support forces. The command forces were composed of staff officers from different specialties. Due to the wide scope and the involvement of various defence system forces and certain security system institutions, the key role of the command forces was coordinating and directing all participants within the operational zone.

The task execution forces were designated to implement the adopted decision and directly carry out specific non-combat tasks. As previously mentioned, the generated task execution forces consisted of diving and pontoon units. However, the key role in the execution of the operation was held by the diving unit, which was responsible for locating the aircraft, assessing damage, and recovering it from the lake. The pontoon units played a supporting role, tasked with providing necessary surface support by forming a floating platform and assisting in lifting the aircraft from the lakebed. Cooperation between the diving and

pontoon units enabled the successful integration of underwater and surface activities. The equipment and resources used during the operation included the following: light diving gear, a diving compressor, a portable recompression chamber, a Zodiac inflatable boat, an underwater sonar model SSK 600, floating elements from the PM-71 pontoon bridge, tugboats type RPP M-68, military motor vehicles (PUH G300, TAM-110, TAM-150, FAP 2026 BDS, FAP 2026 AVG, Zastava Rival van) and a Coles Hydra Husky mobile crane.

The logistical support forces were composed of logistical units from the 98th Air Base, which was located near the operational zone. These units were responsible for providing the participants of the operation with accommodation, food, and other logistical needs.

Reconnaissance is a process conducted during the planning phase of an operation in order to ensure the quality of the decision-making. The main objective of reconnaissance in this operation was to gather as much information as possible about the crash site, access routes, potential locations for assembling and storing equipment, the prevailing conditions in the operation zone, as well as the specific characteristics of that zone in comparison to the usual operational environment of the engaged units (inland waterways – rivers).

Deployment of forces into the operational zone, or their operational development, is the process through which forces are timely positioned in favourable locations to carry out the assigned mission. This is achieved by grouping forces in time and space, as well as forming the operational layout according to the commander's decision. The process is considered complete once all forces occupy their initial positions [2]. The main challenge in this case was to quickly and safely transport all the search and recovery equipment to a relatively inaccessible area that was atypical for the engaged units, which usually operate in riverine environments. However, through effective planning and data gathering during the planning phase, this challenge was successfully addressed.

The commander of the diving unit received the task at 09:30 hours and immediately issued orders for the unit to prepare for transport to the operational zone as quickly as possible. At 12:00 hours, twelve members from the diving company departed for Gruža Lake using the following vehicles: a PUH G300 utility vehicle, a Zastava Rival van, a TAM 110 truck equipped with a portable recompression chamber and a TAM 150 vehicle for diver accommodation. The final position for task execution within the operation zone was reached by 15:00 hours on June 4, 2010, (in less than nine hours of operational time). The remaining equipment and assets, primarily from the pontoon unit, were deployed in the second wave, and by 17:30 hours on the same day, their operational development was completed, thereby officially concluding the preparation phase of the operation.

3.2 Execution Phase of the Operation

The development of a search plan based on an innovative - new search method, which for the purposes of this paper will be referred to as the EAGLE METHOD (Figure 3), provided an original solution and

represented a crucial step in achieving the desired objective, which consisted of the following steps: 1) defining a wider search area (based on available information), 2) the use modern equipment with applying an appropriate search method, and 3) the use of divers with applying a suitable underwater search method. In essence, the EAGLE METHOD solved the challenge of locating a sunken object into big water surface, with insufficient reliable data about accurate position, through a step-by-step approach. First, a wider search area was defined based on available information about the aircraft's crash. Then, this area was narrowed down through the use of appropriate technical means (sonar, in this case). Finally, once the search area was reduced to a micro-location, the location and precise identification of the sunken object were carried out by divers, whose deployment was clearly defined in the diving plan. Choosing the right search method is a key element of the plan, as the success of the operation often depends on that decision which must be adapted to specific conditions of searching.

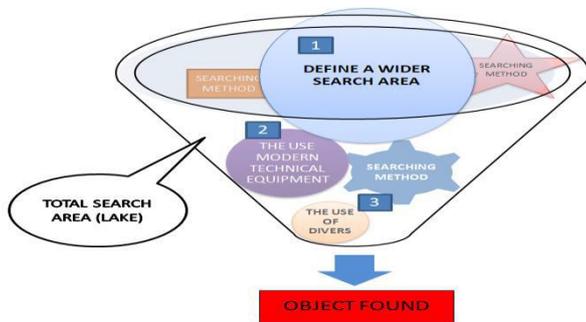


Figure 3. Eagle method of searching

Upon arrival in the operational zone (15:00 hours on June 4, 2010), a data collection effort was organized to determine the approximate location where the aircraft had sunk into the lake, with the goal of defining a wider search area. Eyewitnesses' interviews proved to be of great significance at this stage. Although their statements regarding the aircraft's crash location were quite contradictory, through analysis and cross-referencing of all collected data, some useful information was obtained. As a result, the search area was reduced from 900 hectares to 92 hectares (Figure 4). This information later proved to be crucial for locating the aircraft and for preventing chemical contamination of the reservoir.



Figure 4. Wide area of searching

After defining the wider search area, the searching way is chosen depending on the size of the aquatic

area, and it is carried out either using technical equipment or divers. Given the large surface area involved and the assessment that the object had not sunk deeply into the mud, it was decided to initially use a technical equipment- specifically, an American-made sonar system, the SSS JW Fishers 600 (Figure 5.) [5].



Figure 5. SSS-100K/600K side-scan sonar system by JW Fishers (USA)

After selecting the searching way and assessing the conditions prevailing in the aquatic area (such as current, depth, width, and weather conditions), a decision is made on which search method to apply. For this particular case, the parallel course method was chosen which is mainly used for large areas and is suitable for both types of searches (using technical equipment or divers). This method is characterized by the simplicity of constructing the search polygon and a high level of reliability in locating sunken objects, due to the overlapping of search lanes during the application of this method (Figure 6) [6].

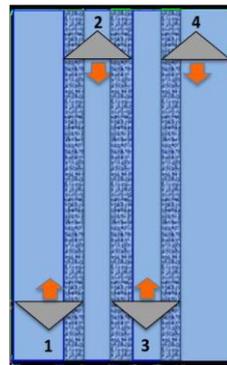


Figure 6. Search lanes.

At exactly 17:50 hours on June 4, 2010, the search of the water area began using the SSS JW Fishers 600 sonar, applying the parallel course method. After 120 minutes (at 19:50 hours on June 4, 2010), an object resembling an aircraft was detected (Figure 7). Its position within the wider search area was then marked with diver buoys.

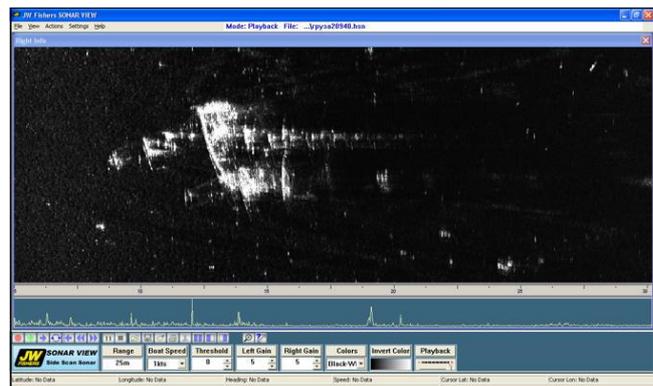


Figure 7. The contours of the sunken aircraft captured by the sonar.

For this type of search, the selected equipment has proven to be highly effective, as the use of sonar provided minimal search time for an extremely large area (120 minutes for about 90) with minimal strain on personnel. The main characteristics of the SSS JW FISHERS 600 sonar are shown in Table 1.

Table 1. Technical specifications for the SSS JW FISHERS 600 sonar

Frequency	600 kHz
Beam width:X*B	1 deg x 40 deg
Pulse duration	0.1ms
Output power	1,000W per channel
Maximum range	60 m along the channel / 122m swath
Maximum depth	150 m
Tow speed	1-12 knots (1.8–22)
Dimensions of sonar fish	
Diameter	10,4 cm
Length	122 cm
Weight	13 Kg.
Cable length	50 m

Since the use of sonar significantly reduced the search area, the process of locating the sunken aircraft continued the following day (June 5, 2010) by applying a different searching way — this time using divers. Unlike the previous day, this time the search method entailed the concentric circle method (Figure 8).

The method is typically used in still waters though it can be applied in mild currents. The principle of the search is as follows: a diver anchors a rope and then swims in a clockwise direction (or counterclockwise). After completing a full circle, the diver increases the distance from the center, and repeats it. If the target object is not found, the center is shifted by a distance equal to two radii of the largest search circle, reduced by the overlap zone. This method is complementary to the previous one, as it is used for searching micro-locations, providing high reliability and a strong probability of detecting the sunken object [6].

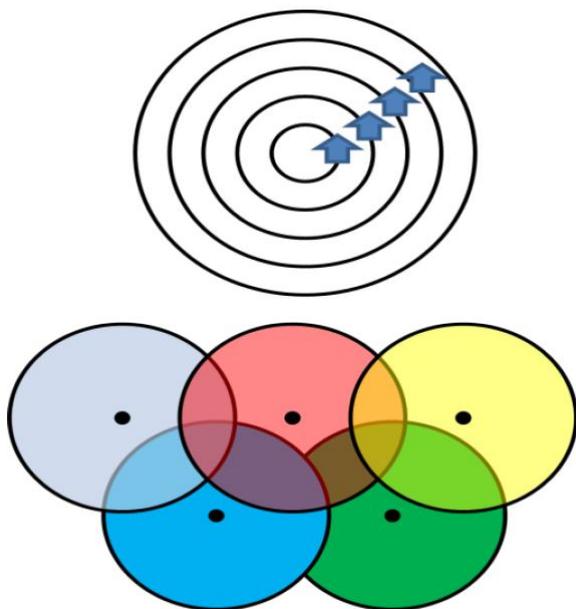


Figure 8. Search using the concentric circle method.

The divers activities are previously defined in a particular document called the dive plan, which, based on all prior analyses, collected data, and required actions, defines the following elements:

- Diving conditions: very difficult (depth up to 15 m and visibility from 15 to 20 cm)
- Diving equipment selection: light diving gear with open-circuit breathing apparatus
- Breathing medium: medical-grade air
- Diving method: buddy diving
- Search method: concentric circles
- Communication: Prearranged signals
- Diving safety measures: immediate (presence of medical personnel and a portable recompression chamber)

Prior to searching the aquatic area by using divers, between 07:00 and 09:00 hours on June 5, 2010, due to poor visibility in the lake (at depth from 15 to 20 cm) members of the diving company went to the airport in order to familiarize themselves with the shape and construction of the aircraft by inspecting the same type of aircraft located on the parking stand. This activity proved crucial to the success of the operation, as acquired knowledge enabled the divers, despite low visibility, to identify key points necessary for safely rigging lifting slings under the aircraft for extraction.

The dive by a diver pair began at 10:00 hours. At depths ranging from 7 to 12 meters, the divers held hands and applied the concentric circle method, swimming counterclockwise. After 45 minutes of diving under extremely difficult conditions, the divers felt something that resembled the aircraft. Upon further inspection, it was determined to be the J-22 ORAO aircraft, intact, although its nose section was crushed up to behind the cockpit. The divers then tied a buoy to the aircraft and surfaced. On the surface, they were handed lifting slings to pass under the aircraft and discuss how to carry out the operation. They returned to the tail section of the aircraft and rigged a sling underneath it, and then proceeded to the nose section. Despite extremely difficult conditions, after almost an hour of diving (by 11:45 hours), they succeeded in threading the slings and let the buoy bring them to the surface where they were secured to the crane hook.

Due to worsened visibility caused by the underwater activity, it was decided to pause the operation to allow silt to settle, ensuring optimal conditions for the final inspection of the sunken object before lifting it to the surface. Upon revisiting the aircraft, it was confirmed that the slings were properly placed and the aircraft was ready to be lifted. The signal was given to the crane operator to begin lifting, and after lifting it 3 meters above the lakebed, the process was paused for an additional inspection. Once it was confirmed that there were no serious obstacles to proceeding, the signal was given for final extraction.

At exactly 13:40 hours, the tail of the aircraft emerged on the lake's surface (Figure 9). For safety reasons, it was decided not to extract the aircraft at the current pontoon location, but instead to tow it and pontoon platform to the lake shore where the aircraft would be extracted in shallow water. There, due to a lower risk of an environmental incident, it would be transferred onto the pontoon. The main reason was the risk of the aircraft's structural failure due to its current condition, which could potentially result in the fuel leak into Gruža Lake and cause an environmental disaster.



Figure 9. The moment when the tail of the aircraft emerged on the lake's surface.

The towing of the aircraft to the shore of the lake took about 45 minutes, after which the aircraft was safely pulled from the shallow part of the lake with the help of a Coles Hydra Husky auto crane, and then to the shore of the lake, as shown in Figure 10.



Figure 10. The extracted aircraft on the pontoon scaffold.

The extraction of the aircraft to the shore of Gruža Lake marked the completion of the second phase of the military operation (execution phase), and the final activities were initiated, including the disengagement of forces in the stabilization phase.

3.3 Stabilization phase

Engagement of units, in accordance with the level of stabilization of the situation in the operation zone, gradually began to reduce military capacities. The first to disengage were the diving units, which, after securing their equipment and resources, departed for the base "Aleksandar Berić" in Novi Sad at 16:30 hours on June 5, 2010. The remaining units sequentially left the operation zone in accordance with the provided instructions and orders.

Upon arrival at the home locations (at 19:30 hours), the equipment was unpacked, and an analysis of the task execution was conducted with the aim of generating lessons learned based on the acquired experiences.

The gained knowledge and experiences during the operation provide a solid foundation for the quality preparation of future similar operations and serve as a source of information for revising existing doctrinal documents. The application of new measures,

activities, and procedures based on lessons learned prevents the repetition of mistakes and oversights that could occur during the execution of future tasks.

4 LESSONS LEARNED AND ACQUIRED EXPERIENCES

The task was received at 06:30 hours on June 4, 2010, and its implementation lasted a total of 33 hours and 30 minutes, with the aircraft being retrieved to the shore at exactly 16:00 hours the following day. This was a remarkable achievement, considering the task's complexity and an uncertain outcome. Of the total time, only one-sixth (3 hours) was spent on planning the operation to leave as much time as possible for the actual execution of the assigned task. The fast and efficient planning of the operation by the command (commanding forces) resulted from excellent training of the officers for planning and high-quality staff assessments.

The preparation, organization, and deployment of forces to perform tasks in the operation zone, followed by the search, discovery, and extraction of the sunken aircraft from Gruža Lake, were also carried out efficiently (30 hours and 30 minutes). Several reasons contributed to this, but the most significant factors were as follows:

- The training of divers to carry out a wide range of tasks
- The application of up-to-date technology (the SSS JW FISHERS600 sonar)
- A modular approach in the formation of forces to perform the task (joint work of diving and pontoon units)
- Problem-solving for searching large water areas by creating an original Search Plan (EAGLE METHOD) consisting of three elements: 1) defining a wider search area, 2) conducting the search using up-to-date technology and narrowing down the search area to a micro-location and 3) diving search (detailed and precise) with applying an appropriate search technique.
- An original approach to solving underwater work problems in conditions of low visibility (the use of an aircraft of the same type at the airport parking stand as a real model for familiarizing divers with structural solutions).
- The doctrinal solutions foresee twice as much time for planning the operation – 1/3 Planning Instructions.
- An original approach to solving the problem of lifting sunken objects without the presence of a floating crane (using a pontoon scaffold with an auto crane instead of a floating crane).
- Logistical support provided by local units of the Serbian Armed Forces.

However, despite the positive aspects, some shortcomings were identified during the implementation of the search and recovery operation of the sunken aircraft, such as:

- Limited autonomy of the laptop used for sonar image projection (battery life is 2 hours; it needs to be recharged thereafter).
- Lack of certain specific equipment for underwater work, such as pneumatic cutters, underwater suction pumps, etc.

- Inability to use floating cranes with higher tonnage for lifting the load.

Additionally, the analysis of the operation's Gantt chart (Figure 11) shows that the operational time for the preparation phase and execution phase was almost identical, which indicates that the search and recovery operation of the sunken aircraft was carried out very efficiently and effectively. For these reasons, the applied measures, activities, and conceptual solutions during the execution of this task can serve as a paradigm for future similar non-combat operations.

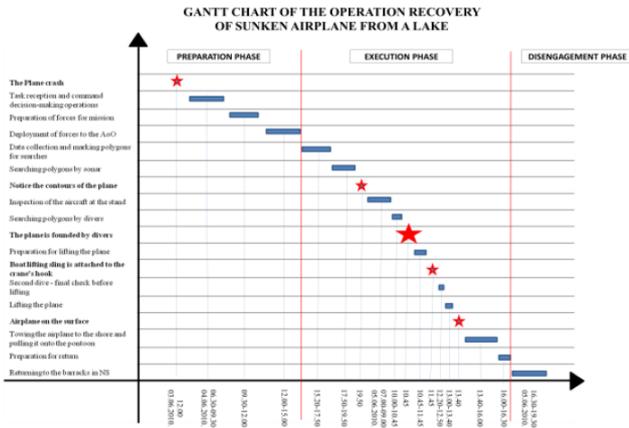


Figure 11. Gantt chart of the operations

5 CONCLUSIONS

The case study presented innovative solutions for the execution of very complex and dynamic tasks. The modular approach to problem-solving, where the use of diving and pontoon units ensured successful interaction and complementarity between underwater work and surface activities, represents a key element in the success of such and similar non-combat operations.

Additionally, the effective application of appropriate search methods, but through a completely different approach, definitely increases the likelihood of locating a sunken object in a large body of water with very few reliable details about the exact location. By developing an original search plan, the optimal number of personnel and resources can be engaged within an acceptable time frame. This approach is highly valuable in crisis situations that require a quick and efficient response.

Finally, the greatest contribution of this work is the fact that all the data, experiences, and knowledge related to the search and recovery operation of the sunken aircraft are consolidated in one place. This can generate a paradigm of best practices, useful for the successful execution of future similar search and rescue tasks.

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