A Priori Planning of ASW Operations: Providing a Robust Mission Advice

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ABSTRACT

New underwater sensors, such as the Low-Frequency Active-Passive Sonar (LFAPS) and the Helicopter Long-Range Sonar (HELRAS), have larger detection ranges than existing sonar systems. Effective and efficient deployment of these sensors in Anti-Submarine Warfare (ASW) operations requires decision support. TNO has performed research on both 'a priori' and 'in situ' planning of such operations, where 'a priori' is about planning at the tactical level, both long (months) and shortly (weeks, days) before a mission, and 'in situ' is about sensor performance and sensor settings during a mission.

A priori planning is used for planning specific missions. This means that the area of operations and the expected threat are roughly known. Still, several uncertainties remain, such as the actual environmental conditions (which hugely affect the detection ranges) and enemy behaviour. These uncertainties may influence the operational effectiveness, e.g. the timely detection of enemy submarines. Hence, they must be taken into account when providing decision support for planning the ASW operation.

The resulting algorithms of the a priori research have been incorporated in a demonstrator called APPAD (A Priori Planning Aid Demonstrator). Much attention was paid to the robustness of the advice on the best way to deploy the participating platforms. A robust tactic should perform reasonably well even if the uncertain parameters (such as the detection ranges) change during the actual mission. A robust mission advice provides the ASW commander with a set of alternative tactics that enable a robust performance. This allows the ASW commander to select the best solution, based on his experience and his knowledge of the actual tactical situation.

1.0 INTRODUCTION

The current operational concept of the Royal Netherlands Navy includes operations in a task group (in transit or stationary), in open waters as well as littoral areas. The defence of a task group, or a single platform, heavily depends on underwater Situational Awareness (SA) through the individual and combined use of both the current and new underwater sensors. The new sensors are the Low-Frequency Active-Passive Sonar (LFAPS) on the M-frigate and the Helicopter Long-Range Sonar (HELRAS) on the NH90.

Within the Dutch Defence research programme 'Co-ordinated deployment of underwater sensors in underwater operations', which was led by TNO, research was carried out on the effective and efficient deployment of these new underwater sensors [1]. This research programme addressed the planning of the use of sensors in underwater operations at two levels: the tactical level and the technical level. The tactical level is about determining where and how the platforms will operate, including the tactic involved, such as the selection of a search pattern and a sonar transmission policy. This can be done 'a priori' (before the mission). The technical level is about selecting the optimal sonar settings, given the search pattern. This can be done 'in situ' (during a mission). In this paper, we focus on the tactical level.

The remainder of this paper is organized as follows. Section 2.0 gives an overview of the ASW operations that we consider. Section 3.0 discusses the aspects related to providing a robust mission advice. Finally, Section 4.0 presents our conclusions.

2.0 ASW OPERATIONS

We consider three types of ASW operations in which acoustic underwater sensors are deployed. These operations are area search, barrier search, and transit. In an area search operation, the objective is to find any enemy submarine. In the other two operations, the objective is to detect any enemy submarine before it poses a direct threat. The operations take place in open ocean (mainly the transit operation) or in littoral waters.

The own assets deployed in the operation are ASW frigates, AAW (anti-air warfare) frigates, and helicopters (land-based or embarked on a frigate). We only take active acoustic detection of the threat into account. The considered sensors are hull-mounted sonar, towed array and the dipping sonar of the helicopter. Other sensors (like radar or infrared) and visual means are not used.

2.1 Area Search Operation

In an area search operation, a certain sea area must be cleared of submarine threats. An area search operation can be used, for example, as preparation for the transit of an HVU (High Value Unit) through the area. A submarine's mission is to build up a surface picture, in such a way that it remains undetected.

The objective of an area search is to find any submarine present in the area. Merely hindering the submarine in its surveillance task and preventing it from performing picture compilation is not sufficient to clear the sea area. We therefore assess the effectiveness of an area search operation mainly on the probability of detecting and classifying an enemy submarine. As secondary measures of effectiveness (MOEs), we look at the size of the area that has been covered or cleared, and the probability that the submarine is 'deterred' in such a way that it could not execute its task.

2.2 Barrier Search Operation

In a barrier search operation, enemy submarines may not cross a certain barrier. This barrier can be a (more or less) straight line, for example in front of a harbour or in a strait. However, the barrier can also be circular, for example when a stationary task group in a sea base must be defended [2]. A sea base may contain HVUs that must be protected.

The main objective of a barrier search operation is to prevent the submarine from passing the barrier. This can be achieved by classifying the enemy submarine, or, if the submarine avoids taking risks, 'deter' it until its limited battery capacity forces it to abort its mission. Therefore, we assess the effectiveness of a barrier search operation by looking at the probability of detecting and classifying the submarine and the probability of 'mission abort'. In addition, we also look at the probability of success for the submarine: the probability that it can pass the barrier, or (for a sea base containing HVUs) the probability that the submarine can come close enough to the HVUs to be able to perform a torpedo attack.

2.3 Transit Operation

In a transit operation, naval units move through a certain sea area. Usually, such an operation is carried out to protect a sea line of communication (SLOC). We focus on transit operations in which naval units convoy a number of HVUs. The defence does not only depend on the capabilities of the naval units, but also on the speed of advance that can be achieved. This speed of advance depends on the performance of the individual assets involved.

The objective is to prevent an enemy submarine from launching a torpedo at one of the HVUs. Because of the task group's speed of advance, a submarine approaching the task group from behind may not be able to overtake the task group. As MOE, we use the probability that a submarine that can intercept an HVU can come within torpedo launch distance.

3.0 PROVIDING A ROBUST MISSION ADVICE

A priori planning is used for planning specific missions. This means that the area of operations and the expected threat are roughly known. Several months or a year ahead of the actual mission, the main question will be which number and types of platforms will be needed to execute the mission effectively. Several days or weeks before a mission, a priori planning will be used to determine or evaluate the actual deployment of the platforms.

When determining the effectiveness of a tactic in a specific mission, the uncertain aspects must be identified and considered. The effectiveness does not only depend on parameters known in advance, such as the objective of the mission and the number of available sensor systems. Parameters that may not be known in advance also play an essential role, such as the detection ranges of the sensors, the environmental conditions, and the expected threat. For the latter, uncertain parameters, assumptions must be made. This means that an expected value must be determined for each of these parameters, including a realistic range within which the parameter value may vary. A robust tactic should perform reasonably well even if the uncertain parameters (such as the detection ranges) change during the actual mission.

A robust mission advice provides the ASW commander with a set of alternative tactics that enable a robust performance. This allows the ASW commander to select the best solution, based on his experience and his knowledge of the actual tactical situation. Providing a set of alternatives is essential, because the simulation used to determine the effectiveness of a tactic cannot take into account every aspect of the operation. For example, coordination with other operations (such as air defence or surface warfare) might be required. Furthermore, it is important to vary the tactic during the actual mission, to prevent that an enemy submarine commander can derive the search pattern and use this information to its own advantage.

The resulting algorithms of the a priori research have been incorporated in a demonstrator called APPAD (A Priori Planning Aid Demonstrator). The APPAD demonstrator was built to test and refine the methodologies to obtain a robust advice. To determine the effectiveness of a tactic, TNO's Underwater Warfare Testbed (UWT) was used.

3.1 The Underwater Warfare Testbed (UWT)

The Underwater Warfare Testbed is a detailed simulation framework for Underwater Warfare (UWW), developed by TNO [3] [4]. It can be used to develop and evaluate operational tactics and future concepts for UWW. The UWT supports the following types of operations:

- anti-submarine warfare (ASW): transit, area search, barrier search (including sea base defence);
- torpedo defence and torpedo deployment;
- mine warfare (MW): mine sweeping.

The UWT accepts existing or parametric platforms and underwater systems as input, and provides insight in the performance of these systems against, or in combination with, other underwater systems in a specific environment. This allows evaluation and formulation of staff requirements and comparison of, for example, candidate underwater systems of different manufacturers.

Within the UWT, various systems have been modelled: platforms (like frigates, submarines, and helicopters), torpedoes, countermeasures (jammers and decoys), and the sensors of these systems (like hull mounted sonars, towed sonars, helicopter dipping sonars, torpedo sonars).

The setup is modular, so new platforms and systems can easily be added. The platform modules (like sonar, launcher, warhead, motion, etc.) can be exchanged between platforms, so new platforms can be built using already modelled systems.

Tactics and decision rules simulate the behaviour of the platforms and their systems and define their interactions. The scenario editor enables the user to create scenarios and change many of the platform parameters. A replay facility is available to visualise a simulated scenario (both real-time during a simulation and afterwards). The output information includes visualisation of the platforms in a top view and provides detailed level analysis support, for example acoustic logging.

3.2 APPAD (A Priori Planning Aid Demonstrator)

In APPAD, an ASW mission can be defined by selecting the operation type, the operation period, the operation area, the own units, and the enemy units. The main window of APPAD is shown in Figure 3-1.

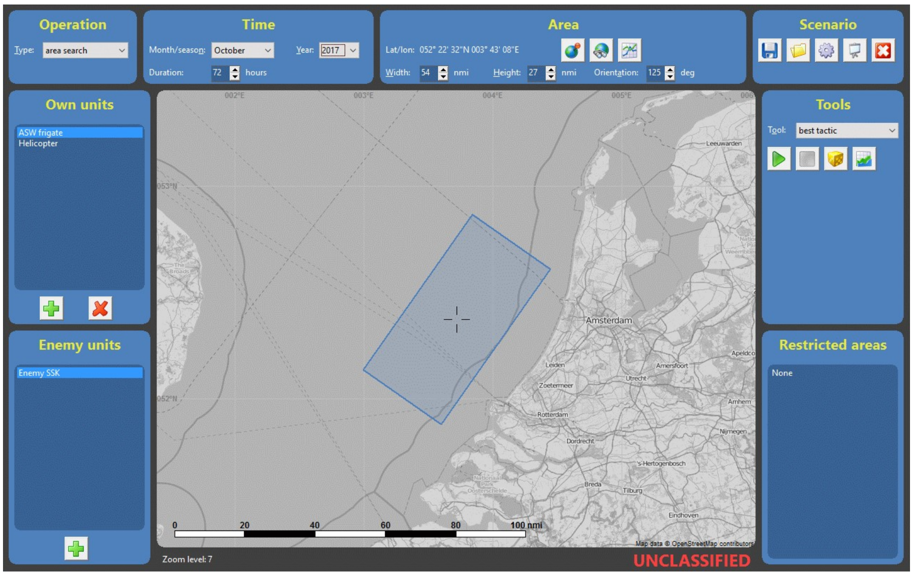

Figure 3-1: The main window, showing the scenario for an area search operation.

The operation type can be one of the three defined types of ASW-operations. For the operation period, either the month of the year or the season (winter, spring, summer, autumn, year) can be selected. These periods correspond to the SVP data in the WOA (World Ocean Atlas) database, which is used for detection range calculations. The operation area can be chosen at any location for which WOA data is available. For the current (unclassified) version of APPAD, an ASW frigate and a helicopter have been defined as own units and an SSK as enemy unit.

APPAD can perform Monte Carlo simulations (including automatic determination of suitable parameter variations), calculate the set of best tactics, and present the results in a concise advice. The advice window currently shows the operational effectiveness of all tactic variations, for the various (relative) detection ranges (see Figure 3-2). Each line in the chart denotes one tactic. If desired, the results can be filtered or viewed in more detail.

Figure 3-2: The advice window, listing advised tactics sorted on effectiveness and robustness.

In addition, APPAD shows how to deal with other a priori questions, such as obtaining an overview of the detection ranges in a specific area, the coverage of moving sensors in the area, or the locations that an enemy submarine can reach undetected (see Figure 3-3).

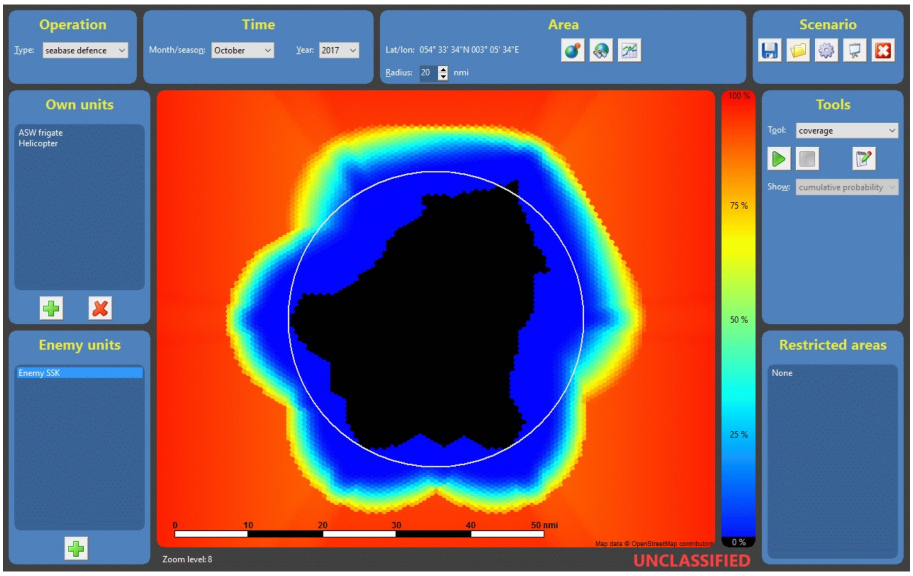

Figure 3-3: Probability view showing the locations that an enemy submarine can reach undetected in a sea base operation (sea base border indicated by a white circle).

4.0 CONCLUSIONS

APPAD was built as a demonstrator for showing how decision support can be provided for a priori planning of ASW operations. Much attention was paid to the robustness of the advice on the best way to deploy the participating platforms.

The effectiveness of an operation does not only depend on parameters known in advance, such as the number of available sensor systems. Parameters that may not be known in advance also play an essential role, such as the detection ranges, the environmental conditions, and the expected threat. A robust tactic should perform reasonably well even if the latter, uncertain, parameters change during the actual mission.

We think that APPAD's advices provide insight in the performance of different tactics. This allows ASW commanders to select the best way to operate from various alternatives, incorporating their own experience and knowledge of the actual situation, which increases the acceptance of the provided advice.

5.0 REFERENCES

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