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DEVELOPING TACTICS USING LOW COST, ACCESSIBLE SIMULATIONS

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ABSTRACT

The Royal Navy's Maritime Warfare Centre (MWC) is responsible to the UK Commander-in-Chief Fleet (CinCFleet) and was formed with the purpose of developing operational tactics and procedures to optimize the capability of the Fleet's platforms, sensors and weapon systems.

Evaluating tactics at sea requires a considerable amount of forward planning and ties up valuable and expensive assets. It is therefore important that the candidate tactics must be developed to a sufficient level of maturity on-shore. This is done through a combination of individual brainpower, paper studies and computer simulation. The computer simulation must be inexpensive, totally flexible, sufficiently accurate, reliable and above all easily available to, and usable by, the individual tactical desk officers.

Any simulations developed need to be easily adaptable. Tactical Development is not a formally structured process; software development is not easy when there are no formal requirements. The MWC have investigated using the Spreadsheet Excel to form the basis of such simulations. This paper discusses the advantages and disadvantages of this approach, in creating simulations that can be used for developing tactics that have the necessary degree of flexibility, integrity and usability. A specific example of an application to a particular problem will be illustrated.

1 INTRODUCTION

The Maritime Warfare Centre is an organization responsible to UK Commander-in-Chief Fleet. It was formed with the purpose of developing operational tactics and procedures to optimize the capability of the Fleet's platforms, sensors and weapon systems. The Maritime Warfare Centre was formed from the tactics section of the Submarine Tactics and Weapons Group, the Fleet Operational Analysis Staff, the Surface Flotilla Tactical Development Group and the Naval Air Warfare Development Group.

The ultimate and final test of any tactic will be how well it works in the environment for which it is intended. This applies equally to the Under Water Warfare (UUW), Above Water Warfare (AWW) or Amphibious Land and Joint Warfare (ALJW) environments.

Figure 1: UWW, AWW and ALJW

While it may take only a single at-sea exercise to prove a tactic to be poor, it can take a number of exercises to prove a tactic to be a good one. Since Tactical Development is mostly an iterative process, a large number of exercises would be required if they were to be the only method for evaluating tactics. With the reduction in Defense spending in the West over the last few years, exercise opportunities are becoming increasingly scarce.

Although modelling tactics using a simulation is not a replacement for at-sea exercises, simulations can be used to ensure that only sensible and reasonably mature tactics are ever trialed at sea, and so reduce the exercise requirement.

Care needs to be taken however, to prevent modelling taking over the Tactical Development process. A tactic that has as its justification, "The computer told us this worked" is unlikely to find much favor at sea. The command at sea needs to understand *how* the tactics work, and large-scale computer modelling is not good at providing such explanations.

However, since most tactics are intended for times of hostility, testing the tactics under peace-time rules or in an exercise scenario may not be entirely realistic. In some cases simulation may be the only way that the effect of any additional factors that apply in time of hostility can be evaluated.

In this paper we discuss the difficulties faced by Tactical Developers as they try to use simulation to help them to understand and evaluate tactics. We describe why traditional methods for creating models and simulations are not suitable for Tactical Development within the MWC and outline the new approach being taken to evaluate tactics by simulation.

2 TACTICAL DEVELOPMENT WITHIN MWC

Tactical Development within MWC is a process undertaken by serving Royal Navy Officers, with the aim of providing guidance to the Command on Royal Navy vessels, on the best use of the Fleet's platforms, sensors and weapons systems. Being in command of an RN Vessel is a very demanding task in a changeable environment and it is not possible to define rigid tactics that the Command can use as doctrine.

As mentioned above what is provided to the Command is *guidance* intended to be taken and adapted to fit the current scenario in which the vessel is operating. The guidance produced by the MWC supplements the existing capability of the Command obtained through training and experience, to provide a coherent tactical approach that can be applied in any given scenario. This is an evolutionary process. It can take several years for a particular tactic to be fully developed.

Traditionally Tactical Development comprises five areas: Tasking, Concept, Exercise, Analysis and Products.

2.1 Tasking

The MWC is tasked to develop tactics to address requirements raised by each CinCFleet Type Commander (i.e. Submarine, Surface and Aviation). These requirements may arise from information received from sea suggesting that existing guidance needs to be questioned, or existing guidance may need to be updated to deal with a new threat or a change in the perception of a current threat. This tasking tends to be very general in nature.

2.2 Concept

The tasking received by the MWC is turned firstly into a loose requirement by Royal Navy Tactical Development Officers and from there into experimental tactics. This normally involves the use of paper or computer simulations. The experimental tactics that emerge must be expressed in a form that can be passed to a command team to be trialed during an at-sea exercise.

2.3 Exercise

An exercise involving a number of platforms will be designed specifically to create scenarios in which the experimental tactics are intended to apply. The Commanding Officers of the platforms must interpret the experimental tactics in the scenario as they see it. In support of the subsequent exercise analysis, the platforms involved are given a detailed list of manual and computer records to be collected.

2.4 Analysis

The data collected during the Exercise, along with the assessment provided by the Commanding Officers, are used by the MWC to determine the success or otherwise of the experimental tactics.

2.5 Products

The analysis process produces a number of deliverables; these include Analysis Reports, Lessons Learnt. This is fed back into the Concept area and the cycle repeated until firm Tactical Guidance can be produced.

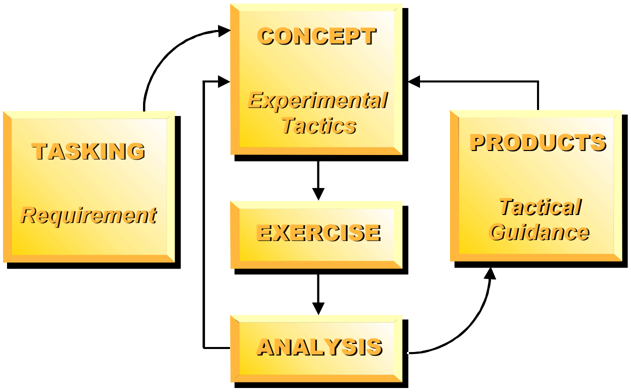

Figure 2: Tactical Development Cycle

3 TACTICAL DEVELOPMENT PROBLEM

3.1 Background

The problems of developing tactical guidance are well illustrated by concentrating on the particular area of Submarine tactical operations.

Submarine tactical operations involve searching for, detecting, approaching, tracking and attacking or evading other platforms. The main tactical problem in all of these phases is how to maneuver the submarine to best advantage (to "maintain tactical control") i.e. when to change course/speed and what to change it to. Much of the Tactical Development therefore concerns when and how to make maneuver decisions.

3.2 Tactical Picture

The submarine is a covert platform - it needs to remain undetected to be effective. It therefore obtains information by using its sonars to listen to the surrounding noise. When a submarine gains contact on another platform through the noise it is making, it only obtains a bearing of the platform.

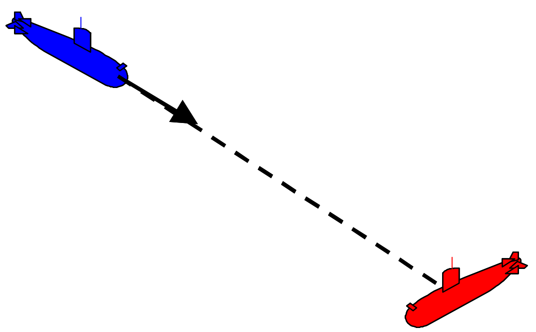

Figure 3: Initial Detection

However, to make tactical decisions, the command team needs to have some idea of the range and velocity of the contacts detected by their sonar system. This must be obtained by moving ownship so as to deliberately change the position of the contacts relative to ownship. From the way that the noise sources move, it is possible to infer the range and velocity of the contacts making the noise and so build up a tactical picture.

This means of constructing a tactical picture results in a picture that contains a certain degree of uncertainty. This uncertainty is very large for a contact when it is first detected and decreases at a rate dependent on ownship and contact movement.

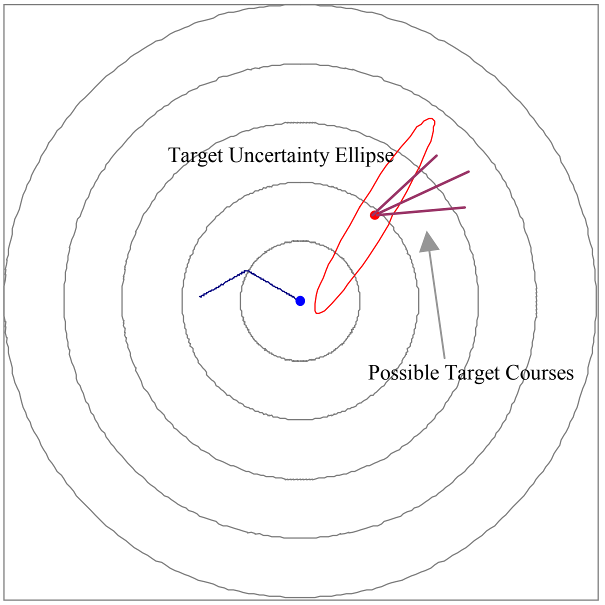

Figure 4: Where is the Contact?

3.3 Tactical Problem

Solving the tactical problem would not be too difficult if the tactical picture provided exact positions and velocities of all the contacts. The Submarine Commander may know where he wants to place his submarine relative to a particular contact, for example to place his submarine at a point X on the contact's beam, but he cannot determine precisely where point X is.

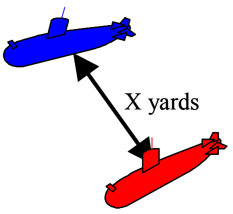

Figure 5: The Tactical Problem

So, decision making for a Submarine Commander combines the problem of how to maneuver his submarine in a situation that is uncertain with the added problem that every maneuver he makes affects that uncertainty. Tactical problems in other domains may involve decision-making in the face of uncertainty and others may involve information gathering to reduce uncertainty, but there is not the same immediate and direct link between the two.

The relationship between submarine maneuvers and uncertainty is well understood but mathematically complex. The precise effect of any maneuver in reducing uncertainty does not depend solely on where ownship is relative to the contact but on how both ownship and the contact got there.

Tactical guidance must take this into account. Because of the infinite number of different ways a scenario could have developed, specific tactical guidance is difficult to produce and rarely appropriate. It therefore comes in the form of advice and high level rules that the command must interpret in the specific situation he finds himself in.

3.4 Tactical Guidance

The Tactical Development requirements that the MWC receives are clear but not necessarily detailed or specific. In the Tactical Development process, solutions will not spring into the mind of the Tactical Developer fully formed, but will have to be worked on. Initially, the solutions will be full of holes and probably contain inconsistencies. Even the final published guidance will not cover every eventuality with definitive instructions. Tactical guidance is not a set of explicit instructions for an autonomous vehicle to follow but useful information for an intelligent and well-trained command team to apply along with all the other tactical knowledge and guidance available to them.

Tactical guidance is *written* guidance and this means that it must be *interpreted* by the reader – so it does need to be as clear and unambiguous as possible while still being adaptable to a range of situations. The challenge of the Tactical Development process is how to ensure the correct balance is achieved.

The Tactical Developer needs a way of assessing his various tactical ideas as he develops them. Making use of his own and other's experience, training and basic common sense is necessary but is not sufficient. Where he has particular difficulty is in assessing ideas that lie outside his own and others direct experience, or where the assessment requires complex or extensive calculation.

For all these reasons, a computer simulation to assess tactics represented as a set of explicit rules is unlikely to be helpful. Certainly, a programmer would not be able to construct such a simulation from the written guidance alone. He would require extensive assistance from the Tactical Developers, which reduces their availability for developing tactics.

What is the way ahead? To see it, we need to examine the simulation requirements more closely.

4 SIMULATION REQUIREMENTS

In the Tactical Development process there are a number of stages. These do not necessarily all follow directly from each other but may contain many internal loops.

If we examine the requirements at each of these stages and possible loops, it is possible to see where computer simulation can be used to assist.

4.1 Initial Formulation of Problem

Tactical problems arise, and will be expressed, in a number of different ways and at different levels of detail. The Tactical Developer needs to translate the problem into a form that he can actually work with. This is not trivial.

A major difficulty the Tactical Developer has is in obtaining a "feel" for the nature and extent of the tactical problem. The MWC staff can provide advice and information, but that is only an incomplete substitute for directly experiencing the problem. To try to gain direct experience by time at sea may be possible but is expensive and time consuming. A simulation in which he can set up the problem in a range of different scenarios and maneuver a submarine through the scenario can play an important part in helping the Tactical Developer understand and evaluate the problem. It can also help to spark ideas as to how to tackle it.

4.2 Initial Tactical Ideas

The requirement at the initial ideas stage is for a rapid turnaround through quick feedback. Paper studies can help but can take some time and effort to conduct. High fidelity modelling of the submarine and its systems is unlikely to be illuminating and may actually get in the way by providing too much information. A simpler simulation could be used to provide a good indicator but, traditionally, such simulations require a complete set of tactical rules to follow before they behave in a sensible manner.

Generating a complete set of rules from tentative tactical guidance purely for use in a simulation can be *very* time-consuming and wasteful. It forces the Tactical Developer to think at a level of detail that is much greater than his current understanding of the problem and much greater than that required in the eventual guidance itself.

Again results are best achieved with a simple simulation in which the Tactical Developer can maneuver the submarine, with feedback and analysis under his control so that he can determine the likely effectiveness of his tactics.

4.3 Draft Guidance

Once tactical ideas become more concrete they are issued as Draft Guidance for comment. By this point the Tactical Developer must be confident that the tactics are worth further consideration. To reach this stage, the tactics must have been rigorously tested "in-house". This is normally achieved by peer review and discussion that relies on experience and opinion. Important aspects that must be considered are the clarity and lack of ambiguity in the tactical guidance.

A simulation that is accessible to all who review the guidance would allow the reviewers to try out the guidance and obtain a much better appreciation of whether they believe it is sound. A degree of independent objectivity could be achieved by defining a set of "standard" scenarios against which each reviewer is to test the guidance. In this way both the effectiveness of the guidance can be examined and ambiguity detected.

An important aspect of this approach is that it is the readers of the guidance who interpret and apply it. Testing the guidance as a set of rules in a computer simulation only tests one particular interpretation of the guidance.

4.4 At Sea Evaluation/Dedicated Exercise

Testing guidance at sea in an exercise involving real vessels is expensive in terms of the assets involved, the planning effort required pre-exercise, and the analysis effort required post-exercise.

An exercise to evaluate tactics has to be highly structured in order to produce the required data. By running the exercise through a simple simulation tool beforehand, confidence that the tactical guidance will be fully tested during the exercise can be gained.

Prior to the exercise, the submarines involved are carefully briefed, but there is still a learning curve to be overcome when applying the tactics for the first time. This could be significantly reduced with the aid of simulation to illustrate the tactical guidance both before and during the exercise.

4.5 Analysis of Results

As part of the analysis process, the data gathered during an exercise can be re-run in a simulation to get a better understanding of how the tactical guidance was applied. Some of the analysis methods developed during the initial Tactical Development period may be re-usable. Exercise data can also be used to help validate the simulation.

4.6 Formal Publication

Published tactics can often be difficult to fully understand and appreciate through text alone. This can be a problem for a command team when they first apply a new tactic for real. This problem could be partially overcome if the written tactics were issued along with a disk containing a simulation and some carefully chosen example scenarios that can be run on a laptop computer.

4.7 Simulation Requirements

The development process described above imposes the following requirements on a simulation:

1. Accessible and available (to whoever wants to use it)
2. Easy to use and understand
3. Adaptable (to different scenarios, tactics and analysis)
4. Cheap
5. Usable by a single user
6. Portable (so that it can be issued to submarines)

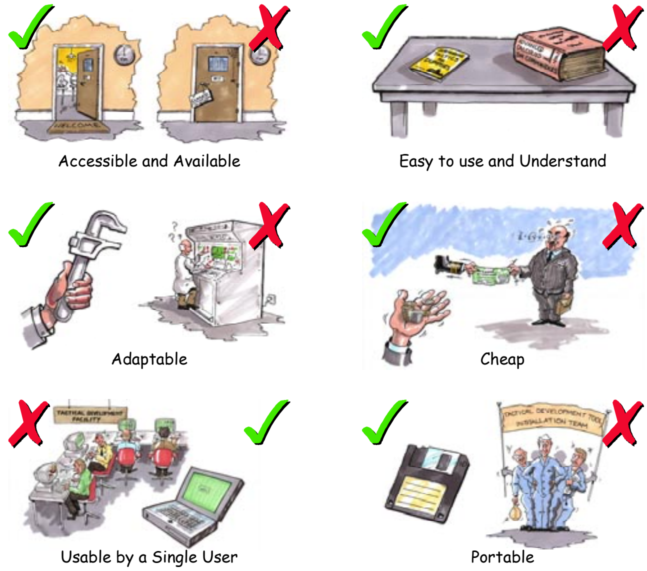

Figure 6: Simulation Requirements

The first three of these take effort to achieve and can result in the fourth not being met. Requirements 5 and 6 are quite constraining and completely rule out large-scale simulations running on dedicated hardware and requiring programming support to set up.

Requirement 5 is interesting. The user cannot try out tactics in a scenario he has defined himself unless there is a method for introducing a certain amount of randomness through the scenario set-up.

Initial investigations indicated that these requirements may be met by making use of a spreadsheet such as Microsoft Excel. This has the advantage that it is installed on most PCs, is familiar to the user and is easy to use and understand. It provides the infrastructure and analysis functionality and can be supplemented with functions designed to simulate particular aspects of the submarine problem.

Whether this can provide a suitable means for building a simulation to support Tactical Development is the subject of an ongoing investigation at MWC that we are reporting here.

5 SIMULATION COMPONENTS – DESCRIPTION

The two main tactical system components within a submarine that the command uses to make tactical decisions are the sonar system(s) and the command system. In a simulation for developing tactics, the performance of these systems must be representative of their actual performance including the appearance of any displays.

The type of tactics that we are interested in are those that only depend on some general level of performance from the submarine systems. We will be interested in how robust the tactics are and how sensitive their effectiveness is to the level of system performance, i.e. the detection range or accuracy of the sonar. Ensuring the tactics extract the very last ounce of performance from these systems is a much more exacting and detailed problem and not really amenable to desktop simulation.

The major effort has concentrated on providing a simulation of the tactical picture compilation process that is realistic in its behavior and can be tuned to represent different levels of performance for real world, at-sea scenarios. Since it is sonar data that is used in this compilation process, some effort has gone into providing simple, but realistic, sonar models.

The user needs to see the tactical picture and sonar data on types of displays familiar to him. This poses particular problems when using Excel. Excel does not provide graphics, only graphs, which are mostly geared towards business rather than scientific or engineering applications. There are also a number of "undocumented features" concerned with manipulating graphs using VBA in Excel that require specific and rather odd methods to be employed.

Simple models of ship motion are required which have realistic, and controllable, acceleration and turning characteristics. The user must also have some control over the platforms in the scenario. There must be the capability to generate random scenarios so that when interacting with targets their position, velocity and maneuver pattern is unknown to him. He must also be able to store, recall and step through scenarios and to do all this in an efficient and simple way so that he is not discouraged from using the tool by the amount of manipulation required.

5.1 Tactical Picture Compilation

The uncertainty in the knowledge about the position and velocity of each platform in the tactical picture depends on:

1. The data used
2. The accuracy of the data used
3. The amount of data used
4. The geometric and dynamic relationships between ownship and the platform over the time period covered by the data
5. The trajectory described by the platform

The simulation of the Tactical Picture Compilation process uses a statistical method known as the Cramer-Rao Lower Bound (CRLB). The CRLB imposes a lower limit on how accurately values for a set of parameters (such as position and velocity) can be inferred from the data used to estimate them.

No algorithm working on the same set of data under the same assumptions can perform better than the CRLB. The CRLB can be used along with a random number generator to generate random estimates of a platform's position and velocity. This can be used to simulate an ideal algorithm for estimating positions and velocities of platforms that are being tracked by sonar. This is the principle. In practice there are a number of problems to overcome.

1. Real tactical picture algorithms have a number of additional errors and mismatches between the assumptions used in the algorithm and reality. The simulation copes with this by using a simple degradation factor that decreases the accuracy. This allows the algorithm to be tuned to match observed performance.
2. Real tactical picture algorithms do not produce random estimates that are independent of each other. There is a high degree of correlation between successive estimates that must be reproduced if the simulation of the tactical picture algorithm is to appear realistic.
3. A real tactical picture algorithm provides an estimate of the position and velocity of each contact plus uncertainty bounds on those estimates. The command team makes use of these bounds when making their tactical decisions. The CRLB applies only to the position and velocity estimates, not to the uncertainty bounds. However, it is reasonable to suppose that a well-behaved algorithm will provide uncertainty estimates that are consistent with its actual performance. Since the CRLB is used to simulate the performance, it can also be used to simulate the uncertainty bounds.
4. The more data that is available to the algorithm, the more that has to be processed by the CRLB simulation. An efficient means of doing this had to be found. A formulation in which the amount of processing is independent of the amount of data was devised so that speed of the simulation remains constant regardless of how much sonar data has been generated.
5. There are a number of minor problems connected with the use of different co-ordinate systems (Cartesian, polar) and conversions between them. Sonar measurements are of bearing, which is a polar co-ordinate and depends on the position of the sonar to define the origin, and of frequency that is affected by ownship and target radial speed along the bearing line. The position and velocity of a platform is however, more conveniently expressed in Cartesian co-ordinates in which the origin can remain fixed.

5.2 Sonar Models

The CRLB method of simulating tactical picture compilation does not require actual sonar data to be generated – it requires only to know that it is being generated and the rate and accuracy at which the measurements are being made.

Simulation of a sonar display will therefore only add value to the overall simulation if it contains important features that are only apparent through that display. The main feature of a sonar display that the command typically sees is the bearing of the contact. This does not require a detailed simulation of a sonar screen. If a realistic simulation were required, it would be beyond the graphical capability of Excel.

The requirement for there to be a sonar model that generates measurements arises from the fact that the submarine command team make decisions based on the observed bearing movement of a contact as provided by the sonar as well as on the tactical picture. This can easily be achieved on a display of bearing against time, which is familiar to all submariners.

The sonar model for generating measurements with sufficient realism does not require to be complex. We need to simulate the following characteristics:

1. Detection Range
2. Arc limits
3. Accuracy
4. Reporting Rate

5.2.1 Detection Range

The detection process is simulated through a defined detection range. A full sonar model would contain the parameters that define the sonar performance, the threat platform and the environment, and combines these with a propagation loss calculation to determine whether the threat platform was detected. When developing tactics questions such as, “How well do these tactics work against submarine type X in area Y in early spring?” over-complicate what the real problem is. It is more appropriate to ask “How well do these tactics work if the detection range against the threat is between X and Y yards?”

As with the tactical picture itself, it is important to consider how the user’s uncertainty in the detection range and the variability in the detection range (both deterministic and random) affects how he employs the tactics. This uncertainty applies in three cases: the range at which the contact is first detected, is lost and is regained. The user can never be confident that the contact is regained at the same range at which it was lost or at which it was initially detected.

The user when setting up the scenario defines the detection range to lie within certain bounds. The actual detection range that applies at any point in the scenario is varied so that the user does not know the precise range at which he will detect, lose or regain contact.

5.2.2 Arc Limits

A sonar does not necessarily have 360 degree coverage. Within the simulation, the arcs that it does cover, relative to ownship heading, are definable by the user.

5.2.3 Accuracy

The accuracy of the sonar measurements is crucial not only in determining the amount of scatter that appears on the time-bearing display but also as an input to the tactical picture simulation.

The two main sonar measurements we are interested in, bearing and frequency, are fundamentally restricted by the beamwidth and the analysis period respectively. Beamwidth in turn depends on the relative bearing and frequency or frequency band of the signal. The analysis period is typically the reciprocal of the reporting rate.

A simple sonar accuracy model can be constructed using a table of beamwidths against relative bearing and frequency, and by making use of the reporting rate.

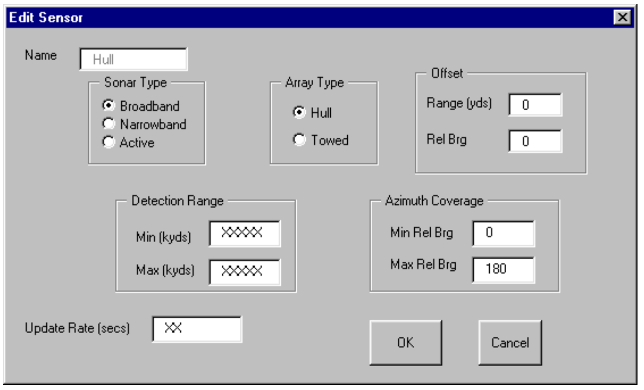

Figure 7: Sensor Setup

5.3 Platform Motion

The motion of the platforms needs to be realistic for the type of tactics being developed. As discussed above, the tactics we are primarily concerned with involve maneuvering the submarine. However, the maneuvers we consider are quite general – e.g. alter course by 30 degrees. We are concerned about how long it takes to make such a turn and where the platform will be at the end of it but the precise trajectory through the turn, dependent on the specific amount of helm and revolutions used is of secondary consideration.

For the threat platforms, we also need to model gradual turns. A particular problem in submarine tactics is detecting when a target has maneuvered and when it has stopped maneuvering.

We therefore need a motion model that generates gradual turns with roughly the correct turn time and movement. We do this by defining simple turning circles for the platforms. We also need to simulate the motion of any towed array during the turn and the time period over which it is unavailable.

5.4 Scenario Control

The user has to be able to control the speed at which the scenario develops. Submarine engagements can last several hours, much of which is spent gathering information rather than making tactical decisions. Clearly faster than real time operation is required but with that is needed the ability to stop the scenario at key decision points so that the user can catch up with the information gathered.

The solution we have adopted is to combine both time stepping and data stepping in the user control. The user specifies the scenario "step" interval in terms of a time step and also in terms of a "number of sonar measurements" step. The actual step taken will be determined by whichever happens first. The user can alter these at any time as the scenario is running. Typically what he would do is set the step size large during a data-gathering period so that he can quickly step through it. When he approaches a decision point he would set the step size small, in order to examine the data more closely.

5.5 Analysis

The simulation code is in its own workbook with individual scenarios stored as separate workbooks. The data used by the simulation is stored within Excel Sheets, e.g. sensor cuts "from the sonar", the solution data from the CRLB, truth data from the scenario etc. are all stored in different sheets. This means that the data is easily available for the Tactical Developer to perform analysis on, using the intrinsic functions within Excel. This is fundamentally different from the types of analysis available with more traditional simulations, where the full extent of the data is not usually accessible to the operator. Limited analysis functions are either hard coded into the simulation or data has to be exported to another application (e.g. Excel) to allow analysis to be performed.

6 ADVANTAGES AND DISADVANTAGES OF USING EXCEL

Inevitably there are disadvantages with using an application as unsophisticated as Excel as the basis for a simulation, compared with a bespoke simulation.

6.1 Disadvantages

The disadvantages are, however, surprisingly few and mainly irritations rather than fundamental short-comings.

1. Excel does not provide graphics, only graphs. Although there are a large number of standard graphs that can be plotted, each individual graph is very constrained in how data can be plotted. For example, a bearing-time graph that can "wrap" around at 0/360 degrees has so far proved beyond us.
2. The programming language behind Excel – Visual Basic for Applications – is an interpreted language, which means that algorithms coded up in VBA might execute slowly. This can be overcome by coding them separately and providing them in DLLs.
3. There is the assumption that all potential users of the simulation will have access to Excel and preferably a particular version – some versions of Excel have not been completely backward compatible.

6.2 Advantages

The disadvantages in using Excel are easily outweighed by the advantages.

1. User familiarity. All the advantages really arise from this. It is the familiarity of computer users with the use of spreadsheets that makes this approach so attractive.
2. Visibility of the data. All the input data used and output data generated is written to worksheets for the user to view.
3. Portability. A PC with Excel is all that is required. There are no installation procedures or special run-time licenses required.
4. Transparency. The user can easily understand the workings of the simulation since all the data used and generated is accessible to him.
5. Analysis. The user is in complete control of the analysis he performs. All the data generated by the simulation is available to him. Each scenario is a separate workbook that can be opened and the results re-analyzed completely independently of the simulation itself.
6. Extendibility. All interfaces with the simulation are through data written to worksheets. This makes for very modular code. New modules to perform particular functions can be generated separately and interfaced to the existing worksheets without re-engineering the entire application.

7 SIMULATION – APPLICATION

The first tactical situation we have applied this approach to – and which acted as the driver for its development – was a one-on-one scenario in which the aim was to go from initial detection of a threat submarine through to a stable tracking position without being counter-detected, and then to maintain that position through a number of opposing submarine maneuvers.

There is a considerable amount of published tactics for this basic scenario. However, as the nature of the threats changes, knowledge about the threats increases, new equipment is introduced and as experience is fed back from sea, this scenario needs frequent reassessment, which is easily achievable by modifying only the parameters already implemented in the simulation.

The simulation has been used to examine the effect of a particular set of tactical constraints on ownship maneuvers on the accuracy of the tactical picture. In particular whether the tactical picture could be maintained sufficiently to allow ownship to obey those tactical constraints in a safe and tactically advantageous way.

This is a classic submarine tactical problem where the tactics depend very closely on the tactical picture and the tactical picture depends closely on the tactics. Trying to disentangle this without computer assistance is very difficult. As a measure of the success of this approach, draft tactical guidance has been published containing graphs of data produced by this simulation to illustrate the effect of the tactics.

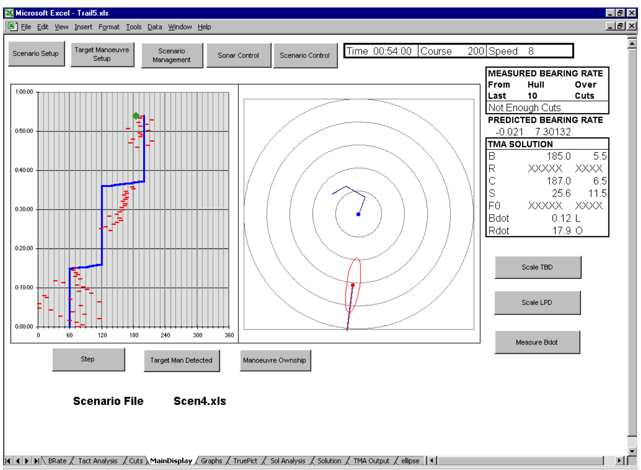

Figure 8: Example Simulation

8 FUTURE

The constraints that Excel imposes on the way simulation must be developed makes it easy to incorporate future enhancements. It is anticipated that in the future the following facilities will be added to the simulation.

8.1 Sonar Model

As already discussed the sonar model within the simulation is very simplistic but sufficient for most scenarios in which only the fact that the target is in contact is important. Future applications may require investigation of search tactics or tactics that require operation at the limits of detectability where a better representation of the gaining and loss of contact will be required. There are a number of parameters that will affect this and a move towards a more realistic representation of the sonar through the sonar equation will be necessary.

8.2 Analysis

Most of the analysis is currently performed on an ad-hoc basis by the user himself. While this provides the flexibility required, it can be time consuming for each user to generate similar analysis methods. When there is a requirement for a specific analysis capability this can be developed and added to a library of analysis functions that can be loaded along with the simulation.

This has already been seen in the example shown. An important consideration in developing covert tactics is whether ownship is likely to have been detected by the target's sonar. To assist in the analysis of this, some specific analysis functions have been developed and included with the simulation.

8.3 Recording and Replay

Due to the nature of tactical guidance there is often some ambiguity in the interpretation of the guidance. While tactics are trialed at sea the Command is required to keep a detailed Narrative of why they have made decisions when they did. A similar facility within the simulation for recording decisions made would be useful and would make the use of the simulation for formally testing tactics much simpler.

It is also possible to reconstruct the interaction of the units involved in an at-sea exercise from data recorded by them. A facility to replay actual scenarios through the simulation and examine the decisions made at the time would be useful both for better understanding of the thought processes of the command at sea and for validation of the simulation itself.

9 CONCLUSION

The MWC have identified the requirements for the type of computer simulation that can assist them in developing tactics.

These requirements have driven them away from complex, bespoke computer models towards a simpler approach making use of a software package, Microsoft Excel, widely available and familiar to all likely users.

A simple simulation has been developed to test whether these requirements can actually be satisfied. The conclusion is that, with a few minor problems, it can and has been done so successfully.

MWC have now identified further developments and are continuing to investigate to what extent they can be satisfied by such a simple and cheap package.

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