

The Study of Surface Vessel Integrated Underwater Defence Effectiveness Evaluation on newly Decision-centric warfare

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Abstract. Surface vessels face the multi-level targets from air, surface and underwater. Due to the complex characteristics, the underwater targets draw the special focus of weapon system and tactics designer. Facing the severe challenge which carried out by the underwater weapon technology to the underwater defense system software, the paper analyze the elements which effect the underwater defense operation, characteristics and strategy of integration of typical soft countermeasure and hard killing weapon, the paper put forward the underwater defense effectiveness evaluation index system, emulation evaluation methods, so as to improve the current technology from the perspectives of functionality and utility.

Keywords: Decision-centric warfare; underwater defense; effectiveness evaluation; combat decisions.

1. Introduction

As an effective weapon against surface ships, torpedo has been an indispensable and important weapon on the naval battlefield. After more than one century of development, torpedo technology towards high speed, long range, low self-noise, active-passive joint guidance, intelligence and other trends. Moreover, aircraft carrier battle groups and large escort formations will be the core strategic and tactical forces and important strike forces in the future. In a future possible sea war, the formations may face multi-level and multi-faceted threats from the enemy's air and underwater. Due to the concealment of submarines and the complexity of marine environmental conditions, submarines and submarine-launched torpedoes pose a more serious threat to naval formations. Based on the development of torpedo technology, the every navy has become more in-depth and strict in the development of surface ship torpedo defense equipment for actual operational use. The ability to effectively counter torpedo targets is not only a criterion for judging the success of torpedo defense system development, but also the key to victory on both sides of the battlefield. [1-2]

2. Overview of Decision-Centric Warfare

Decision-centric warfare is an operational concept proposed by the Center for Strategic and Budgetary Assessments (CSBA) in a December 31, 2019, study titled "Reclaiming Maritime Dominance: Advancing the Transformation of U.S. Surface Ship Forces for the Implementation of Decision-Centric Warfare"; it was followed by a February 11, 2020, report titled Mosaic Warfare: Using Artificial Intelligence and Autonomous Systems to Conduct Decision-Centric Operations," which describes the concept of mosaic warfare, an example of decision-centric warfare, and recommends abandoning the concept of attrition warfare and sustaining long-term advantage by making decisions faster and better than adversaries to achieve success.

The concept of "decision-centric warfare" focuses on the operational requirements of great power confrontation, is based on maintaining and consolidating U.S. maritime dominance, and aims to drive the U.S. military from "control of information dominance" to "control of decision dominance. The concept of "decision-centric warfare" focuses on maintaining and consolidating U.S. maritime superiority, and aims to promote the transformation of the U.S. military from "information

superiority" to "decision superiority. The concept of "decision-centric warfare" marks a higher stage in the information construction of the U.S. military, and will become an important traction for the intelligent transformation of the U.S. military.



Figure 1. Two significant studies made by Center for Strategic and Budgetary Assessments (CSBA)

The U.S. military's current main combat unit is based on the idea of large-scale and concentrated force operations, with the disadvantage of poor operational flexibility and the vulnerability of the main combat unit to detection and tracking lock, resulting in a lower probability of survival of combat troops. Decision-centric warfare is no longer seeking to destroy the opponent's forces, but to deter war and achieve U.S. national strategic objectives by bringing difficulties to the opponent's decision making.

The report argues that from an operational perspective, "Decision-centric warfare" can be seen as a deepening of the concept of "distributed warfare," or as a remedy or solution to the defense effectiveness problems that can arise from network-centric warfare. In real-world scenarios where the United States is fighting a powerful enemy, it is impossible for the U.S. military to achieve the ideal state of seamless battlefield connectivity and awareness required by network-centric warfare. Therefore, improving the decision-making capabilities of frontline commanders is the key to winning.

The U.S. Navy is changing its current attrition-centric operational paradigm and adopting a new maneuver operational paradigm. The surface fleet focuses on increasing its own decision-making and operational speed, and reducing the corresponding capabilities of the adversary, as well as making it impossible for the adversary to grasp U.S. operational intent and tactics.

Make offense as defense. The large combat platforms, like U.S. Navy cruisers and destroyers, only 25% of vertical launch systems are used for offense and 75% for defense (primarily air defense). As missile technology developed, the difficulty and cost of such defense will never end. Therefore, the report therefore recommends simply adopting a large number of smaller, unmanned, and single (less) functional or even offensive-only platforms to create a favorable offensive for defensive situation.

3. Integrated Underwater Defense Effectiveness Prediction Technology

Currently, the interception defense of incoming torpedoes is mainly through two ways: the soft countermeasures of using acoustic means to interfere and deceive acoustic self-guided torpedoes and the hard killing means of using direct destruction of incoming torpedoes. Both soft and hard killing means have their advantages and applicable occasions, and the study of the effectiveness prediction technology of the integrated defense use method of soft and hard killing weapons can effectively combine various torpedo defense means, so as to give full play to their respective advantages and improve the effectiveness of underwater defense of surface ships.

3.1 Integrated underwater defense use features and advantages

Soft countermeasure devices such as decoys and jamming bombs only require the position information to carry out interference and decoy use in response to incoming torpedo threats, and the requirements for alarm information are relatively low, and the parameters of current sensor equipment match well, and their role in countering traditional acoustic self-guided torpedoes cannot be underestimated, but it is difficult to play a role in the new intelligent torpedoes with increasing resistance to interference and decoys, as well as non-acoustic self-guided torpedoes. [3]

For non-acoustic self-guided torpedoes including tail current self-guided, direct flight and other torpedoes, the use of hard -killing weapons to directly destroy the torpedo or destroy the key components of the incoming torpedo to disable it in order to ensure the completion of the defense mission. However, hard-killing weapons require the near contact with the incoming torpedo in order to implement the destruction, which places high demands on target detection and alarm information. The surface ship current sensor equipment detection accuracy is not fully meet the operational needs of hard-killing torpedo defense weapons.

3.2 Effectiveness evaluation index system establishment

To establish a marine defense software effectiveness assessment index system is to arrange and combine a series of assessment elements involved in the effectiveness assessment according to a certain structural hierarchy, so that they become an organic whole. A complete maritime defense software effectiveness evaluation system is the centralized embodiment of the overall comprehensive performance of the weapon system. Long-term experience in effectiveness evaluation research proves that the establishment of a scientific and reasonable effectiveness evaluation index system is the most critical part of effectiveness evaluation research, without the effectiveness evaluation index system, evaluation research cannot be conducted. Without an effectiveness assessment index system, the assessment study cannot be conducted. If the index system is unreasonably built, it is impossible to talk about the correctness of the assessment conclusion. Therefore, it is necessary to follow certain principles to construct the index system.

The so-called system refers to a higher-level system consisting of various systems that are functionally interrelated and interact with each other to accomplish certain tasks. It can be seen that the system itself is also a system, a higher level system. Therefore, the system also has the basic characteristics of the system, that is, in the structural composition of the hierarchical characteristics. In addition, the system also has other characteristics of the system, such as wholeness, relevance, decomposability, etc.

Based on the basic characteristics of system hierarchy and decomposability, the hierarchical decomposition method can be adopted to construct the evaluation index system of integrated underwater defense software effectiveness. For the structure and functional characteristics of the integrated underwater defense (system), the index system is reasonably layered, and then the corresponding defense software effectiveness indexes are determined layer by layer.

The surface ship integrated underwater defense software can complete the establishment of the corresponding index system from the following perspectives, namely, the detection system effectiveness index system, the accusation/fire control system effectiveness index system, the launch system effectiveness index system and the weapon effectiveness index system. Among them, the weapon effectiveness index system is also established from different types of weapons for the corresponding index system.

3.3 Effectiveness assessment methods

On the basis of the WSEIAC system effectiveness analysis method, combined with the combat application effectiveness analysis method, the exploration study of underwater defense effectiveness estimation technology was carried out, which laid the foundation for the next step of in-depth combat effectiveness estimation technology evaluation scheme and validation research study.

Defense effectiveness needs to be analyzed and evaluated by effectiveness indicators, and how to design a reasonable and accurate indicator system is a more critical step in defense effectiveness analysis. At present, in the system effectiveness analysis, the most commonly used and most reflective of the nature of the system are two methods, one is the U.S. Industry Weapons Systems Advisory Committee (WSEIAC) proposed system effectiveness analysis method, and the other is the combat operational effectiveness analysis method. Of these two methods, the former is static and the latter is dynamic, each reflecting the effectiveness of the system from different sides and levels. In the comprehensive defense effectiveness analysis, the system object studied is the defense against enemy submarines and torpedoes, and the purpose of the study is mainly to examine the impact of each design technical index of the system on the defense effectiveness. The system's ASW defense effectiveness should be reflected in the process of offensive and defensive confrontation, and for the characteristics of operational use under offensive and defensive confrontation conditions, it is proposed to use a combination of static and dynamic effectiveness analysis methods, and to draw on the WSEIAC system effectiveness analysis method from a macroscopic perspective to divide the system defense effectiveness indicators into three parts: effectiveness, trustworthiness, and capability according to the operational process:^[4-6]

WSEIAC defines system effectiveness as a measure of how well equipment can meet (or accomplish) a specific set of mission requirements [4]. System effectiveness is determined by the availability, reliability, and capability of the equipment, all of which can be expressed probabilistically.

$$E^T = A^T [D][C] \tag{1}$$

Eq.:

E^T —Efficient row vectors;

A^T —Usability row vectors;

$[D]$ —Trustworthiness Matrix;

$[C]$ —Capability Matrix;

When there are m quality factors, the effectiveness row vector can be expressed as

$$E^T = (e_1, e_2, \dots, e_m) \tag{2}$$

Eq.:

e_k —k quality factor values;

Any element in Eq. (3-2) can be obtained from the following equation

$$C_k = \sum_{i=1}^n \sum a_i d_{ij} C_{jk} \tag{3}$$

Eq.:

a_i —The probability that the system is in state i at the start of the task;

d_{ij} —The probability that the system is known to be in state i during the execution of the task and in state j during the execution of the task;

C_{jk} —The ability of the system to be in the jth state during the execution of the task and to complete the kth task.

The probability of a system accomplishing a specific task is the most dominant indicator of system effectiveness, and it is the center and foundation of other effectiveness indicators. For integrated underwater defense systems, system effectiveness is generally defined as the probability of the system accomplishing a specific task, such that equation (1) translates to:

$$E = A^T [D]C \tag{4}$$

Eq.:

- E — an effectiveness row vector (one element);
- A^T — the usability row vector;
- $[D]$ — plausibility matrix;
- C — capability vector.

3.3.1 Usability vectors

Availability is a measure of the state that the equipment is in at the moment of the task start. Therefore, the availability vector consists of the probability that the equipment is in all possible states at the start of the mission.

Usually, the equipment consists of N units, and each unit is divided into only two states: "normal operation" and "failure", so there are possible n states of the equipment at the beginning of the task. In the case of this analysis, the expression of the availability vector of the equipment is

$$A^T = (a_1, a_2, \dots, a_n) \quad (5)$$

Eq.

- a_i — The probability that the equipment is in state i at the start of the mission.

N possible states constitute the sample space, so there must be $\sum_{i=1}^n a_i = 1$

According to reliability theory, the availability of equipment and its units at moment t are instantaneous concepts. If both failure and repair obey exponential distribution, the instantaneous availability of the k th unit is expressed as

$$\begin{aligned} A_k(t) &= \frac{\mu_k}{\lambda_k + \mu_k} + \frac{\lambda_k}{\lambda_k + \mu_k} e^{-(\lambda_k + \mu_k)t} \\ &= \frac{MTBF_k}{MTBF_k + MTTR_k} + \frac{MTTR_k}{MTBF_k + MTTR_k} e^{-(\lambda_k + \mu_k)t} \end{aligned} \quad (6)$$

Eq.

- $MTBF_k$ — Mean time between failures of the k th unit;
- $MTTR_k$ — Average repair time for the k th cell;
- λ_k — Failure rate of the k th unit;
- μ_k — Repair rate of the k th cell;
- t — Combat readiness standby time experienced.

In practical engineering calculations, the steady-state availability expression (i.e., the first term in the above equation) is generally used

$$A_k(t) = \frac{MTBF_k}{MTBF_k + MTTR_k} \quad (7)$$

For a specific equipment object, as long as the equipment reliability block diagram and the , values of each unit during the equipment standby period are known, it is only necessary to list the relationship between the equipment state and the state of each unit (normal and fault), and the availability value of the i th state of the equipment can be obtained according to this state relationship table and equation (7).

If the state of the equipment at the beginning of the mission is divided into "normal operation" and "failure", the availability vector of the equipment in the case of this analysis is expressed as follows

$$A^T = (a_1, a_2) \quad (8)$$

Eq.

a_1 —The probability that the equipment is in normal usable condition at the beginning of the mission;

a_2 —Probability of equipment being in a faulty state at the start of the mission.

Obviously

$$a_1 + a_2 = 1 \tag{9}$$

$$a_1 = A_s = \frac{MTBF_s}{MTBF_s + MTTR_s} = \frac{1/\lambda_s}{1/\lambda_s + 1/\mu_s} \tag{10}$$

$$a_2 = 1 - A_s = \frac{MTTR_s}{MTBF_s + MTTR_s} = \frac{1/\mu_s}{1/\lambda_s + 1/\mu_s} \tag{11}$$

Eq.

$MTBF_s$ —Mean time between failures of the kth unit;

$MTTR_s$ —Average repair time for the kth cell;

λ_s —Failure rate of the kth unit;

μ_s —Repair rate of the kth cell.

3.3.2 Trustworthiness Matrix

(1) Reliability matrix for serviceable equipment

Credibility is a measure of the state in which the equipment is in during the execution of the mission. The equipment is in any moment at the beginning moment of the mission and either remains in the original state during the execution of the mission or is transformed into other n-1 possible states due to the change and maintenance management within the equipment. If there are n possible states of the equipment at the beginning moment of the mission, it will present $n \times n$ possible change states during the execution of the mission. Thus the plausibility matrix is a square matrix of order $n \times n$, i.e.

$$[D] = \begin{bmatrix} d_{11} & d_{12} & \dots & d_{1j} & \dots & d_{1n} \\ d_{21} & d_{22} & \dots & d_{2j} & \dots & d_{2n} \\ \dots & \dots & \dots & \dots & \dots & \dots \\ d_{i1} & d_{i2} & \dots & d_{ij} & \dots & d_{in} \\ \dots & \dots & \dots & \dots & \dots & \dots \\ d_{n1} & d_{n2} & \dots & d_{nj} & \dots & d_{nn} \end{bmatrix} \tag{12}$$

where: d_{ij} the probability that the equipment is in the ith state at the task start moment and in the jth state during the execution of the task.

Since, any state that the equipment is in at the moment of the task start, the N transformation states during the execution of the task constitute the space of this state transformation sample. Therefore, the sum of the elements of each row in $[D]$ must be equal to 1, i.e.

$$\sum_{j=1}^n d_{ij} = 1, \quad i = 1, 2, \dots, n \tag{13}$$

If the state of the equipment at the beginning of the mission is simply classified as "normal operation" or "malfunction" by equipment, then in the case of this analytical examination, the credibility matrix of the equipment is expressed as

$$[D] = \begin{bmatrix} d_{11} & d_{12} \\ d_{21} & d_{22} \end{bmatrix} \quad (14)$$

Where.

d_{11} - the probability that the equipment is in a normal state at the beginning of the mission and remains in a normal working state during the execution of the mission.

d_{12} - the probability that the equipment is in a normal state at the beginning of the mission and in a faulty state during the execution of the mission

d_{21} - the probability that the equipment is in a malfunctioning state at the beginning of the mission and in a normal working state during the execution of the mission

d_{22} - the probability that the equipment is in a faulty state at the beginning of the mission and remains in a faulty working state during the execution of the mission.

If it is known that the failure rate of the equipment during the execution of the task λ_m , the repair rate μ_m , and failure and repair are subject to exponential distribution, the elements of equation (14) can be derived from the following equation.

$$d_{11} = \frac{\mu_m}{\lambda_m + \mu_m} + \frac{\lambda_m}{\lambda_m + \mu_m} e^{-(\lambda_m + \mu_m)t} \quad (15)$$

$$d_{12} = 1 - d_{11} = \frac{\lambda_m}{\lambda_m + \mu_m} [1 - e^{-(\lambda_m + \mu_m)t}] \quad (16)$$

$$d_{21} = \frac{\mu_m}{\lambda_m + \mu_m} [1 - e^{-(\lambda_m + \mu_m)t}] \quad (17)$$

$$d_{22} = 1 - d_{21} = \frac{\lambda_m}{\lambda_m + \mu_m} + \frac{\mu_m}{\lambda_m + \mu_m} e^{-(\lambda_m + \mu_m)t} \quad (18)$$

Where: t - the task work time of the equipment.

(2) Trustworthiness matrix for non-maintainable equipment

Many weapons and equipment cannot be repaired in the course of a mission. For non-repairable equipment, if the equipment is in a faulty state at the beginning of the mission, the equipment can only continue to be in a faulty state during the execution of the mission and cannot be converted to a normal working state. In a broad sense, if the equipment is in a fault state at the beginning of the mission, the equipment can only continue to maintain this fault state or transform into a fault state with more faults (more serious faults) during the execution of the mission, but not transform into a fault state with fewer faults (light faults). Therefore, if the elements a_{ij} in (14) are ordered according to the rule that the larger the number in the lower right corner, the more or more severe the failure, then $i > j$ are impossible events, there must be $d_{ij} = 0$. In this way, the plausibility matrix of the non-repairable equipment becomes a triangular matrix, i.e.

$$[D] = \begin{bmatrix} d_{11} & d_{12} & \dots & d_{1j} & \dots & d_{1n} \\ 0 & d_{22} & \dots & d_{2j} & \dots & d_{2n} \\ \dots & \dots & \dots & \dots & \dots & \dots \\ 0 & 0 & \dots & d_{ij} & \dots & d_{in} \\ \dots & \dots & \dots & \dots & \dots & \dots \\ 0 & 0 & \dots & 0 & \dots & d_{nn} \end{bmatrix} \quad (19)$$

If the state of the equipment at the start of the mission is simply classified as "normal working" or "malfunctioning" by equipment, the plausibility matrix of the non-repairable equipment in the case of this analysis is expressed as

$$[D] = \begin{bmatrix} d_{11} & d_{12} \\ d_{21} & d_{22} \end{bmatrix} \quad (20)$$

Substituting $\mu_s = 0$ into equations (15) to (18), the expressions for the elements in (19) can be obtained.

$$d_{11} = e^{-\lambda_m t} = R_m(t) \quad (21)$$

$$d_{12} = 1 - d_{11} = 1 - e^{-\lambda_m t} = 1 - R_m(t) \quad (22)$$

$$d_{21} = 0 \quad (23)$$

$$d_{22} = 1 - d_{21} = 1 \quad (24)$$

$$[D] = \begin{bmatrix} e^{-\lambda_m t} & 1 - e^{-\lambda_m t} \\ 0 & 1 \end{bmatrix} \quad (25)$$

is still a triangular matrix. where $e^{-\lambda_m t}$ is the mission reliability of the equipment.

3.3.3 Capability Matrix

The capability of the equipment is the degree to which the equipment accomplishes the specified mission. It is determined by the tactical and technical performance indicators of the equipment and is generally expressed in terms of the probability of completing the specified task. The capability of the equipment is closely related to the state of the equipment in the process of performing the task. In different states, the ability of the equipment to complete the required tasks is also different.

For complex equipment with m specified mission tasks, the capability matrix of the equipment is a matrix of order $n \times m$, i.e.

$$[C] = \begin{bmatrix} c_{11} & c_{12} & \dots & c_{1l} & \dots & c_{1m} \\ c_{21} & c_{22} & \dots & c_{2l} & \dots & c_{2m} \\ \dots & \dots & \dots & \dots & \dots & \dots \\ c_{j1} & c_{j1} & \dots & c_{jl} & \dots & c_{jm} \\ \dots & \dots & \dots & \dots & \dots & \dots \\ c_{n1} & c_{n2} & \dots & c_{nl} & \dots & c_{nm} \end{bmatrix} \quad (26)$$

Eq.

c_{jl} --capability vector for completing the lth mission when the equipment is in the jth state during the execution of the lth mission.

Usually, most equipment has only one mission task, in which case the capability matrix is transformed into a capability vector, i.e.

$$C = \begin{bmatrix} c_{11} \\ c_{21} \\ \dots \\ c_{j1} \\ \dots \\ c_{n1} \end{bmatrix} = \begin{bmatrix} c_1 \\ c_2 \\ \dots \\ c_j \\ \dots \\ c_n \end{bmatrix} \quad (27)$$

Where c_j - equipment in the process of carrying out the task in the j th state, the ability to complete its specified task value.

If the equipment has only one mission task, and the equipment in the process of performing the task is only divided into "normal work" and "failure" two states, then the equipment capacity vector can be simply expressed as follows.

$$C = \begin{bmatrix} c_1 \\ c_2 \end{bmatrix} = \begin{bmatrix} c \\ 0 \end{bmatrix} \quad (28)$$

Eq.

c_1 - the value of the ability to complete the task when the equipment is in the "normal working" state during the execution of the task, which can be expressed as $c_1 = c$;

c_2 --equipment in the process of performing the task in the "fault" state, the ability to complete the task value, obviously, $c_2 = 0$.

Some simple weapons and equipment are capable of satisfactorily completing their prescribed tasks as long as they are in normal operating condition, and the computational model of capability is relatively simple. However, for large weaponry and complex weapon systems, being in a normal operating condition does not necessarily mean that they can satisfactorily accomplish their specified tasks. The quantitative value of the capability of these weapons and equipment to complete their prescribed tasks in normal conditions is determined by the combined probability of occurrence of many contingent events.

For example, the capability c_j of an artillery weapon system in state j during a mission is the product of the probability of detection p_{dj} , the probability of service p_{sj} , the probability of destruction p_{kj} , and the probability of survival p_{vj} of the artillery weapon system against the target in that state, i.e.

$$c_j = p_{dj} p_{sj} p_{kj} p_{vj} \quad (29)$$

For example, the capability c_j of a missile weapon system in the j state during a mission is the product of the probability of detecting the target p_{rj} , the probability of destroying the target p_{kj} , and the probability of survival p_{sj} of the missile weapon system in that state, i.e.

$$c_j = p_{rj} p_{kj} p_{sj} \quad (30)$$

It can be seen that, due to the complexity and variability of each random event that determines the capability of large weapons and complex weapons systems, the methods and models for analyzing and establishing the probability of these random events are quite complex and difficult. Therefore, in the system effectiveness calculation of weapons and equipment, the analysis and calculation of capability C is the most complicated and difficult problem, and the workload is also the largest. The analysis and numerical calculation of many sub-models of capability C is the key to the success of the system effectiveness evaluation of weapons and equipment.

4. Impact of Decision Centered Warfare on the Operational Model of Effectiveness Prediction Technology

In the operational model of decision-centric warfare, the U.S. Navy's proposed surface fleet combat capability focuses on three areas: first, increasing the complexity of the naval surface fleet; second, forcing the adversary to increase the size of the flanking attack; and third, increasing the offensive power of the naval surface fleet. These three areas are also the areas that the adversary needs to focus on. In the course of operations, effectiveness prediction techniques for these three factors can provide the technical basis for operations and operational decision making.

First, a complete system of effectiveness assessment indicators is established to analyze the factors that affect the effectiveness of integrated defense. Decision center warfare is used to achieve the control system, which also requires a comprehensive grasp of the formation, surface ships equipped with various types of sensors, weapons composition, technical indicators, the process of combat, with the detection of the enemy, dynamic supplementation of the content of the enemy's combat elements and their capabilities, so as to gradually improve the effectiveness of underwater defense prognostic indicator system.

Second, improve the ability to quickly assess and combat the effectiveness of multiple types of weapons in concert. As the decision center warfare required is to create more operational complexity for the enemy, which also requires a faster decision and objective evaluation of the effectiveness of the detection system, armed control system, hair control system and the synergy of each type of weapon respectively, mastering the integrated use of various detection means and weapon systems to detect, identify, intercept, destroy, and confront the threat targets from underwater and other methods of use of the operation, and based on the available for Combat command department to develop operational programs and commanders to make the right decision important reference conditions.

Finally, as the combat process unfolds, real-time dynamic assessment of underwater defense operations, the engagement process can be based on real-time analysis of the changes in sensor detection, as well as the engagement of the use of various platform elements, weapons synergistic confrontation, which can be carried out system-level real-time dynamic assessment, can be implemented for the combat command department to develop operational programs and correct decisions of the commander.

5. Conclusion

The decision-centered warfare concept is expected to be the operational paradigm of the United States for some time to come, which will require the other side to make aggressive adjustments in the surface ship operational paradigm to better respond to future defense requirements. Adjustments and improvements in existing operational models and methods such as weapons employment will in turn enhance underwater defense effectiveness prediction techniques with minimal modification of existing technologies and methods in order to better respond to changes in the situation.

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