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SOFTWARE REQUIREMENTS ANALYSIS FOR AN EXTENDED ASW MODEL

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b) Underwater warfare	b) Undervannskrigføring
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8) ABSTRACT

The FFI-project 795 "New Frigates" is a support study for the project SMP6088 "New Norwegian Escort Vessels" under the direction of the Royal Norwegian Navy’s Materiél Command. The main purpose of the study will be to ensure that the acquisition of the frigates will be achieved within the framework defined by the System Segment Specification for the Integrated Weapon System. A part of this study aims at the operational capability and efficiency of an ASW force escorting a high value surface unit under the threat of a submarine utilising one or more torpedoes as its weapon. This involves simulating such an ASW force including both tactical and technological aspects.

This document describes the requirements for such a simulation and will be input to the later stages of specification and development of the necessary tools for accomplishing this task. An underlying assumption in this document is that extensions to and integration of already in-house models will be utilised for these simulations. These models are OSCAR, LYBIN and USIM. Nevertheless, this document can also be studied for a more general overview of requirements for such simulations and used as basis for selecting simulation tools.

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1 INTRODUCTION

The project 795 "New Frigates" under direction of FFI (Norwegian Defence Research Establishment) is a support study for the project SMP6088 "New Norwegian Escort Vessels" under the direction of the Royal Norwegian Navy’s Materiél Command (NAVMATCOM-NOR). The main purpose of the study will be to ensure that the acquisition of the frigates will be achieved within the framework defined by the System Segment Specification for the Integrated Weapon System (1), as well as other constraints. This will involve studies of performance as well as tactics development for the combined ship and helicopter platform system in its ASW function. For a more detailed account of the study's goals, see (2).

In previous FFI studies that supported the concept and design phases of the project, a primary analysis tool was the OSCAR simulation model[1], originating at DERA/CDA(N), Portsdown, UK (3). OSCAR enables the study of the operational capability and efficiency of an ASW force escorting a high value surface unit. The user can create scenario configurations that contain various types and numbers of platforms and equipment with an associated array of runtime features for both single run and multiple replications (Monte Carlo).

In the concept stage, the model, with some suitable modifications, was used by FFI to answer questions pertaining to issues such as (cf (4)):

- The impact on operational effectiveness of alternative detection ranges for vessel and helicopter based sonar sensors
- The efficiency gain of the ASW force by adding organic helicopters in various tactical roles
- The optimum search speed for escort vessels taking into account limitations imposed by self-generated noise.

During a follow-up study, it was considered necessary to expand OSCAR with a confined (littoral) waters feature as well as enhancing other aspects of its ASW functionality, including maritime patrol aircrafts, ASW-radars for MPAs and helicopters as well as torpedo counter-measure systems. Due to various circumstances, these features were not all implemented to a degree meriting application in a full analysis. Thus, the open ocean scenario was again used in studies for the definition stage (4) (5).

Due to these limitations, it is realised that the present version of OSCAR is not fully suited for solving the problems that have been raised concerning the tactics and effectiveness of the new frigates. The requirements for a suitable model will be specified in this document, focusing on a confined waters scenario.

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[1] OSCAR is an acronym for "Object-oriented Simulation for the Combat Analysis of Requirements"

2 PROBLEM IDENTIFICATION

The NFs (New Frigates) will be delivered with an IWS (Integrated Weapon System) that detects, classifies and tracks perceived threats. The RNoN (Royal Norwegian Navy) must develop tactics and reaction rules to deal with these threats effectively. The performance of the IWS may vary significantly, depending on the chosen tactics.

The NFs will have a significantly more advanced IWS than today's Oslo-class frigates. It will use a hull mounted and a low frequency towed array sonar, both capable of operating in active and/or passive mode for submarine and torpedo detection. NF will also be equipped with an organic helicopter, carrying ADS (active dipping sonar), sonobuoys and torpedoes. Moreover, it will be able to launch acoustic decoys. This makes it possible to use more complex reaction rules to deal with the perceived threats. To make the best out of the new system and its possibilities, one has to establish a new set of ASW tactics and new torpedo countermeasure reaction rules for the NF. The new set of reaction rules need to be developed specifically for the system onboard the NF while taking into account the official NATO tactics and procedures.

Given a specified scenario and environmental parameters, the contribution from NF to the overall effectiveness of an ASW force can be estimated using relevant modelling tools, thus permitting the evaluation of the tactics of individual components (platforms) participating in the joint effort. Specifically, the model can be used as a tool for developing NF's sensors and weapons tactics in ASW, as well as in the planning of the test and verification procedures. An extended OSCAR model is proposed as this tool.

Basically, we need to:

a) Provide an adequate modelling tool to evaluate the effectiveness of the NFs IWS in the ASW function against an ensemble of threat scenarios, and find an efficient solution for a given scenario.
b) Assist in the development of test and verification procedures for the NFs IWS (SAT2 test).

Therefore, the extended OSCAR model should be able to use data extracted from exercises, such as bathy profiles and false alarm rates, as input to the extended model.

3 GENERAL SYSTEM DESCRIPTION

3.1 System Purpose

This chapter describes the general purpose of the extended OSCAR model and for which scenarios or operations the extended OSCAR model will be used. Moreover, the limitations of the current modelling of the ASW scenario and tactics are described.

3.1.1 Current Limitations

The current OSCAR model presupposes operations of an ASW force escorting an HVU in an Open Ocean scenario. Official NATO tactics and reaction rules are implemented according to

ATP1 (10) and ATP28 (11). However, torpedo countermeasure reaction rules are only rudimentary. Their implementation will be substantially improved in the extended OSCAR, both for assets and threats. Moreover, aspects of various EXTACs (12) should be considered.

3.1.2 The Purpose of the Extended OSCAR Model

The primary purpose of the extended OSCAR model is to evaluate the effectiveness in the ASW-function of an escorting ASW force in shallow and/or confined, littoral waters.

The model comprises the following main elements:
a) Frigates with their sensors (HMS and TA)
b) Helicopters with their sensors (ADS, sonobuoys and ASW radar)
c) ASW torpedo launched from frigates or helicopters
d) The submarine threat.
e) Submarine-launched anti-shipping torpedo.

These elements will interact to constitute a truly joint ASW effort. Specifically, the model will permit monitoring of the various platform interactions to determine essential parameters, such as the probability that the NF can keep a sonar contact until it can be engaged by a helicopter. Moreover, it will be possible to log the use of helicopter sensors and the time consumed by different tasks, such as relocation of lost contacts. The submarine's escape tactics is also considered. However, the level of detail regarding the torpedo modelling will not correspond to that of a dedicated torpedo defence tactical model, such as (13).

Given a specified scenario and environmental parameters, the ASW force overall effectiveness and can be estimated, thus permitting the evaluation of the tactics of individual components (platforms) participating in the joint effort. Specifically, the model can be used as a tool for developing NF sensors and weapons tactics in ASW. This constitutes its primary purpose.

Initially, the model will simulate ASW in an open ocean scenario, and will subsequently be adapted to a confined, littoral setting. This is primarily a question of adequate modelling of sensor performance in such waters, specifically related to bottom representation and range dependence. Furthermore, torpedo behaviour and sonar false alarm rate must be appropriately modified, e g with a torpedo land avoidance feature.

The secondary purpose of the extended OSCAR model is to analyse, compare and evaluate scenarios and exercises, including the SAT2, as to establish the effectiveness in the ASW-function of assets, sensors and tactics for the relevant scenarios.

3.1.3 Technical Background and Simulation Framework

We will initially provide a rudimentary sketch of the model’s basic philosophy, then proceed with a more explicit discussion of the recent modifications. For a detailed account of the model’s technical specifications, we refer to (7) and (8).

The model software has been developed within an object-oriented approach, using Borland C++ with a Microsoft Windows Application Programming Interface (API). This links the

Windows Operating System with the OSCAR specific code of the model, into which an advanced memory manager and a simulation event handler has been built. This provides the basis for a closed, stochastic model driven by discrete events.

The OSCAR specific code is basically a set of program objects that represent maritime capabilities through their data and interactions. These objects can be linked to form scenarios, cf section 3.1.6.

As indicated above, both single and multiple replications (Monte Carlo) are possible. Data generated during multiple replications are transferable to Microsoft EXCEL using the Dynamic Data Exchange (DDE) mechanism of inter-process communication supported by Windows.

The OSCAR user interface is consistent with the look and feel of a Microsoft Windows application, and provides the user with several important features to facilitate operations:

a) Data regarding platforms and their equipment, entered in order to construct specific scenarios, can be readily inspected through pop-up dialog boxes.
b) Initial deployment of platforms and equipment is displayed in a map window.
c) The enfolding of events in "real-time" can be displayed both in the map window and in a dialog window.

3.1.4 Scenario Elements and their Functionality

The ASW force can be composed of various platforms, such as escort vessels, towed array ships, helicopters and air cover units, protecting the high value unit against a threat represented by a single submarine, surface-action groups and fighter-bomber groups. In the following we will present only those elements of the current model version that are relevant for the detection and prosecution of the submarine. The scenarios will include range independent and range dependent environments in both littoral and deep waters.

3.1.4.1 Platform Elements

High Value Unit (HVU): The HVU is the central platform of BLUE forces. Its current position acts as a reference point from which all other platforms calculate their range and bearing, cf Figure 3.1. In absence of any detected threat, the HVU will follow one of three predefined tactics:

a) Fixed zigzag: The HVU follows a fixed pattern of course changes defined as a leg time[2] and an offset from the Mean Line of Advance (MLA).
b) Random zigzag: The zigzag is defined as a random course change between two limits and a random leg time between two limits.
c) Zigzag plan: The plan is defined as a set of data pairs indicating the actual bearing and length of time for the leg.

[2] Leg time is defined as the time spent by the HVU on performing the leg.

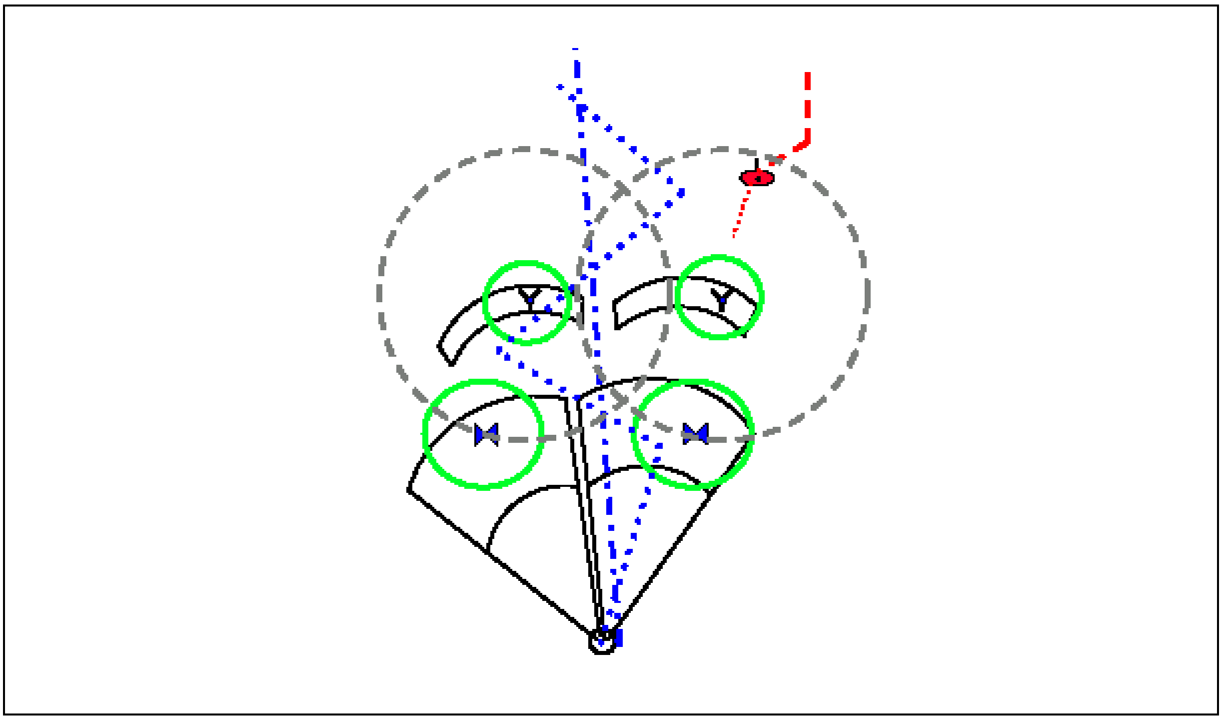

Figure 3.1 Illustration of HVU MLA and zigzag course, also indicating patrol sectors for escorts and helicopters as well as normalised sensor ranges (fully drawn lines representing sonars, dashed lines radars).

If a submarine detection should occur by any platform and be regarded as an immediate threat to the convoy's main body, the latter will start to evade at a predefined running speed and at an appropriate heading. The HVU will regain its previous MLA and zigzag tactic once it has distanced itself from the submarine. The rest of the main body will continue to track the HVU and will execute the same evasion manoeuvre.

The HVU is capable of carrying helicopters and can be equipped with Hull Mounted Sonar (HMS) and ship launched torpedoes.

<u>Escort</u>: An escort is given a patrol sector that is defined by a maximum and a minimum range and bearing from the HVU, cf Figure 3.1. At the start of each run, an escort's initial position in its patrol sector is calculated. While the simulation is running, the escort tracks the HVU, i e it moves within its patrol sector with respect to the MLA of the HVU. At the end of a zigzag leg, the escort will pick a random point within its sector and plot a course to move to that point over the course of the next HVU zigzag leg.

The escort is capable of carrying helicopters and can be equipped with HMS and ship launched torpedoes.

<u>Helicopter</u>: In OSCAR, the helicopter platform assumes one of the following three roles:

a) Screening: The helicopter is on ASW screening in a patrol sector defined with respect to the MLA of the HVU, cf Figure 3.1.

b) On Standby: The helicopter is on board a parent ship, prepared to take over screening duty for any screening helicopters that have run out of endurance.
c) Reactive: The helicopter will remain on board the parent ship until a submarine (or surface) threat is detected. It will then become available for prosecution.

If a helicopter is unable to complete its current task due to the lack of endurance, it will place a request for an available helicopter to take over the task. A screening helicopter will place a request for any fully prepared screening helicopter in its group. A prosecuting helicopter will first request for a reactive, then a fully prepared screening, then an operating screening helicopter depending on current availability. Should no helicopter be available, the request is stored until a helicopter becomes fully prepared. The helicopter can carry ADS, sonobuoys and air launched torpedoes.

While screening, a helicopter will dip randomly within its patrol sector until a detection is made. The dip length is a user-defined parameter. If a helicopter has detected a submarine contact with its own sensors, then that helicopter will investigate the contact. If a submarine contact has been gained on a TA or HMS, a request is broadcasted for an available helicopter to intercept the submarine at its expected position, where it will start dipping. Moreover, if equipped with sonobuoys and while stock lasts, the helicopter will deploy a single buoy at each subsequent dip position. Should the helicopter lose contact with the submarine it will enter a lost contact procedure (LCP). The LCP will depend on the equipment being carried by the helicopter. Should they be available, the helicopter will deploy three, equally spaced sonobuoys on a circle of radius equal to the buoy mean detection range, centered on the submarine's last known position. Otherwise, the helicopter will dip at three similarly oriented points. Should this fail to relocate the submarine, the helicopter will return to its task prior to prosecution.

If the helicopter gets within torpedo launch range of the submarine at any of its dip positions, it will deploy a torpedo. Searching will continue to see whether the torpedo was effective. Should a helicopter run out of torpedoes while prosecuting, a request is placed for a helicopter fit with an appropriate weapon to take over the prosecution.

<u>Towed Array Ship</u>: The Towed Array Ship follows a simple sprint and drift tactic. The drift heading is identical to the MLA of the HVU. Its assigned position is defined by a distance relative to the HVU and a bearing relative to the MLA. After a drift, the TA Ship will sprint until it gets back to its assigned position.

The TA Ship is capable of carrying helicopters and can be equipped with HMS, TA sonar and ship launched torpedoes.

<u>Submarine</u>: In the simple ASW scenario under consideration, the submarine is the central platform of the RED forces. In approaching its target, the HVU, it will assume that while position estimates are readily available, speed and course estimates may be unreliable due to the inaccuracy of the sensors used to obtain this information. Observe that, in contrast to the other platforms, the submarine is not explicitly modelled with sensors. Therefore, the submarine is assumed to gain PIM (Position and Intended Movement) information at an

interval defined by a user specified HVU course update rate. The submarine then attempts to intercept the target, updating its course at this rate. This simplified approach tactic practically ensures that the submarine will come to an engagement with BLUE forces in each modelling run.

As soon as the submarine obtains a firing solution, it will launch an attack, firing a salvo or a single torpedo (user specified). As soon as the attack has been launched, the submarine will commence evasion, which will continue until sufficient separation from the closest BLUE surface vessel has been obtained. The submarine will subsequently re-launch an attack. OSCAR assumes that the submarine's priority is to attack its intended target and it will therefore not evade unless it is under attack. Evasion tactics implies a zigzag course with user defined elements such as speed, heading and leg duration. The submarine will evade whenever it has launched an attack or an attack has been launched on the submarine. Should the latter case arise, the submarine will, if possible, fire a single torpedo at the attacking BLUE platform before commencing evasion.

3.1.4.2 Equipment Elements

Sonar: In order to take account of both cookie-cutter and convergence zone detection, the sonar, whether active or passive, has been modelled as follows: a user-defined set of concentric circles about the sonar will establish a series of annuli centered on its position. The probability of detection of a submarine within any particular annulus is defined by the user according to a look-up table (LUT). LUT data can be changed or added either by loading in a default LUT from file or by entering numeric data manually with the help of a dialog box. There are four different sonar types, Hull Mounted (HMS), Towed Array (TA), Active Dipping Sonar (ADS) and sonobuoys. HMS and TA can be mounted on any surface vessel, while Sonobuoys are deployed from airborne platforms only. Moreover, HMS and TA will be operating continuously (for Towed Array Ships the TA will, however, be operating during drifting periods only), while Sonobuoys, once they have been deployed, not will be activated until after a predetermined activation time interval has passed. Once the sonobuoy's lifetime has been exhausted, it is removed from the simulation.

Whenever either the submarine or the sonar parent platform change course, the simulation predicts the intersection of any boundary of the sonar annuli with the boundary of the submarine's noise circle, based on the current speed and bearing of both platforms (cf Figure 3.2). The user-defined noise circle relates to the sonar detection range by indicating a velocity dependent boundary, i e the periphery of a circle centered on the sonar's position, beyond which no detection of the submarine, given its current speed, can occur. The radius of this circle is taken to be equal to the sum of the radii of the submarine's noise circle and the circle representing the outer boundary of the most distant annulus as seen from the sonar's position. For active sonars, the submarines noise circle radius is set to zero.

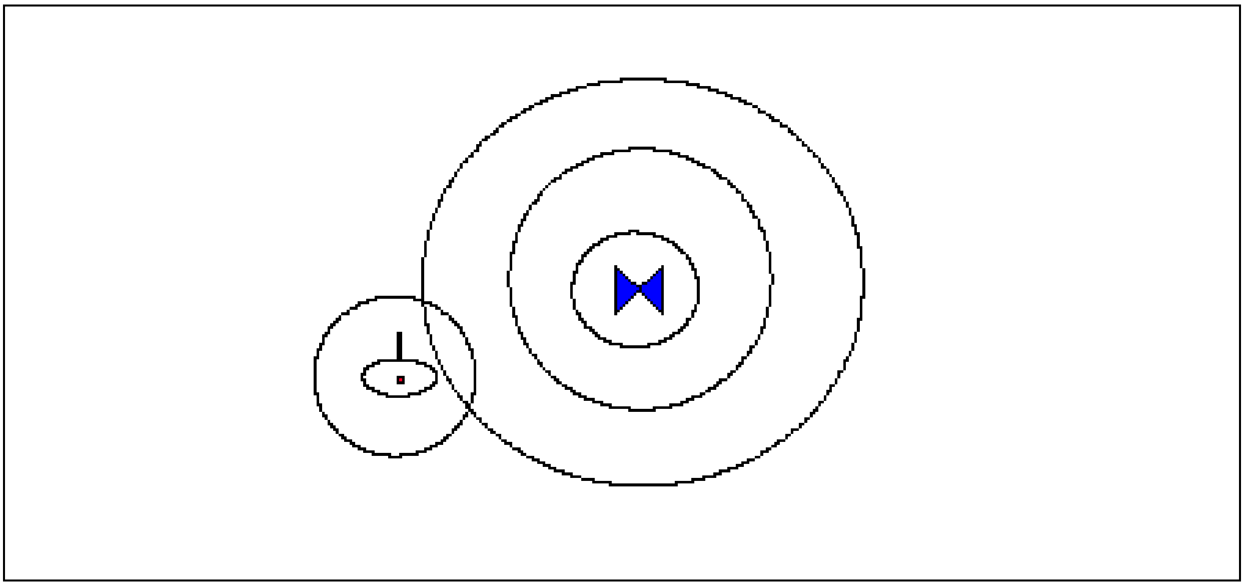

Figure 3.2 Dynamics of submarine detection in OSCAR as illustrated by the concepts of sonar detection annuli and submarine noise circle.

Assuming the submarine's noise circle intersects the outer boundary of a specific sonar detection annulus before any subsequent course changes take place, the probability of detection for that annulus is compared against a random number to ascertain whether a detection will occur. Should this be the case, an event will be scheduled to inform the sonar's parent platform at the appropriate time. An active sonar will provide both range and bearing estimates for the position of the submarine, while a passive sonar will only provide a bearing estimate. Actual prosecution of the submarine will depend on the prosecution assets available at that time during any particular run.

A surface ship being informed of a submarine detection by its sonar will first fire a ship launched torpedo (if available and in firing range) against the submarine, then ask available ASW helicopters to intercept the contact and commence their prosecution cycle. Submarine detection by a helicopter with its own sonar capability will cause that platform to prosecute the submarine, regardless of other platforms, according to the description in section 3.1.4.1. For any HMS or TA included in the scenario configuration, a false alarm rate will define the number of false alarms experienced during the course of a run. Each false alarm will be prosecuted by the relevant platforms according to the procedure described above. The position of a false contact is calculated to a random range (within the limits of the sonar detection capability) and bearing from the sonar equipment.

Torpedo: Torpedoes can be used in either RED on BLUE (i e submarine against surface ship) or BLUE on RED (i e helicopter or surface ship against submarine) engagements. They are launched whenever the parent platform gets within firing range of its target and that the latter has been detected.

The torpedo tracks its target at assessment intervals based on its speed and endurance. At each interval a new course is plotted to intercept with the target. Should the torpedo run out of endurance it will be registered as a miss and removed from the simulation. However, should the torpedo intercept its target, a detonation event will occur. Kill probability will be assigned to this event by two LUTs, one depending on the percentage of its endurance the torpedo has travelled at the time of detonation, the other depending on the torpedo's angle off the target bow when it was fired.

3.1.5 The OSCAR Enhancements at FFI

Once having decided upon the desired changes regarding platform types, functionality and equipment, the basic philosophy behind the enhancement of OSCAR has been to efficiently employ the existing, powerful tools described in the previous section, minimising the necessary modification of the original code. However, the features listed below have been found sufficiently important as to merit the effort of implementation, and essential aspects thereof are therefore discussed below. The changes are as follows (p = preliminary version):

a)	Settings:	-Confined Waters (p)
b)	Platforms:	-Maritime Patrol Aircraft
c)	Equipment:	-New Sonar
		-New Torpedo
		-ASW Radar for MPA and helicopter (p)
		-Torpedo Countermeasure System for BLUE platforms (p)
		-Bi-static Sonar (under consideration)
d)	Tactics:	-Several changes, but most do not require substantial modification of the model proper as they can be implemented by clever manipulation of input parameters.

3.1.5.1 Confined Waters Setting

The confined water setting has been implemented in a way similar to a corresponding solution for the CVSG(R) simulation (8). For a given ASW configuration, a confined waters scenario is constructed by adding one or more confined areas in which the force is going to operate, thus constraining its movements to be either enclosed by or barred from the area. A confined area is generally defined by a set of points, constituting the vertices of a polygon. During a simulation run, the polygon is stored by the computer in the form of an array of "point" objects. This generic solution has to be substantially refined and optimised for speed in the actual model implementation.

3.1.5.1.1 The ConfArea Class

To administer the interaction of platforms and a particular area, a confined area object is created as an instance of a new class, ConfArea. The class will, in addition to the point array, contain an identifying label, a drawing routine to assist with the visualisation process as well as procedures for calculating the equation of an edge and a function to predict collisions of platform objects with any given edge, the latter event being referred to as a boundary crossing.

Boundary crossings are established based on an algorithm determining the intersection of two lines. The confined area uses the current position and velocity of the platform to generate a linear equation describing its path. Using this equation and an equation for each side of the polygon in turn, a simultaneous equation is solved. The resultant co-ordinates define an intercept point, whose validity as a part of the polygon is determined by checking it against the end points of the side in question. If they lie within the correct bounds, the time to interception is calculated and a boundary-crossing event is scheduled for that time. Possible interceptions are calculated for every platform at the beginning of each new HVU leg, and again in the case of any event that implies a change in a platform's course.

3.1.5.1.2 Confined Waters Platform Functionality

Below we will specify the interaction of each component of the simulated ASW force with the confined area.

HVU: The HVU will move according to its predefined tactics until either itself or one of its screening (i e non-prosecuting) escorts intercepts a confined area boundary. It will then reflect off the boundary at an angle equal to half the grazing angle, cf Figure 3.3. In order to facilitate the study of an ASW force transiting through a confined area, we have chosen not to adjust the HVU's MLA accordingly.

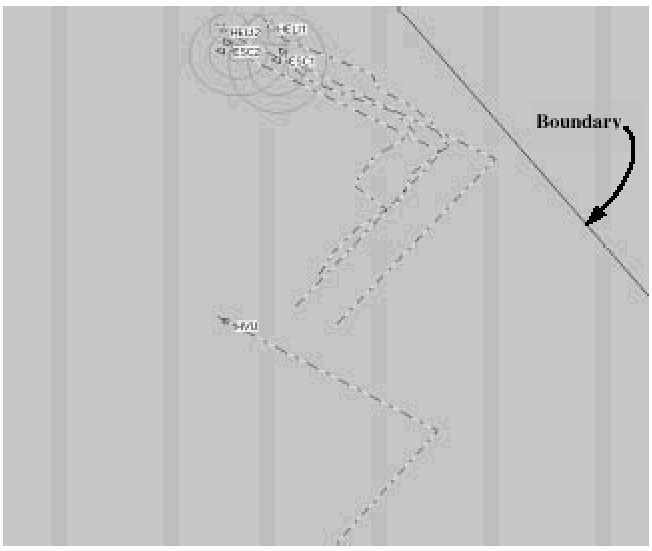

Figure 3.3 HVU and escorts interacting with the boundary of a Confined Area

Escort: Whenever the HVU is reflected off a boundary, its escorts will be set to change courses as to keep up with the subsequent changes in the definition of their patrol sectors. Should an escort intercept the boundary while prosecuting the submarine, its speed will be set to zero as to ensure that it will remain at the intercept point until a new heading takes it away from the boundary.

Towed Array Ship: If the TAS should intercept a confined area boundary, its speed will be set to zero, ensuring that it will remain at the intercept point until an event changing the HVU's bearing occurs or a pre-set time limit is reached, after which it will start sprinting to reach its assigned position.

Helicopter: If the next assigned dip location for a helicopter implies that it will have to cross a confined area boundary then, regardless of the situation, the dip is reset to take place at the boundary intercept point.

Submarine: The submarine will be oblivious of the confined area until it starts evading. If its evasion course should imply an intercept with a boundary, the submarine will start following the boundary from the point of actual intercept in the direction removing it from the HVU. As a consequence, the submarine can, under the right circumstances, become cornered. In such a case, it will remain cornered until a situation develops that allows it to plot a course removing it from the HVU.

MPA: Specifics regarding the interaction of MPA with a confined area boundary have not been considered, since its operability may be severely restricted in confined waters setting. In scenarios where the use of MPA is considered relevant, adequate manipulation of the regular functionality and input parameters should be sufficient (cf section 3.1.5.2).

3.1.5.1.3 Confined Waters Equipment Functionality

Equipment functionality will not change significantly in the confined area setting. However, fundamental changes will be made as to how the equipment is implemented in the extended model. We have limited modifications of functionality to the following:

Torpedo: Firing will be prohibited if, at the time of launch, a confined area boundary will intersect the Torpedo's initial path at a point lying between the Torpedo and its target.

The torpedo vs target engagements will be handled in a separate model (USIM, Cf section 3.3) interacting with OSCAR through HLA. This includes torpedo tracking, torpedo and target manoeuvres as well as hit/kill-assessment, eliminating the need for LUTs.

Sonar: The probability of detecting the submarine will come to reflect several new aspects such as bottom topography, range dependence and differences in bearing relative to the sonar parent platform.

The detection of platforms will be handled through a new acoustic feature built into OSCAR, based on the kernel in the acoustic model LYBIN (9) developed by NAVMATCOMNOR. The computing kernel of LYBIN will be extracted and provided with an interface (API) through which basic LYBIN functionality and data will be accessible. The API will be implemented either as a class interface or as an active-X control, the latter thought to be the most flexible approach. The idea is to use the new feature whenever there was to be a call to a LUT in the "old" model, thereby eliminating the concept of sonar LUTs and submarine noise circles altogether. Whenever either the submarine or the sonar parent platform performs relevant course changes, the extended OSCAR is to perform calculations of detection probabilities of each sonar vs every platform tracked by the sonar parent platform.

3.1.5.2 Maritime Patrol Aircraft

The Maritime Patrol Aircraft introduced into OSCAR has an ASW capability based upon sonobuoy sensors and torpedoes. For simplicity, the MPA is assumed to be land-based and will be patrolling continuously for the entire length of the simulation or until the stock of sonobuoys has been depleted.

The basic strategy for the MPA is to deploy passive sonobuoy search fields at positions determined by the tactics in use, cf Figure 3.4:

a) Area search - An area is defined as a box with a minimum and maximum range from the HVU and a width centered about a patrol angle. Search fields are deployed at random positions within this area.
b) Sector search - Tactics will be as for Area search, but the area boundary will be given as a sector with minimum and maximum ranges and headings.
c) Pre-defined flight plan - The flight plan is defined as triples of data indicating the range and bearing from the HVU, as well as the orientation of the field with respect to the HVU course. The flight plan must be loaded from a file having the following format:

   First line: No of tactics tuples
   Second line: range 1, bearing 1, field orientation 1
   Third line: range 2, bearing 2, field orientation 2 etc.

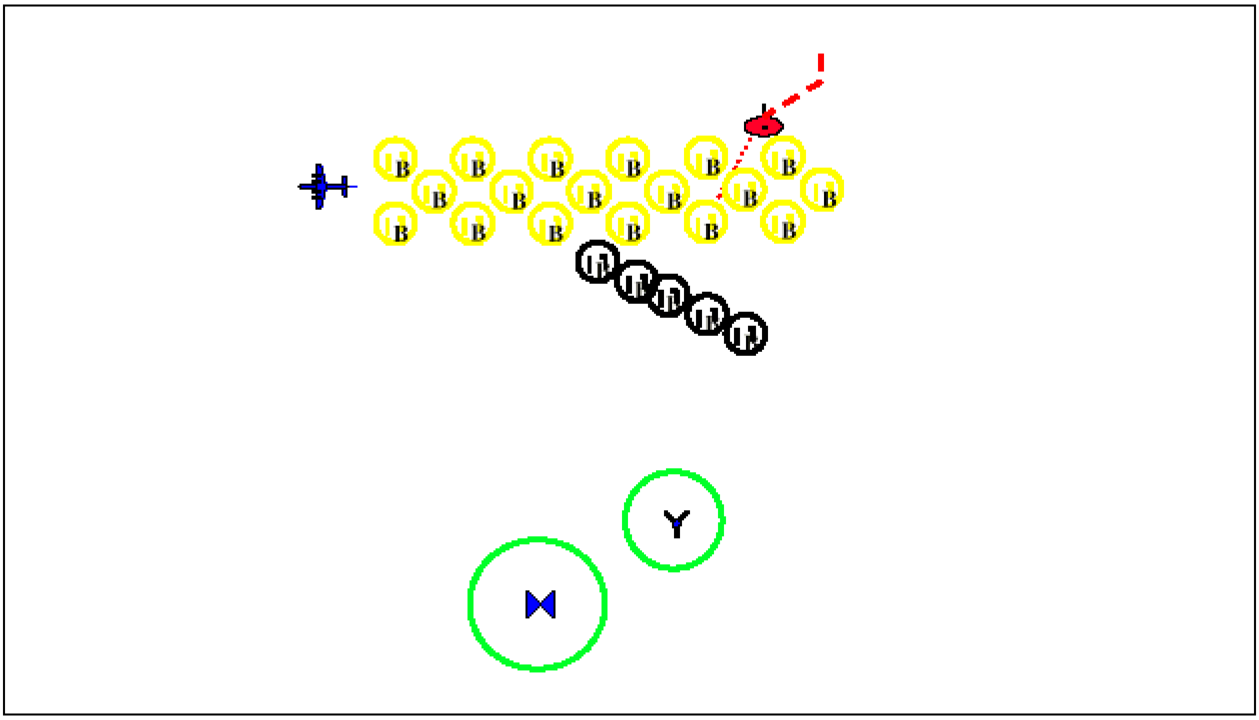

Figure 3.4 MPA prosecuting a submarine with sonobuoys

If detections are not made in the lifetime of the search field, then successive fields are deployed according to current tactics. Assuming the field makes a detection, the MPA will, after a user-defined delay for Target Motion Analysis (TMA), deploy a (active) localisation barrier in front of the submarine’s expected position (marked with boldface circles in Figure 3.4). Should the localisation barrier then regain and keep the contact for a period corresponding to TMA, the MPA will deploy a torpedo at the submarine’s expected position. Searching will continue to assess whether the torpedo was effective.

If, however, the localisation barrier should fail to redetect the submarine, the MPA will enter a LCP, deploying three, equally spaced active sonobuoys on the periphery of a circle with radius equal to the sonobuoys mean detection range and centered on the submarine’s last known position. If contact is re-established with the LCP field and held for a period allowing TMA, the MPA will again fire a torpedo and make a hit assessment. This cycle will continue until either the MPA runs out of torpedoes, the submarine is hit or the LCP field detection fails, in which case the MPA will return to patrol duty.

3.1.5.3 Equipment Enhancements

ASW Radar: So far the ASW radar exists in a preliminary test version for helicopter only, according to the principles indicated below.

It is assumed that the submarine will generally be unwilling to use its masts to obtain a firing solution, except in a confined water setting imposing severe constraints on operability and/or very unfavourable sonar conditions (e g a fjord environment). The submarine therefore is expected to expose masts only in immediate connection with a torpedo launch. Accordingly, the use of an ASW radar for helicopter can be emulated by calling, for every screening helicopter, an appropriate procedure whenever the submarine commences evasion after having fired on the HVU. The procedure draws a random detection event, based upon currently available data for the ”radar” detection probability and, in case of ”detection”, informs the relevant helicopter’s ADS, thus prompting the helicopter to start prosecution and the HVU to start evasion.

Torpedo Countermeasure System: The current solution for the TCM also must be regarded as temporary. It is supposed to simulate a hard kill system that bases its torpedo detection capability upon a HMS in passive mode, thus capable of being installed on any surface ship. Moreover, this choice implies that continuous operation can be assumed.

The chosen implementation emulates TCM by calling a procedure activating the ”HMS” of the torpedo’s target platform at the beginning of each torpedo tracking interval. The procedure draws a random detection event based upon currently available data for the ”HMS” detection probability. Should ”detection” occur, the torpedo’s kill probability in the eventual case of torpedo impact is modified by a factor reflecting the efficiency of the hard kill part of the TCM, the targeted platform’s active HMS is alerted to check for submarine detection and the HVU is ordered to start evasion.

Bi-static Sonar: Currently, the question whether to introduce bi- (or multi-) static sonar to OSCAR is under consideration. It is unclear how an implementation should be made using the LYBIN-based acoustic feature.

3.1.5.4 Platform Tactics in Confined Waters Settings

In this section we sketch how basic tactics of components of the ASW force is implemented in the Confined Waters setting of the enhanced OSCAR. Additionally, modification of sensor capacities in the relevant setting must be carefully studied by available means and applied appropriately.

HVU: In areas implying severe restrictions on movement, the HVU is set to move according to a fixed (zigzag) plan, taking care to exploit advantageous features of the topography and preferably at speeds reducing cavitation by escorts. In more open areas, a reasonably random zigzag is preferred. Evasion will be away from the perceived threat (but within the confinement of the area), including those elements of the main body that do not participate in submarine prosecution.

Escort: Escorts will again be deployed in patrol sectors. In the case of very confined areas, these sectors should be constructed as corresponding to positions in a skeleton screen.

Towed Array Ships: No formal changes, but TAS positioning relative to the HVU should be considered with care. The platform will not participate in evasion if carrying a helicopter.

Helicopter: In confined waters, having a helicopter available for prosecution appears to be particularly important. Therefore, the ASW resources should be managed as to ensure always having a helicopter on standby. Otherwise, no tactical modifications have been made.

MPA: Since operative restrictions severely reduce the availability of MPA for the ASW force in confined waters, cf section 3.1.5.1.2, there has been no modifications of MPA tactics for this case. However, where relevant, restrictions can be implemented by letting the MPA operate according to an appropriately pre-defined flight plan.

Submarine: In confined waters setting, the submarine will have the advantage of being able to hide from the ASW force by exploiting topographical features. We let this be reflected in the simulation by not imposing restrictions upon the submarine’s approach tactics. However, during evasion this advantage is greatly reduced, so the submarine is set to follow the confined area boundary, cf section 3.1.2, when evading. Firing policies can be moderated by choosing various torpedo endurances and firing ranges.

3.1.5.5 Platform - Platform and Equipment - Platform Interactions

	HVU	Escort	Helicopter	MPA	TAS	Submarine
HVU						[Evading]
Escort	Tracking		Parenting			[Attacking]
Helicopter	Tracking	Tracking				Attacking
MPA	Tracking					Attacking
TAS	Tracking		Parenting			[Attacking]
Submarine	Tracking Attacking	[Evading] [Attacking]	[Evading]	[Evading]	[Evading] [Attacking]	

Table 3.1. Platform - Platform interactions in the Extended OSCAR model. First column is read as active. Action in brackets valid only when the active platform is under attack.

	HVU	Escort	Helicopter	MPA	TAS	Submarine
Sonar	[Parented]	Parented	Parented	Parented (buoys)	Parented	Detecting
ASW-Torpedo	[Parented]	Parented	Parented	Parented	Parented	Attacking
ASW-Radar			Parented	Parented		Detecting (mast)
Anti-shipping Torpedo	Attacking	Attacking			Attacking	Parented

Table 3.2. Equipment - Platform interactions in the Extended OSCAR model. First column is read as active. Brackets indicate optional equipment.

3.1.6 Scenarios for Analysis

The scenarios should at least include the following:

a) An ASW force of two NF with their organic helicopters escorting a HVU in an open ocean environment.

b) An ASW force of two NF with their organic helicopters escorting a HVU in a confined, littoral waters environment.

c) A MNTF (Multi-National Task Force) ASW group, including an NF with its organic helicopter, escorting a HVU in an open ocean environment.

d) An MNTF ASW group, including an NF with its organic helicopter, escorting a HVU in a confined, littoral waters environment.

3.2 System Boundaries

The system boundaries provide insight into the role of the extended OSCAR model in the organisation and the environment of the system (input, output and communication with other systems).

3.2.1 Role in the Organisation

The extended OSCAR model will initially be a stand-alone unit with an acoustic sub-model, based on the RNoN model LYBIN, included. It will deliver input for statistical analyses of tactics for individual platforms of an ASW force. In the final version, torpedo engagements will be simulated separately (USIM model) and communicated to OSCAR through HLA.

3.2.2 Input & Output

The environment of the extended OSCAR model consists of the input and the output listed in Table 3.3.

Input	Output
Number and types of assets Area (incl map data) Environment (incl map data) Threat parameters Start points Tactics (Zig.zag plans, flight plans etc.) Torpedo engagement results	Data for export to EXCEL Workbook (DDE) Log file for detailed analysis Map window Log window Torpedo firing data (to USIM / HLA RTI)

Table 3.3. Input & output related to the extended OSCAR model.

3.3 The USIM Model

USIM was originally developed for studying submarine evasion against an autonomous, acoustic homing torpedo. Both manoeuvres and countermeasures (i e static jammers and mobile decoys) are represented in the model. Detection ranges submarine vs torpedo(-es) and torpedo vs submarine are input parameters. Consequentially, the model is non-acoustic. Other important parameters are torpedo speed, range and sonar coverage. Calculations are made in 3D. The behaviour of the model components seems to correspond well to the rather "generic" OSCAR level of detail, while still allowing to study the effect of decoys, jammers and platform manoeuvres.

USIM will be called when a torpedo has been launched in OSCAR, allowing the main model to execute regularly until this point, at which (in case of "deliberate attack") detection ranges and other required parameters (such as target speed, course, range and bearing) are transferred to USIM using the HLA mechanism. The engagement is then simulated and the outcome transferred back to OSCAR, allowing the main simulation to resume. Updates of relative positions can be transferred to the main simulation when required, i e even before the USIM simulation has terminated.

When a torpedo is launched, it can be set in one of three modes: CC (Collision Course), search pattern (with optional forerun) or heading for last known submarine position. When set in CC mode, the torpedo will go for the nearest target, including decoys. The effect of jammers is to reduce detection ranges.

As soon as the submarine detects a torpedo, it will initiate an escape manoeuvre. Currently, such manoeuvres are limited to 2D.

In case of "urgent attack", or if the torpedo has been dropped by a helicopter or an MPA, relevant search patterns are used. Moreover, in these cases the submarine is set to detect the attacking torpedo immediately.

Currently implemented search patterns are valid for ASW torpedoes only. It should, however, be possible to implement patterns valid for autonomous anti-shipping torpedoes without a major restructuring of the model. In this case, the target depth must be set to zero and its manoeuvres must be modified appropriately. Since firing distance is much larger for these torpedoes, it is no longer reasonable to assume immediate torpedo detection by the surface units. These torpedoes would have to be detected by the OSCAR acoustic sub-model (in passive mode), possibly during a position update, and their detection subsequently transferred to the enfolding torpedo simulation.

USIM does not itself contain any mechanism restricting torpedo behaviour. Such features will have to be implemented in OSCAR, see e g section 3.1.5.1.3. Moreover, it should again be emphasized that the level of detail regarding the torpedo and countermeasures modelling will not correspond to that of a dedicated torpedo defence tactical model.

3.4 User Groups

The following potential users of the extended OSCAR model can be identified:
a) FFI / SFK
b) FFI / KNM T

The different users main interests are/may be:
a) FFI/SFK will use the extended OSCAR model to plan, analyse, compare and evaluate the effectiveness of assets, sensors and tactics in several scenarios in connection with SAT2.
b) FFI / KNM T can use the extended OSCAR model to plan, analyse, compare and evaluate ASW screening tactics for NF. It can also be used for analysing exercises.

4 USER REQUIREMENTS

4.1 Definition of a Requirement Notation

The notation used for the requirements contains an identification of the requirement, the requirement itself, the priority of the requirement, a description of the requirement and additional comments.

ID:	Requirement:	Priority:
Description:		
Comment:		

Table 4.1. The notation standard for the user requirements.

The fields in Table 4.1 are read as follows:

a) *ID* – A unique identification of the requirement used for reference purposes in other requirements. The format is XY.
X may have one of the values E, A, T, I, O where:
E = environmental requirements
A = asset requirements
T = threat requirements
I = input/output requirements
O = other user requirements
Y is a serial number running from 01.
b) *Requirement* – A text field giving a brief description of the requirement.
c) *Priority* – A number from 1 to 3 describing the priority of the requirement where:
1 = Essential - to be implemented.
2 = Important - should be implemented if adequate resources are available.
3 = Desirable
d) *Description* – A text field giving a detailed description of the requirement.
e) *Comment* – Additional information, e.g. relations to other requirements.

4.2 Requirements for an Extended OSCAR Model

4.2.1 Environmental requirements

ID:	Requirement:	Priority:
E01	Area	1
Description:		
The simulations are performed in a "2+1-dimensional" underwater environment.		
Comment:		
For calculations in OSCAR and LYBIN, only 2D are required. Only the torpedo model USIM performs full 3D calculations.		

ID:	Requirement:	Priority:
E02	Area characteristics	1
Description:		
An area shall be characterised by: a) Land/Sea boundary b) Simplified bottom topography c) Bottom type d) Sound speed profile e) Environmental conditions (weather, background noise etc)		
Comment:		
Area characteristics as relevant to the degree required by LYBIN, OSCAR and USIM models. The basic solution will include current confined waters solution for OSCAR and linear LYBIN bottom profile with range independent bottom type.		

ID:	Requirement:	Priority:
E03	Acoustical model	1
Description:		
An acoustical model will calculate the performance of the underwater sensors. This model shall take into account: a) Signal level from the sound source b) Transmission loss from source to receiver and vice versa c) Background noise level (non-variable) d) Reverberation levels, surface-, volume- and bottom reverberation e) Target strength		
Comment:		
We assume the model supplies both active and passive modes (passive for torpedo detection). LYBIN with some extensions is the preferred model. Current LYBIN as basic solution.		

ID:	Requirement:	Priority:
E04	Radar Model	2
Description:		
The performance of the radar sensors will be calculated by a radar model. This model shall take into account signal level from source, RCS of submarine mast, environmental conditions, radar antenna parameters, etc.		
Comment:		
Radar model will calculate PoD of submarine mast from a helicopter or an MPA. Possible use of radar sub-model from an in-house sensor model suite (MSM) interacting with OSCAR through HLA.. This sensor suite also permits the inclusion of other above water sensors, such as IR. Current ASW radar solution for (enhanced) OSCAR in basic solution.		

4.2.2 Assets requirements

<table>
<tr><th>ID:</th><th>Requirement:</th><th>Priority:</th></tr>
<tr><td>A01</td><td>Platform</td><td>1</td></tr>
<tr><th colspan="3">Description:</th></tr>
<tr><td colspan="3">A platform has:
a) a position, course and speed
b) a search tactic
c) an attack tactic
d) a countermeasure tactic

A platform can have:
a) a depth
b) an elevation
c) sensors
d) weapons
e) a radiated noise signature, broad- and narrow-band

A platform may have a limited operating time.</td></tr>
<tr><th colspan="3">Comment:</th></tr>
<tr><td colspan="3">A platform can be a surface vessel, helicopter or MPA. Radiated noise signature implemented as a LUT. In basic solution, no broadband signature.</td></tr>
</table>

<table>
<tr><th>ID:</th><th>Requirement:</th><th>Priority:</th></tr>
<tr><td>A02</td><td>Sensors</td><td>1</td></tr>
<tr><th colspan="3">Description:</th></tr>
<tr><td colspan="3">A sensor can be active or passive.
An acoustic or radar model calculates the performance of a sensor.</td></tr>
<tr><th colspan="3">Comment:</th></tr>
<tr><td colspan="3">Cf requirement E03 and E04.</td></tr>
</table>

<table>
<tr><th>ID:</th><th>Requirement:</th><th>Priority:</th></tr>
<tr><td>A03</td><td>Weapons and countermeasures</td><td>1</td></tr>
<tr><th colspan="3">Description:</th></tr>
<tr><td colspan="3">The following weapons and countermeasures shall be modelled:
a) ASW torpedo
b) Acoustic decoys (transponder and echo repeater).
c) Active torpedo jammer</td></tr>
<tr><th colspan="3">Comment:</th></tr>
<tr><td colspan="3">Decoy modelling depends on choice of decoy for NF, and whether this choice can be appropriately handled by the USIM model. In basic solution, ASW torpedo only.</td></tr>
</table>

ID:	Requirement:	Priority:
A04	Acoustic sensors	1
Description:		
The following acoustic sensors shall be modelled: a) Hull Mounted Sonar (HMS), active (FM and CW) and passive. b) Active towed array sonar (ATAS). c) Active dipping sonar (ADS). d) Sonobuoys, active and passive.		
Comment:		
Cf requirements A02 and A03.		

ID:	Requirement:	Priority:
A05	False alarm rate	1
Description:		
The model shall include a (rudimentary) false alarm rate model for the acoustic sensors.		
Comment:		
The model may use input data extracted from exercises such as FLOTEX. Current OSCAR mechanism in basic solution.		

ID:	Requirement:	Priority:
A06	Platform screening tactics	1
Description:		
The platform executes a screening tactic to minimise submarine threat according to ATPs and EXTACs. A tactic consists of: a) Start-points in the area of operation. b) Speed and course. c) Sensor policy.		
Comment:		
Cf requirement A01.		

ID:	Requirement:	Priority:
A07	Countermeasure tactic	1
Description:		
A platform executes a countermeasure tactic when attacked by a weapon. A countermeasure tactic consists of: a) Manoeuvres b) Decoy deployments		
Comment:		
Cf requirements A01and A03. In basic solution, manoeuvres only. Decoys depending on HLA-link to USIM.		

ID:	Requirement:	Priority:
A08	2D target noise model	2
Description:		
Target noise model shall depend on targets bearing relative to receiver. For active sonars this applies to the target echo strength model.		
Comment:		
Implemented as noise- and echo strength LUT. In basic solution, uniform target strength and passive sonar as current OSCAR.		

4.2.3 Threat requirements

ID:	Requirement:	Priority:
T01	Threat	1
Description:		
The threat is a torpedo-firing submarine, having: a) a position, course and speed b) a target echo strength c) an attack tactic d) a countermeasure tactic e) a radiated noise signature, broad- and narrow-band		
Comment:		
Torpedo engagements will be modelled by USIM, cf requirement T04. Target echo strength and radiated noise signature implemented as LUTs. In basic solution, no broadband signature.		

ID:	Requirement:	Priority:
T02	Depth	1
Description:		
The submarine and torpedo can operate at any depth in the water column.		
Comment:		
Cf requirements E01, E03 and T04. In basic solution, non-variable depth only (parameter).		

ID:	Requirement:	Priority:
T03	Weapons and countermeasures	1
Description:		
The submarine will fire anti-shipping torpedoes. The torpedo shall be autonomous and acoustically homing. The submarine can deploy acoustic decoys and active torpedo jammers.		
Comment:		
Cf requirements A03, T01, T04 and T07. In basic solution, current OSCAR mechanism for anti-shipping torpedoes. No decoys or jammers.		

ID:	Requirement:	Priority:
T04	Torpedo firing	1
Description:		
The submarine can fire either a single torpedo or several torpedoes in a salvo against one target. Surface vessels and airborne platforms can fire single shots only (but may do so repeatedly). The submarine will fire torpedoes according to predefined rules (after a target is detected). Torpedo will avoid land to the degree allowed by the OSCAR model.		
Comment:		
New land avoidance feature in OSCAR will be based on topography from map/database. Cf requirement E02. In basic solution, current (enhanced) OSCAR mechanism.		

ID:	Requirement:	Priority:
T05	Wire-guided AAW missile	2
Description:		
The submarine can fire a wire-guided AAW missile against helicopters.		
Comment:		
The TRITON concept will be considered as a model for such a missile. Not in basic solution.		

ID:	Requirement:	Priority:
T06	Threat sensors	3
Description:		
The following threat sensors shall be modelled, and their performance calculated by an acoustic model: a) Submarine hull mounted acoustic sensor b) Submarine passive towed array sensor		
Comment:		
Cf requirement E03 and A04. Not in basic solution.		

ID:	Requirement:	Priority:
T07	Wire-guided torpedo	3
Description:		
The torpedo can be wire-guided from the submarine and thus use information from the submarine passive towed array sonar.		
Comment:		
Not in basic solution.		

4.2.4 Input/output requirements

ID:	Requirement:	Priority:
I01	Input	1
Description:		
The input of the extended OSCAR model consists of: a) Number and types of assets and threats b) Environment, including bottom topography and land contours c) Asset and threat parameters, such as position, speed and course. d) Tactics (manoeuvres, etc.)		
Comment:		
Cf also requirement E02. Bottom topography and land contours shall be imported from file. A relevant identifier, i e a geographical position related to the mapped area, must be specified.		

ID:	Requirement:	Priority:
I02	Output	1
Description:		
The output of the extended OSCAR model consists of: a) The MOE values b) Tools for detailed analysis of single simulation runs, i.e. an event log file. c) File containing data resulting from multiple (Monte Carlo) simulations		
Comment:		
Data file containing specified parameters can be transferred to Excel Workbook using DDE. Detection probabilities generated by LYBIN for OSCAR detection events shall be logged.		

ID:	Requirement:	Priority:
I03	MOE	1
Description:		
MOEs that will be used are: – Pd, Phit, etc for specified platforms and threats. – Standard normalized MOE (S_MOE) – Probability of escaping a torpedo, given a torpedo countermeasure reaction rule.		
Comment:		
Cf requirement I02. Countermeasure reaction rules are limited to those that can be represented in USIM. S_MOE is a measure balancing hits in assets and threats.		

ID:	Requirement:	Priority:
I04	Real data input	1
Description:		
Measured data can be used as input to the extended OSCAR model.		
Comment:		
Data could be e g bathy profiles, false alarm rate profiles or other input to the extended model. Cf also requirement A05. As basic solution, current LYBIN. False alarm rate as uniform distribution.		

4.2.5 Other requirements

ID:	Requirement:	Priority:
O01	Torpedo model	1
Description:		
The threat and asset torpedoes shall be modelled at an aggregate level, suited to the level of detail in the extended OSCAR ASW-model.		
Comment:		
The model in question is the FFI-model USIM. Cf requirements A03, T03 and O02. In basic solution, current OSCAR mechanism.		

ID:	Requirement:	Priority:
O02	PC performance	1
Description:		
The extended OSCAR model shall be used as a stand-alone unit, shall interact with the USIM torpedo model through HLA and shall be capable of running both single simulations and Monte Carlo simulations.		
Comment:		
The extended OSCAR model includes sonar performance modelling through elements from the LYBIN sonar model. USIM and OSCAR can be run on separate platforms if desirable. HLA and USIM not in basic solution.		

ID:	Requirement:	Priority:
O03	Graphical User Interface	1
Description:		
The GUI shall consist of the following: a) Area of operation in map window. b) Assets and threats (by symbols). c) Route of the assets and threats.		
Comment:		
Cf also requirements I01, A01 and T01. Relevant land contours shall be displayed in the map window.		

ID:	Requirement:	Priority:
O04	Change scenario during simulation	3
Description:		
It shall be possible to stop the simulation at any moment in time to change the scenario. After this the simulation will go on taking into account the changes made.		
Comment:		
Not in basic solution.		

ID:	Requirement:	Priority:
O05	Interactive simulation	3
Description:		
It shall be possible run the simulation interactively where the user, among other features, can initiate manoeuvres and countermeasures.		
Comment:		
Not in basic solution.		

5 NOMENCLATURE

ADS	Active Dipping Sonar
API	Application Programming Interface
ASW	Anti Submarine Warfare
CC	Collision Course
HLA	High Level Architecture
HMS	Hull Mounted Sonar
HVU	High Value Unit
IWS	Integrated Weapon System
LCP	Lost Contact Procedure
LUT	Look-up Table
MLA	Mean Line of Advance
MNTF	Multi-National Task Force
MPA	Maritime Patrol Aircraft
MSM	Maritime Sensor Model
MTW	Mini Torpedo Welcome
NF	New Frigate
OSCAR	Object-oriented Simulation for the Combat Analysis of Requirements
PIM	Position and Intended Movement
RTI	Run-Time Infrastructure
TA	Towed Array sonar
TAS	Towed Array Ship
TCM	Torpedo Countermeasure system
TMA	Target Motion Analysis

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