The design and development of software simulating interactive Marine Radar and Electronic Navigation Instruments based on a PC Platform.

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DECLARATION

I, the undersigned, hereby declare that the contents of this dissertation and the developed software

The design and development of software simulating interactive Marine Radar and Electronic Navigation Instruments based on a PC Platform.

represent the personal work of Kieron Michael Tesling Cox. The opinions contained therein are therefore those of the author, and not of the Technikon Natal.

Signed

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Capt M.Stewart of Technikon Natal who encouraged me to record my work in this dissertation and has supervised this work.

My Family for the sacrifices they made while I worked on this project.

Abstract

This study was intended to develop suitable software to emulate Marine Radar and other Electronic Navigation Systems found on Merchant vessels. This equipment includes Radar with or without Automatic Radar Plotting facilities, Navstar Global Positioning Systems, Echo Sounders, Radio Direction Finder as well as Decca Navigator. Certain of these aids are required in the Radar Simulator Specifications [ref 1] to which the SAMSA - South African Maritime Safety Authority (formerly the South African Department of Transport) adheres. SAMSA is the authority which approves Maritime training and Simulators in South Africa in compliance with International standards as laid down by IMO - International Maritime Organisation. The software will allow full interaction between a number of computers simulating vessel encounters in various geographical areas in real time. Software design has been allowed to include up to 8 student 'vessels' (using either one or two computers each) interacting with each other as well as a control terminal where other vessels are controlled by the Simulation Controller.

Introduction

It is a prerequisite laid down by International Maritime Organisation [ref 2 - STCW Radar Simulator Specification Section A-1/12 Standards governing the use of Simulators] that the training of Deck Officers contains a component of simulator training specifically with reference to Radar and Electronic Navigation Systems. South Africa currently models itself on the British requirements in this regard and the specifications for such equipment are laid down in the Radar Simulator Specifications [ref 1].

Until about 1984, specialised hardware and software were costly thus limiting the number of institutions that were prepared or able to install the required hardware. In 1982 the South African Merchant Navy Academy 'General Botha' installed a simulator of the type discussed. The final cost of this installation was slightly in excess of R 600 000 [ref 3] at a time when the exchange rate was R 1,60 to £ 1. Similar Radar Simulators today cost in excess of R 5 000 000.

Since 1984, the advance in microcomputer power has allowed the development of such simulators on standard computers. However, systems imported from other countries have had many problems. In discussion with Capt W.R.Douglas (formerly simulator lecturer at the Training Centre for Seamen, now Head of Seamen's Church Institute in Paducah, Kentucky, USA) as well as Capt A.Parkinson (lecturer now Head of Department, Maritime Studies, Technikon Natal) as well as from personal experience it is apparent that software is sometimes not user friendly, not totally debugged, that backup is non-existent and also costly because of exchange rates.

A typical example relates to the Simulator purchased by SAMNA General Botha in 1982. This still had a bug when it was decommissioned in 1995 in that the displayed CPA (Closest Point of Approach) of vessel 'A' to vessel 'B' would not be the same as the displayed CPA of vessel 'B' to vessel 'A'.

The aim of this study was to design an efficient, cost effective software package so as to create an interactive radar simulation using a network of relatively standard computers. This development was designed with reference to both the STCW Radar Simulator Specifications [ref 2] as well as the UK Radar Simulator Specifications [ref 1]

Algorithms were developed to give realistic range fall off of targets, coast and other navigational objects, as well as realistic shadowing caused by obstructions.

In addition the exchange of information by the computers used in the system has been enhanced and documented for further expansion.

The project was aimed at developing a flexible, expandable, adaptable Marine Radar and Electronic Navigation Instruments Simulator to meet statutory requirements as well as suiting the requirements of Training Institutions, for training marine students at all levels. It is suggested that for this system to be truly modifiable and cost effective that it would be produced locally so that feedback can be used to improve and expand the system as new technological trends occur.

This dissertation will cover various aspects needed to raise the software developed prior to 1993 by the author to a level that meets the statutory requirements. In this regard certain aspects have been assumed.

The simulated performance of the Radar and ARPA conforms with the IMO Specifications for the appropriate equipment [ref 4] although the ARPA tracking algorithms were developed prior to this dissertation and will be assumed to be available for this purpose.

Additional algorithms were incorporated so as to resolve various hyperbolic calculations for position determination on a terrestrial spheroid. This ensures that the readings that various equipment display is indicative of the position of the vessels as determined by the simulator.

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CHAPTER 1

INTRODUCTION

PROPOSAL

This study is intended to develop suitable software to emulate Marine Radar and other Electronic Navigation Systems. The software would allow full interaction between various computers, representing different vessels operated by separate groups of students encountering each other as well as other 'vessels' in various geographical areas in real time.

The software will be designed to comply with both STCW radar Simulator Specifications [ref 2] as well as UK Radar Simulator Specifications [ref 1] as required by the South African Department of Transport.

To achieve this result various software modules need to be developed as well as integrating various software modules developed previously by the author for Part Task Training. This latter refers to Electronic Navigation Aids such as a Decca 21, Radio Direction Finder and Global Positioning System developed by the author in order to train and assess students in the correct setting up and interpretation of the equipment being represented. In addition ship handling characteristics and ARPA tracking algorithms will be integrated but not discussed within this dissertation.

The additional modules that need to be developed includes the following.

- Suitable software to enable the transfer of data from one computer to another using a suitable network to allow full interaction and monitoring.
- Develop algorithms for displaying targets, land and other navigational objects that reasonably display these objects in an acceptable manner with respect to height and radar detection, shadowing, range fall-off and on a rotating sweep similar to that seen

on a real radar.

- Develop algorithms to emulate radar controls for gain, tuning, STC (Sensitivity Time Control or Sea Clutter Control), FTC(Fast Time Constant - Rain Clutter Control) etc

END USERS

For the success of this project, the possible institutions, organisations and companies that might require a simulator for their training need to be identified. At the same time the actual participants in the simulation exercises need to be identified so that the simulator can meet their needs specifically.

It would clearly be desirable for most institutions in this country to use common software and systems. Advantages would include the following.

- Cost effective - the more a product is used the cheaper it becomes. If a product is shared by a large number of users, the major costs of research and development are shared. In the case of computer software specifically, these are in effect the only costs incurred. If standard hardware can be used, this may already be available on site and is not part of the costing. In the case of this project however, there are certain hardware requirements that are specific if full approval by various authorities is required. An advantage, however, is that lower level simulations (not approved by the authorities) could be run on identical software as a much lower cost. This would for example, allow students at a lower level (such as NSRI - National Sea Rescue Institute, the leisure market, secondary school Maritime students, etc), who previously did not have access to radar simulation, to derive benefit from the advantages of full Simulation.

- Feedback - a major advantage of locally produced equipment or software is to obtain as many ideas and viewpoints that affect the local situation as possible. Therefore the greater the number of users the faster the feedback period. Problem areas would be more clearly identified by other users. Complications could be resolved by contacting any other simulation controller - not of necessity the developer.

- Familiarity - students, who due to various circumstances, change the centre of learning during their career, will meet the same equipment at other centres. Ideally all the software that he uses should follow similar protocols. Although there is a trend in this direction from the major software suppliers there are distinct differences in the protocols adopted in educational software. Certain PC based simulators use dedicated keyboards, others use the standard keyboard while others use mouse or trackball. In addition to these protocols, there are also software concepts that vary from program to program. An example might be how a user exits from the program.

- Common standards - if similar equipment is used at different institutions there is a far greater possibility of common standards being applied. For example if two institutions use different simulators, then the strengths of each are likely to be highlighted in their respective courses. In a previous situation two institutions had different equipment with different geographical areas. This prevented exercises being exchanged by the operators. Effective exercises could be exchanged by simply forwarding a disc of data.

- Distance - South Africa is a large country and for training to be cost effective, it is desirable that students are able to undergo training at centres near their normal place of residence. For this reason, the author believes that multiple facilities are required in South Africa rather than a single system at one centre. At low level training, a single person equipped with a couple of discs can in effect run a full simulator using relatively standard hardware. Students could in fact carry out Part Task Training using identical software on a single computer in preparation for a full interactive course. Radar simulation combines a number of skills which the student is trained to carry out. For example to satisfactorily gain benefit from radar simulation a student must be able to operate the radar controls correctly, interpret the display, be able to carry out radar plotting, be able to apply his knowledge of the Rule of the Road, carry out chart work and so on. This simulator will be designed so that it can be run either fully interactive as well as on a single computer so that a student may gain confidence in the radar controls outside of the simulator facility. This could conceivably be done at any computer.

Possible users in the Republic of South Africa include the Department of Maritime studies of both Technikon Natal and the Cape Technikon, the Training Centre for Seamen (Cape Town), various private educational organisations training the leisure market as well as semi professional organisations such as the National Sea Rescue Institute - in this case the course, and simulator, can be taken to the various centres and training carried out at that place. This is, of course, cost effective in terms of logistics.

Other organisations that have been identified include certain companies that are desirous of running in-house upgrading courses such as Irvin and Johnson (Trawling Division) and Portnet. The South African Navy could also benefit from a cost effective system for training at multiple centres rather than from a single, very expensive unit at a single centre.

North of our borders there are two educational institutions in Namibia - the Seamen's Training Centre in Walvis Bay, and the Rossing Foundation in Luderitz. Both institutions have in fact purchased low level *Radsim* simulators. Other possibilities are in Maputo, Mozambique as well as Luanda in Angola and also export to the rest of the world.

Provided that it meets the requirements of various authorities, it will also be acceptable in the United Kingdom at a cost below that of any similar product available in that country. It is anticipated that this product, running a 4 ship simulator could be installed at a cost of under R 300 000 including all hardware. In 1992 (exchange rate R5.3 =£1) a similar system from Sea Information Systems (UK) cost R 410 415 [ref 5] while from Microsim (UK) the quotation was R 514 100 [ref 6]. Acceptance locally and thorough fault finding would be desirable before attempting to export though.

HISTORICAL DEVELOPMENT

The author's first contact with personal computers was in 1983 with the Apple 2 computer. Subsequently a BBC microcomputer was purchased. One of the first programming attempts was in fact an ARPA (Automatic Radar Plotting Aid) display with basic ARPA functions being demonstrable for teaching purposes. The graphics capability was, in those days, spectacular but far from acceptable.

In December 1987, the author sighted a radar simulation written for the BBC computer by Sea Information Systems. With some coercion from W.R.Douglas (of the Training Centre for Seamen - now at Seamen's Church Institute in Paducah, Kentucky), the challenge was accepted to produce a similar version. Within two months an operational radar plotting trainer was developed in BBC Basic on the microcomputer. Exercises could be loaded and radar plotting practised. However due to the limited memory and speed of the computer, there was little that could be done to enhance or expand the simulation.

In 1988 an IBM compatible XT computer with Hercules monitor was purchased. The program was rewritten in True Basic and operated successfully with 10 targets. Although coastline and interactive operation were planned, lack of finance precluded rapid development.

By the end of the 1988, an EGA (or VGA medium resolution) compatible version was available.

By August 1989 a demonstration version with a crude coastline (straight line only) was available.

In 1992 the first interactive simulator (using serial communication) was installed at Irvin & Johnson (Trawling Division) and subsequently two more installations were made at Luderitz and the Training Centre for Seamen in Cape Town.

The coastline was gradually improved and in 1993 a realistic radar picture was produced.

The above developments could only occur with a parallel technological advances in microcomputer development. As indicated above early developments were made on a 6502 processor moving to an IBM compatible computer (Intel 8086) running at 8 MHZ.

Advances in computer technology through the so called AT (Advanced Technology or 80286 processor) through the 386 up to the 486 computer running at 100 MHZ has allowed the addition of more features while still maintaining an acceptable display. In addition advances in Video Cards and Monitors from Hercules, through EGA, VGA to Super VGA with resolutions of up to 1024 by 768 pixels has been essential for approval.

With respect to the Development Software available to the author, the prime advances have been in development of video drivers suitable for the resolution required.

The intention of this dissertation is to advance work so that the simulator will meet all the requirements of laid down specifications.

COMPARATIVE SYSTEMS

SOLARTRON

The author's experience on simulators was first as a student on an Analogue Solartron Simulator driving two 'own ships' and four 'targets'. A limited number - normally 4 or 6 students - were divided into two groups so as to man each 'own ship' and carry out navigation, blind pilotage and collision avoidance while interacting with the other 'own ship' as well as the four 'targets' controlled by the Simulator Controller. The coastline was stored on photographic plates and presented on real radar sets.

As a lecturer, the author has controlled a newer digital Solartron Simulator driving 3 own ships, 66 targets with certain electronic navigation aids being available on one ship. Realistic equipment was again used and the coastline, stored in digital format, was very realistic.

When this system was purchased, Capt F.Bester (Simulator lecturer at SAMNA General Botha and now with the Department of Transport) selected this system as the most suitable for the college. It was considered by the staff (Capt Bester, Capt Dernier and the author) as being very sophisticated and was of course, very expensive at that time costing just over R 600 000 [ref 3]. A number of disadvantages became apparent over the years.

- The software was written for a PDP 11/34 mini computer (two 8" floppy discs, 5 MByte hard drive, 64 K ram - magnetic core, etc). The computer operated through proprietary electronic circuitry (requiring two racks of circuit boards) with a second processor handling the coastline. This data was then sent in radar format to a series of different radar displays supplied by different companies.

  Within 10 years it was impossible to obtain new spares for the PDP11/34 and only spares from other old computers could be used. Purchase of disc drives or 8" floppy disc media became almost impossible.

A failure in any single component generally caused complete failure and was difficult to trace. Approximately 60 PCB's (Printed Circuit Board) were used in the proprietary circuitry alone. Generally one component was replaced at a time until the offending component was identified. On one occasion two components failed, resulting in a very time consuming exercise of replacing two components at a time until both these components were identified.

- Other information was transmitted via a two wire interface, in a serial format, to control panels and instruments. Failure of this two wire interface would effectively make running a simulation impossible although everything else may have worked perfectly.

- Finally the instructor used a outdated teletype to load exercises and an IKAT (Interactive Keyboard And Terminal) to control and monitor the exercise. Plotting of the exercise was carried out on an analogue XY Plotter. This IKAT was proprietary equipment and a spare unit was kept in case of failure. On the first IKAT failure it became known that the company no longer produced nor supported this equipment.
  By 1992 analogue XY plotters were very rare and expensive while digital plotters became far cheaper and more reliable.

- No updates or improvements to the software have been forthcoming. Any software modifications would require some major hardware modifications.

- It is doubtful whether anyone would understand the source code even if this was made available. Software programming for this computer was done in PDP Assembler which is now outdated and superseded by newer Assembler code developed for the successors of this computer. The programmers themselves, probably are employed by companies other than Solartron now.
- Failure of electronic components followed the typical expected pattern and the MTBF

(Mean Time Between Failures) gradually settled to a reliable and relatively stable system which could be used for extensive periods within failure. After 8 years of service simulator courses were being interrupted by equipment failures at a level where the educational objectives could no longer be met within the period allocated within the course duration. In one case, an ARPA (Automatic Radar Plotting Aid) course was being run where the only ARPA worked for approximately 4 hours out of the 30 hours course duration allocated.

- Hardware, is of course, very dated and obtaining components for maintenance will simply become impossible.

- The software was basically crude, and difficult to work with particularly by modern standards. The hardware system was supplied only with a teletype to act as a controller for exercise loading. An example of the difficulty is attempting to scan a disc for available exercises. Unlike a modern computer where the operating system (which will list files on a disc) is immediately available on booting the computer, the PDP is unable to load this file searching software in addition to loading the software to run a simulation. Therefore in order to check files requires loading a set of file Utilities instead of loading the simulation. This process is clumsy and slow.

- Loading an exercise took approximately 3 minutes and required the controller's presence to answer a number of questions. These questions could all have been asked up front by the computer so that the controller would be free to debrief the students.

- Exercise preparation was unnecessarily complicated. Ships were first designed and could not be tested till the entire exercise was created. A frame was created next, selecting ship types, navigational aids, radar characteristics, etc. Finally this frame was loaded and vessels placed in position with selected courses and speeds. Setting this information generally required the use of a hand held programmable calculator to ensure the correct positioning. Various idiosyncrasies came through. The Radio Beacons were fixed by latitude and longitude whereas vessels are placed according to an internal grid. There was no apparent conversion routine available to the operator which made placing a distress radio beacon on a vessel highly difficult. The ship may have drifted due to currents but the Radio Beacon remained fixed to the position it was placed in.

- The author also found that obtaining information between two vessels was slow and clumsy and also inaccurate (if both vessels had different currents set). This information was critical for adding targets during an exercise. Placing targets in the exercise area was also rather hit and miss.

- The plotter kept track of a limited number of targets by plotting a dot every 30 or 90 seconds. The end result was a mass of lines (all in the same colour) and unless the controller added marks, became quite undecipherable. Coastlines could not be drawn on the plotter unless painstakingly carried out by the controller and then photocopied. Certain maps took over 8 hours to create even though all the data was in fact contained in the computer.

- Although the software had not broken (as expected) the hardware failures had become progressively worse and extremely costly and time delaying to resolve.

- Furthermore the real equipment supplied with the simulator is now no longer used at sea and is no longer representative of equipment currently in use. The system is a closed box inasmuch as no enhancements (other than adding a second ARPA) had been possible even though electronic navigation methods had changed dramatically during that decade.

Even though the previous section is highly critical of the Solartron System, most are in fact improvements which would naturally be expected due to technical evolution but have been prevented by distance and design. The author has trained over a thousand students quite satisfactorily using this equipment and few complaints have been lodged from the students with respect to the equipment and its limitations, other than down time. Most of the complaints are therefore the author's own with respect to that which he would like to have done to enhance the course and making the simulation more effective.

The Solartron was decommissioned in July, 1994 due to the building alterations that were carried out at the Department of Maritime Studies, Cape Technikon. It was decided that the Solartron Simulator would not have been able to be moved and later reinstalled at the new premises without costing far more than developing a PC based radar simulator from scratch. It has served the Industry for 12 years and over 1 000 students have gained valuable experience from this system.

Other simulator systems that the author has obtained information on or used include

SEAGULL

This is the system that was in use at the Training Centre for Seamen in Cape Town. This is based on Commodore PET micro computers also driving a number of own ships using real radars. However all ships are identical and if the main own vessel should alter course, all radars reflect this. This prevents any student interaction, which is in fact a statutory requirement and in the opinion of the author, is essential. The coastline displayed on radar is a simple 20 line presentation restricting and limiting realism. Similar problems have been noted by their controller (Capt W.Douglas) regarding hardware failures and poor response to problems by the supplier.

The microcomputers used are now obsolete and the software is not transferable to more modern platforms. Again expansion could have taken place gradually enhancing the simulator had a closer liaison been maintained with the supplier. Dedicated hardware modifications were also made to the computers preventing alternative use.

SEA INFORMATION SYSTEMS

This simulator has many aspects that are similar to the author's system, in as much that it is PC based and has grown over a period of years but apparently recently development has halted. Many demonstrations as well as fully functioning 3 ship simulator have been sighted and used by the author. Many similarities exist between their development and the author's own development difficulties. Both have used the local Sea Rescue Operations (NSRI in my case, RNLI in the case of SIS radar) to prove the concept. Both believe in using as little specialised hardware as possible. Both organisations present radar and electronic navigation aids on a computer screen. Development has continued to a point where both systems use realistic rotation. One advantage that SISradar enjoyed was approval for use on ENS (Electronic Navigation Systems) courses in 1988 even though their system fell far short of simulation specifications.

- SISradar uses a second screen attached to the computer (text based only) to display Electronic Navigation Instruments. Due to the restriction of text only, this limits the quality of the information displayed. For lower level systems, SISradar reverts to screen swapping, again to a text based screen. Although fast and in the opinion of the author quite adequate, the UK Radar Simulator Specifications do not allow for screen swapping as a means of displaying this data. According to the specification, the radar display must be available continuously during the simulation and all instrumentation must appear on a second screen.

- SISradar tends to advocate the use of a dedicated keyboard apparently representative of a real radar controls. The author is of the opinion, however, that this is undesirable due to the fact that enhancements are prevented by this methodology. In this respect the author's development is intended to be ongoing and various features have been added (ie gain, tuning, FTC, STC, brilliance). For SISradar, when they added tuning to their version 4, they had to return to the standard keyboard. (ALT F12 followed by either SHIFT F2 and SHIFT F3). In the author's opinion, this is undesirable. Failure of this special keyboard means returning the student to the standard keyboard and having to know the keys and what they do. The author was particularly unimpressed with the key selection and deciphering their manual.

- SISradar has adopted a policy of selling different versions of their software at different prices on a per vessel basis. This has resulted in Technikon Natal purchasing one version 4 and two version 3 ships. Therefore the students need to be rotated so as to obtain the benefits that version 4 offers. The author's policy is that a single system is installed and that the only differences between various end users would be hardware (screen size, number of own ships, CPU type, etc). The software used should be identical although maybe configured to suit the end user's budget.

- SISradar has a controller exercise setup routine that appears unwieldily and requiring more steps that is necessary . It is also poorly explained in their manual. Because of the distance to the supplier, telephonic assistance would be extremely costly.

- SISradar has followed none of the normal computer software development trends. Such trends include pull down menus, proper mouse use, selection of files etc. The use of the trackball/mouse is particularly poor. Two buttons are used for range scale change and the other for acquiring targets. The mouse cannot be used by itself but only with the keyboard. Normal practise today would be using either keyboard or mouse in any combination.

- In a few areas, the author found SISradar deficient. In the case of ARPA (Automatic Radar Plotting Aids) tracking the software does not actually track the target (the way the real ARPA works) but rather uses the data that displays the target as a data source. In this way targets may be unrealistically acquired and data displayed well under the 3 minutes that is required in the real world. This data is also far more precise than that normally obtained in the real world and alterations by other vessels are instantaneously detected by the student's equipment. This, plus the fact that *target swop* [ref 22 page 61] (a major limitation in the operational use of ARPA and possibly a cause for future accidents at sea) cannot be demonstrated, limit the effectiveness of the simulation.

- In two other sections SISradar has not used a very sophisticated algorithm for displaying the coast. These precise problems have been identified by the author and solutions applied in his own system. This included the display of straight quays when near by - included in chapter 5 - and the time slot allocated to the many calculations that need to be carried out. SISradar stops the sweep at Top Dead Centre to do these computations whereas the author has elected to these calculations during the sweep period itself.

Having indicated dissatisfaction with the system, the author, however, acknowledges the fact that this company is the first company to successfully produce and market a Software Engineered Radar Simulator on a PC platform. The author has used this system as a yardstick for developing *Radsim*, with the intention that the product be superior in every aspect.

POSEIDON

This company based in Norway, has also produced a PC based Radar Simulator. The radar presentation is particularly unimpressive and their representation of Electronic Navigation Instruments is in the opinion of the author poor and bears no resemblance to the real equipment. The coastline is produced as a series of straight lines and there is no sweep rotation at all. As this system is clearly far from specification, little can be gained from it. A new version was released in 1998 but is expensive. Poseidon does use good mouse techniques, pull down menus and like the author has disdained the use of specialised keyboards.

This company, not requiring to meet third party standards, uses screen swapping to display different Electronic Navigation aids.

MICROSIM

This company, again British in origin, selected the BBC Archimedes™ (RISC technology) as their platform. Multiple versions are available. This company believes in windowing Navigational Instruments on screen (as does the Author's product) but have also produced a second screen (text only) version and have done admirable work in housing the equipment in realistic consoles. The product has a fairly realistic picture and appears to have high fidelity. The cost, however, is higher than the other suppliers mentioned above (25% more than SISradar - [ref 4 and 5]

RADSIM

This is the author's product. The basic premise is to use no specialised hardware. a mouse or standard keyboard (not recommended) should be used to control the student's station. It should be as simple to use as possible and should be intuitive for students thus requiring minimal orientation time while still being expandable. The author has therefore designed the software so that it is configurable for each exercise. Thus first exercises will display a radar set with minimal buttons available to the student resulting in only those that are applicable being available. The screen will therefore be fairly uncluttered. Gradually as exercises become more complex the intention is to expose more controls till the stage is reached that the full complexity of the simulation is available to the student.

There is adequate precedent for using computer technology such as mouse (trackball) or touch screen as a means to controlling a radar or other instrument. Sperry produced a sophisticated Touch Screen radar over 6 years ago. Kelvin Hughes uses a trackball and 3 buttons to control their latest system [ref 7].

The author is convinced that vessel's equipment will become more computer based. Developments by Kelvin Hughes and Sperry as mentioned above are indicative of these trends. Control of instruments will generally become either standard 101 keyboard or a pointing device. Whatever new technology that rises to the fore will therefore be implementable on the simulation software as well. It is also the author's (as well as Capt W.R.Douglas (ex Training Centre for Seamen), G.Kings (Rossing Foundation in Ludertitz), et al) experience that non computer literate persons have no difficulty operating computer based simulations provided that suitable controls are available and that the software is produced so that controls are reasonable instinctive. With reference to extensive research carried out by Capt W.R.Douglas, he claims that

> *.....response fidelity should be regarded as more important than stimulus fidelity.*
>
> [ref 7 - A Potential of Simulation as a Strategy for Teaching at the Andragogic Niveau, with special reference to Maritime Training - Cape Technikon 1993, chapter 4]

This in fact means that the controls, although may not be accurate representations of real controls, must react accurately and that this aspect is more important.

With respect to the instrumentation, the author prefers the use of pop up miniatures but in order to comply with specifications, will produce software for a second computer in each cubicle so as to display realistic looking equipment on a student selected basis. This second

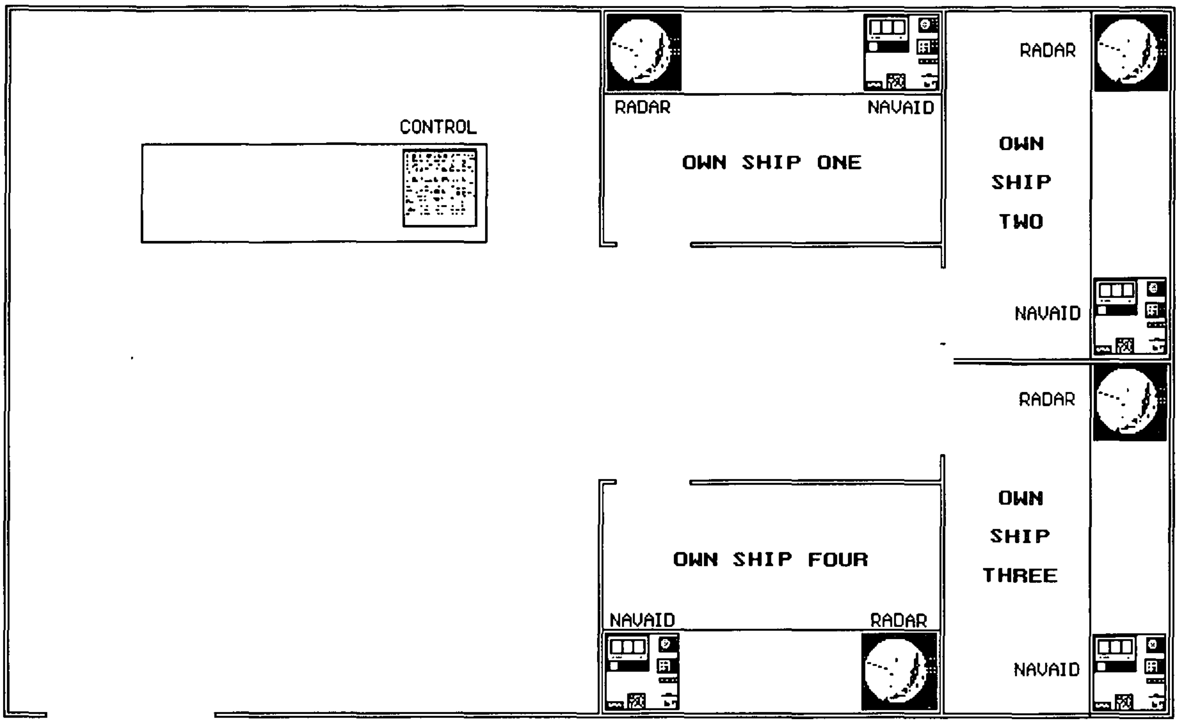

Figure 1 - Typical Simulator Layout

computer actually offers some powerful alternatives. For certain exercises it may be used as a visual display of the outside scene. Although this is not part of this project at this point in time, this expansion path offers interesting possibilities. The second computer could also be used as a communication centre, such as a Global Maritime Distress and Safety System (GMDSS) simulator running concurrently with the Radar Simulator. Alternatively Electronic Chart Display and Information System (ECDIS) data could be displayed on this second screen. In these case temporary backtracking to displaying Navigation Instruments on the radar display will be reverted to. The software has been written with these expansion paths in mind.

In addition when low level training is required, the cubicles could be divided in two allowing twice as many student ships. Each computer would then display radar information with the aforementioned onscreen Navigation Instrumentation.

The intention therefore, is to design a very flexible system. The end user should be able to expand the system to suit the financial restraints and specific needs. Finally and possibly the most important, the hardware should not be dedicated to radar simulation but also used as Computer Based Training cubicles.

TEKLOGIC

Teklogic is another South African based company that normally develops software and computer systems for military applications. They are currently in the process of developing a Marine Simulator but have not reached the state of *Radsim*. The author has had many interesting communications with D.Houston of that company with respect to development direction and concepts. Teklogic determined the size of the project from scratch and then determined their hardware requirements to satisfy these criteria. The author defines this a Top Down approach. Interestingly, hardware has now evolved to a state where they are using similar hardware to the author.

The author has worked using the Bottom Up approach - that is to design a system within the constraints of the hardware and software. Gradually, as the hardware and developmental software has improved, so the simulation has grown from a low level plotting trainer to the stage where it is a fully approved Interactive Marine Radar Simulator.

HARDWARE

CPU

The minimum platform chosen for this project are 486 DX machines running at 100MHz. Slower computers might be adequate but will allow no room for further development. The aforementioned equipment is only slightly more expensive than slower equipment, but it is my experience that in real time simulation that speed is critical. However, Pentium power is now cost effective at this point in time and the software will not have to be modified to run on these more powerful machines. The time critical area of the solution is the conversion of adequate number of points from rectangular to polar co-ordinates. This needs to be carried out during the normal rotation period of a radar (3 seconds) and displayed simultaneously. In the foreseeable future, clients may upgrade their equipment to Pentium (or faster processors) and provided this is cost effective the author intends expanding the simulation.

VIDEO DEVICE

Selection of a suitable video device was also taken under similar constraints. Lower resolution such as CGA(Colour Graphics Adapter), EGA (Enhanced Graphics Adapter) and Hercules™ have inadequate resolution to handle the density of information on the screen. The specifications for a simulator require 700 line resolution but due to previous development and to the availability of standard VGA (Video Graphics Adapter) this resolution is still supported by the software. Many end users have suitable VGA equipment but due to the multiplicity of standards, higher resolution systems are fairly simply defined.

The most suitable video driver with more than 700 vertical lines is either the IBM 8514 monitor or the VESA standard. The author used both systems and finally selected VESA as it is more universal, is cheaply available and under the development software used, less problems were encountered. The first video card used was only 8514 compatible (not genuine 8514) and needed a TSR (Terminate and Stay Resident) program to operate. This seemed to clash with the mouse driver and caused many unforseen problems. On the other hand upgrading the VGA version to VESA at 1024 x 768 resolution was comparatively easy and no unsolvable problems were experienced with this driver.

In addition the 8514 driver altered the size (in pixels) of the default font making the size larger than desirable. VESA simply maintained the same size effectively making writing on screen smaller and clearer.

Finally the VESA standard cards and monitors are less expensive than the IBM 8514 monitor and cards.

OTHER CONSIDERATIONS

The developed software currently has a low storage requirement (under 2 Mbytes) so standard hard drive capacities are totally adequate. Access to the program and subsequent files, with one exception, only occurs before running the simulation, so high speed data transfer was not critical. Data, for later replay, is however stored at regular intervals (15 minutes) from the control terminal. The packet of data thus stored is however, very small (± 200 Bytes) so again rapid transfer rates are not necessary. This data could have been transferred more rapidly to a RAM drive but as it was not noticeable, it was decided that it would be stored directly to hard drive in case of power failures. a further enhancement has been added allowing the exercise configuration to be altered at runtime so that exercises can be modified during the running of an exercise. This means that provided the controller pre empts a power failure and saves the current configuration, he would be to be able to restart the exercise from the last save in case of a power failure. This could be done automatically possibly every 5 minutes and is a subject for future development.

SOFTWARE

It is the author's considered opinion that the language used to produce a software package is entirely transparent to the user provided it does the following.

- The software timing cycle must be such that the user is unaware of any computational delays. There must be no annoying delays while the computer does its calculations.

This can be avoided by one of three alternative methods.

1) Good software design and ensuring that all calculations are completed in an adequately short period.
2) Ensure that the calculations are carried out in steps - each step being extremely short - and thus carrying out all the required computations in time slices.
3) Write time expensive modules in a faster code such as assembler.

All three alternatives are in fact invoked in this project.

- The software engineer must be competent in the computer language of choice. In this way efficient code can be produced in a relatively short time and hence be cost effective. The author's first exposure to Borland's Turbo Pascal ™ (version 3) was due to enrolling and completing a Diploma in Datametrics through Unisa from 1988 to 1990. It was found that the language was powerful, with a blindingly fast compiler and easy to use. Version 3 was fairly crude however, and would not support EGA, VGA etc. In addition its graphical capabilities were poor. The release of version 4, 5, 6 and 7 have been consistent improvements over previous versions with the last version incorporating two major improvements. One was the VESA drivers that are an essential part of this project. The second is the linear type memory map that Turbo uses to allow the development of larger more complex projects.

- The language must not restrict development by any peculiarities that it might have. For this reason all instrumentation etc is also produced in Turbo Pascal rather than importing through the use of other software packages.

- Other languages such as C++ might also have been suitable but is discarded due to the high development time that has already gone into the project (in excess of 10 000 hours) and the amount of reusable code already developed by the author that will be integrated into the proposed project as well as other developments that the author wishes to incorporate at a later stage such as visuals and ECDIS.

- The operating system used is Microsoft™ Disc Operating System. Version 6.22 is recommended but there is no reason why earlier versions will not work provided adequate memory is available. DR Dos™ from Digital Research™ has also been tested. Other operating systems such as Windows™ have been contemplated but none of the advantages of Windows™ would be utilised. It can however be initiated from Windows™ but task swapping does not operate correctly and would be undesirable in this case as the student is expected to concentrate fully on the simulation and is not expected to carry out other functions such as word processing. Many of the platforms running this simulation package are older slower machines and hence changing operating system platforms might be costly with no real benefits.

DATA TRANSFER

METHOD

Initially a serial communication system was used. A control terminal was fitted with 4 serial ports (one extra card at a cost of around R 60,00). This computer was then linked to up to 4 others using a seven wire serial cable and dedicated software written in assembler by the author but based on protocols obtained from various Borland™ Turbo Pascal Manuals.

This software allowed a reasonably high reliability but with a fairly slow data transfer cycle (9k6 baud). In the last version communication takes place from the controller to a slave every 5 seconds. This means that the controller only communicates with a particular student terminal every 20 seconds. This in the opinion of the author, is less than desirable although acceptable. However, in the software protocols adopted, a failure of one terminal would also hang up the controller, although the other student terminals would continue running. Interaction would, however, cease.

A faster algorithm was developed from a shareware version of a communication section. This version was plighted with bugs and was very sensitive to different computer speeds and would only run on balanced fast machines. This protocol has now been dropped and no further development will proceed along this route.

Those institutions that require high speed sophisticated simulation will be advised to network their computers as finance becomes available. Those institutions that do not require such sophistication will continue to use serial communications although the upgrade path will exist. A simple parameter pass will determine which data transfer is to be used. The serial connection no longer requires support as all users have upgraded to network systems.

In selecting the network method to be used, I consulted a number of people including M.McLeod of Technikon Natal, D. Fellows of DF Communications cc and Vincent Reichert of intouch S.A. After much discussion, the author decided to install a low level, economical Network consisting of thin Ethernet Coaxial cables on combination cards although UTP and hubs have been tested and makes no difference to the simulator operation. Windows for Workgroups™ was selected by the author for his own Network operating system, although so far as possible protocols and algorithms used will be unaffected by the actual network operating system used. More recently Windows 95™ and Windows 98™ have been successfully used. During the research it was found that Windows™ itself is unnecessary (undocumented by Microsoft) and that just the Dos (Disc Operating System) Add On™section is required on all machines. With this configuration all machines may share their resources but for this project only one computer need do so. For convenience and logical reasons only the control terminal is used as a resource and offers access of its peripherals to the other computers in the system, and does not in fact need to access the student machines at all.

Specifically a small RAM (Random Access Memory) drive is shared. The student computers load the program and then read and write data every radar cycle to the Ram Drive. These computers under Windows for Workgroups™ only need to access the control computer Ramdrive but do not need to share any of their own resources and hence the connection is simple and can be made from the Dos Add On™ which is a very cost effective package.

By complying with normal protocols and not in fact writing specific Network code, it is immaterial as to what Network operating system is utilised.

The reasons for this choice are as follows.

- Only two institutions of those interviewed is connected to and has the rights to expand their Network (Technikon Natal and the South African Navy). All other interested institutions are using independent computers and will generally require only a low level network for the foreseeable future.

- Distance between computers is very short and the probability is that the computers used on this project will be dedicated to Marine Training and Simulation only.

- Provided the system performs on low level systems, then it should run - with possible minor adaptions - on more powerful networks just as efficiently.

- The Network operating system used is capable of interconnecting to more sophisticated Networks.

Data is transferred to and read from the Ramdrive by the student terminals every radar cycle (ie approximately three seconds). The software is designed so that if a terminal should be worked hard by a student, then that student should have absolute priority, and that the data transfer is delayed until such time as is convenient to that computer. It is estimated that data transfer will at worst case take place within 5 seconds.

The data transfer required every cycle is very small at under 700 Bytes each cycle from control to student and under 50 Bytes in the opposite direction.

SUMMARY

In this chapter the various simulators that have influenced the author in the design and style of *Radsim* have been explored. The historical background clearly indicates the growth of this project as it has proceeded from a basic training system to the point where it is a fully approved interactive marine radar simulator. The future evolution is also mapped out with possible avenues for expansion into visual display as well as Global Marine Distress and Safety System and Electronic Chart Display and Information System.

CHAPTER 2

SYSTEM DECISIONS

INTRODUCTION

When originally contemplated, it was decided by the author, based on the explanation by Solartron as to their use of a grid as opposed to using Latitude and Longitude, to use a similar system to Solartron. The original grid was determined at 1 metre intervals. Using Borland Pascals Long Integers allowed a range of -2147483648 to 2147483647 metres (11 million nautical miles). Although this is a vast grid, the next standard integer type - an INTEGER - only has a range from -32 768 to 32 767 metres or -17,69 to 17.69 nautical miles. This is clearly inadequate in practise as well as not meeting specified requirements [ref 1].

In the early versions the update cycle was deliberately long and had little influence on this decision. After a discussion with Captain F.Bester of the Department of Transport, it was decided that a more logical time cycle for target (and other items) would in fact be the natural rotational period of a radar display ie 3 seconds. This has proved to be highly desirable and in fact eliminates many other problems.

However, the distance that a vessel moves in 3 seconds cannot be measured in metres as this would result in a maximum accuracy of the vessel's velocity as one metre in three seconds. This converts to 20 metres per minute or 20 x 60 / 1852 knots or 0.6479 knots.

To prevent this problem, the design has been altered to rather position all objects with 1 centimetre potential resolution. Vessel's speeds can now be monitored correctly to a resolution of 0.006479 knots (this is in compliance with the Simulator specifications [ref 1]). This reduces the full grid dimensions to 110 000 nautical miles which is clearly adequate.

All points of land are initially stored in Latitude and Longitude format, converted to *Radsim* format and when necessary returned using a reverse algorithm to lat/long. *Radsim* format converts difference in latitude (dlat) from reference point (converted to centimetres at 185200cm to a minute of latitude) and departure (based on latitude of the point) from the reference longitude using a similar measure.

This modified Transverse Mercator system [ref 9 - American Practical Navigator] results in slight inaccuracies particularly in bearings at the edges of the exercise area (maximum on North/South bearings). Also due to the simplified formula distances measured East/West are also compromised. It is felt that the errors so caused are acceptable (see below) and the author recommends using the co-ordinate system whenever high precision of target placement is required. If the x co-ordinate is identical to the own vessel, then the target will appear due North/South even though the longitudes of the two vessels may differ. The latitude/longitude co-ordinates should be seen as a guide rather than being absolute.

For the purpose of evaluating these discrepancies, an arbitrary point was selected for Dover. This position was taken as 50°48,00' N, 001°16,30' E.

Using the *Radsim* program targets were placed 100 miles North and West, North and East, South and West, South and East of this point thereby forming a 200 mile (*Radsim* co-ordinates) square encompassing the exercise area (as required by specification).

Position 1	52°28,00' N	001°27,85' W
Position 2	52°28,00' N	004°00,43' E
Position 3	49°08,00' N	001°16,53' W
Position 4	49°08,00' N	003°49,08' E

	RADSIM	ACTUAL (Mercator Clarke 1880)
1 to 3	180° x 200,0	177,9° x 200,1 miles
2 to 4	180° x 200,0	182,0° x 200,1 miles
3 to 2	045° x 282,84	045,1° x 283,4 miles
4 to 1	315° x 282,84	314,9° x 283,4 miles

From the above it is apparent that the error is maximum on North/South bearings at the extreme sides of the required exercise area with a maximum error of 2,1° irrespective of range (ie this error will be almost consistent from 1 mile up to 200 miles). It should be noted that for angles approaching 45° this error (less than 0,1°) becomes negligible and may for practical purposes be ignored. Ranges start to deteriorate above 45° but at this angle are within 0,2% which is well within radar specifications (ref 4 - Marine Radar Performance Specification 1968). Distances are based on simple departure formula so at 90° the error is identical to the difference between parallel sailing and corrected parallel sailing [ref 9].

It is believed that the above inaccuracies will have little effect on practical training provided that the lecturer in control of the simulation exercises due care when positioning targets with high precision in mind. Results of student's computations should be compared with the *Radsim* data within these limitations.

The use of Longints causes a slight overhead in data storage and data transfer (more bytes are in fact used than is strictly necessary, but in the opinion of the author, this is a small penalty to pay for using standardised forms. The data transfer is in any case very tight and storage of data is not great.

These decisions have permitted reasonably high accuracy of target positioning yet relatively simple protocols to be adopted while being in full compliance with requirements.

COASTLINE

The coastline is simply entered at present as a simple text file of latitude and longitude points. Breaks are indicated by a zero latitude and a zero longitude. Comments are permitted beyond the space required for the position. 1000 points was arbitrarily chosen as the limit for storage purposes. This decision has proven itself inasmuch as adequate accuracy for close range and reasonable coastline sizes are possible. SISradar in fact limit their coastline to 600 points [ref 10], Solartron store their coast in 256 kBytes [ref 11] and obviously have far bigger mapped areas in storage at one time - easily 24 hours steaming in memory at one time.

In order to meet the specifications laid down in the Simulator Specifications [ref 1] that the exercise area must cover at least 200 nautical miles by 200 nautical miles and due to the vast amount of data contained within an area of this size, it was decided to swap coastline files into and out of memory as the vessel progresses across the total area. SISradar does not in fact comply in this respect but has a single relatively small coastline and would require a new exercise to be loaded when leaving that area. The concept of swapping coastlines is similar but not identical to the methodology that Microsim uses - Microsim [ref 12] divides the total area into 16 x 16 smaller squares - *Radsim* has a number of overlapping rectangular sections with change over borders stored within each coastline data file. As the vessel crosses a change over border, another section of coastline is loaded into memory overwriting the previous coastline. The size of the rectangle varies according to the amount of detail required by the coastline. The time used for this transfer is however hardly detectable although major changes to the software were required. This methodology will however allow for extensive charts to be created. The only limitation is the inaccuracy as previously described when larger areas are used.

The coastline is converted to the simulator grid by first reading in the latitude and longitude of a reference point (which is also arbitrarily taken as 50 million centimetres or 269.9784 miles North East of the zero point - Solartron allows the controller to alter this value but the author has found that this merely complicates record keeping for the controller and has thus encoded this making the reference point fairly transparent to the operator.

Thereafter an algorithm is used to convert all latitude and longitude points into the grid using Long Integers. In line with normal convention North and East are taken as positive and South and West as negative.

The earlier versions of this program merely drew a series of straight lines representing the coast. Later developmental stages converted this XY co-ordinate system to a series of ranges and bearing from the own ship and subsequently reduced them to positions on the screen. This resulted in a crude land representation usable for basic training but insufficiently realistic and lacking range fall off, shadowing or apparent scanner rotation.

In order to comply with the Radar Simulator Specifications [ref 1], it became necessary to meet additional specifications such as range fall off, realistic shadowing as well as height and depth of displayed coast. The author determined after much deliberation that 16 levels of heights should be allowed as well as 16 different depths. Thus the characteristics of all targets, coast, ships and buoys can be contained in one byte or two nybbles. The selection of these values allows realistic coastlines without being memory intensive. Effectively 256 different coast types are possible. SISradar have three different land types and three target sizes. In *Radsim* ships are also defined with 10 different sizes. Part of the rest of the possible values (10 to 40) allocated to rain size and density. Rain is therefore simply a ship type target and controllable as such.
The other possible values (41 though 255) are at present undefined.

VALUE	COAST HT metres	RANGE miles	SHIPTYPE	BUOYS ETC
0	0	0	invisible	
1	1	1.5	liferaft	
2	2	3	lifeboat	Small buoy
3	4	4.8	15 metre boat	
4	6	7	100 tonne	Buoy
5	10	10	500 tonne	
6	14	14	1000 tonne	LightVessel
7	20	18	5000 tonne	
8	35	21	10 000 tonne	
9	60	24	50 000 tonne	
10	80	28		
11	120	32		
12	160	36		
13	200	40		
14	260	44		
15	230	48		

Figure 2 - Coast/Target/Range relationship

Detection range is affected by aerial height of the own vessel as well as the setting of the tuning and gain controls.

4 level quantization has also been included to improve the realism of the radar picture. The 4 levels are determined by range, gain, tuning etc and are reflected in the colour of the target on the screen - Bright green for strong or close targets fading to medium and dark green for poorer targets and finally black for background. The author has not seen any other PC based system that includes this enhancement although many rasterscan radar have implemented this improvement.

ECHO SOUNDINGS

```
Rng := round(range(Depth^.Xpos[i]-Ex.Target[1,Xco],
                        Depth^.Ypos[i]-Ex.Target[1,Yco]));
brg := round(direction(Depth^.Xpos[i]-Ex.Target[1,Xco],
                        Depth^.Ypos[i]-Ex.Target[1,Yco]));

j := brg div 90;                {determine which of 4 quadrants}
  if TempRng<esr[j] then        {if it is closer the last one then..}
     begin
        esr[j] := Rng;
        esd[j] := Depth^.sounding[i];
     end;

{esr and esd are arrays as indicated in the next figure}
```

Figure 3 - Echo Sounder Array Fill

1000 spot points are declared for depths. Depths are fed in latitude and longitude, converted to grid and a single byte contains the depth data. Depths allowed are integer values in metres. Maximum depth is clearly 255 metres but a restriction has been placed at 200 metres and additional values from 201 to 255 will be used for future expansion. The echo sounder will simply have a maximum depth of operation of 200 metres.

```
Function DepthCalc : real;
var I, c    : Word;
   Display : Real;

Function Shortest(a,b:LongInt):Longint;
begin
   if esr[a]<esr[b] then Shortest := a else Shortest := b;
end;

begin
   c := Shortest(Shortest(0,1),Shortest(2,3));
   Display := esd[c]/1;
   for I := 0 to 3 do if esr[i]<>0 then Display := Display +
          (0.25 * (esd[i] - esd[c]) * esr[c]/esr[i]);
   DepthCalc := Display;
end;

{elsewhere in the program the 4 closest depths and their}
{ranges from the vessel are stored in the next two arrays}
{esd is an array[0..3] of depths}
{esr is an array[0..3] of ranges to these depths}
```

Figure 4 - Function DepthCalc

During the cycle period of approximately three seconds, four of the one thousand soundings (including possibly one or more coastline points - depth 0 metres) are identified as being in close proximity to the vessel - one each of the four quadrants. The range and depth is recorded and a relatively simple calculation selects the closest and adjusts this value depending on the other three depths and ranges. This depth is then displayed to one decimal place with a slight random figure to give a realistic trace. This method of calculation is relatively slow and needs to be time sliced. The control station obtains the depth data from the student computers (to save computational time) but calculates the depth at a single point (the crosshair).

Solartron stores spot soundings on a hard drive and frequently reads this device to show depths. Unfortunately, although depths are available for all three ships, only the controller and own ship one have a data display. In addition it is difficult and extremely time intensive to check these soundings. Sisradar uses 600 spot soundings and calculates a display value from the nearest two. Their algorithm is fast and near instantaneous readings are possible.

An alternative means is to run contours. This may be a good method in the future. An enhancement on this or the current method, is to use the spot soundings in the system and then before running convert these to a grid of depths approximately 100 metres apart. The amount of data would be very high, but could be stored on RAM disc or hard drive for retrieval. The grid will simply be a coarser version of the simulator grid by MODding by 10000. Interpolation could still be used. This would require in excess of 1 MByte of storage (based on DOVER area). A resolution of 10 metres would obviously require in excess of 100 MBytes and is clearly unacceptable with current computer technology.

SHIP POSITIONING

As the system is designed to be used both in interactive and in stand alone mode, it is essential that each computer can keep each target moving. In other words even if communications should fail, each student computer will continue to determine the correct position of the targets assuming that they maintain course and speed. With respect to the own vessel this is more critical, as realistic ship handling is included. Therefore during a turn by the own ship, the position is determined each scanner rotation, while direction and speed are determined approximately every second. All manoeuvre data is therefore effectively made up of 3 second straight lines.

In the interactive mode, each station is responsible for maintaining the own ship data as well as updating target information. Only own ship data (28 bytes with position, course, speed, desired course, desired speed, rangescale, optimal gain and tuning, actual gain, tuning, FTC and STC setting) is however, transmitted to the controller, which then sends back the information on all other vessels in the simulation. This message is 835 bytes long and includes a multipurpose string of 255 bytes that allow special encoded messages to be sent to a particular vessel. It would be possible to send telex type messages using this string as well as allowing data to be transferred regarding equipment failures etc.

For this purpose each own vessel station assumes that it is vessel number one and that the rest are chronologically ordered from 2 to 30. This is simply a matter of programming protocol and is transparent to the user. A configuration file contains the actual ship number (in a serially connected system the connection itself controls the actual ship number) and when student station two transmits that data is correctly stored as ship two. The return transmission from the control station sends back own ship 1 data (stored on the student station as vessel two) followed by three, four, ... thirty (which correspond exactly). The only point where a numbering system is in fact assigned that is visible is at the control station. Under the serial communication protocol the student station software is actually unaware of what number it is in the system - this number is entirely dependant on which COM port of the controller it is connected to. Under the network protocol, a number is assigned in the configuration file for that computer.

The controller station, therefore is only responsible for positioning the target vessels and collating the data from the student stations. Under serial communications this data exchange is around 20 seconds between communications with any specific vessel. As the author wished to record manoeuvres made by the own ships for demonstration of panic situations, the limits of manoeuvres is effectively settled at around 30 seconds. Under a network communicating every 3 seconds, the storage of this data could effectively be almost in real time, not at specific intervals. It is suggested that recording own ship manoeuvres in real time would be an area of future development.

Likewise the controller also stores the positions of vessels at regular intervals for playback. This is done at one minute intervals (it may be desirable to reduce this to ¼ minute intervals for port approaches and close work). At regular intervals (15 minutes) this is dumped to disc under a replay filename. This process is virtually instantaneous and is only detectable by the hard drive noise and light (typically less than ¼ second). This is the only time that access is made to any drive by any computer in the system. It has already been proposed that a future development might be to dump a full status situation at the same time so that a power failure or similar would not affect the situation. In this case the author suggests that 15 minute intervals are probably too long and would suggest that 5 minute intervals would be more appropriate. This would be easy to implement (simply change one constant) but would increase the hard drive access. Each data dump is 240 bytes per storage period. Three hours is proposed by the author as the maximum limit (Simulator specifications specify a minimum of 2 hours). Under this decision 43 200 Bytes are needed to store a 180 minute exercise at 1 minute exercise. This amount of data is easily transferable to removable media such as 1.2 Mbyte FDD or 1.44 Mbyte FDD. If it is desired to store data regarding a particular course (not required but could be done easily), it would require 36 hours [ref 13 - Navigation Control Course] or about 518.4 kBytes of storage. Add to this a set of files recording the actual manoeuvres made by the vessels (typically less than the positional data) means that an entire course would fit on one piece of high density media (1.2 MByte FDD or 1.44 MByte FDD). The author believes that standard media should be used rather than mass storage devices such as 100 Mbyte ZIP drives or DAT tapes and therefore has developed software that uses minimal storage and data structures that are space optimised.

Any other files added for power failure purposes, would in fact overwrite a temporary storage file (exercise data is currently set at 1003 bytes). Even with enhancements, the exercise data file is not likely to exceed 2 byte in the near future.

CHAPTER 3

DATA TRANSFER

INTRODUCTION

As mentioned earlier the network system used is transparent to the system and a single computer must be equipped with a Ram drive (for speed of reading/writing) with a capacity to handle all the exercise data and status files. Currently these requirements are extremely modest and 5 kByte is adequate to handle a eight ship simulator. With enhancements, more vessels etc it is proposed that 64 kBytes (also the default size) should be adequate for the foreseeable future and if this is allocated at this stage no additional problems in this respect should ever occur. In any case bigger amounts of data transfer would slow down the system to unacceptable levels.

In order to remain as flexible as possible, different configurations are catered for in the design stage and a simple parameter pass selects data transfer method. Subsequent to this the program reads either a RADSIM.CFG or RADSIM.NET (ASCII files) to ascertain information as to the more specific configuration information. This file must be stored on the individual computers but could conceivably be stored on removable media or hard drive. Paths to the Ram drive, (on the host computer sharable drive), and ship number are contained in RADSIM.NET whereas RADSIM.CFG contains serial speed (if required) and serial port used for data interchange. A simple set of parameters passed when running the program determine the configuration to be used - single user or interactive, network or serial communication, screen resolution to be used (SVGA or VGA), twin screen or independent computers.

In this way the configuration can be altered by writing and running different batch files.

SERIAL CONNECTIONS

As indicated earlier the initial developments used a standard 7 wire serial cable and a relatively slow data transfer rate (9k6 baud). This system has allowed development of the simulation to evolve using a cost effective data transmission.

With this development, network hardware and software prices have dropped dramatically allowing the system to be transferred to a faster more robust platform and still be cost effective.

NETWORK

As indicated the author has used NE2000 compatible series network cards with thin Ethernet coaxial cable running under Windows for Workgroups Dos Add On ™NetWare but has designed the software to run on any network configuration with the following minimum requirement :

- a Ramdrive (64 kBytes) on one computer must be shared with all computers for both reading and writing.
- SHARE.EXE [ref 14] must be run on all computers to control simultaneous access of files.

METHOD

CONTROLLER

The control terminal loads the coast and exercise and prepares the hard drive for exercise replay data.

It then saves the following files to the shareable RAM drive

MAIN	Contains data as to course, speed, x coordinate, y coordinate and size of all 30 vessels (targets and own ships) in Long Integer format.
STATUS.00x	Status of equipment of own ship x with respect to current velocity and direction, sea clutter, yaw, equipment status.
START.00x	The parameters for the ship type and handling characteristics of own ship x.
EXSTATUS.000	This file contains data for stopping, pausing the exercise.

FILES CREATED BY CONTROLLER			
COAST		10	Coastname in ASCII
MAIN		600	Data for each of 30 vessels
WEATHER.	WX	705	Weather report in ASCII for Navtext
BRIEFS	.BRF	2496	Students briefing sheets
START	.001	65	Starting data for each possible own ship
....			
START	.008	65	
STATUS	.001	22	Status of equipment of each own ship
....			
STATUS	.008	22	
EXSTATUS	.000	3	Exercise status - paused, quit etc.
FILES CREATED BY EACH VESSEL			
SHIP	.001	28	Positional and movement data.
RADAR	.001	14	Radar control settings data.

Figure 5 - Ramdrive Files

Finally a text file is written (COAST) containing the map name to be used by the exercise. Student computers that are running, wait until this file appears before proceeding. This system also allows student computers to be started after the control terminal.

Thereafter the control program does the following every cycle (currently set at 5 seconds arbitrarily) :

- All vessels including possible own ships are moved forward according to course, speed and actual time lapse in centi-seconds. This position is determined in a centimetre resolution grid.

- Any messages changing ship or exercise status are stored in record form.

At the point of data transfer, the following is carried out in sequence for all own ships allowed for:

- The control terminal looks for a file called SHIP.00x. If this is found it returns data as to the position, course and speed as determined by that computer. If it is not found, that vessel is deemed not to be under student control and its parameters are treated as a target vessel under control of the lecturer.

- Once all own ships are checked, the controller then rewrites MAIN with the updated information of all 30 vessels.

- The STATUS and EXSTATUS files are also rewritten.

This entire process on a Network takes typically less than ¼ second and will wait if the computer is actively being used by the controller. Indicators show that data is being loaded and saved.

If data is being read or written by any other computer, the terminal will try repeatedly until is has access to the required files - normally Dos™ [ref 14] allows 3 retry's only but this has been modified by a call to Interrupt $21 so that it will try up to 1000 times. A loop is executed 100 times to delay the period before reattempting to access the file. On exit from the program this is reset to the defaults.

To use shared resources the Dos™ program SHARE.EXE (a co-resident program that prevents file sharing access violations) must be loaded.

```
Procedure Retry;
begin
    asm
      mov cx,100
      mov dx,1000
      mov ax,$440B
      int $21
    end;
end;


Procedure ResetShare;
begin
    asm
      mov cx,0
      mov dx,3
      mov ax,$440B
      int $21
    end;
end;
```

Figure 6 - Procedure Retry

STUDENT MACHINES

Various parameters can be passed when the program is run

M - Multi machine interactive as opposed to single machine.

N - Network as opposed to serial communications.

A - Navaids on a second screen as opposed to on screen display.

S - SVGA as opposed to VGA - only Vesa Mode 2 (1024 x 768 pixels) is supported by this program.

These computers on being started look for a RADSIM.CFG (serially connected) or RADSIM.NET (Networked) file to determine their configuration.

Thereafter the following occurs.

- The computer looks for a text file on the Ramdrive called COAST. When this is found the program reads the coast name and loads the coast file, echo sounding file (if it exists), and the ARPA map file (if it exists). If COAST is not found it indicates that the controller has not yet been started. In this case the student machines loops through a routine until the Controller has been started and COAST has been found. It then loads data from START.00x to determine shiptype and handling characteristics.

- STATUS and EXSTATUS are loaded.

- MAIN is loaded to determine the current positions of all vessels including itself.

Thereafter this computer writes a file SHIP.00x containing the same positional information that it has received. This effectively indicates that the student has control of that specific vessel. In addition another file is written called RADAR.00x which contains feedback about the radar settings themselves (Gain, Tuning, STC, FTC, rangescale as well as offset of centre).

If the navaids and therefore control of the ship is from a second computer the last statement is ignored and in this situation no data (other than RADAR.00x) is currently written to the Ramdrive but rather only MAIN is read giving updated positional, course and speed data.

Every Radar cycle the following data is transferred :

- If only a single computer is used then SHIP.00x as well as RADAR.00x are written so that the controller can update MAIN and monitor the radar settings.

- MAIN is read but own ship data is ignored.

- STATUS and EXSTATUS are read.

This protocol insures that the student process can start at any time before or after the simulation has started. If a student computer should fail, an error routine is entered that erases SHIP.00x thus indicating to the controller that this vessel has returned to instructor control.

At the end of the exercise the controller erases COAST and the student computers erase SHIP.00x to prepare for the next exercise.

If a second computer is used to control the ship and display navaids and other data then the radar computer simply reads updated information every cycle. As a matter of interest, each computer is capable of running dead reckoning if data should not be read although failure of the control computer will cause an I/O error (Input/Output Error). This error could be trapped but in the Author's opinion the simulation should cease if there is a failure.

When a twin computer system is in operation, the Navaids computer then takes over the writing of SHIP.00x every cycle and as there is no data in MAIN that the Navaids Computer needs, only the STATUS and EXSTATUS files are read. These files contain data used by both computers fitted in each cubicle. In other words the positional data, course and speed of the ship is determined by the Navaids Computer and written to SHIP.00x. This data is read by the controller and rewritten to MAIN where the Radar Computer now reads and subsequently displays the required picture.

CHAPTER 4

ELECTRONIC NAVIGATION AIDS

INTRODUCTION

It is a requirement by the local authorities [ref 1] that all navigational aids are displayed on a screen separate from the radar display so that the radar display is uncluttered with extraneous information. Although the author appreciates this viewpoint, the contention is that many navigational aids will or have disappeared leaving effectively only radar, echo sounder and GPS. Both of these additional aids need minimal display requirements and its argued that there are occasions when a single display with radar and navaids together may be desirable.

For example, a small college could only afford 5 computers on a network. They could either have one controller and four own ships or one controller and two own ships with two screens each. In this case training would be very expensive for the luxury of having a separate Navigation aids display (which in this case may not be used that often).

For a larger institution such as a Technikon, there are different levels of training. At the lowest level the classes are large and basic radar skills are required. In this case as many radar displays as practical would be desirable. At higher levels, students are expected to use all their sensory equipment to control their vessels. In this case the classes are generally smaller and controlling a large number of own vessels is undesirable if optimal training is to be achieved.

In the design of *Radsim* it was felt that both objectives could be met, as well as a few others mentioned later in this chapter. The student's radar program is run with a number of parameters. If the parameter A is included at runtime, the program assumes that there is a second screen available and will not display any navigation aid buttons or manoeuvring control panel. It is up to the controller to ensure that a second computer runs a different program to run up navigation aids and manoeuvring control panel. In this computer a file called NAVSIM.NET is included which like RADSIM.NET determines the location of the Ramdrive as well as the vessel being represented. In this case two computers are assigned to each ship, one running Radar software and the other running navigational aids and manoeuvring control panel.

If the parameter A is not passed, the Radar Computer displays navigational aid buttons and manoeuvring control panel. By pressing the navigation aids control buttons a small non controllable icon will appear (off the radar screen) displaying the appropriate information.

When the second screen is used, all navigational aids are fully operational and all controls are functional.

Effectively in this manner the simulator may be used in either of two modes and is extremely flexible. In one installation with 9 computers, 4 twin screen own ships or 8 own ships, a small configuring program has been created that allows the controller to determine exactly how many ships are required. Each of the 4 cubicles can be assigned to be one vessel or two. An added advantage is that if any piece of equipment should fail its functionality can be taken over by another machine within the system. This flexibility allows the controller to select any number of vessels from 4 to 8 depending upon his class size (less ships may of course be used as the control terminal recognises only those computers that have been switched on).

By implementing this relatively complex system, *Radsim* is able to be used by a far wider range of institutions running from a relatively inexpensive fairly portable system with around 4 computers up to a system where in excessive of 20 computers can be used.

At any stage however, the maximum number of own ships is limited to 8 by the current software. Modifying this value would cause a number of problems particularly in the screen display but it is also the contention of this author and others [ref 15 - personal correspondence with Capt A.Bole formerly of Liverpool Polytechnic] that a lecturer cannot interact with more than eight student vessels at low level, nor more than five at high level.

Experiments have been carried out in real time simulation where two screens are available to make use of the second (normally the navigational aid computer) for other functions. In this case the navigation aids panel and manoeuvring controls need to be transferred back to the radar display.

The second display has then been used to display a visual scene (which can be panned through 360° showing all vessels within visual range of own ship) or has been used to display the characteristics of a Rasterscan Chart Display integrated to the GPS. Changing to these alternative configurations can be done remotely from the control terminal and then simply rebooting all the student terminals.

AUTOBOOT

If a set of computers is used solely for *Radsim* it is feasible to make the system autoboot to any desired configuration. In this case, when the control terminal is switched on, a ramdrive is created in memory and a number of batch files called 1.BAT, 2.BAT, 3.BAT..... (One for each student computer) is copied from the hard drive to the Ramdrive. If the Configuration program is run, these batch files are modified, saved to Ramdrive as well as to hard drive. In this way, the configuration is saved for later use.

When the student computers are booted, the network connects before the final stages of the AUTOEXEC.BAT file. The final line in the AUTOEXEC.BAT file is simply D:\1.BAT. In this case the computer looks to D drive (ie the Ram drive on the main computer and executes the contents of 1.BAT (or 2.BAT etc). Each computer in this case will have a different number to execute. These numerical batch files contain instructions to run the desired program.

To change the configuration, it is necessary to run the configuration program on the main computer which then alters these numerical batch files on both hard drive and Ramdrive. Thereafter the easiest method is to simply reset the student computers and allow them to reboot.

In this manner it is possible to have many different programs on each computer. On rebooting the last selected configuration will start on each student machine.

SOFTWARE COMPUTATIONS

There are a number of Electronic Navigation Aids that have been included in *Radsim*. These include GPS (Global Positioning System), Decca Navigator, RDF (Radio Direction Finder) and Echo Sounder. Other possible Navaids such Omega (hardly used), Transit Satellite Navigator (recently discontinued) and Loran (not used in South Africa) have not been included. Of these only Loran is current and could be added relatively easily. All hyperbolic conversions as well as station locations as at the end of 1995 are available to the author.

GPS

The GPS display is fairly straight forward and a simple algorithm which reverses the *Radsim* grid co-ordinates to Latitude/Longitude is the primary requirement. A message from the controller can implement either a random or fixed error. Other features of the GPS [ref 16] is a waypoint facility as well as Course to Steer, Cross track error, distance to go. These algorithms are fairly straight forward and include rhumb lines by Mercator projection as well as Great Circle Sailing. All of these computations are freely available.

Decca

In the case of Decca (and Loran and Omega) hyperbolic conversion calculations are essential. An excellent algorithm by Rex H.Shudde [ref 17 - Journal of the Institute of Navigation] does computations for Loran C. This program listing was implemented in Turbo Pascal by the author and utilised in a standalone Loran Simulator some years ago.

Thereafter the same algorithm was modified to handle Decca co-ordinates and zone/lane systems and a standalone Decca Simulator developed. Effectively this sub-program has simply been utilised in *Radsim*.

Again an error level, random wandering etc were implemented for full control from the controller.

The Algorithm used is not an exact result as the velocity of propagation of the transmissions is assumed to be constant. In Loran only one frequency is used and the velocity of propagation is simply a declared variable. In Decca 4 frequencies are used, resulting in 4 different velocities of propagation. The algorithm can only handle 1 velocity of propagation and therefore a mean value is used. This results in slight inaccuracies which increase as the simulated receiver moves to the extremity of chain coverage. The values achieved were well within the accuracy claims of the real system and it was felt that this was therefore acceptable. In any case, Decca has been discontinued in South Africa (01 - Apr - 1998) and will be discontinued worldwide in the near future.

RDF

For the Radio Direction Finder, a separate list of Radio beacons including position and frequency is included in the files used by *Radsim*. Great Circle [ref 18 - Munro's Navigation] computations are again used with a quadrantal and semicircular error [ref 19 - Radar and Electronic Navigation] based on constants. By using constants instead of variables the

Calibration curve is always identical and can be permanently printed and available in the student cubicle. The alternative of having a different curve for each vessel would lead to far more paperwork and confusion and in the author's opinion the disadvantages of the controller having to hand out a new diagram for each own ship and exercise, outweigh the advantages of using a new curve. In any event, in the real world, these students will serve for up to 6 months using the same curve for that period.

Echo Sounder

Elsewhere in this dissertation is the full computation for determining depth of water above chart datum. Simply a sinusoidal tide with variable range and starting time determined by the controller, has been applied as well as the draft of the vessel model before display of the results. The display of sounding data has been kept relatively simple.

Compass

Radsim has the ability to show either True Courses (as per Gyro Compass) or Compass Courses (as shown by a Magnetic Compass). As with the RDF constants have been used instead of variables for the same reason. All 5 co-efficients (A,B,C,D,E) [ref 20] are declared as well as the Variation which is included in the chart data. From this a table of deviations has been prepared which, with the variation determines the total compass error on all headings.

CHAPTER 5

DISPLAY OF COASTLINE ON A RADAR TYPE DISPLAY

INTRODUCTION

Real radars update the screen with a radial sweep in a period of typically 3 to 4 seconds. Potentially all targets within the radar range scale selected by the operator may need to be displayed on the screen. For this project the maximum range of the radar is set at 48 miles as this is the normal maximum range of most radars that are to used by the target group. However, the radar cannot see low targets behind higher ones and cannot see much beyond the horizon. Certain targets may not normally be detected due to being too small. The intention of this section of the simulation development is to ensure that presentation of land specifically appears realistic. Obviously the height of the own ship scanner and the position of the vessel within the exercise area will determine what objects should appear on the screen and how they should appear. [ref 21]

REQUIREMENTS

With reference to the Specifications for a Marine Simulator [ref 1] the minimum manoeuvring area for use in the Simulator must be 200 Nautical miles square and must include a part of Dover including North Foreland, Calais Cap d'Antifer and Beachy Head. Two areas must be included. For this project the area selected for Dover therefore covers from 48°04'North to 51° 24' North and from 001°57' West to 003°30' East. The second area would include a similar sized area covering the Western Cape around Cape Town. Projections by the writer estimate that between 5 000 and 10 000 points would be required to achieve a coastline suitable for navigation of a vessel during final port approach. This is clearly a vast amount of data and earlier experiments showed that this would slow down the computational speed considerably and would make the system unacceptable. To overcome this problem various chart rectangles are defined. The size of the rectangle is variable depending upon the detail contained in that area. A full exercise area therefore may contain one or more rectangles of data that are grouped to form the exercise area. These are referred to as CHARTS in *Radsim*. A group of charts therefore forms an exercise area. All charts in a group have the same reference point (in the case of the Western Cape Group, Robben Island Light is used), similar Radio Direction Finding station data, DF calibration, as well as Variation and Deviation data. Along with the actual coast data and this ancillary data are stored four sets of co-ordinate data with other CHART names. For convenience the first co-ordinate is the North followed by South, West and East. If the reference object should go beyond one of these points, the program will automatically determine the coastline (if any) that lies on that boundary and load the new data. The amount of data loaded is under 20kBytes and is hardly noticeable. Where there is no adjacent chart in a particular direction, this is indicated by a zero co-ordinate and a Chart name of 'NOMAP' and it is assumed that the current chart goes to infinity in this direction.

In this way the data being handled by the processor never exceeds 1 000 points of land and 1 000 points of soundings though it is theoretically possible to run a continuous exercise of any length.

When drawing up the coastlines that form a group it is necessary to ensure that there is an overlap area of about 40 nautical miles (to allow a reasonable radar image both backwards and forwards from either chart) with the changeover barrier approximately midway through the barrier. Groups can be reasonably easily extended by simply creating a new chart, determining the changeover point and modifying the adjacent chart's boundary structure. The echo soundings do not have to go beyond the change over line by more that one reading.

In all associated programs, there must be a similar facility to switch charts. In case of the student system, the reference object is the position of his vessel whereas on the

Preparation, Control and Replay programs the reference object is the controller's cursor. Simply moving to another chart area causes that one to be loaded and displayed.

METHOD

In *Radsim* the coastline consists of up to 1 000 points stored in long integer X/Y co-ordinates which have been converted from a text based Latitude/Longitude format. The resolution of this grid is one centimetre with the centre point arbitrarily assumed at any convenient point on the chart. Lines joining points are assumed to be contiguous unless a break is indicated (grid value 0, 0). A relatively simple routine allows this entire map to be reproduced on the controller screen for dynamic control of the simulation as well as for setting up and replaying an exercise. The form of this map is really a set of straight lines joining each contiguous set of points and for display purposes for the controller is optimal. A common routine allows for zooming, unzooming and panning.

For the students radar display, this is far more complex as the land must be displayed during the rotational sweep period of a radar. In addition the update is based on a radial motion of the sweep of a real radar and range falloff and depth of paint must appear realistic.

For the last two reasons an additional byte per point is included giving the attribute of that point of the coastline. This attribute is made up of two components - height and depth of slope - each component using 4 bits allowing 16 variations of each. The heights have been chosen as best representing the land and is also interconnected with ship target size. A height of 0 equates to an invisible object gradually growing to 15 representing as high object. For vessels only 0 through 9 are allocated and values above this are reserved for representing rain.

A slope of 0 indicates again invisible, 1 would be a sheer cliff and 15 a gentle slope hence a deep paint on the radar screen.

Effectively every point of the coast is converted to a range and bearing from the own vessel. The line between two consecutive points is recreated by one of two methods. If the difference in bearing between the two points is less than 20° then a simple proportional algorithm is used to fill every degree of bearing between the two points. This causes a slight distortion but is acceptable. For larger differences in bearing the angle is split and an additional temporary midpoint is inserted. This routine is recursive and allows as many binary splits as will connect the points. This routine is time expensive but allows quays etc to be represented as straight lines on the radar screen. Certain other simulators use the first method but does no splitting and this causes noticeable distortion.

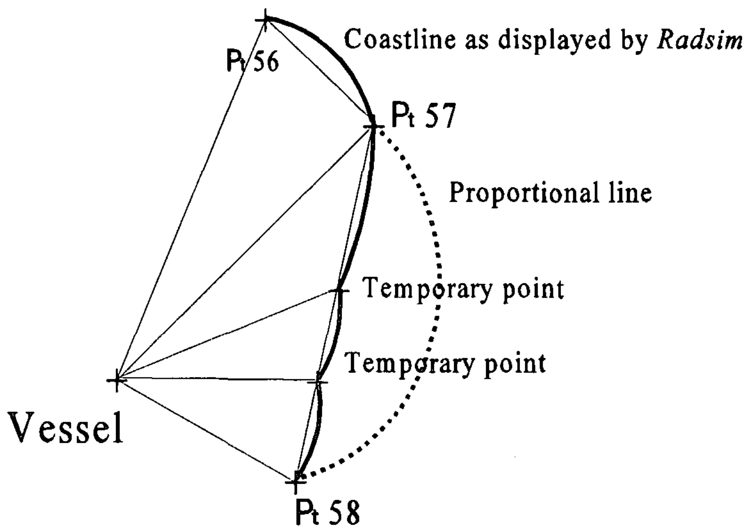

Figure 7 - Coastline as displayed on screen.

To convert all potential land points from X/Y to radial co-ordinates takes a noticeable period of time. Originally the author experimented with carrying out the computations when the sweep is at top dead centre but subsequently decided that this caused an unacceptable delay to the rotational sweep. Instead, the computation was time sliced to do 3 out of the 1000 computations for every 1° of rotation. This information is stored for display during the subsequent rotation. This does cause a lag of 3 seconds for updating the display but the author believes that this is more acceptable that the alternative optical delay.

3 points of land per sweep are handled and converted to range/bearing co-ordinates from

the X/Y system. This allows 360 times 3 points per revolution or a maximum of 1080 points to be converted. The protocol is limited arbitrarily to 1000 points by default so there is little wastage. Where two contiguous points are far apart a recursive algorithm splits the two points to create a series of midpoints that are not greater than 20° (this value was determined by trial and error) apart thus ensuring that straight lines such as a quays are indicated as such on the screen. Objects closer than 20° apart use a simpler algorithm simply averaging range and bearing to fill in the missing bearings. Thus every 1° of bearing is allowed for and stored in a multi dimensional array allowing up to 3 objects per degree.

The array at right is used to store the radial coast data and is stored using a pointer to heap space. Storage required is 25 920 bytes.

```
type  RadialType  = array[0..3, 0..359, 0..2, 0..2] of word;
RadialCoast                   : ^RadialType;
```

Figure 8 - Radialtype

The first element (0..3) has 4 possible values. A value of 0 refers to the currently loading array. A value of 1 indicates the current display array, 2 the afterglow array and 3 indicates the rubout array.

The second element stores 360° of information for a full rotation with 1° resolution. In drawing the sweep, it is in fact repeated twice to fill the screen thus sweeps occur at ½° intervals.

The third element (0..2) allows up to 3 objects to be displayed on a single bearing. When a point of land or target is computed to be on bearing θ, it is sorted and placed so that the closest target is at level 0 and the furthest (that will appear) will occupy level 2. Objects further than this point are rejected. During the sorting process the fourth element is also checked for height so that small objects are not seen behind high objects.

The fourth element of the array (0..2) contains first (0) the range of the object in pixels, (1) the depth of paint for the particular object also in pixels and (2) the height of the object (0..15 levels) . The second cell of this dimension (the depth of paint cell) also carries an intensity value which is included by multiplying the intensity (valid values are 0 to 3) by 256. This is obtained later on by DIVing this value by 256, while the length is recreated by MODding by the same value. This intensity control allows multi level quantization making the radar picture more acceptable and bringing the simulation in line with the processes that are carried out in most newer radars as well. In addition 5 other bits are used to store either SART (Search and Rescue Transponder) and Racon (Radar Beacon) information. 16 Racons are feasible per map area and 4 bits are used to store which Racon is used so that the correct pattern can be associated with the object equipped with Racon.

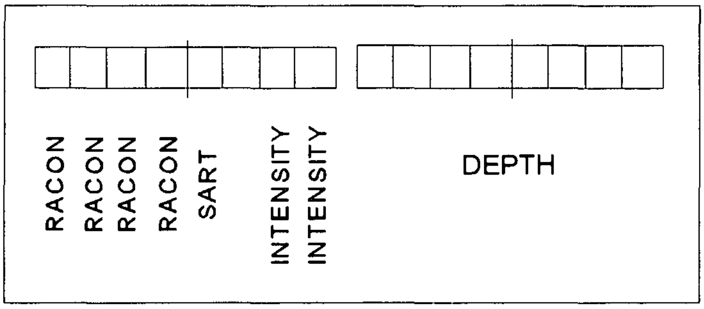

Figure 9 - CoastType Byte

This array (RadialCoast^[0,x,x,x]) is filled during rotation *r*.

When the sweep reaches top dead centre this array is transferred down to the next element of the same array and this dimension is reset to a value twice as great as the range scale (ie

```
For j := 3 downto 1 do RadialCoast^[j,i] := RadialCoast^[j-1,i];
For I := 0 to 359 do
   begin
       RadialCoast^[0,i,0,0] := 2*Radius;
       RadialCoast^[0,i,0,1] := 0;
       RadialCoast^[0,i,0,2] := 0;
   end;
```

Figure 10 - Resetting RadialCoast at top dead centre

nothing visible). The data stored during rotation *r* is then used for display purposes during rotation *r+1*. During this rotation the first dimension of the array is again loaded with new data to be ready for display on rotation *r+2*.

The range of targets is reset at twice current range to allow for an offset display and as currently set will not paint on the screen.

The function shown on the right is used extensively in the loading process and determines the angular difference in bearing allowing for crossing the 360° barrier as well as clockwise or anticlockwise differences.

```
Function diff(b1,b2:Integer) : word;
var  a : word;
begin
   a := abs(b1 - b2);
   if a>(360 div 2)
      then diff := 360 - a
      else diff := abs(a);
end;
```

Figure 11 - Function Diff

The procedure *Join* is called by other routines to connect a pair of points. Other routines ensure that the points are never more than 20° apart. Every degree of bearing between the two points is then loaded with a proportional range, target depth and height and it is sorted at the correct distance from the centre.

If necessary the current data is shuffled outward.

```
Procedure Join(b1,b2:word;r1,r2:word);
var  h, j, k, l, m : integer;
     level, r      : word;
begin
   l := b1;
   m := b2;
   j := l - m;
   l := r1;
   m := r2;
   k := l - m;
   if diff(b1,b2)>2 then
     for h := b1 to b2 do
       begin
         if (r1<RadialCoast^[0,h,0,0]) then level := 0 else level := 1;
         if (r1<RadialCoast^[0,h,0,0]) and (Height<RadialCoast^[0,h,0,2]) then
           begin
             RadialCoast^[0,h,1,0] := RadialCoast^[0,h,0,0];
             RadialCoast^[0,h,1,1] := RadialCoast^[0,h,0,1];
             RadialCoast^[0,h,1,2] := RadialCoast^[0,h,0,2];
           end;
         if (level=0) or ((level=1) and (Height>RadialCoast^[0,h,0,2])) then
           begin
             l := r1 + ((k * (h - b1)) div j);         {proportional range for each bearing}
             if l>(radius*2) then r := (radius*2) else r := l;
             RadialCoast^[0,h,level,0] := r;
             RadialCoast^[0,h,level,1] := TargetSize;
             RadialCoast^[0,h,level,2] := Height;
           end;
       end;
end;
```

Figure 12 - Procedure Join

The range determined for each bearing uses a simple proportional routine as they are always close together and the distortional effect is negligible.

Procedure *SortOut* determines whether the pair of points to be connected are clockwise or anti-clockwise from each other. It also sorts out bearings across the 360° barrier. Ie if Pt 1 is bearing 348° and Pt 2 is 005° then 348° is connected to 360° and 000° is connected to 005°

The procedure Split that follows determines the difference in bearing between two consecutive points of land. If the points to be joined are less than 20° then a simple fast algorithm is used as shown on the previous page. If the angle subtended is greater than 20° a recursive binary split is used.

```
Procedure SortOut(b1,b2:word;r1,r2:word);
var  h, j, k, l : integer;
begin
   k := b1;
   l := b2;
   h := k - l;
   j := (r1+r2) div 2;
   if h>(360 div 2) then
     begin
        join(b1,(360-1),r1,j);
        join(0,b2,j,r2);
     end;
   if h<-(360 div 2) then
     begin
        join(b2,(360-1),r2,j);
        join(0,b1,j,r1);
     end;
   if (b1<b2) and (abs(h)<(360 div 2))
             then join(b1,b2,r1,r2);
    if (b1>b2) and (h<(360 div 2))
        then join(b2,b1,r2,r1);
end;
```

Figure 13 - Procedure Sortout

```
Procedure Split(x1,y1,x2,y2:LongInt;b1,b2: Integer;r1,r2:word);
var  dx, dy    : LongInt;
     ranger    : real;
    Brg , rng  : Integer;
begin
     dx := (x1 + x2) div 2;                {find the midpoint x co-ordinate}
     dy := (y1 + y2) div 2;                {find the midpoint y co-ordinate}
     x := dx * Radius/(185200 * RangeScale);
     y := dy * Radius/(185200 * RangeScale);
     Ranger := Sqrt(sqr(x)+sqr(y));
     If Ranger>(Radius*2) then Ranger := (Radius*2);
     brg := dir(dx,dy);                    {find the bearing of the midpoint}
     Rng := Round(Ranger);
                    {check each of the two bearings to midpoint bearing }
    if (diff(b1,brg)<20) then SortOut(b1,brg,r1,Rng) else Split(x1,y1,dx,dy,b1,brg,r1,rng);
    if (diff(b2,brg)<20)  then SortOut(b2,brg,r2,Rng) else Split(x2,y2,dx,dy,b2,brg,r2,rng);
end;
```

Figure 14 - Procedure Split

This effectively adds midpoints between each pair of points over 20° apart and on screen results in straight quays and breakwaters being displayed as such.

Firstly one sweep is drawn per allocated cycle. To handle high resolution (SVGA 1024 x 768) a line 3 pixels wide is used to draw at ½° intervals and this allows an unbroken display almost to screen edge. On every sweep, the first function is to ensure that the mouse, if it is on the radar screen and near the sweep , is removed. Thereafter the program erases the last trace, paint the afterglow if it is on and finally paint the last loaded array on the screen.

```
Procedure CoastDraw(i:word);        { I  is bearing to be painted}
var  paint   : boolean;
     colour  : word;
begin
    paint := true;
    If (Ex^.Preset[1].ShadowsOn=1) and InSector(I) then Paint := false;
    if (Gcursor<>1) and (abs(I-Mbrg)<10) then HideMouse;
    SetLineStyle(0,0,3);                    {thick solid line}
    Colour := black;
    ColorIn(3,i,0);                         {rubout routine}
    ColorIn(3,i,1);
    ColorIn(3,i,2);
    if trails and paint then Colour := 7 else Colour := black;
    For j := 2 downTo 1 do                  {AfterGlow for 2 traces}
       begin
           ColorIn(j,i,0);
           ColorIn(j,i,1);
           Colorin(j,i,2);
       end;
    if paint then Colour := 15;
    ColorIn(1,i,0);                         {Paint the primary radar picture}
    ColorIn(1,i,1);
    ColorIn(1,i,2);
    SetLineStyle(0,0,1);                    {Reset the line style for normal use}
    If  (Gcursor<>1) and (abs(I-Mbrg)<10) then ShowMouse;
end;
```

Figure 15 - Procedure CoastDraw

If necessary the mouse cursor is reactivated and displayed on the screen. The function

InSector is a boolean function returning false if the current sweep bearing is in a radar shadow sector and this shadow sector is active. This effectively blanks this sector from any radar returns.

The routine *ColourIn* draws the appropriate lines as shown below.

If the target is strong (has maximum intensity) an extension is applied by increasing the painted depth with the medium and low levels of green to make the coastline appear more realistic.

```
Procedure ColorIn(a,b,c:word);
var  j, k                   : word;
    RefX,  RefY            : Integer;
begin
    RefX := CX[a];                  {CX is the x co-ordinate of the electronic centre}
    RefY := CY[a];                  {CY is the y co-ordinate of the electronic centre}
    if (RadialCoast^[a,b,c,0]<(Radius*2))and (RadialCoast^[a,b,c,1]>0) then
      begin
        len := (RadialCoast^[a,b,c,1]) mod 1000;     {split range from intensity}
        col := (RadialCoast^[a,b,c,1]) div 1000;
        if (colour = 15) and (col = 2) then colour := 7;
        if (colour = 15) and (col = 1) then colour := 10;
        for j := 0 to 1 do
         begin
           SetColor(colour);
           k := j*360+I;
           x := round(RadialCoast^[a,b,c,0] * table[k,Xcor]);
           y := -round(RadialCoast^[a,b,c,0] * table[k,Ycor]);
           x1 := round((len div round(RangeScale+1))*table[k,Xcor]);
           y1 :=-round((len div round(RangeScale+1))*table[k,Ycor]);
           LineCheck(RefX+x,RefY+y,RefX+x+x1,RefY+y+y1);
           If Colour = 15 then SetColor(11);
           If Colour = 10 then SetColor(7);
           if (len>36) then LineCheck(RefX+x+x1,RefY+y+y1,
                              RefX+x+x1+x1 div 2,RefY+y+y1+y1 div 2);
           If Colour = 15 then SetColor(7);
           if (len>36) then LineCheck(RefX+x+x1+x1 div 2,RefY+y+y1+y1 div 2,
                              RefX+x+x1+x1,RefY+y+y1+y1);
         end;
      end;
end;
```

Figure 16 - Procedure ColorIn

The procedure *LineCheck* is an extension of the Pascal routine *Line* that ensures that if either point referred to is not on the radar screen, then the line drawn will draw to the edge of the circular radar screen only. This routine caters for offset as well as centred displays and is extensively used throughout the program. It effectively allows the program to declare a circular viewport and clip all lines that are not within this viewport.

SUMMARY

In this section the author has shown algorithms that will display a radially rotating display similar to that used in a radar set. All the algorithms shown here are used in *Radsim* and operate fast enough on suitable hardware, to appear realistic. Shortcuts have been taken where these will not detract from the realism but where speed is critical.

Various programming techniques have been used including a recursive binary split as well as time sliced programming to distribute evenly computations over the natural rotational period of a radar of between 3 and 4 seconds.

CHAPTER 6

RADAR CONTROLS

INTRODUCTION

During Radar Training it is essential that the student has the ability to set up a radar set correctly and has the ability to identify maladjustments of the radar. Normally this is done on real equipment. However, due to the cost of this equipment and the relatively high number of students attending this type of course, it is not cost effective to examine students individually on real equipment. Effectively about 20 minutes would be required per student and therefore a class of 20 students would take an entire day.

In the simulation, provided the controls indicate a reasonable level of fidelity, it would be possible to examine as many students as ship stations exist (maximum of 8) at a single session. As the controls are digital it is feasible to get an exact assessment of students ability. With a feedback mechanism to the controller, the lecturer can in fact check all students virtually simultaneously.

In addition realism is heightened.

In certain cases, it would be desirable that the radar is set up at the beginning of the exercise, thus moving straight into the simulation proper. In other cases the it may be desirable that the student has no control over the display. Finally, we may require the student to set up the radar from scratch at the beginning of the exercise. When setting up the exercise a byte is used to determine radar status at the beginning of the exercise and each of the above permutations is possible as well as complete radar failure.

On running the exercise, each computer determines the radar status as well as selecting a random number for optimum settings of gain and tuning. If the radar is preset then the actual settings of gain and tuning would be made equal to optimal gain and tuning. If the radar is OFF the actual settings are zeroed. SAC (Sea Clutter) is dependant upon exercise weather conditions while FTC (Rain Clutter) is always set to zero initially.

Optimal setting on initialization

```
RadarSettings.OptimalGain := 19 + random(13);
RadarSettings.OptimalTune := 8 + random(17);
```

Figure 17 - Gain and Tuning initialisation

The algorithms displayed below allow the actual setting to be altered up or down by the student. Side refers to either direction of control - 1 is turning down, 2 turns up.

GAIN

```
if side = 1 then dec(RadarSettings.actualGain) else inc(RadarSettings.ActualGain);
if RadarSettings.ActualGain<1 then RadarSettings.ActualGain := 0;
if RadarSettings.ActualGain>36 then RadarSettings.Actualgain := 36;
if RadarSettings.OptimalGain>RadarSettings.ActualGain
    then amplification := RadarSettings.ActualGain/RadarSettings.OptimalGain
    else Amplification := 1;
 if RadarSettings.OptimalGain>RadarSettings.ActualGain
    then DeltaGain := RadarSettings.OptimalGain - RadarSettings.ActualGain
```

Figure 18 - Amplification routine

Gain works on 37 possible positions with the optimal value being between 19 and 32. The

```
Procedure OverGain(I: word);
var  k, Result : ShortInt;
begin
   Result := RadarSettings.ActualGain - RadarSettings.OptimalGain;
   if Result<0 then result := 0;
   k := 16 - Result;
   if k<1 then k := 1;
   if (I mod k = 0) and (Result<>0) and (Ex^.Preset[1].radar<>0) and (PowerFn=2)
       then Noise(i,true) else Noise(i,false);
end;
```

Figure 19 - Procedure Overgain

student adjusts the actual gain which will affect the variable *Amplification* which is used to determine the picture described later. The maximum value of *Amplification* is 1. If the gain is turned up to high then a second variable *DeltaGain* is used to add noise to the screen indicating overgain.

TUNING

```
if side = 1 then dec(RadarSettings.actualTune) else inc(RadarSettings.ActualTune);
if RadarSettings.ActualTune<1 then RadarSettings.ActualTune := 0;
if RadarSettings.ActualTune>36 then RadarSettings.ActualTune := 36;
```

Figure 20 - Tuning Routine

Tuning has 37 positions, the optimal position being between 8 and 25. The difference between Actual and Optimal setting will affect a tuning bar and the picture as seen on the screen.

BRILLIANCE

Brilliance is used to emulate a brilliance control. By simply increasing or decreasing a variable *Bright* the 4 shades of green used on the radar screen are changed according to the algorithm displayed on the right without affecting the other colours used in the system.

```
if side = 1 then dec(Bright) else inc(Bright);
if Bright<1 then Bright := 0;
if Bright>60 then Bright := 60;
{4 colours of green are affected }
SetRGBPalette(7,0,Bright div 2,0);
SetRGBPalette(58,0,bright * 2 div 3,0);
SetRGBPalette(59,0,bright * 2 div 3,0);
```

Figure 21 - Brilliance Routine

STC

STC (Sensitivity Time Control) is set at one of 19 levels and the effect is shown further on in this section. It will have an effect on sea clutter and al nearby targets allowing these

```
if side = 1 then dec(RadarSettings.STC) else inc(RadarSettings.STC);
if RadarSettings.STC<1 then RadarSettings.STC := 0;
if RadarSettings.STC>18 then RadarSettings.STC := 18;
```

Figure 22 - STC routine

targets to be erased if too high.

FTC

Similarly FTC (Fast Time Constant) can be set at any of 19 positions and will affect the depth of paint of all targets on the screen.

```
if side = 1 then dec(RadarSettings.FTC) else inc(RadarSettings.FTC);
if RadarSettings.FTC<1 then RadarSettings.FTC := 0;
if RadarSettings.FTC>18 then RadarSettings.FTC := 18;
```

Figure 23 - FTC routine

FEEDBACK

The Actual and Optimal settings of all controls is written to the Ramdrive and displayed on the Controller's Terminal so that the Controller may ascertain how well each student's console is set up.

RANGE FALL OFF DUE TO TARGET SIZE AND CONTROL SETTINGS

The next table shows how Antenna height, target size as well as *Amplification* and *TuneEffect* will determine the MaxSignal value which finally determines size and intensity of the target painted on the radar screen. Both the above variables (*Amplification* and *TuneEffect*) have a maximum value of 1 when the controls are set optimally.

The other computation allows antenna height of the observer to be taken into account and has been modified to simulate target echo strength as well as line of sight detection. For example a liferaft may be physically visible (mathematically speaking) [ref 21 page 88] to an antenna 10 metres above sea level at a range of 6,99 miles + 1,5 miles = 8,49 miles but due to the poor target response in these calculations would only be detected at 6 miles less ie at 2,49 miles [ref 21 page 81]. This assumes optimal settings of all other controls.

```
Function MaxSignal(TgtSize,OwnSize:byte):real;
var value1, value2 : real;
    target         : byte;
begin
   { detection range in miles}
   Case TgtSize of
      0 : value1 := 0;   { invisible }
      1 : value1 := 1.5; { liferaft }
      2 : value1 := 3;   { lifeboat }
      3 : value1 := 4.8; { 15 metre }
      4 : value1 := 7;   { 100 GRT }
      5 : value1 := 10;  { 500 GRT }
      6 : value1 := 14;  { 1000 GRT }
      7 : value1 := 18;  { 5000 GRT }
      8 : value1 := 21;  { 10 000 GRT }
      9 : value1 := 24;  { 50 000 GRT }
     10 : value1 := 28;
     11 : value1 := 32;
     12 : value1 := 36;
     13 : value1 := 40;
     14 : value1 := 44;
     15 : value1 := 48;
    end;
   {height of antenna in metres}
   Case OwnSize of
      0 : value2 := 0;   { invisible }
      1 : value2 := 3;   { liferaft }
      2 : value2 := 3;   { lifeboat }
      3 : value2 := 6;   { 15 metre }
      4 : value2 := 8;   { 100 GRT }
      5 : value2 := 10;  { 500 GRT }
      6 : value2 := 12;  { 1000 GRT }
      7 : value2 := 15;  { 5000 GRT }
      8 : value2 := 21;  { 10 000 GRT }
      9 : value2 := 24;  { 50 000 GRT }
    end;
   Value1 := value1 - 6 + 2.21 * sqrt(value2);  {6 used to be an 8}
   if value1>0 then MaxSignal := value1 * Amplification * TuneEffect else MaxSignal := 0;
end;
```

Figure 24 - Function MaxSignal

```
Function TargetSize:word;
var value, STCamp, ActualSignalStrength, MaxStrength : Real;
   temp : word;
begin
    {rain clutter first}
    If PulseLength>10 then value := PulseLength - (RadarSettings.FTC * 3)
                  else value := PulseLength - RadarSettings.FTC;
    if value<1 then value := 1;

    {deep targets accounted for}
    if Slope>1 then
      begin
          value := (value * Slope)/5;
          value := value*4 + Random(round(value*2));
      end;

    { take into account size, gain and STC }
    if Ex^.Target[1,size] = 0 then Ex^.Target[1,size] := 9;
    if actualRange<>0 then MaxStrength := MaxSignal(height,Ex^.Target[1,size]) / ActualRange else
           MaxStrength := 1;
    MaxStrength := MaxStrength - 1;
    if MaxStrength<0 then MaxStrength := 0;
    if MaxStrength>2 then MaxStrength := 2;
    STCamp := 1+(ActualRange/3)-(RadarSettings.STC/9);
    If STCAmp>1 then STCAmp := 1;
    If STCAmp<0 then STCAmp := 0;
    ActualSignalStrength := MaxStrength * Amplification * STCAmp * TuneEffect;
    if ActualSignalStrength>1 then ActualSignalStrength := 1;

    value := value * ActualSignalStrength;
    if value<0 then value := 0;
    if value<256 then Temp := round(value) else Temp := 255;

    { allow weak targets to paint in another shade of green }
    If (ActualSignalStrength>=0.5) and (ActualSignalStrength<0.7) then Temp := Temp+1000;
    If (ActualSignalStrength>0.3) and (ActualSignalStrength<0.5) then Temp := Temp+2000;
    TargetSize := Temp;
end;
```

Figure 25 - Function TargetSize

APPLICATION OF SEA CLUTTER, RAIN CLUTTER AND PULSE LENGTH

The above Function combines the pulse length (determined by ranges scale selected), with STC and FTC setting with the MaxSignal computed in the previous section to determine a value for both TargetSize (which determines depth of paint on screen) as well as a Signal strength indicator which is used to determine the colour of the paint on the screen to satisfy the 4 level quantization mentioned previously. The Function TargetSize returns two values which are combined. The lower byte indicating depth of paint and the value div 1000 will determine the intensity of colour (inversely).

SUMMARY

In the above manner, the targets and coastline as seen on the display will have range falloff, intensity and depth of paint proportional to all the following factors

- Range from own ship
- Depth of target
- Height of target
- Height of scanner
- Pulse length determined by range scale selected
- Setting of Tuning
- Setting of Gain
- Setting of STC
- Setting of FTC

CHAPTER 7

DEBRIEFING SOFTWARE

INTRODUCTION

It is as important to be able to successfully debrief after the exercise as it is to run a Simulation. In this respect it is essential that relevant information is stored by the program during the exercise so that the actions of students can be analysed accurately after the Simulation. Different suppliers use different methods for displaying what happened in an exercise. The following were points that the author deemed critical.

- Replay must be fast. It must be possible to rapidly move to a point of interest in an exercise of up to 3 hours long (specifications limit recording to 2 hours).

- It must be possible to back step from that point to analyse events leading to the incident.

- A power failure near the end of an exercise should not corrupt the whole replay data file.

- Adequate data must be available to allow accurate debriefing.

METHOD

At this point it has been deemed that for most cases positional information of every vessel used in the exercise should be stored at 1 minute intervals. There are some exercises where it may be desirable to increase the frequency (and therefore size of storage file) to ¼ minute intervals. This could be done relatively easily and may be an enhancement at a later stage.

Due to the unknown exercise length, (anything from 30 minutes upwards) and therefore the unknown file size, it has been decided to allow the exercise to run for 15 minutes (or to the end of the exercise - whichever is first) and then allow the controller to dump the data to hard drive at this interval. At the end of 30 minutes the second 15 minute dump is simply concatenated to the first data file. This continues each time 15 minute intervals are reached. When the program is exited the final section of recording is simply added to the file. At present the program is capable of storing virtually unlimited exercise lengths although the replay program currently is limited to arbitrarily 200 minutes.

In a 15 minute time slice, 15 positions of 30 vessels are stored in x/y co-ordinates using LongInts - hence storage for a single time slice is 15 x 30 x 2 x 4 bytes = 3 600 bytes. This file size is small and fast to dump to disc and storage should never be excessive.

This replay data is stored within a coastline directory and the controller is able to give this file any legal 8 character name before the exercise starts. The extent .RPL is automatically assigned by the program. A temporary ASCII file called REPLAY.DTA is created on the Control hard drive and the name and Coast is written to this file. When running the replay program, it is possible for the system therefore to pick up the last exercise run automatically although there is a directory system to allow any exercise that has been run to be replayed. This allows students to view previous exercises that may be of interest to the current debrief.

REPLAY

The debriefing program called REPLAY.EXE loads the entire playback file into memory. At the time of development it was deemed that the file limit would be 48 000 bytes and would work rapidly within memory. If it is determined that more frequent recording intervals than one minute are required or that the exercise length may exceed 200 minutes, it would be reasonably easy to modify the program to read data sequentially off the disc thus enabling greater flexibility.

The debrief program uses many sections of code that would appear on the Control Terminal. Common algorithms are used to display the coastline, load the appropriate section of coast depending on the area being viewed and the ability to zoom, unzoom and pan.

Different controls are however used to control the debrief which ideally is displayed using a video projector on a large screen. The controller has the ability to step forward of backward one minute at a time, as well as being able to zoom, unzoom and pan. Each of the own vessels is colour coded (as in the rest of the system) while target tracks are indicated in light gray.

Due to possible confusion when 30 vessels are being tracked for 200 minutes, it was also decided to be able to limit which period should be displayed. In other words if an incident occurred at minute 120 then it is possible to display from minute 100 to minute 120 and exclude the tracks from minute 1 to minute 100 which would clear a lot of information.

It was also deemed necessary to have some means to measure ranges between vessels during the debriefing. Any vessel, be it target or own ship can be selected as reference and distance from cursor to that vessel is continuously displayed.

OWN SHIP MANOEUVRES

Besides recording the actual position of all targets during the exercise, the author found it desirable to also record certain student actions during the exercise, specifically engine and steering commands. A series of contradictory commands would not normally be picked up from the positional data. Therefore every time a student moves the engine or steering controls this is recorded in a contiguous file with the same name as the replay file but with the extension .MAN. This file may be printed or displayed on screen and is a useful indicator to show when a student is panicking due to the frequency of orders as well as the lack of time for the vessel to react to the commands given. As the program steps through the minute by minute positions of all vessels, the current desired course and speed of each own vessel is displayed in a window.

This function allows accurate recording of student's actions.

During the exercise itself, the Controller has a screen which may be called up listing the last manoeuvres made by each own vessel.

SUMMARY

The replay program is stand alone from the rest of the program suite. This allows future expansion without modifying the main programs provided that adequate data is already being stored during the exercise.

There are many enhancements that may be added and nice to have that could be added in the future as feedback becomes available. For example it would be fairly straightforward to dump any screen display to a laser printer so that a hardcopy of the exercise may be kept. As the REPLAY program is completely standalone, it is possible to download certain files and run the REPLAY at a remote station without having to copy the entire *Radsim* directory. These files would fit very easily onto a 1.4 MB disc.

CHAPTER 8

CONCLUSION

At the beginning of this project, various needs were identified and certain procedures were indicated to solve various of the problems that would be encountered. The software for Radar Simulation has been completed, although modifications and improvements are feasible, and the system carries out all the features laid down by International legislation. The system has been supplied to various institutions, some before this dissertation was commenced, and some during the progress of this dissertation. Currently all users are on the same upgraded versions and have been thoroughly tested on students throughout South Africa.

Some Thirty Thousand lines of code were used in the project and time expended exceeded Fifteen Thousand hours to achieve a close knit program that fulfils all the requirements of a Radar Simulator.

FUTURE MODIFICATIONS

In the past 24 months, the system has run without failure or downtime which is indicative of a fairly stable platform which could now be expanded if desired. Various improvements have been identified throughout this thesis. One client, the South African Navy, has added their Military Specific own module to the system by simply using the interface provided by the Ramdrive mechanism for data interchange.

VISUALS

Experiments have been conducted for adding visuals by simply using the same data file to present targets on visual screens. This could be enhanced by adding coastlines, buoys etc but would of necessity be very expensive on hardware. Each own vessel would have ideally between 3 and 5 large screen displays to represent the visual windows looking out. The cost of this hardware would be more per vessel than the entire cost of a *Radsim* system and I doubt if at this time the educational institutions have the resources for this type of simulation desirable though it may be.

A single 20" screen (attached to its own computer) may be a viable alternative, with the ability to pan through 360° thus emulating a visual simulator.

ELECTRONIC CHART DISPLAY AND INFORMATION SYSTEMS

An additional requirement in the future will be for ECDIS (Electronic Chart Display and Information System). Due to the magnitude of this project and the amount of alternative software currently available, it may be desirable to supply an interface from *Radsim* to connect to suitable ECDIS in the future. Again experiments have been conducted already using *Radsim* with a scanned Rasterscan chart on a separate display and there would be no problem sending track information down to an additional computer. International Standards have been defined for Vector Charts but require computers more powerful than those used within this project.

As computer technology improves and CPU's increase in speed, it can be expected that standard hardware will be capable of displaying complex ECDIS charts adequately.

VESSEL TRAFFIC SERVICES SIMULATOR

At the time of completing this dissertation, a requirement for a VTS (Vessel Traffic Services) Simulator was required locally. Based on the success of Radsim and a demonstration of of the proposed simulator, the client (Portnet) placed an order for the VTS simulator. This project has been completed using techniques and technology developed for Radar Simulation. This project was developed to be fully compatable with Radsim although using a student terminal designed to emulate the actual equipment supplied by the supplier (Daimler Chrysler Aerospace).

The supplier has since indicated that that this will be the preferred simulator for future clients Internationally.

CONCLUSION

The author believe that *Radsim* could now be extended with modifications throughout its useful life to handle many of the challenges of the next ten years. It is an economical alternative to many of the solutions offered from other countries.

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GLOSSARY

ARPA	Automatic Radar Plotting Aid
Charts	Normally refers to a paper chart. In *Radsim* it refers to a rectangular section of coastline stored in digital format.
Controller	The educator in control of the simulation.
CPA	Closest Point of Approach
Decca	A short range (250 Nautical Mile) Hyperbolic Navigation System developed by England during World War 2
ECDIS	Electronic Chart Display and Information System. A display of a chart system on a hi resolution colour monitor.
Echo Sounder	An electronic device for measuring the depth under the vessel
GPS	Navigation by satellite time and ranging Global Positioning System.
IMO	International Maritime Organistation
Loran	Longe Range Navigation system - A Hyperbolic Navigation system (1000 Nautical Mile range) developed by the United States since World War 2 till present
Nautical Mile	The measurement of arc on the earth's surface of one minute of latitude. By convention its length is taken as 1852 metres
Omega	A world wide hyperbolic system developed by the United States
Own Ship	A cubicle containing suitable equipment manned by students, emulating a vessel under the control of those students.
Part Task	Simulation for experiencing a specific aspect of a vocational function.
Racon	Radar Beacon
Radar	Radio Detection and Ranging
RAM	Random Access Memory
RAMDRIVE	A pseudo drive stored in RAM - very fast access
Rasterchart	A techique where a chart is scanned pixel by pixel for display on a daylight monitor.

Rasterscan	A technique where a radar picture is converted to a digital picture and displayed on a daylight monitor
SART	Search And Rescue Transponder
STCW	Standard Training Convention for Watchkeepers
Target	Simulated vessels controlled by the Simulator Controller that interact with the student vessels. Also refers to any vessel being tracked by an ARPA.
TCPA	Time of Closest Point of Approach
Vector Chart	In this case the coastline is stored as a series of short straight lines and can be displayed on a daylight monitor.
VTS	Vessel Traffic Services

INDEX TO FIGURES AND ALGORITHMS

INTRODUCTION

This specification outlines the minimum requirements and performance standards for a navigational equipments simulator which can be used to meet the equipment requirements specification for the conduct of the Department of Trade Navigation Control Course (NCC).

The full specification covers requirements for the Navigation Control Course for training in the use of electronic navigational aids and, especially, the use of radar as an aid to collision avoidance. The requirements for radar simulation are set out in section 1. The requirements for additional features used in training on electronic aids to navigation other than radar are covered in section 2.

Section 1

1.1 General

The simulator shall employ at least three *own ship* radar displays [1], each of which is of a type which has been awarded a Department of Trade Certificate of Type Testing to the 1968, or later, Marine Radar Performance Specification. The simulator shall provide the facility for each *own ship* display to be operated independently of the other *own ship* displays and for the *own ship* manoeuvring controls associated with each display to be independent of the settings of the *own ship* controls at the other display positions.

1 reference also Clause 1.5 and clause 1.8.3

1.2 Simulator Provisions

1.2.1 The simulator shall provide for each *own ship's* display:

Time base rotation at the antenna rotation speed required by the relevant IMCO specification for marine navigational radar equipments to obtain a plan position indicator type of presentation.

1.2.2 The effects on the display of *own ship's* movement with means of setting course and speed and altering course and/or speed of *own ship* whilst the equipment is in use.

1.2.3 At least twenty ship target echoes not being echoes of the other *own ships* provided by the simulator with means of setting and altering the course and/or speed of each target independently whilst the equipment is in operation.
The course, speed and individual turn points of the targets may, additionally, be programmed prior to an exercise. The courses and speeds of pre-programmed target ships shall be relative to the ground.

1.2.4 *Own ship's* heading marker.

1.2.5 *Ship's head up* unstabilized relative motion, compass stablised relative motion and *true motion* types of presentation and means of rapidly changing from one type to another.

1.2.6 A compass repeater showing *own ship's* course, a speed indicator showing *own ship's* speed, together with helm, rudder angle and propellor revolution indicators.

1.2.7 The effects on the radar display of yaw of *own ship.*

1.2.8 Sea clutter, precipitation clutter, receiver noise and mutual radar interference, together with a means of adjusting the level of injected signal by the Instructor shall be provided. The radar display controls should operate realistically in respect of gain, sea clutter, rain clutter and (mutual radar interference suppression where provided).

1.2.9 Realistic echoes from land targets representative of at least two coastline areas, one of which shall be the Dover Straits including the following geographical points: North Foreland, Calais Harbour, Cap d'Antifer and Newhaven Harbour with a manoeuvring area not less than 200 x 200 nautical miles.

1.2.10 Effects of currents[1] to be applied to all ships in the manoeuvring area. Additionally, the simulator shall be capable of applying the effects of currents to each *own ship* individually. The currents to be variable in direction and speed.

1 the word currents used in this specification includes tidal streams.

1.2.11 Shadow sectors due to typical ship-borne obstructions.

1.2.12 The Instructor to be provided with either a radar display to act as a slave monitor to any of the *own ship* displays, or a graphics display which will provide a representative picture of any of the *own ship* displays. Additionally, the graphics display or another display may provide the selected scenario involving *own ships*, ship targets, navigation marks and land, including true vectors of the *own ships* and ship targets with relevant alpha-numeric labelling of these vectors.

1.3.1 Display Accuracies

The picture shown on the radar displays at each *own ship*, position must, on all ranges f'rom minimum range on the ¾ mile range scale to maximum range on the twenty four mile range scale, be similar in respect of definition and echo size and shall comply with the range and bearing accuracy requirements for the display of a shipborne marine radar set which had been awarded a Certificate of Type Testing to the 1968, or later, marine radar specification. Effects of pulse length and prf changes with range to be taken into account.

1.3.2 The effects of operating or adjusting. the controls of a display unit Inust be visible only on the display with which the controls are associated and must be independent of all other displays used with the simulator. In the case of any slave displays fitted to an *own ship* position the effect of PRF and Pulse Length may be controlled by the master display at each *own ship's* position.

1.3.3 A reflection type plotting aid shall be provided for each radar display other than the ARPA display (see clause 1.5). In the latter case a reflection plotter may be fitted.

1.4 Exercise Recorder

An X-Y type plotter or graphics terminal with recording facilities shall be provided for the use of the Instructor, so that an historical record can be available for de-briefing sessions. The record shall show the action taken by each *own ship* and the ship targets during any exercise for a period of up to 2 hours. The recorder shall be capable of handling up to four *own ships* and twenty targets. The graphics terminal playback may be provided with x10 playback facility.

1.5 ARPA Display

At least one of the radar displays shall be of a type which complies with the IMCO Performance Specification for *Automatic Radar Plotting Aids (ARPA)* (ref IMCO Resolution A.422 (XI)). The simulator input to the ARPA display shall be such that the ARPA display is capable of being used by the trainee to achieve the practical objectives in ARPA training as laid down in IMCO Resolution A.482(XII).

The display required by this clause may be one of the displays required by clause 1.1 employing integrated ARPA data or additionally a 'stand-off' ARPA display may be provided.

1.6 System Performance

1.6.1 Speeds

a[1] *own ship* variable to at least 90 knots ahead.
own ship variable to at least 10 knots astern.
in steps of not more than 1 knot.

b *ship targets* variable to at least 30 knots ahead,
at least one target variable up to 90 knots ahead.
in steps of not more than 1 knot.

Accuracy of indicated speed ± 2% of the maximum speed or ±0.25 knots, whichever is the greater.

1 Speed data of own ships to be determined by a mathematical model for each own ship.

1.6.2 Courses own ship and ship targets continuously variable 0° to 359°. Accuracy of course set or course made good for *own ship* and *ship target* ± 1°

1.6.3 Manoeuvring Characteristics of *own ships*

The simulator shall provitle the facility, at the choice of the Instructor, for representing the manoeuvring characteristics of a selection of typical merchant ship designs. The range of ship types must be at least five including a VLCC of about 250,000 tdw in the loaded and ballast conditions.

1.6.3.1 Alteration of speeds of each *own ship* type

acceleration : $S = (V - v)(1 - e^{-t/k}) + v$

deceleration : $S = (V - v)\ e^{-t/k} + v$

when S = speed at t minutes after alteration has been made

V = the higher speed

v = the lower speed

k = a constant which simulates the chosen type of ship and is either a fixed value between 2 and 25 or continuously variable over this range.

1.6.3.2 Alteration of courses of each *own ship* type

Rate of turn at full speed and maximum rudder angle to be a value between 20 and 120 degrees per minute. Rate of turn shall decrease with lower values of speed and rudder angle. Delay between application of helm and commencement of turn variable 5 to 60 seconds; or alternatively advance in miles during a turn of 90° at maximum rudder angle variable between l% and 5% of own ships speed in knots.

1.6.4 Random yaw of *own ships* : To be programmed to take account of sea state and ship type, or be under independent instructor control of rate and amplitude.

1.6.5 Sea clutter : Variable in intensity to a maximum of 8 miles. The intensity of the clutter to be sufficicnt to mask appropriate targets.

1.6.6. Landtargets : Echo strength shall decrease with increasing range. The means of simulating land targets must provide a realistic picture up to a range of 16 miles. The effects of land contours creating shadows must be shown. The displayed data shall have the following resolution:

a Range : 30 metres or better.

b Bearing : Not more than 0.7° at 30 rpm.

1.6.7 Current : Direction variable 0° to 359° in steps of 1°

Speed variable 0 to 10 knots, in steps of 1 knot.

1.6.8 Range *fall-off* : Range *fall-off*, for both ship and land targets shall be realistic as well as being compatible with the antenna height of *own ships* (the effect to be provided in the *own ship's* model). Provision is to be made for the Instructor to cause selected targets to fade completely or randomly (this facility is required for certain topics of the ARPA training programme *eg the effects of target loss, target swop etc*).

1.6.9 Shadow sectors : Not less than two each of whicli to have a width capable of being preset by the Instructor (each *own ship*).

1.6.10 Precipitation clutter

An area of clutter representing precipitation echoes shall be provided. This clutter shall be variable in area and density up to that necessary to preclude, if required, the detection of targets. The area of clutter shall be capable of being moved across the radar display at a constant velocity.

The area, density, position and motion may be preset by the Instructor Control(s) required by clause 1.7.1.7.

1.7 Controls

There shall be a set of controls available to the Instructor to enable him to rapidly set up an exercise and to alter the courses and speeds of ship targets during an exercise. In addition to the Instructor's controls there shall be separate controls available to the trainee to enable him to alter course and to stop, start and to alter speed ahead and astern, of own ship.

1.7.1 Instructor's Input Data Controls

1.7.1.1 For each *own ship*

i A control for rapidly setting the initial position of each own ship within the manoeuvring area.

ii A control or controls to set the ship's model.

iii A control to enable initial speed to be rapidly set.

iv A control to enable initial heading to be rapidly set.

v A yaw control.

vi A control to mask each own ship from the other own ships.

1.7.1.2 Ship Targets The following controls shall be provided for each ship target :

i Target on/off.

ii Controls for rapidly setting the initial position of each target.

iii Speed setting and alteration of speed.

iv Course setting and alteration of course.

v A control to fade selected targets.

1.7.1.3 Sea Clutter (for each own ship)
i On/off.
ii Density and range of sea clutter.

1.7. 1.4 Land Targets (coastline generator)
i On/off.
ii Control for setting relative positions of land and own ships, (if required).

1.7. 1.5 Current
I Direction (a) for all ships in the manoeuvring area, and
ii Speed (b) individually, for each own ship.

1 7.1.6 Freeze Control
i A control to stop and restart all movement during the running of an exercise.

1.7.1.7 Precipitation Clutter

i On/off.

ii Position.

iii Density and area.

iv Direction and speed.

1.7. 1.8 Playback : Means to playback exercises of a duration of up to 2 hours.

1.7.1.9 Malfunction : Facilities for the Instructor to cause each *own ship's* radar and navigational aids (individually) to fail.

1.7.2 The Trainee's Control Panel

1.7.2.1 Each trainee's control panel shall be capable of controlling only his *own ship* at any time. It shall be completely separate from that for the Instructor and it should be capable of being separated from the simulator by a distance of up to 20 metres.

1.7.2.2 The controls provided for each *own ship* in addition to all the operating controls on the radar display, shall be:

1.7.2.2.1 *Own ship* speed ahead and astern. This control may be of the type whichgives continuous

variation of speed or RPM control or of the type which gives speeds of stop/dead slow/slow/half/full ahead and astern. The variation in speeds demanded shall be determined by the ship's model. An indicator showing propeller revolutions shall also be provided.

1.7.2.2.2 Indicator of *own ship's* speed.

1.7.2.2.3 *Own ship* steering control and compass repeater, together with indicators showing helm and rudder angle.

1.7.2.2.4 A simulated radio-telephone link between each own ship and the Instructor's position
(Ie 'ship to ship' and 'ship to shore' dual watch, 6 channel selection, including channel 16 VHF).

1.7.2.3 Mechanical Noise
Noise from the simulator must be kept below the level at which it would interfere with normal conversation in a small room in which the simulator is installed.

1.8 Optional Provisions
The following optional facilities may be provided.

1.8.1 Fog Signals : For each own ship, and selected ship targets a fog signal may be provided. In the case of own ship's fog signals the signal should be controlled at the students control panel, the amplitude and approximate direction of each fog signal when heard at the trainee's position should correspond to the related source of the signal. Fog signals caused by target ships may be automatically initiated by the computer but should be capable of being muted at the choice of the Instructor.

1.8.2 Additional Targets : Additional targets may be provided. These may be representative of ship targets or Land targets and Instructor controlled.

1.8.3 Additional ARPA Facilities : The simulator may provide for:

i An additional ARPA display to that required by clause 1.5, or

ii An additional ARPA display which may be a graphics display of ARPA features with appropriate representative ARP controls and fitted additional to one of the radar displays required by clause 1.1.

This provision shall ensure that the ARPA data is compatible with the display of radar data at its *own ship* position and capable of being used by the trainee to achieve the objectives of the NC Course with respect to ARPA training.

Section 2

The simulation of each of the following electronic navigational aids shall be provided:

Medium frequency ship-borne Direction finder

Decca Navigator

Echo Sounder

The following optional facilities may be provided:

Loran C

Omega Navigator

Satellite Navigation

2.1 Simulation input to navigational aids

Each *own ship* position shall be provided with display units having output data representative of:

1 a ship's MF DF set

2 a Decca MKXXI or MKXXX navigator

3 a ship's echo sounder

Where display units of optional facilities are provided they should be in at least one own ship's position.

2.2 Systems Accuracy

2.2.1 MF DF : The simulator shall provide 20 simulated DF signals each capable of being related to a charted DF beacon station, the position of the DF beacon being set to within 200 metres of the selected chart position. Each beacon signal shall represent the correct coded transmission signal and sequence of the signal as described in the Admiralty List of Radio Signals

Vol II; one of the DF signals should be capable of simulating Radio Distress transmissions from a casualty; the position of the casualty being set by the Instructor. The accuracy of bearing obtained at the *own ship's receiver* being to within ±1° of the relative bearing between own ship and the DF *station* when the *own ship*, is within the specified range of the DF beacon(s).

Means shall be provided for introducing quadrantal and semicircular errors to the simulated DF signals.

The simulator may drive an actual DF display, or a representative display, or a graphics display or in alpha-numeric form.

2.2.2 Decca Navigator : The simulator shall provide a realistic Decca pattern over the manoeuvring area (where appropriate). The area chosen shall be compatible with the playing area(s) provided for the radar land video specified in Section 1 paragraph 1.2.9 of the specification where such an area is covered by an existing Decca pattern. The positions of the Master and slave *stations* generated by the simulator shall conform as closely as possible to those charted for the area in use. The simulator may drive an actual Decca Mark XXI or Mark XXX display or a representative display or a graphics display or in alpha-numerics. The accuracy of displayed Decca data shall be at least equal to that obtained by the use of live Decca data. Errors of the system shall be capable of being inserted by the Instructor within the limits typical of the position occupied by own ship. Where appropriate the facility for inter-chain fixing shall be provided.

2.2.3 Echo Sounder : The simulator shall be capable of simulating the charted depth of the position of each own ship in a manoeuvring area to a value, in the absence of tide, within 10% of the value given on the most open scale chart of the area. The scale value of such a chart to be not more than 1 : 50,000. The maximum number of available sounding points need not exceed 50,000. The soundings shall be displayed on either a commercial marine echo sounder display or a representative display or a graphics display or in alpha-numerics and realistically conformto the typical profile of the sea bed below the position for own ship.

Tide levels and rate of change of these levels shall be sinusoidal with a specified phase and amplitude common over the manoeuvring area. A draft/depth interlock shall be provided.

2.2.4 Loran C (if provided) : The simulator shall provide a realistic input to either an actual Loran C receiver or a representative display or a graphics display or in alpha-numerics of Loran C data compatible with the charted Loran C data. The data readouts shall be sufficiently realistic to enable the trainee to obtairl a Loran fix to an accuracy typical of the position of own ship within the manoeuvring area.

2.2.5 Omega and Satellite Navigation (if provided) : The simulator shall provide inputs to these instruments (either actual displays or representative or graphics displays or in alpha-numerics) compatible with the data readouts obtained within the manoeuvring area.

General : The above simulated navigational instruments, including radar (when used for position fixing) shall enable the trainee to obtain a fix of *own ship's* position within the manoeuvring area using methods of data extraction and plotting on a navigational chart in a manner consistent with good navigational procedures. The data provided should enable the trainee to either plot a fix of high accuracy when the displayed data is extracted under the most optimum practical conditions relating to any one system, or plot a position or positions under conditions where the displayed data suffers from typical low accuracy readouts obtained during adverse system conditions. The results obtained should thus vary, at the discretion of the Instructor, between high and low level position fixing accuracy using these aids. The trainees should, therefore, be given the opportunity to appreciate and practise navigational procedures within varying confidence levels appropriate to the overall aims of the Navigational Control course; at the same time having cognizance of, and practice, in, a full and varied range of collision avoidance techniques using radar to the limits of current technology.

Department of Trade

Marine Division 1980

Amendments to the "Specification for a marine navigational equipments simulator (1980)" w.e.f. 03/11/88

Section 1

1.1 General

The simulator shall employ at least three own ship radar displays, each of which is of a type which has been awarded a Department of Transport Certificate of Type Testing to the 1968, or later, Marine Radar Performance Specification or, alternatively, each radar display may be a colour graphics display having the following minimum characteristics:

(a) not less than a 20" diagonal colour tube which provides a nominal 12" diameter radar display

(b) not less than a 700 lines, non-interlaced 60Hz raster

(c) operator controls representative of those on a type approved radar or ARPA display. The simulator shall provide the facility for each own ship display to be operated independently of the other own ship displays and for the own ship manoeuvring control.s associated with each display to be independent of the settings of the own ship controls at the other display positions.

1.3.3 A reflection type plotting aid shall be provided for each radar display other than the ARPA display (see clause 1.5). In the latter case a reflection plotter may be fitted. Where a graphics display is provided under clause 1.1 a method of plotting at least equivalent to a reflection plotter shall be provided to the satisfaction of the Department of Transport.

I.5 ARPA Display

At least one of the radar displays shall be of a type which complies with the IMO Performance Specification for Automatic Radar Plotting Aids (ARPA) [ref IMO Resolution A.422(XI)). The simulator input to the ARPA display shall be such that the ARPA display is capable of being used by the trainee to achieve the practical objectives in ARPA training as laid down in IMO Resolution A.482(XII)

The display required by this clause may be one of the displays required by clause 1.1 employing integrated ARPA data or additionally a 'stand off' ARPA display may he provided. Alternatively a graphics display may be provided as in clause 1.1.

Department of Transport

Marine Directorate

3rd November 1988

Section A-I/12

Standards governing the use of simulators

PART 1 - PERFORMANCE STANDARDS

General performance standards for simulators used in training

1 Each Party shall ensure that any simulator used for mandatory simulator-based training shall:

.1 be suitable for tile selected objectives and training tasks;

.2 be capable of simulating the operating capabilities of shipboard equipment concerned, to a level ofphysical realism appropriate to training objectives, and include the capabilities, limitations and possible errors of such equipment,

.3 have sutficient behavioural realism to allow a trainee to acquire the skills appropriate to the training objectives,

.4 provide a controlled operating environment, capable of producing a variety of conditions, which may include emergency, hazardous or unusual situations relevant to the training objectives;

.5 provide an interface through which a trainee can interact with the equipment, the simulated environment and, as appropriate, the instructor; and

.6 permit an instructor to control, monitor and record exercises for the effective debriefing of trainees.

General performance standards for simulators used in assessment of competence

2 Each Party shall ensure that any simulator used for the assessment of competence required under the Convention or for any demonstration of continued proficiency so required shall:

.1 be capable of satisfiring the specified assessment objectives;

.2 be capable of simulating the operational capabilities of the shipboard equipment concerned to a level of physical realism appropriate to the assessment objectives, and include the capabilities, limitations and possible errors of such equipment;

.3 have suflicient bchavioural realism to allow a candidate to exhibit the skill appropriate to the assessrment objectives;

.4 provide an interface through which a candidate call interact with the equipment and simulated cnvironinent;

.5 provide a controlled operating environment, capable of producing a variety of conditions, which may include emergency, hazardous or unusual situations relevant to assessment objectives, and

.6 permit an assessor to control, monitor and record exercises for the effective assessment of the performance of candidates.

Additional performance standards

3 In addition to meeting the basic requirements set out in paragraphs 1 and 2, simulation equipment to which this section applies shall meet the performance standards given hereunder in accordance with their specific type.

Radar simulation

4 Radar simulation equipment shall be capable of simulating the operational capabilities of navigational radar cquiprnent which meets all applicable

performance standards adopted by the Organization* and incorporate facilities to:

.1 operate in the stabilized relative motion mode and sea and ground stabilized true motion modes

.2 model weather, tidal streams, current, shadow sectors, spurious echoes and other propagation effects, and generate coastlines, navigational buoys and search and rescue transponders; and

.3 create a real-time operating environment incorporating at least two own ship stations with ability to change own ship's course and speed, and include parameters for at least 20 target ships and appropriate communication facilities.

* See resolutions A.222(V11) - Performance Standards for Navigational Radar Equipment, A.278(VIII) - Supplement to the Recommendation on Performance Standards for Navigational Radar Equipment, and resolution A.477(XII) - Performance Standards for Radar Equipment.

Automatic Radar Plotting Aid (ARPA) Simulation

5 ARPA simulation equipment shall be capable of simulating the operational capabilities of ARPA's which meet all applicable performance standards adopted by the Organization*, and shall incorporate the facilities for:

.1 manual and automatic target acquisition;

.2 past track information;

.3 use of exclusion areas;

.4 vector/graphic time-scale and data display; and

.5 trial manoeuvres.

* See resolution A.422(XI) - Performance Standards for Automatic Radar Plotting Aids and resolution A.823(19) - Performance Standards for Automatic Radar Plotting Aids (ARPAs).

PERFORMANCE STANDARDS FOR

AUTOMATIC RADAR PLOTTING AIDS (ARPA)

1 INTRODUCTION

1.1 Automatic radar plotting aids (ARPA) should, in order to improve the standard of collision avoidance at sea:

.1 reduce the workload of observers by enabling them to automatically obtain information so thatthey can perform as well with multiple targets as they can by manually plotting a single target;

.2 provide continuous, accurate and rapid situation evaluation.

1.2 In addition to the general requirements contained in Chapter 1.1 of this publication, ARPA should comply with the following minimum performance standards.

2 DEFINITIONS

2.1 Definitions of terms used in these performance standards are given in Annex 1.

3 PERFORMANCE STANDARDS

3.1 Detection

Where a separate facility is provided for detection of targets, other than by the radar observer, it should have a performance not inferior to that which could be obtained by the use of the radar display.

3.2 Acquisition

3.2.1 Target acquisition may be manual or automatic. However, there should always be a facility to provide for manual acquisition and cancellation: ARPA with automatic acquisition should have a facility to suppress acquisition in certain areas. On any range scale where acquisition is suppressed over a certain area, the area of acquisition should be indicated on the display.

3.2.2 Automatic or manual acquisition should have a performance not inferior to that which could be obtained by the user of the radar display.

3.3 Tracking

3.3.1 The ARPA should be able to automatically track, process, simultaneously display and continuously update the information on at least:

.1 20 targets, if automatic acquisition is provided, whether automatically or manually acquired;

.2 10 targets, if only manual acquisition is provided.

3.3.2 If automatic acquisition is provided, description of the criteria of selection of targets for tracking should be provided to the user. If the ARPA does not track all targets visible on the display, targets which are being tracked should be clearly indicated on the display. The reliability of tracking should not be less than that obtainable using manual recordings of successive target positions obtained from the radar display.

3.3.3 Provided the target is not subject to target swop, the ARPA should continue to track an acquired target which is clearly distinguishable on the display for 5 out of 10 consecutive scans.

3.3.4 The possibility of tracking errors, including target swop, should be minimized by ARPA design. A qualitative description of the effects of error sources on the automatic tracking and corresponding errors should be provided to the user, including the effects of low signal-to-noise and low signal-to-clutter ratios caused by sea returns, rain, snow, low clouds and non-synchronous emissions.

3.3.5 The ARPA should be able to display on request at least four equally time-spaced past positions of any targets being tracked over a period of at least eight minutes.

3.4 Display

3.4.1 The display may be a separate or integral part of the ship's radar. However, the ARPA display should include all the data required to be provided by a radar display in accordance with the performance standards for navigational radar equipment.

3.4.2 The design should be such that any malfunction of ARPA parts producing data additional to information to be produced by the radar as required by the performance standards for navigational equipment should not affect the integrity of the basic radar presentation.

3.4.3 The display on which ARPA information is presented should have an effective diameter of at least 340 mm.

3.4.4 The ARPA facilities should be available on at least the following range scales:

.1 12 or 16 miles;

.2 3 or 4 miles.

3.4.5 There should be a positive indication of the range scale in use.

3.4.6 The ARPA should be capable of operating with a relative motion display with "north-up" and either "head-up" Or IICOUrSe_UPII azimuth stabilization. In addition, the ARPA may also provide for a true motion display. If true motion is provided, the operator should be able to select for his display either true or relative motion. There should be a positive indication of the display mode and orientation in use.

3.4.7 The course and speed information generated by the ARPA for acquired targets should be displayed in a vector or graphic form which clearly indicates the target's predicted motion. In this regard:

.1 ARPA presenting predicted information in vector form only should have the option of both true and relative vectors;

.2 an ARPA which is capable of presenting target course and speed information in graphic form should also, on request, provide the target's true and/or relative vector;

.3 vectors displayed should either be time-adjustable or have a fixed time-scale;

.4 a positive indication of the time-scale of the vector in use should be given.

3.4.8 The ARPA information should not obscure radar information in such a manner as to degrade the process of detecting targets. The display of ARPA data should be under the control of the radar observer. It should be possible to cancel the display of unwanted ARPA data.

3.4.9 Means should be provided to adjust independently the brilliance of the ARPA data and radar data, including complete elimination of the ARPA data.

3.4.10 The method of presentation should ensure that the ARPA data are clearly visible in general to more than one observer in the conditions of light normally experienced on the bridge of a ship by day and by night. Screening may be provided to shade the display from sunlight but not to the extent that it will impair the observer's ability to maintain a proper lookout. Facilities to adjust the brightness should be provided.

3.4.11 Provisions should be made to obtain quickly the range and bearing of any object which appears on the ARPA display.

3.4.12 When a target appears on the radar display and, in the case of automatic acquisition, enters within the acquisition area chosen by the observer or, in the case of manual acquisition, has been acquired by the observer, the ARPA should present in a period of not more than one minute an indication of the target's motion trend and display within three minutes the target's predicted motion in accordance with paragraphs 3.4.7, 3.6, 3.8.2 and 3.8.3.

3.4.13 After changing range scales on which the ARPA facilities are available or resetting the display, full plotting information should be displayed within a period of time not exceeding four scans.

3.5 Operational warnings

3.5.1 The ARPA should have the capability to warn the observer with a visual and/or audible signal of any distinguishable target which closes to a range or transits a zone chosen by the observer. The target causing the warning should be clearly indicated on the display.

3.5.2 The ARPA should have the capability to warn the observer with a visual and/or audible signal of any tracked target which is predicted to close to within a minimum range and time chosen by the observer. The target causing the warning should be clearly indicated on the display.

3.5.3 The ARPA should clearly indicate if a tracked target is lost, other than out of range, and the target's last tracked position should be clearly indicated on the display.

3.5.4 It should be possible to activate or de-activate the operational warnings.

3.6 Data requirements

3.6.1 At the request of the observer the following information should be immediately available from the ARPA in alphanumeric form in regard to any tracked target:

.1 present range to the target;

.2 present bearing of the target;

.3 predicted target range at the closest point of approach (CPA);

.4 predicted time to CPA (TCPA);

.5 calculated true course of target;

.6 calculated true speed of target.

3.7 Trial manoeuvre

3.7.1 The ARPA should be capable of simulating the effect on all tracked targets on an own ship manoeuvre without interrupting the updating of target information. The simulation should be initiated by the depression either of a spring-loaded switch, or of a function key, with a positive identification on the display.

3.8 Accuracy

3.8.1 The ARPA should provide accuracies not less than those given in paragraphs 3.8.2 and 3.8.3 for the four scenarios defined in Annex 2. With the sensor errors specified in Annex 3, the values given relate to the best possible manual plotting performance under environmental conditions of plus and minus ten degrees of roll.

3.8.2 An ARPA should present within one minute of steady state tracking the relative motion trend of a target with the following accuracy values (95 per cent probability values).

Data	Relative Course	Relative Speed	CPA
Scenario	Degrees	Knots	Miles
1	11	2.8	1.6
2	7	0.6	
3	14	2.2	1.8
4	15	1.5	2.0

3.8.3 An ARPA should present within three minutes of steady state tracking the motion of a target with the following accuracy values (95 per cent probability values).

Data	Relative Course	Relative Speed	CPA	TCPA	True Course	True Speed

Scenario	degrees	knots	miles	minutes	degrees	knots
1	3.0	0.8	0.5	1.0	7.4	1.2
2	2.3	0.3			2.8	0.8
3	4.4	0.9	0.7	1.0	3.3	1.0
4	4.6	0.8	0.7	1/0	2.6	1.2

3.8.4 When a tracked target, or own ship, has completed a manoeuvre, the system should present in a period of not more than one minute an indication of the target's motion trend, and display within three minutes the target's predicted motion, in accorddance with paragraphs 3.4.7, 3.6, 3.8.2 and 3.8.3.

3.8.5 The ARPA should be designed in such a manner that under the most favourable conditions of own ship motion the error contribution from the ARPA should remain insignificant compared to the errors associated with the input sensors, for the scenarios of Annex 2.

INTERACTIVE RADAR SIMULATOR

Version 17.0

INDEX

INTRODUCTION

This suite of programs are designed to create a powerful, versatile interactive Radar simulator on relatively cheap Personal Computers. This version requires all computers to have VGA monitors and the CPU should be a 80486 (or Pentium) running at the highest possible speed (486 66MHz DX 2 is the minimum recommended). Both VGA (640 x 480 pixels) and Vesa standard high level resolution graphics (1024 x 768 pixels) are supported.

Various features are included to suit the officer sailing on foreign going vessels down to fairly small fishing vessels. The display is similar to that of a rasterscan radar found on ships at sea today with certain additional information found on the side. The display, like most radar, works in North up, Head up or True Motion modes. Range rings may be activated and the radar has an Electronic Bearing Marker, Parallel Index, Fixed Range rings as well as a variable range marker. Up to 29 targets may be selected for plotting. A clock running in real time (an instructor selected time not actual time) is displayed along with Range scale, EBL, VRM and course and speed. ARPA facilities may also be activated.

The controls of the radar and exercise are keyboard or mouse operated (mouse or trackball preferred).

The program may be run with up to eight interactive student vessels operating in the exercise area with between 22 and 29 targets under Lecturer control. Alternatively the program may also be run in single mode, ie the student can operate independently without interaction.

In both cases exercise data is automatically stored on disc and can be replayed after completion of the exercise.

Two primary areas are available. The one area covers the English Channel from Cherbourg to Zeebrugge including Le Havre and Southampton approaches. The second area is off the Western Cape of South Africa from Cape Columbine to Cape Hangklip and includes Saldanha Bay, Cape Town and False Bay. Both Luderitz and Walvis Bay are also currently available.

Various configurations are possible using exactly the same software. This allows a smooth and simple upgrade depending on client requirements. It also allows different configurations dependant on student numbers and level.

Stand alone system (single machine)
This allows students to test out their individual skills using a single computer without interaction with other students but with up to 29 preset targets. Navaids are of the pop up window type.

Networked system
In this case up to eight own ships are possible. Single student stations are possible with pop up window navaids for cost effective training. The same software can also be configured so that each own vessel has two computers (one for ARPA/radar and the other has Navaids and Ship control). This is in order to comply fully with South African and British requirements for simulationl.

With the network version, the controller has control of all vessels until the student machine comes on line. The taking over of a vessel is thus fully automatic. If an own ship is closed properly, that vessel is immediately handed back as an instructor controlled vessel.

Microsoft workgroups software (Dos Add-on only) is recommended for the network (very cost effective) although any network will work provided the control station can allocate a Ramdrive of 100 kilobytes that is accessible to all stations.

SIMULATION CONTROL TERMINAL

GLOSSARY

Own ship - a vessel under the control of a student at a remote computer.

Target - a vessel under the control of the Lecturer from his terminal.

Vessel - either an *own ship* or a *target.*

Selected Vessel - any vessel that is selected for manipulation by the Lecturer. Generally selected by a Function key.

Reference Vessel - any vessel that is selected to be used as reference vessel by the Lecturer. Information about the *selected vessel* is available with respect to the *reference vessel.* This allows the controller to accurately set vessels to pass at desired distances from any other vessel.

Stand alone system - a single student ship system interacting with preset targets.

Network System - an interactive system with one control terminal and up to 8 computers connected representing either 4 own ships with twin screens, or 8 own ships with one screen only. A network system is required as specified in the technical section.

Single screen system - Each *own ship* has only one screen on which is displayed radar/ARPA, popup window navaids and ship controls. This may be desirable for low level training in basic radar usage and radar plotting.

Twin screen system - Each *own ship* has two computers. The first is allocated to radar/ARPA and the second computer is used for Navigational aids and ship control. This configuration is required for South African and British approval for type approval as a full simulator.

Actual course and speed - The actual course and speed of any vessel through the water.

Desired course and speed - The course and speed through the water that the vessel has ordered.

Routed vessel - A *target* that has been selected to follow a predetermined track and alter course automatically at various waypoints.

Leg - The point at which a route changes direction ie a waypoint.

Invisible vessel - either an *own ship* or *target* that is not visible on the students terminals although positioned and running on the control terminal. This is useful for keeping track of an object that is moving across the exercise area.

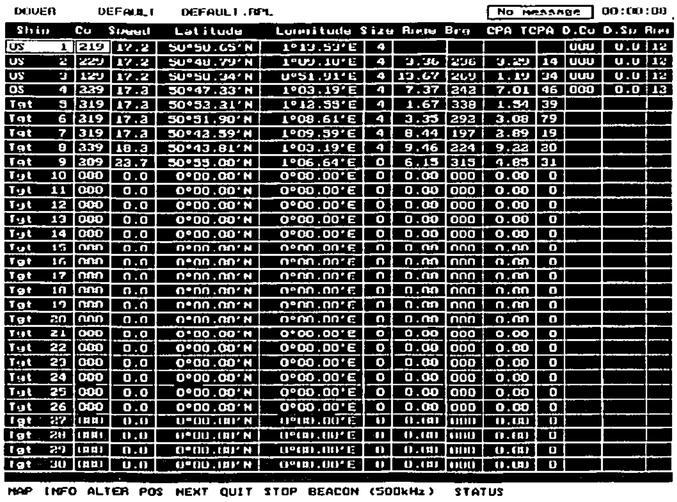
X/Y mode - The positions indicated are shown in Nautical miles in Northings and Eastings from an imaginery point at the bottom left of the exercise area.

Lat/Long mode - The positions indicated are shown in traditional latitude and longitude and although not as accurate as the Radsim co-ordinates should be sufficiently accurate for most purposes. (See section on Technical specifications)

The Control Terminal has 5 screens of information. These are known as the Main Screen, Graphics Screen, Status Screen, Tide Screen and Information screen.

MAIN SCREEN

The main screen appears similar to the block shown at right.
The top bar is an information bar and the Coast name, Exercise name, and save name for later replay appear first. At the extreme right is a clock running in exercise time. The area in between is used to show communication between terminal and student. Messages waiting to be sent appear on a Magenta background while just to the left of that block frequent rapid blocks shows data being transferred to each student in turn. In the network version this tracks the number of data transfers.



DOVER DEFAULT DEFAULT.RPL No message 00:00:08

Ship	Co	Speed	Latitude	Longitude	Size	Rnge	Brg	CPA	TCPA	D.Co	D.Sp	Rim
OS 1	219	17.2	50°50.65'N	1°13.53'E	4					000	0.0	12
OS 2	229	17.2	50°48.79'N	1°09.10'E	4	3.36	236	3.29	14	000	0.0	12
OS 3	129	17.2	50°50.34'N	0°51.91'E	4	13.67	269	1.19	34	000	0.0	12
OS 4	339	17.2	50°47.33'N	1°03.19'E	4	7.37	242	7.01	46	000	0.0	13
Tgt 5	319	17.2	50°53.31'N	1°12.55'E	4	1.67	338	1.54	39			
Tgt 6	219	17.2	50°51.90'N	1°08.61'E	4	3.35	292	3.08	79			
Tgt 7	319	17.2	50°42.59'N	1°09.59'E	4	8.44	197	2.89	19			
Tgt 8	339	18.3	50°43.81'N	1°03.19'E	4	9.46	224	9.22	30			
Tgt 9	209	23.7	50°55.00'N	1°06.64'E	0	6.15	315	4.85	31			
Tgt 10	000	0.0	0°00.00'N	0°00.00'E	0	0.00	000	0.00	0			
Tgt 11	000	0.0	0°00.00'N	0°00.00'E	0	0.00	000	0.00	0			
Tgt 12	000	0.0	0°00.00'N	0°00.00'E	0	0.00	000	0.00	0			
Tgt 13	000	0.0	0°00.00'N	0°00.00'E	0	0.00	000	0.00	0			
Tgt 14	000	0.0	0°00.00'N	0°00.00'E	0	0.00	000	0.00	0			
Tgt 15	000	0.0	0°00.00'N	0°00.00'E	0	0.00	000	0.00	0			
Tgt 16	000	0.0	0°00.00'N	0°00.00'E	0	0.00	000	0.00	0			
Tgt 17	000	0.0	0°00.00'N	0°00.00'E	0	0.00	000	0.00	0			
Tgt 18	000	0.0	0°00.00'N	0°00.00'E	0	0.00	000	0.00	0			
Tgt 19	000	0.0	0°00.00'N	0°00.00'E	0	0.00	000	0.00	0			
Tgt 20	000	0.0	0°00.00'N	0°00.00'E	0	0.00	000	0.00	0			
Tgt 21	000	0.0	0°00.00'N	0°00.00'E	0	0.00	000	0.00	0			
Tgt 22	000	0.0	0°00.00'N	0°00.00'E	0	0.00	000	0.00	0			
Tgt 23	000	0.0	0°00.00'N	0°00.00'E	0	0.00	000	0.00	0			
Tgt 24	000	0.0	0°00.00'N	0°00.00'E	0	0.00	000	0.00	0			
Tgt 25	000	0.0	0°00.00'N	0°00.00'E	0	0.00	000	0.00	0			
Tgt 26	000	0.0	0°00.00'N	0°00.00'E	0	0.00	000	0.00	0			
Tgt 27	000	0.0	0°00.00'N	0°00.00'E	0	0.00	000	0.00	0			
Tgt 28	000	0.0	0°00.00'N	0°00.00'E	0	0.00	000	0.00	0			
Tgt 29	000	0.0	0°00.00'N	0°00.00'E	0	0.00	000	0.00	0			
Tgt 30	000	0.0	0°00.00'N	0°00.00'E	0	0.00	000	0.00	0			

MAP INFO ALTER POS NEXT QUIT STOP BEACON (500kHz) STATUS

The central area shows a table of 30 vessels that may used in the exercises. The first 1 to 8 vessels may be allocated as required as *own ships* under student control depending on configuration and the remaining *vessels* (up to 29) are *targets* under the lecturer's control. Own ships revert to lecturer control when the exercise is paused. Running across the table are the respective vessel's actual course, actual speed, current position (either Latitude/Longitude or X/Y coordinates) and size. The course and speed of routed targets is indicated as course and speed over the ground (ie these vessels are compensating for the exercise current). The course and speed of all unrouted targets and ownships is course and speed through the water (ie the log and gyro readouts). The final two columns show the visual ship type (optional) as well as alphanumeric symbol of whistle signal (optional).

This data may be altered by the Lecturer in respect of the *targets* only (size of *own ships* may be altered as well). The following columns show that vessel's bearing, range, CPA and TCPA to the *reference* vessel. The *desired course and speed* of targets and own ships are shown next. If the vessel is an *own ship* this information is displayed normally in green along with selected range scale. The exception to this is if the own ship deselects the autopilot, the desired course column will then show desired rudder angle in the appropriate colour (red for port, green for starboard and yellow for amidships). For *targets* this information is in dark gray unless it differs from the *actual course or speed* ie it is highlighted if the *target* is altering course or speed. When a target is *routed* the Route number and leg number are indicated instead. In this case the information is shown in cyan.

Any *vessel* can be selected to be *reference* vessel. Pressing **F1** through **F10** selects vessel 1 through 10 respectively. Pressing **SHIFT** at the same time as pressing **F1** through **F10** selects vessels 11 through 20 respectively. Pressing **CTRL** and **F1** through **F10** selects 21 to 30. The *reference vessel* is shown with a yellow background and empty range, bearing, CPA, TCPA blocks.

The other yellow block can be used to alter a *target's* actual course, actual speed, desired course, desired speed, size, position and whistle signal. While the exercise is running, only the size of an *own ship* may be altered. When the exercise is *paused* then *own ship's* positions, courses and speeds may also be altered. This yellow square is moved using the cursor keys or mouse to the desired block. The value in the selected cell may be incremented by pressing + or right mouse button and decremented by pressing either - or left mouse button. Alternatively for large changes press ALTER and the new value may be typed in directly. Sound signals can be input using ALTER and the morse letter of the signal to to be sent(or you may press +/- to scroll through. Valid characters are T, M, E, I, S, H, 5, D, B, C, G, Z and R.

When positioning vessels, a range and bearing from *reference vessel* may be input and the X/Y co-ordinates will be altered automatically. Alternatively, the position may not be altered directly provided that the terminal is in X/Y mode and not Lat/Long mode. Change to X/Y coordinates first, alter the position and if desired return to Lat/Long mode by pressing CO-ORD which toggles the position display mode. Note that the co-ordinate system is used internally and is more precise than the latitude/longitude co-ordinates displayed.

Vessels not currently in use have their data shown in dark grey so as not to intrude visually. Changing the position of a *target* to any value other than 0 causes its colour to change to light grey. This means that the *vessel* is not yet visible to the students so allowing it to be correctly positioned before activation by increasing the size to more than 0. Note that these targets move according to course and speed (exercise current does NOT affect invisible targets) even though not visible on the student radar sets. Visible vessels appear in white. *Target* size values above 9 are reserved for rain.

APPROXIMATE SIZES

0 - Invisible	1 - Liferaft	2 - Lifeboat
3 - 15 metre boat	4 - 100 tonne	5 - 500 tonne
6 - 1000 Tonne	7 - 5 000 tonne	8 - 10 000 tonne
9 - 50 000 Tonnes		

COLOUR CODING ON MAIN PAGE

Various colours are used to identify special cases.

White	- *Vessels* currently in use - no special notes
Light Gray	- *Vessels* that have been positioned, but are still invisible and are not moving.
Dark Gray	- *Vessels* not in use
Red	- An *own ship* that has been classified as a Casualty - stopped.
Magenta	- A *vessel* with a 500 kHz transmitter or SART- visible. (Letters **S**art and/or **B**eacon will appear)
Dark Green	- *vessel* with a 500 kHz transmitter or SART- invisible (the SART will also be invisible)
Cyan	- A *routed target.*
Light Green	- desired course and speed as well as rangescale in use on an *own ship*

The bottom line appears blue with various commands that are available shown with the required key highlighted. These commands include **M**AP, **I**NFO, **A**LTER, **P**OS, **N**EXT, **Q**UIT, **S**TOP, **B**EACON. **S**TATUS, **E**X.SAVE, **D**ISTRESS and **V**ISUAL

MAP	- Pressing **M** or **TAB** changes to the graphic display.
STATUS	- Changes to the status screen to allow monitoring of radar controls as well as altering the status of navaids etc.
INFO	- Changes to page containing list of own ship manoeuvres.
VISUAL	- This option is not available on this system. It is used to change the visual vessel type, state of darkness/fog and change the navigational lights on the optional visual module.
TIDE	- Changes to the Time, tide and currents page so that exercise time, time of High Water and unrouted target currents may be altered.
CO-ORD	- Toggles between Lat/Long and X/Y coordinate display.
BEACON	- Toggles a 500kHz DF station on the *reference vessel.*
SART	- Toggles a SART on the *reference vessel*
PAUSE	- Pressing **P** will freeze the exercise until **P** is pressed again. The control terminal may be used normally in this mode and this option allows various exercise data to be modified for the creation of a new exercise that may then be saved.
EX.SAVE	- The current positions, courses, speeds of all vessels including tides and status are saved as an exercise to be continued at a later stage. It may also be used if you have setup a new exercise from the control terminal or prior to a predicted power failure.
ALTER	- Allows the value in the yellow box to be altered.
NEXT	- Stops current exercise and exits the control terminal only. The student's sets are reset for the next exercise. (Hold ALT key and type N)
QUIT	- Ends the current session and closes down all computers. (ALT key and Q)

The mouse may also be clicked on these words instead of using the hot key.

STATUS SCREEN

OWNSHIP EQUIPMENT STATUS								
OWN SHIP	1	2	3	4	5	6	7	8
ShipType	CARGO	BULK	TANKER	CARGO	BULK	CARGO	CARGO	CARGO
Range scale	12	12	12	12	12	12	12	12
Gain Act/Opt	0/ 0	0/ 0	0/ 0	0/ 0	0/ 0	0/ 0	0/ 0	0/ 0
Tune Act/Opt	0/ 0	0/ 0	0/ 0	0/ 0	0/ 0	0/ 0	0/ 0	0/ 0
STC	0	0	0	0	0	0	0	0
FTC	0	0	0	0	0	0	0	0
Radar Type	ARPA	ARPA	ARPA	ARPA	ARPA	ARPA	ARPA	ARPA
Shadow sect	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF
Radar inter	7	7	6	0	0	0	6	7
Sea Clutter	15	15	15	15	15	0	0	0
Yaw	3	3	3	3	3	0	0	0
Current dir	045°	045°	045°	045°	045°	000°	000°	000°
rate	1.2	1.2	1.2	1.2	1.2	0.0	0.0	0.0
Decca dir	000°	000°	000°	000°	000°	000°	000°	000°
rnge	0 m	0 m	0 m	0 m	0 m	0 m	0 m	0 m
lock	ON	ON	ON	ON	ON	ON	ON	ON
GPS dir	000°	000°	000°	000°	000°	000°	000°	000°
rnge	0 m	0 m	0 m	0 m	0 m	0 m	0 m	0 m
lock	ON	ON	ON	ON	ON	ON	ON	ON
Tide	11.7 m	11.7 m	11.7 m	11.7 m	11.7 m	11.7 m	11.7 m	11.7 m
Draft	6.2 m	10.2 m	12.5 m	6.2 m	10.2 m	0.0 m	0.0 m	0.0 m
E/S reading	11.7 m	11.7 m	11.7 m	11.7 m	11.7 m	11.7 m	11.7 m	11.7 m
RDF	ON	ON	ON	ON	ON	ON	ON	ON
Rad Controls	PRESET	PRESET	PRESET	PRESET	PRESET	PRESET	PRESET	PRESET
Engine	ON	ON	ON	ON	ON	ON	ON	ON
Helm	ON	ON	ON	ON	ON	ON	ON	ON
angle								
Casualty	Normal	Normal	Normal	Normal	Normal	Normal	Normal	Normal
Click here or press ESCAPE to return to the Main page								

On this screen the mouse or cursor keys may be used too select the appropriate cell. The mouse buttons may be used (left button to decrement, right button to increment) or alternatively press + to increment or - to decrement. Either of these keys will also toggle certain functions. F1 to F8 may still be used to select current vessel if the keyboard is being used.

The status screen has 8 columns (1 for each vessel) and the following rows.

- Shiptype - as selected for the exercise. This may be altered if the exercise is *paused.*
- Rangescale - This indicates the currently selected rangescale being used by the student
- Gain Act/Opt - the actual gain setting and optimal gain settings are shown for each vessel. Where the actual gain is identical to the optimal setting these values will be displayed in green otherwise they will appear in red.
- Tune Act/Opt - the actual tuning setting and optimal tuning settings are shown for each vessel. Where the actual tuning is identical to the optimal setting these values will be displayed in green otherwise they will appear in red.
- STC - as selected by the student - range is from 0 to 15
- FTC - as selected by the student - range is from 0 to 15
- Radar Type - Indicates whether the radar type selected is
  HUP-mag - Meaning that a relative motion unstabilised display with magnetic courses only.
  HUP-gyro - as above but with a true course display on the ship control panel.
  NU-stab - the student may choose between Head up, North up stabilized or True Motion.
  ARPA - full ARPA facilities including Head up, North up, Relative Motion or True Motion may be selected. This may only be altered if the exercise is *paused.*
- Shadow Sect - Indicates whether Shadow sectors (if programmed for the shiptype) will operate or not. If selected *indirect echoes* will appear in the shadow sector based on the reciprocal bearing.
- Radar interf - Instructor controlled as to the amount of mutual radar interference that will

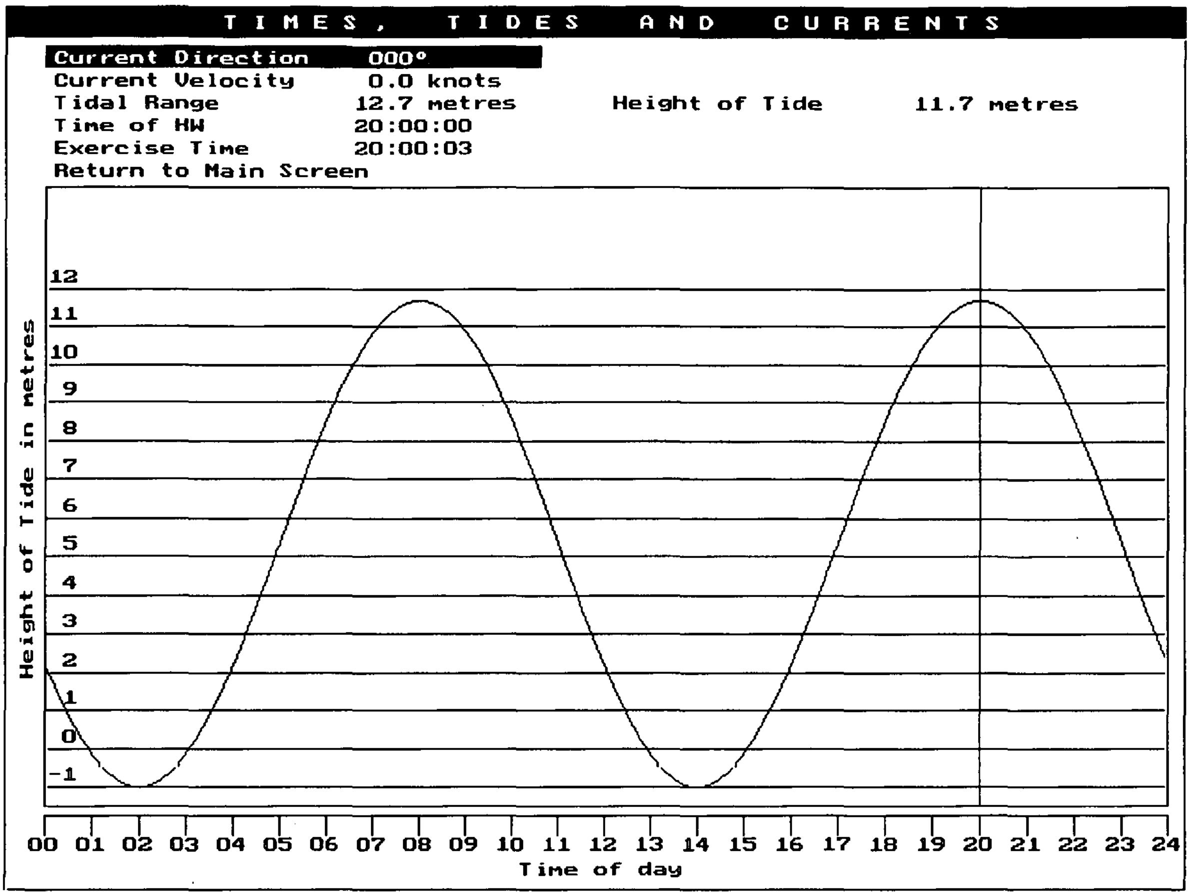
	appear on the selected *student's radar* display - range from 0 to 7.
Sea Clutter	- Instructor controlled as above - range from 0 to 16
Yaw	- Instructor controlled as number of degrees yaw about selected course - range is from 0° to 9° - period of yaw is determined by the ship characteristics.
Current dir	- Each own ship has its own current speed and direction and is independant of the exercise current. Instructor controlled as above - range from 0° to 359°
Rate	- Each own ship has its own current speed and direction and is independant of the exercise current. Instructor controlled as above - range from 0.0 to 20.0 knots
Decca Dir	- Allows a direction error in steps of 45° to be input to the Decca receiver.
Rnge	- Allows a range error of 0, 50, 100, 250, 500, 1000, 2000 or 4000 metres in the direction indicated above from the correct position.
Lock	- Toggles from N/A (Not available), No Lock and ON. No lock will cause the positions indicated to be random in any direction, and random in range up to that selected above.
GPS Dir	- Allows a direction error in steps of 45° to be input to the GPS receiver.
Rnge	- Allows a range error of 0, 20, 50, 100,250, 500, 1000 or 2000 metres in the direction indicated above from the correct position.
Lock	- Toggles from N/A (Not available), No Lock and ON. No lock will cause the position indicated to lock to the last position before loss of lock.
Tide	- Exercise status only. The tide is displayed on this screen but is determined on the Time, Tide and Current screen based on Tidal range, time of High Water and Exercise Time.
Draft	- Exercise status only. The draft is determined by the shiptype and cannot be altered.
E/S reading	- Feedback from the student's terminals as to depth of water below the keel. Toggling this cell allows the echo sounder to be enabled/disabled.
RDF	- Disables/enables RDF.
Radar controls	- Toggles radar failure on/off. 4 states are possible. ZEROED and PRESET apply only to new exercises and determines whether the controls are zeroed or optimally set when the exercise is started. OFF indicates failure of the display. RESTRIC selects PRESET (optimal settings) but prevents students from controlling the following controls: POWER, BRILL, TUNE, GAIN, STC, FTC, MODE, and the Navaids if available.
Engine	- Toggles the engine to on/off and stops the engine if off. The student's terminal will make a sound at regular intervals to indicate engine failure.
Helm	- Disables/enables the vessel's steering. Defaults to amidships if disabled.
Angle	- The rudder can be disabled at any angle from Port 32° to Starboard 32° and can be enabled by toggling the cell marked HELM. Rudder angle is indicated in red for port and green for starboard.
Casualty	- Press to indicate collision or grounding (Message at control states NORMAL or COLLIDE). Pressing again will release the vessel. A message stating 'MARINE CASUALTY' appears on student's radar terminal, the radar will go blank, the autopilot disengages, steering is disabled at amidships, revs, power and speed are immediately zeroed. The student's terminal will make a sound at regular intervals to indicate engine failure.

ESCAPE may be used to return to the Main page.

Where writing is bright indicates an active remote station - where dark these vessels have allocated as *targets* and are under Instructor control. In this case attempting to alter certain parameters will result in an error message on the screen (THIS IS NOT A STUDENT VESSEL)

TIME, TIDE AND CURRENT PAGE

This screen allows the Exercise time, target current direction and velocity as well as tidal data to be



set. Setting of this data can only be carried out while the exercise is paused.

The bar is moved using the up/down cursor keys or mouse. The selected values are altered by pressing + (or right mouse button) to increase or - (or left mouse button) to decrease.

The graph indicates a 24 hour day from midnight to midnight at the bottom.

Height of tide is displayed at left and the green vertical line represents the Exercise Time related to the tide. Changing the Tide range, Time of Highwater or Exercise Time will cause the current tide to be recomputed and the graph will be modified. Tide is computed every minute of a running exercise and is appliued equally to all *own ships.*

The current direction and velocity applies only to *targets.* It has no effect on *own ships* as these values are altered on the STATUS SCREEN. Be careful of using currents on targets. The course and speed data displayed will be course and speed steered, while vectors shown are ground tracks. Routed targets are unaffected by currents and coiurse and speed displayed for these vessels will be ground track courses and speeds.

Pressing ESCAPE or clicking the mouse on the last option will returrn you to the MAIN SCREEN.

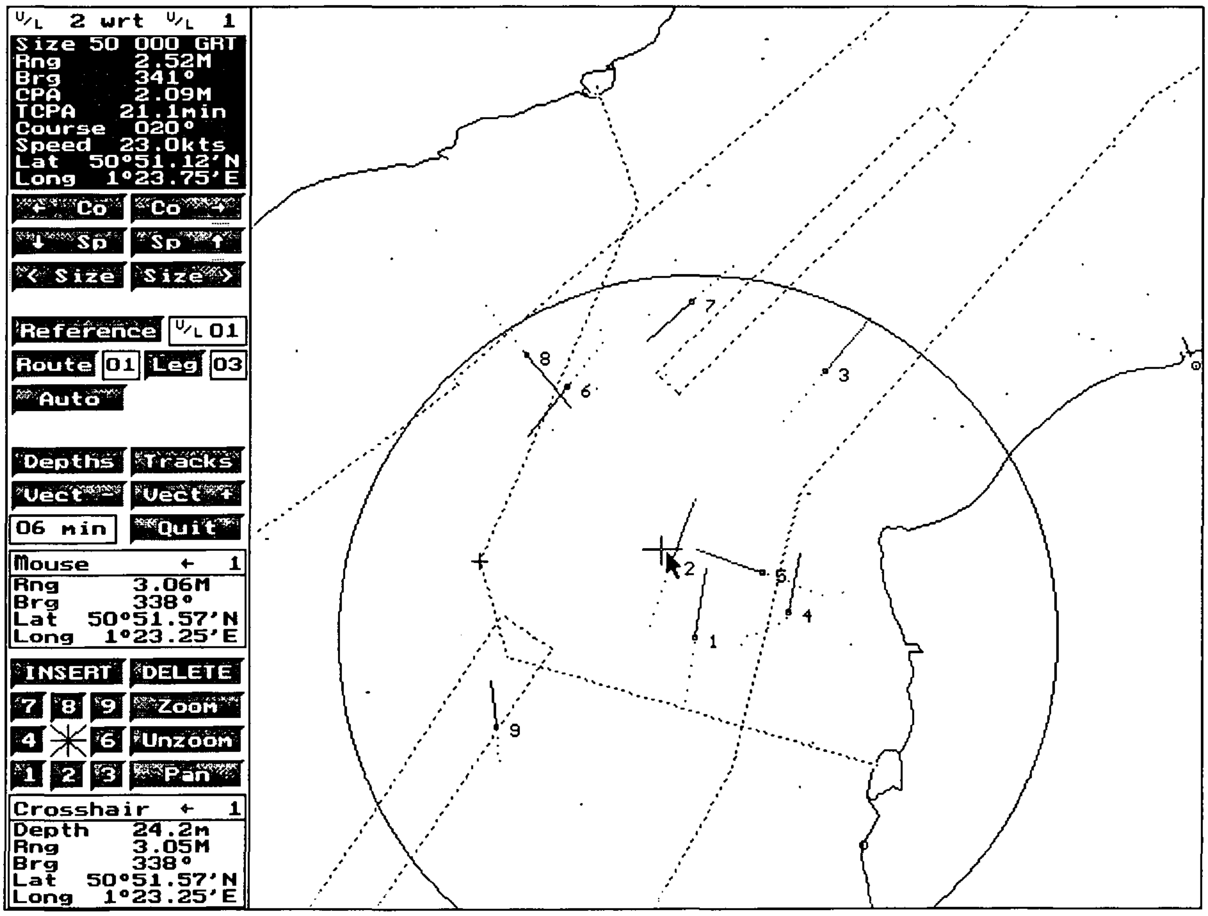
When the exercise is running and this screen is selected, the bar will not appear and data on this sreen is for information only. Hitting any key or clicking the mouse will return you to the MAIN SCREEN.

GRAPHICS SCREEN

The graphics screen shows the coastline with targets (with speed vectors and trails). The Lecturer may **ZOOM**, **UNZOOM** and **PAN** the display. The crosshair is moved using the numeric keypad and on executing one of the above functions recentres the map on itself. If the mouse is clicked on the map area the crosshair jumps to that position.

Various *own ships* appear in different colours to aid identification. This will only occur if the *own ship* is visible. The colour system is consistent in exercise preparation, exercise running and exercise replay.

Own Ship 1	Light Red
Own Ship 2	Blue
Own Ship 3	Light Magenta
Own Ship 4	Yellow
Own Ship 5	Dark Red
Own Ship 6	Dark Cyan
Own Ship 7	Light Green
Own Ship 8	Brown



Targets appear with light grey vectors and tails if visible and dark grey if invisible. These vectors always indicate Ground Track. Light Cyan vectors are shown if the *target* is *routed*. Each *vessel* is numbered as well. By pressing **INSERT** (or clicking on the word INSERT) a new *target* may be inserted directly on the chart at the crosshair position. When the crosshair is near a *vessel* that vessel's data appears at the top of the screen. If the vessel is a *target* then its actual course and speed may be altered directly from this screen. This is done by clicking on the appropriate button or using the cursor keys. Size may also be altered by < or >.

The table of data at top left gives information of the *selected vessel* with respect to the *reference vessel*. The *reference vessel* has its number and spot in light green on the map so as to aid rapid identification. Other *targets* have yellow numbers and a white spot while *own ships* have yellow writing and a red dot.

The range and bearing of the crosshair from the *reference vessel* is indicated at bottom left along with depth of water and latitude and longitude. The range and bearing of the mouse pointer from *reference vessel* is indicated about midway on a dark gray background.

The Vector time may be altered by using the mouse and the appropriate buttons or by pressing + or -. Valid vector times are from 0 to 99 minutes. All vectors on this screen are displayed as ground stabilised.

In addition TRACKS may be switched on or off. The tracks will only display for up to the last 15 minutes although the positions are recorded on disc for much longer periods (3 hours).

D will display all the soundings used on the map. This may be toggled off by typing **D** again. Depths below 10 metres are shown in Red, between 10 and 20 in Yellow and greater than 20 metres in Cyan.

RDF beacons are shown as Magenta circles. If you zoom in sufficiently the frequency is indicated alongside the beacon.

Racons (maximum of 20 per chart area) are also indicated by Magenta cicles with the notation *RACON* alongside the circle.

Routes appear as brown dashed lines with a yellow cross at the selected leg. **O** is used to select the next route for display. There are 10 possible routes. Pressing **O** when on route 10 will blank the routing system. Pressing **O** again will cycle to Route 01.

Pressing **L** for leg will cycle leg by leg through the 10 waypoints allocated to each route. A small yellow crosshair will be displayed on the map if that point is visible within the borders of the screen.

Pressing **A** for Auto will cause the *reference vessel* to alter course to the current leg of the current route. Once on the leg it will continue along the track till the end of the route. Control can be taken of the target by simply altering it's course from the graphics or the main page. When using auto, the computer will request confirmation. Press Left mouse button or Y to accept or press the right button or N to cancel. Note that the routed vessels are unaffected by current (it may be assumed that the control of these targets is automatically compensating for current). The course and speed displayed on the main page and upper table indicates course and speed over the ground. All other targets indicate course and speed through the water.

QUICK REFERENCE FOR GRAPHICS SCREEN

QUIT	- Return to MAIN SCREEN
ESC	- Return to MAIN SCREEN
ZOOM	- Zoom in with the screen centred on the crosshair
UNZOOM	- Zoom out with the screen centred on the crosshair
PAN	- Pan with the screen centred on the crosshair
INSERT	- Insert a new *vessel* at the crosshair
DELETE	- Deletes the *selected target* if there is one.
DEPTH	- Display all soundings on chart.
REF	- *Selected vessel* becomes *reference vessel.*
TRACKS	- Display up to 15 past positions of all *vessels* at one minute intervals
<	- Reduce the size of the *selected vessel*
>	- Increase the size of the *selected vessel*
Cursor keys	- Used to alter or set the *selected vessel's* course and speed.
Numeric keypad	- Used to position the the crosshair.
+	- Increases vector time by one minute (maximum 99minutes).
-	- Decreases vector time by one minute
F1..F10	- Change *reference vessel* to 1 through 10.
SHIFT F1..F10	- Change *reference vessel* to 11 through 20.
CTRL F1..F10	- Change *reference vessel* to 21 through 30.
ROUTE	- Select the next route for display on the map - cycles though 10 and no route.
LEG	- Select next leg for the current route - indicated by a yellow cross.
AUTO	- Changes the *reference vessel* to a *routed vessel* altering course to join the selected route at the selected leg. Confirmation will be requested.

INFORMATION SCREEN

From the main screen Pressing INFO gives a fourth page showing as many past own ship manoeuvres as is possible. Press any button or click the mouse to return to the main screen. This page is useful in determining the amount of manoeuvres that a student has made and generally indicates the level of panic or indecision on his part.

CONTROL TERMINAL RADAR (OPTIONAL)

With this additional software and a second computer system at the control terminal, the controller can monitor any of the student radar screens.

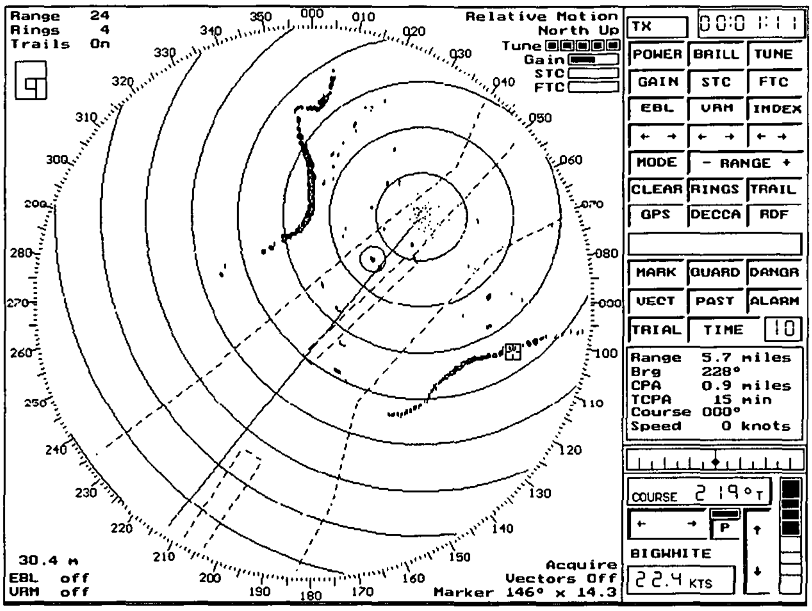
A set of buttons on the right hand side of the radar selects the own ship radar to be viewed.

In addition the controls for that screen can be set to the current settings as selected by the student or directly to optimal settings.

Range scale and off centering will be determined by the settings made by the student.

A VRM, EBL and parallel index are available for the controller.

STUDENT'S TERMINAL



The student has a radar screen with various controls on the right.

In the square surrounding the radar picture there are various messages.

Starting at top left is the current range scale, the distance between fixed range rings (or off) as well as an indication of whether trails are on or off.

At top right are indicators of Relative/True Motion and either Head up or North up.

Below the screen on the left an EBL bearing and VRM range.

Below the screen on the right is indicated the position of the mouse/track pointer if on the radar screen itself. In addition if in ARPA mode there is indication of ground or sea stabilised mode, the current MARK mode (Acquire target, designate target, cancel target, offset centre or map move) as well as VECTOR mode (True, relative or off).

In the elongated panel to the right is a digital clock running in Exercise Time.
Below this is a panel of buttons that are used to operate the radar controls. The buttons may either be pressed by using the mouse or by pressing the Hot keys indicated by the white letter.
The first six buttons are split keys. Place the pointer on the required side of the screen button before depressing any mouse or trackball button. (Alternatively the pointer may be placed anywhere on the screen button and left button used to turn down and right button to turn up - this alternative mode may be activated by running the radar receiver program with the parameter B included).

Power	- **Escape** turns to the left, **Enter** to the right. Positions are OFF, STANDBY and TRANSMIT. In the *stand alone system* STANDBY is a pause control and switching further left exits the program.
Brill	- The brilliance of the radar screen can be decreased and increased by pressing [or] respectively.
Tune	- The radar may be tuned using < and > respectively. 5 LEDS on the screen light up when optimally tuned.
Gain	- **Q** and **W** allow the gain to be adjusted with a display on screen.
STC	- **A** and **S** allow the Sensitivity Time Control to be adjusted with a display on screen.
FTC	- **Z** and **X** allow the Fast Time constant to be adjusted with a display on screen.
EBL	- Toggles the Electronic Bearing Line on and off.
VRM	- Toggles the Variable Range Marker on and off.
INDEX	- Toggles the Parallel Index on and off.

The following three buttons are split keys and are used for adjusting the EBL, VRM and parallel index. Alternatively the function keys **F3** and **F4** control the first button (turning the EBL). Likewise **F5** and **F6** adjust the VRM and **F7** and **F8** alter the Parallel Index.

MODE	- Toggles between RM Head Up, RM North Up and TM North up if the exercise is set for North Up.
- RANGE +	- Increases or decreases the Range Scale in use from ¼ to 48 miles.
CENTRE	- Clears and centres the screen.

RINGS	- Toggles the fixed range rings on/off.
TRAIL	- Toggles synthetic afterglow on/off.
GPS	- Pop up GPS receiver with Latitude/Longitude display. (stays on until a key is pressed). Only available if single screen system is being used.
DECCA	- Pops up an automatic Decca Navigator which displays chain selected as well as Red, Green and Purple Lines of Position.(stays on until a key is pressed). Only available if single screen system is being used.
RDF	- Pops up an Automatic Radio Direction Finder that remains on till switched OFF. This unit may be tuned digitally to any DF frequency. Only available if single screen system is being used.

ARPA controls appear below this if selected.
These 9 buttons match the 9 buttons on the numeric keypad of the computer.

7 Mark	- The mark shown on the screen and moved by the mouse control may be used for acquiring targets, (start tracking), designate target, (display data for selected vessel), cancelling a target, offsetting the screen or moving the map. Pressing the button toggles through the five modes.
8 Guard	- A guard zone may be placed on the screen on any bearing, at any range and with a subtended angle up to 40°. This is done by using the EBL, VRM and TIME buttons. Pressing Guard again accepts these changes.
9 Danger	- A CPA and TCPA limit can be set to determine dangerous targets. Altered by using VRM and TIME buttons.
4 Vectors	- Three modes (TRUE, RELATIVE and OFF) and toggled each time it is pressed.
5 Past	- 4 past position indicators on every tracked vessel may be toggled on or off.
6 Alarm	- Acknowledge alarm.
1 Trial	- Trial manoeuvres may be carried out. The EBL and TIME keys are used to alter Own Ship's proposed course and speed.
2/3 Time	- A split button used primarily for altering the vector time.

MAP and VECTOR brilliance are also individually controlled. If in high resolution these controls are displayed. In low resolution (VGA) the controls do not appear but are still active.

Map Bril	- On certain coasts an additional file contains the separation scheme applicable. This map will appear on all programs as well as on ARPA selected systems. The brilliance of this map can be independently controlled.
Vector Bril	- Pressing this button will alter the brilliance of Vectors and past positions.

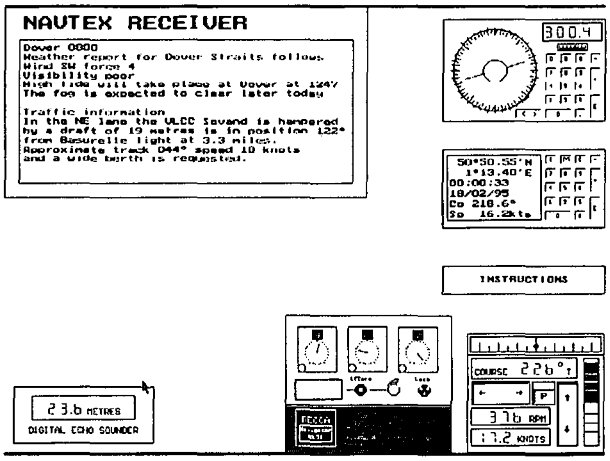
SHIFT + {	decrease map brilliance
SHIFT + }	increase map brilliance
;	decrease vector brilliance
'	increase vector brilliance
?	Toggles between Ground stabilised and sea stabilised displays.

In ground stabilised mode it is assumed that the equipment is ground locked by GPS or similar (ie it is correct) and the maps are locked and true vectors shown will represent ground tracks. In sea stabilised mode the maps will drift but true vectors will indicate correct aspect.

At the bottom is the ship control panel. The Red buttons are split type and the cursor keys may be used to increase or decrease power or to set the Auto pilot/Rudder. Pressing PILOT will toggle between Autopilot and manual steering. Note that there is a rudder angle indicator with desired rudder angle indicated by two yellow triangles, the upper triangle representing actual rudder and the lower triangle indicating desired rudder. Current course, revs and speed is displayed digitally in this panel. 3 When setting the auto pilot or power the course/speed display temporarily changes to show selected course/speed. It will change back to actual course/speed within a few seconds.

If the *twin screen system* is operational then the control panel and navaids are automatically transferred to the second screen.

NAVAIDS PANEL



When using a *Network system* it is possible to run a *twin screen system* as an optional extra.

In this case the Navigation aids are more sophisticated and along with control panel these are displayed on a seperate screen.

Run N.BAT to activate ensuring that the RADSIM.NET file contains the numerical value of the vessel referred to. ie Both the Radar Computer and Navaid Computer must reflect the same vessel number.

Active Icons are used in this panel. This means that if you click on the Instrument Icon it will enlarge so that it may be properly controlled. When displayed as an Icon, it may still be used and will update the information.

Hotkeys will also function although a mouse is desirable.

RDF will bring up the RDF and the numeric keypad may be used. The left and right cursor keys must be used to align the compass with the gyro. The red end of the needle displays the correct bearing and may be read as both true and relative bearings. Frequency may be dialled up by inputting the value and ENTERing or by + or - for small changes. The displayed signal strength is related to distance from the required transmitting station. Calibration errors are preset as indicated in the calibration curve in the appendix.

DECCA is a mk 21 and works in exactly the way the real one operates. A mouse must be used for this machine. This receiver may give results offset from the true results depending on the Control Terminal.

GPS is a generic GPS with waypoints etc. Course and speed displayed is ground track. The numeric keypad may also be used for this machine. This machine may also give false readings depending on the Control Terminal. If no lock is achieved for any reason, the receiver will display the last known position.

USING WAYPOINTS

The vessel's current position is always 0. If a route of waypoints is set up, and you wish to start from the current position, then your route must start as Waypoint 0. When the route is entered this waypoint is tranferred to waypoint 21 and left constant while waypoint 0 continues to change.
The route of points must first be stored in different wayoints and then strung together.
To create a waypoint press MENU (/ on keyboard), followed by 3 (Navigate). Press + or - until an empty waypoint appears then press EDIT (or * on keyboard). Type in the latitude and if necessary simply tap the ± Key (.key on keyboard) to re-enter data. Backspacing is not possible. Change the the N to S and visa versa with the ± Key. When the latitude is correct press + to move to the longitude line. Press ENTER when the input is correct to leave the EDIT mode.

Enter as many waypoints as is desired, then proceed to ROUTE from the menu and enter the order of the wayoints . This may be in any order but will probably be

00 > 01 > 02 > 03 > 04 etc.

This will change to

21 > 01 > 02 > 03 > 04 etc

A route has now been created proceeding from Current Position to Waypoint 1 to 2 etc.
Return to the MENU and press 2 for RNG/BRG/XTE and if it has been set up correctly it will display current latitude and longitude, track from to indication, as well as range and bearing to next waypoint, and perpendicular distance from the line joining the last and next waypoint (XTE).

ECHO SOUNDER is mouse controlled and only the range scale may be altered. Both graphical and digital displays are used. Multiple echoes are displayed on this system. The maximum range of the echo sounder is 160 metres.

WEATHER produces a Navtext receiver which will display data placed in .WX file if previously setup for the exercise being run.

INFORMATION reproduces the applicable briefing sheet if it has been produced.

SOUND SIGNALS allow one of 13 sound signals to be made by the own ship. This signal will take a period of time (less than 30 seconds) before being audible and below the FOG SIGNAL BOX will be displayed the words OWN SOUND SIGNAL. Signals made by other *own ships* of by *targets* will be indicated by the Morse letter appearing as well as relative bearing (to the nearest 10°) and the range of the signal. This is so as to give an idea of the relative position of the vessel making the signal. Once an *own ship* signal has been transmitted to the network, the signal will default to none. In other words students must send their signals manually at the required intervals.

The ship's control panel is identical to that used on the radar set.

Further information on the operation and use of the above instruments is available on software using similar equipment with guidance and directions as well as testing. These simulations are available from the producer.

STARTING INSTRUCTIONS

STANDALONE SYSTEM

Starting an exercise
To boot up a *Stand alone system* it is simply a matter of running R [ENTER]. The terminal will show the software logo. Thereafter a message saying "Press Space Bar to Continue" will appear. Pressing the Space Bar will cause a radar screen to be drawn.

A menu of coastlines will appear on the Screen. Use the up and down cursor keys to select the Coastline to be used. A second menu of exercises within that coast area will then appear and must be selected as well. Finally a last menu will display a list of stored names and ask for a name in which to store the data for replaying the exercise. Type in any 8 letter name or simply hit [ENTER] to use the name DEFAULT.RPL. The mouse may be clicked to achieve the same default name save. It is recommended that the default is used unless you wish to REPLAY and store the exercise.

The program will begin to execute immediately thereafter.

Stopping the exercise
In this system press **ESC**APE repeatedly until one step beyond OFF. The computer will ask if you wish to do another exercise. Type **NO** or press right mouse button to exit or **YES** (or left mouse button) if you wish to run another exercise.

NETWORK SYSTEM

Starting the system
Switch on the CONTROL Computer first. This computer must offer its network resources before the student computers are switched on. Thereafter switch on all student computers that are required. It is not necessary to start all the computers if they are not required. *Own ships* that are not allocated will revert to being *target vessels.*

It is not essential that the student computers are running for the control terminal to operate correctly. Student terminals may even be started during the running of an exercise but the indicated time on these machines will not correspond with the exercise time until the exercise is *paused*. After restarting the indicated times will correspond within 10 seconds.

Student Terminal
The student computers will automatically look for a file on the Ramdrive of the Control Terminal and start thereafter automatically. For information on this batch file and parameters used please refer to the section on batch files.

Control terminal
Select Radar Simulator from the menu and press [ENTER] and the logo will appear. Press the space bar.
A coastline menu will appear. Select the desired Coastline using either the first letter of the coast or the cursor keys and ENTER when the desired coastline is highlighted. The next menu to be displayed will be exercises saved in the specific COAST directory. If you wish to create a new exercise, select the exercise called BLANK otherwise select the desired exercise.

A third and final menu will appear asking for a name for the playback file. The name STANDARD is offered if you do not wish to save the file for archival purposes. Otherwise you may call the file anything you like using up to 8 alphanumeric characters. Note that this file will be stored automatically and this option cannot be bypassed.

The program will start automatically and then go into *pause mode*. All the student computers will communicate with the control terminal and then indicate *Paused*. The student's navaids terminal will display the student's Instruction sheet if one has been prepared. The control terminal may be used to alter the exercise at this point. All vessels may be repositioned, exercise time, currents, tides, navaid status etc may all be altered. If you wish to save a modified status, proceed to the MAIN SCREEN (press ESCAPE on any other screen) and press E (for Exercise save). A menu will appear and you may now store the current status as a new exercise or overwrite an old exercise. This file may be recalled at any other time under the selected Coast directory.

To release the *pause mode* press **P**. Within one minute the computer will determine which student ships, if any, are running. Those vessels will automatically be taken over by the student computers. If a student computer is closed down through CTRL C or other error (other than a reboot), the control terminal will regain control of that vessel and it will become a *target*. In other words, if an *own ship* is no longer required, but the simulation must continue, press CRTL C or CTRL BREAK on both the navaids and radar terminals. The radar terminal will normally display a screen of colour. Press ESCAPE to return to the Dos prompt and if you wish, these two computers may now be switched off.

While the simulation is running, the computers in any cubicle may be switched on. These computers will automatically load the simulation software, start the program and will immediately take control of their respective vessels. The exercise time however, will indicate the incorrect time until the exercise is *paused* from the control terminal and then released again.

Stopping the simulation
Change to the MAIN SCREEN if necessary and press **ALT** and **NEXT** if you wish to run another exercise or **ALT** and **QUIT** to exit.

Normally if another exercise will be run that day, Alt Next should be used. This command will close down the simulation and prepare the student's terminals for the next exercise. The control terminal will return to the Dos prompt so that the exercise may be debriefed.
If this is the last exercise for the day, press Alt Quit and the student terminals will return to the Dos prompt in order to be switched off.

No damage to the program or hardware can occur if the student computers are reset or switched off while the simulation is running.

Switching off the control terminal or resetting this machine will cause unpredicatable results at the student terminals (although hardware and software will not be damaged) and will cause loss of exercise replay data.

After replaying and debriefing start only the control terminal byselecting Radar Simulator and [ENTER]. The student terminals will start automatically as indicated in the above section.

QUICK REFERENCE FOR STARTING AN EXERCISE

To run the exercise called *EXERCISE* contained in the directory *DOVER* carry out the following steps
Switch on the Control Terminal. Allow this computer to boot up to the menu.
Switch on the required student computers.
From the Control terminal menu select Radar Simulation and [ENTER].
When the Author's logo screen appears press [SPACE BAR].
Select the coastline directory for the required exercise - ie DOVER - and press [ENTER]
Select the exercise - ie EXERCISE - and press [ENTER]
Type in a name for the exercise recording - NC0197 (possibly Navigation Control exercise 01 of 1997) - and press [ENTER]
Check that all computers are displaying Radar and Navaids in paused mode.
Press P from the Control Terminal to start the exercise running.

EXERCISE PREPARATION

Exercises are created by editting an exercise template called BLANK from the control terminal. In this case it is unnecessary to switch on the student computers although they may be on.
Select a coastline and a previous exercise. A save for later replay will be requested and it is suggested that this is saved as STANDARD as this file will not normally be needed.

While the program is in *paused mode* the template may be editted. It is recommended that the STATUS SCREEN is used first and that the respective shiptype of each of the *own ships* is selected first. Thereafter the rest of the STATUS SCREEN parameters may be altered although the option to return at.a later stage is available.

Thereafter it is recommended that the vessels are positioned in the exercise area.
This may be done by changing to the MAP SCREEN. The crosshair should be precisely positioned at the desired spot for each vessel in numerical sequence and then INSERT typed to position the vessel at this point.

Alternatively, the MAIN SCREEN may be used and the co-ordinates of each vessel in Northings and Eastings typed in (if this method is preferred, change the co-ordinate system from latitude/longitude to X/Y co-ordinates by typing C.

The third method assumes that a single vessel has been placed and that this vessel is selected as the *reference vessel* (Press F1 through F10, SHIFT F1 through SHIFT F10 or CTRL F1 through CTRL F10) to select a reference vessel) . By altering the range and bearing on the MAIN SCREEN of any other vessel, that vessel can be placed relative to the *reference vessel.*

Adjust the course and speed of each vessel as desired from either the MAIN SCREEN or MAP SCREEN. If required route the target vessels as defined on the MAP SCREEN.

If required, change to the TIDE SCREEN and select a time of High Water, range of tide and exercise time as well as a current for unrouted *targets*. Note that *own ship* currents are specified on the STATUS SCREEN.

Return to the MAIN SCREEN and type E for Exercise Save. A directory of previously created exercises will appear. Name your new exercise with up to 8 alphanumeric characters and ENTER.

A fuller explanation and full example is shown in the next chapter

An optional utility program called PREP is available for controlling various other optional modules.

EXERCISE PREPARATION - AN EXAMPLE

Example
Suppose that an exercise involving 4 *own ships*, all in the same position, all Bulk Carriers and hidden from each other, with three *targets* (one crossing, one end on and an overtaking vessel) is required for a particular exercise. Each own ship is equipped with a gyro stabilised radar but no other equipment. The sea is fairly calm and the students are not required to set up the radar but may alter settings during the exercise. The situation as seen by all *own ships* will be identical and there will be no student interaction. The coastline to be used in near Cap D'Antifer in the exercise area Seinebay. The filename will be 'TUT01.EX'. We will not run the exercise immediately and therefore do not need to record the positions of targets for later replay.

In order to prepare an exercise it is necessary to run the Control Terminal and it is recommended that the student terminals are not even switched on although this is not essential.

Once the control terminal has completed its boot procedure and the menu program appears select CONTROL TERMINAL (or type R [ENTER] from the C> prompt). The producer's Logo page will appear with the message 'Press any key to continue' at the bottom.

Pressing any key (or clicking a mouse button) will blank the screen and a blue bar will appear at the top of the screen along with a box headed 'SELECT'. A list of coastlines appears in the box and a blue highlight bar will appear on the top line.

Move the bar down to SEINEBAY by one of the following methods.

1. Move the mouse down and the bar will move downwards. Continue until SEINEBAY is highlighted.
2. Use the cursor up/down keys to select SEINEBAY.
3. Type the first letter (ie S). The highlight bar jumps immediately to the first coastline beginning with S (ie SALDANHA). The highlight bar may now be moved down to SEINEBAY.

When SEINEBAY is highlighted press [ENTER] or click the left mouse button.

The coastline name is indicated on the top left of the screen in the blue bar.

A second box will appear with a list of all the exercises contained under the coast directory SEINEBAY.

As we are creating an exercise move the highlight bar to the filename BLANK (BLANK is a template

that is used to produce exercises - any old exercise may, in fact, be used to create a new exercise). Press [ENTER] or click the left mouse button to select .
The exercise name is indicated to the right of the coast name in the blue bar.

A third block will appear headed 'SAVE'. This is a file created automatically to record the positions of all vessels during the exercise at one minute intervals. It is used for replaying the exercise for debriefing purposes. If the exercise is to be run immediatley after its creation, type in a user determined name of up to 8 alphanumeric characters. In this case save the replay data under the default filename 'STANDARD' that is offered to you by simply pressing [ENTER] or clicking the left mouse button.

The replay filename with the extention .RPL is indicated to the right of the exercise name.
Thereafter the MAIN SCREEN appears as indicated above. At the top will appear the message PAUSED! PRESS P indicating that the control terminal is in *paused mode*. To setup an exercise it is essential that the terminal is in *paused mode* so do <u>not</u> press P.

All the vessel data appears in dark grey and the word Tgt (ie target) appears in front of each vessel number because no vessels have yet been positioned and control has not been taken by the student terminals.

As the program is in *paused mode* the template may now be edited. Proceed to the STATUS SCREEN by either hitting S on the keyboard (highlighted letter of the second word on the bottom line) or buy moving the mouse bar to the word and pressing a mouse button.

SEINEBAY BLANK STANDARD.RPL | PAUSED! | PRESS P | 00:00:03

Ship	Co	Speed	Latitude	Longitude	Size	Rnge	Brg	CPA	TCPA	D.Co	D.Sp	Rng
Tgt 1	000	0.0	0°00.00'N	0°00.00'E	0					000	0.0	
Tgt 2	000	0.0	0°00.00'N	0°00.00'E	0	0.00	000	0.00	0	000	0.0	
Tgt 3	000	0.0	0°00.00'N	0°00.00'E	0	0.00	000	0.00	0	000	0.0	
Tgt 4	000	0.0	0°00.00'N	0°00.00'E	0	0.00	000	0.00	0	000	0.0	
Tgt 5	000	0.0	0°00.00'N	0°00.00'E	0	0.00	000	0.00	0	000	0.0	
Tgt 6	000	0.0	0°00.00'N	0°00.00'E	0	0.00	000	0.00	0	000	0.0	
Tgt 7	000	0.0	0°00.00'N	0°00.00'E	0	0.00	000	0.00	0	000	0.0	
Tgt 8	000	0.0	0°00.00'N	0°00.00'E	0	0.00	000	0.00	0	000	0.0	
Tgt 9	000	0.0	0°00.00'N	0°00.00'E	0	0.00	000	0.00	0	000	0.0	
Tgt 10	000	0.0	0°00.00'N	0°00.00'E	0	0.00	000	0.00	0	000	0.0	
Tgt 11	000	0.0	0°00.00'N	0°00.00'E	0	0.00	000	0.00	0	000	0.0	
Tgt 12	000	0.0	0°00.00'N	0°00.00'E	0	0.00	000	0.00	0	000	0.0	
Tgt 13	000	0.0	0°00.00'N	0°00.00'E	0	0.00	000	0.00	0	000	0.0	
Tgt 14	000	0.0	0°00.00'N	0°00.00'E	0	0.00	000	0.00	0	000	0.0	
Tgt 15	000	0.0	0°00.00'N	0°00.00'E	0	0.00	000	0.00	0	000	0.0	
Tgt 16	000	0.0	0°00.00'N	0°00.00'E	0	0.00	000	0.00	0	000	0.0	
Tgt 17	000	0.0	0°00.00'N	0°00.00'E	0	0.00	000	0.00	0	000	0.0	
Tgt 18	000	0.0	0°00.00'N	0°00.00'E	0	0.00	000	0.00	0	000	0.0	
Tgt 19	000	0.0	0°00.00'N	0°00.00'E	0	0.00	000	0.00	0	000	0.0	
Tgt 20	000	0.0	0°00.00'N	0°00.00'E	0	0.00	000	0.00	0	000	0.0	
Tgt 21	000	0.0	0°00.00'N	0°00.00'E	0	0.00	000	0.00	0	000	0.0	
Tgt 22	000	0.0	0°00.00'N	0°00.00'E	0	0.00	000	0.00	0	000	0.0	
Tgt 23	000	0.0	0°00.00'N	0°00.00'E	0	0.00	000	0.00	0	000	0.0	
Tgt 24	000	0.0	0°00.00'N	0°00.00'E	0	0.00	000	0.00	0	000	0.0	
Tgt 25	000	0.0	0°00.00'N	0°00.00'E	0	0.00	000	0.00	0	000	0.0	
Tgt 26	000	0.0	0°00.00'N	0°00.00'E	0	0.00	000	0.00	0	000	0.0	
Tgt 27	000	0.0	0°00.00'N	0°00.00'E	0	0.00	000	0.00	0	000	0.0	
Tgt 28	000	0.0	0°00.00'N	0°00.00'E	0	0.00	000	0.00	0	000	0.0	
Tgt 29	000	0.0	0°00.00'N	0°00.00'E	0	0.00	000	0.00	0	000	0.0	
Tgt 30	000	0.0	0°00.00'N	0°00.00'E	0	0.00	000	0.00	0	000	0.0	

MAP STATUS INFO [illegible] TIDE CO-ORD BEACON SART PAUSE EX.SAVE ALTE

A lightgey screen headed OWNSHIP EQUIPMENT STATUS appears.
Below the heading, the columns are marked as Own Ship 1 through 8. Down the left side are various headings referring to the item to be set.

The highlight bar may be moved from item to item by either

1. Using the 4 cursor keys

2. the mouse may be used
3. Pressing the function keys F1 through F8 will move the highlight bar to the respective column indicated by the function key.

Ensure that the highlight bar is in column one next to ShipType (ie CARGO is highlighted).
Press either [ENTER], [SPACE BAR] + or - . A menu of ShipTypes appear. Select the type required by moving the highlight bar to BULK and press [ENTER].

Move the highlight bar down. It will bypass 4 rows which are purely for information and highlight GYRO. The vessel we are using has a gyro compassd so leave this option ON.

The next option refers to stabilisation of the radar. If stabilised the student can change radar display mode from Relative Motion head up, relative motion north up or true motion north up. Leave this option ON.

Sea clutter can be set from 0 to 15 depending on sea state. Highlight this option in column one and increase the value to 4 by tapping the + key or by clicking the right mouse key. If necessary you can decrease the value by pressing - or by clicking the left mouse button.
A value of 4 gives a faint sea clutter equivalent to around force 2 on the Beaufort scale and is unlikely to mask targets.

The yaw value will be left at 0 and the vessel will proceed without yaw.

The current direction and rate will be left at 0.

Move the highlight bar to Decca lock. Press [ENTER], [SPACE BAR] or+ till N/A (Not Available) appears. The values against dir(direction) and rnge (range) will appear in red.
The Decca is now disabled.

Move the highlight bar to GPS lock. Press [ENTER], [SPACE BAR] or + till N/A (Not Available) appears. The values against dir(direction) and rnge (range) will appear in red.
The GPS is now disabled.

The following two rows are for information only. The tide is computed from another screen and draft is predetermined from the shiptype. The E/S reading is not valid until the exercise runs but the echo sounder may be switched off on this line. Switch the echo sounder OFF by pressing [ENTER], [SPACE BAR] + or -.

The RDF (Radio Direction Finder) may also be switched off by pressing [ENTER], [SPACE BAR] + or -.

Next to the heading Radar, the are 4 permutations. These are PRESET (the radar will be on,correctly tuned and gain optimally set when the exercise is run), ZEROED (the radar will be switched off and all controls at the zero position when the exercise starts), RESTRICT (the radar will be preset but the following radar controls are disabled - Power, Brill, Tune, Gain, STC, FTC and Mode) and OFF (Radar failure). Select PRESET as we do not wish the students to waste time setting up the radar sets.

Next to ARPA press [ENTER], [SPACE BAR] + or - to deselect the ARPA facility.

The Engine should be left ON so that the student vessel will proceed. OFF will cause the engines to fail.

The Helm should be left ON so that the student may alter course. The rudder angle should also not be changed as this will jam the rudder.

Casualty will be left as NORMAL otherwise the engines, helm and radar on the student terminal will fail.

The STATUS SCREEN should now appear as shown below.

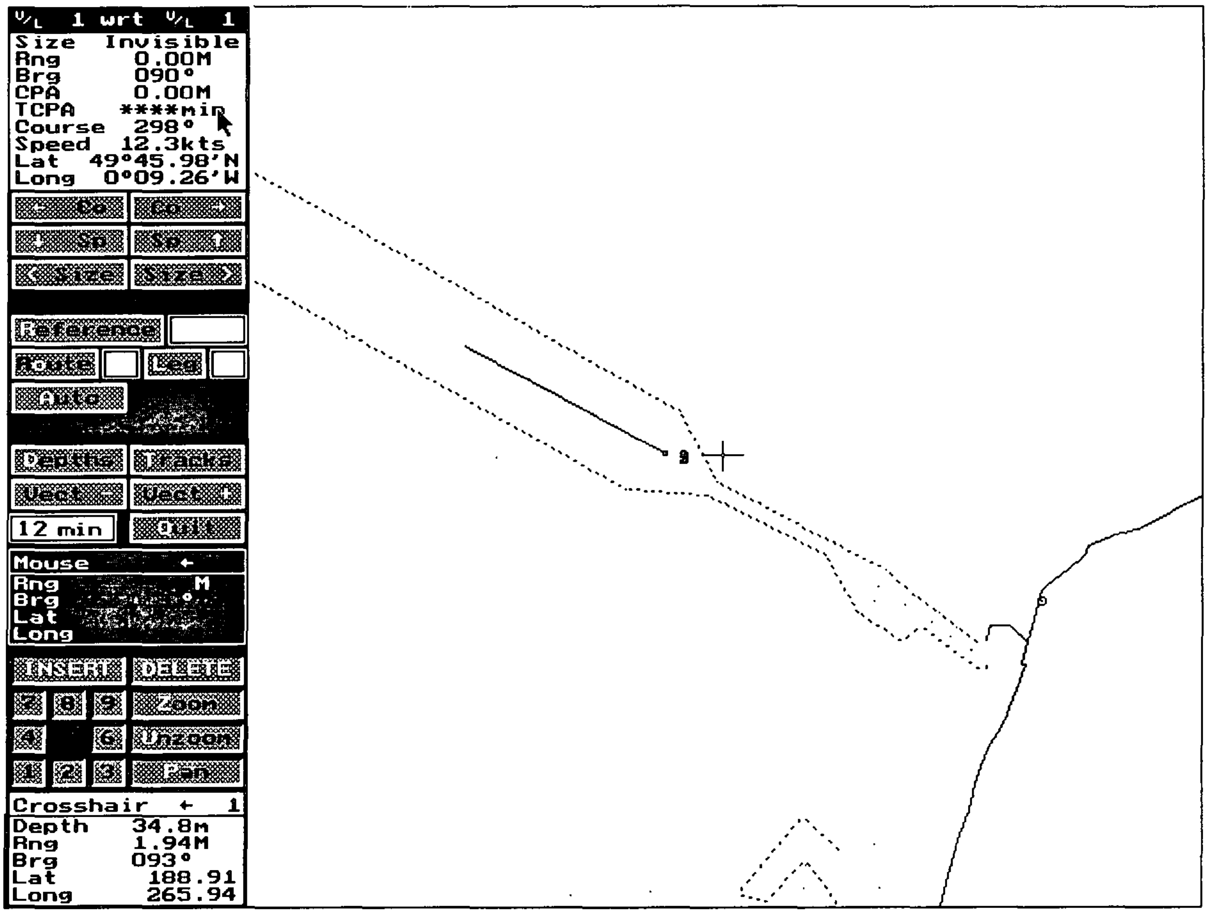
O W N S H I P			E Q U I P M E N T			S T A T U S		
OWN SHIP	1	2	3	4	5	6	7	8
ShipType	BULK	CARGO	CARGO	CARGO	CARGO	CARGO	CARGO	CARGO
Range scale	12	12	12	12	12	12	12	12
Gain Act/Opt	0/ 0	0/ 0	0/ 0	0/ 0	0/ 0	0/ 0	0/ 0	0/ 0
Tune Act/Opt	0/ 0	0/ 0	0/ 0	0/ 0	0/ 0	0/ 0	0/ 0	0/ 0
STC	0	0	0	0	0	0	0	0
FTC	0	0	0	0	0	0	0	0
Gyro	ON	ON	ON	ON	ON	ON	ON	ON
Stabilised	ON	ON	ON	ON	ON	ON	ON	ON
Sea Clutter	4	0	0	0	0	0	0	0
Yaw	0	0	0	0	0	0	0	0
Current dir	000°	000°	000°	000°	000°	000°	000°	000°
rate	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Decca dir	000°	000°	000°	000°	000°	000°	000°	000°
rnge	0 m	0 m	0 m	0 m	0 m	0 m	0 m	0 m
lock	N/A	ON	ON	ON	ON	ON	ON	ON
GPS dir	000°	000°	000°	000°	000°	000°	000°	000°
rnge	0 m	0 m	0 m	0 m	0 m	0 m	0 m	0 m
lock	N/A	ON	ON	ON	ON	ON	ON	ON
Tide	11.7 m	11.7 m	11.7 m	11.7 m	11.7 m	11.7 m	11.7 m	11.7 m
Draft	10.2 m	0.0 m	0.0 m	0.0 m	0.0 m	0.0 m	0.0 m	0.0 m
E/S reading	OFF	11.7 m	11.7 m	11.7 m	11.7 m	11.7 m	11.7 m	11.7 m
RDF	OFF	ON	ON	ON	ON	ON	ON	ON
Radar	PRESET	PRESET	PRESET	PRESET	PRESET	PRESET	PRESET	PRESET
ARPA	OFF	ON	ON	ON	ON	ON	ON	ON
Engine	ON	ON	ON	ON	ON	ON	ON	ON
Helm	ON	ON	ON	ON	ON	ON	ON	ON
angle								
Casualty	Normal	Normal	Normal	Normal	Normal	Normal	Normal	Normal
Click here or press ESCAPE to return to the Main page								

Now proceed to change the type and status of equipment for vessel two, three and four so that it appears exactly the same as for vessel one. As we will not be using own ships five, six seven and eight these may be left alone. Press ESCAPE to return to the MAIN SCREEN.

O W N S H I P			E Q U I P M E N T			S T A T U S		
OWN SHIP	1	2	3	4	5	6	7	8
ShipType	BULK	BULK	BULK	BULK	CARGO	CARGO	CARGO	CARGO
Range scale	12	12	12	12	12	12	12	12
Gain Act/Opt	0/ 0	0/ 0	0/ 0	0/ 0	0/ 0	0/ 0	0/ 0	0/ 0
Tune Act/Opt	0/ 0	0/ 0	0/ 0	0/ 0	0/ 0	0/ 0	0/ 0	0/ 0
STC	0	0	0	0	0	0	0	0
FTC	0	0	0	0	0	0	0	0
Gyro	ON	ON	ON	ON	ON	ON	ON	ON
Stabilised	ON	ON	ON	ON	ON	ON	ON	ON
Sea Clutter	4	4	4	4	0	0	0	0
Yaw	0	0	0	0	0	0	0	0
Current dir	000°	000°	000°	000°	000°	000°	000°	000°
rate	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Decca dir	000°	000°	000°	000°	000°	000°	000°	000°
rnge	0 m	0 m	0 m	0 m	0 m	0 m	0 m	0 m
lock	N/A	N/A	N/A	N/A	ON	ON	ON	ON
GPS dir	000°	000°	000°	000°	000°	000°	000°	000°
rnge	0 m	0 m	0 m	0 m	0 m	0 m	0 m	0 m
lock	N/A	N/A	N/A	N/A	ON	ON	ON	ON
Tide	11.7 m	11.7 m	11.7 m	11.7 m	11.7 m	11.7 m	11.7 m	11.7 m
Draft	10.2 m	10.2 m	10.2 m	10.2 m	0.0 m	0.0 m	0.0 m	0.0 m
E/S reading	OFF	OFF	OFF	OFF	11.7 m	11.7 m	11.7 m	11.7 m
RDF	OFF	OFF	OFF	OFF	ON	ON	ON	ON
Radar	PRESET	PRESET	PRESET	PRESET	PRESET	PRESET	PRESET	PRESET
ARPA	OFF	OFF	OFF	OFF	ON	ON	ON	ON
Engine	ON	ON	ON	ON	ON	ON	ON	ON
Helm	ON	ON	ON	ON	ON	ON	ON	ON
angle								
Casualty	Normal	Normal	Normal	Normal	Normal	Normal	Normal	Normal
Click here or press ESCAPE to return to the Main page								

We now wish to position the vessels in the exercise area. Change to the MAP SCREEN by pressing M. The Crosshair will appear at the reference point of the CHANNEL AREA (ie Greenwich Buoy) and we need to move this crosshair to Cap D'Antifer (to the South West of the refernce point). Press U (Unzoom) three times. The area around Isle of Wight is visible. Either hold down the numeric key 2 until the crosshair is level with the magenta circle near Cap D'Antifer or move the mouse pointer to this area and click the left mouse button.

Press Z twice to zoom into this area and move the crosshair to the area where the channel leaving Cap D'Antifer widens.
Hit the INSERT key and vessel one is now positioned at the crosshair. We will now move this vessel slightly from the MAIN SCREEN and add the other three own ships. Press ESCAPE or Q to return.



From the MAIN SCREEN type C for co-ordinate change and the Latitude/Longitude table changes to Northings and Eastings. Move the highlight bar to Northings in the top row. Type A for alter and ---.-- will appear. Type 18900 (no decimal required) to precisely set vessel one. Move to the Eastings column and press A (for alter) type 26400.

Vessel one is now positioned at co-ordinate 189.00 and 264.00 from the bottom left corner of the exercise area. It will appear in light gray to represent that it is positioned but invisible (size is set to 0). Move the bar to the course column and type A298 to alter his course to 298°. Move to the speed column and type A123 to set his speed to 12.3 knots.

Vessel two, three and four now need to be positioned at the same point with the same course and speed. For vessel two move to the second row in the course column and type the following sequence. A298[RIGHT CURSOR] A123[RIGHT CURSOR]A18900[RIGHT CURSOR]A26400[RIGHT CURSOR]. This row should now correspond with row one up to the column marked size.

For vessel three we will try another approach. Set it's course and speed as indicated above. We will now place this vessel at exactly the same spot as vessel one by specifying a range from vessel one. In the extreme left column Tgt 1 should be highlighted. If it is not highlighted press F1 (Function key one) to make this vessel the *reference vessel.* Now move the other highlight bar to vessel three and move across to the column headed rnge (range) adjacent to the size column. At this point to set vessel three on top of vessel one type A (alter) and 0000. This will set target three 00.00 miles from the *reference vessel.* The Northings and Eastings should now correspond. Normally the bearing can also be set but will not be necessary in this case.

Set vessel four at the same co-ordinates. The MAIN SCREEN should now appear as follows.
We now need to position the three targets (overtaking, end on and crossing). This will be done using different methods to show alternative ways of doing this.

The first target will be placed using the co-ordinate system (this may have been worked out on graph paper) and will be positioned at co-ordinate 196.00 and 261.00 (7 miles North and 3 miles to the west of the own ships) and it will be set to have a collision with the own ships.
Move the yellow block down to Target 5 and across to Northings and type A (Alter) followed by 19600. Move to the right and type A26100. The Rnge and Brg columns should indicate 7.62 (miles) by 337 (°) with CPA and TCPA at 4.79 (miles) in 29 (minutes).
Select a speed for this target of 10 knots and a *approximate* intercept course of 200°.
(Move to the Column marked Co and type A200→A1000).

The Rnge and Brg have not altered but the CPA and TCPA now read 0.40 miles in 27 minutes. Move

SEINEBAY BLANK STANDARD.RPL PAUSED! PRESS P

Ship	Co	Speed	Northings	Eastings	Size	Rnge	Brg	CPA	TCPA	D.Co	D.Sp	Rng
Tgt 1	298	12.3	189.00	264.00	0					298	12.3	
Tgt 2	298	12.3	189.00	264.00	0	0.00	090	0.00	**	298	12.3	
Tgt 3	298	12.3	189.00	264.00	0	0.00	090	0.00	**	298	12.3	
Tgt 4	298	12.3	189.00	264.00	0	0.00	090	0.00	**	298	12.3	
Tgt 5	000	0.0	500.00	0.00	0	0.00	000	0.00	0	000	0.0	
Tgt 6	000	0.0	500.00	0.00	0	0.00	000	0.00	0	000	0.0	
Tgt 7	000	0.0	500.00	0.00	0	0.00	000	0.00	0	000	0.0	
Tgt 8	000	0.0	500.00	0.00	0	0.00	000	0.00	0	000	0.0	
Tgt 9	000	0.0	500.00	0.00	0	0.00	000	0.00	0	000	0.0	
Tgt 10	000	0.0	500.00	0.00	0	0.00	000	0.00	0	000	0.0	
Tgt 11	000	0.0	500.00	0.00	0	0.00	000	0.00	0	000	0.0	
Tgt 12	000	0.0	500.00	0.00	0	0.00	000	0.00	0	000	0.0	
Tgt 13	000	0.0	500.00	0.00	0	0.00	000	0.00	0	000	0.0	
Tgt 14	000	0.0	500.00	0.00	0	0.00	000	0.00	0	000	0.0	
Tgt 15	000	0.0	500.00	0.00	0	0.00	000	0.00	0	000	0.0	
Tgt 16	000	0.0	500.00	0.00	0	0.00	000	0.00	0	000	0.0	
Tgt 17	000	0.0	500.00	0.00	0	0.00	000	0.00	0	000	0.0	
Tgt 18	000	0.0	500.00	0.00	0	0.00	000	0.00	0	000	0.0	
Tgt 19	000	0.0	500.00	0.00	0	0.00	000	0.00	0	000	0.0	
Tgt 20	000	0.0	500.00	0.00	0	0.00	000	0.00	0	000	0.0	
Tgt 21	000	0.0	500.00	0.00	0	0.00	000	0.00	0	000	0.0	
Tgt 22	000	0.0	500.00	0.00	0	0.00	000	0.00	0	000	0.0	
Tgt 23	000	0.0	500.00	0.00	0	0.00	000	0.00	0	000	0.0	
Tgt 24	000	0.0	500.00	0.00	0	0.00	000	0.00	0	000	0.0	
Tgt 25	000	0.0	500.00	0.00	0	0.00	000	0.00	0	000	0.0	
Tgt 26	000	0.0	500.00	0.00	0	0.00	000	0.00	0	000	0.0	
Tgt 27	000	0.0	500.00	0.00	0	0.00	000	0.00	0	000	0.0	
Tgt 28	000	0.0	500.00	0.00	0	0.00	000	0.00	0	000	0.0	
Tgt 29	000	0.0	500.00	0.00	0	0.00	000	0.00	0	000	0.0	
Tgt 30	000	0.0	500.00	0.00	0	0.00	000	0.00	0	000	0.0	

MAP STATUS INFO TIDE CO-ORD BEACON SART PAUSE EX.SAVE ALTE

the yellow square back to the Course Column and type + twice. The CPA has changed to 0.27 miles still in 27 minutes. Keep hitting the + key till the CPA indicates
0.00 (Course of 207°). The TCPA is now 29 minutes.

This target needs to be made visible by changing the size column to the value 8. This can be done by pressing the + button while the yellow block is on Tgt 5 and Size.

This vessel is now ready and we can now proceed to place target 6 as the end on vessel directly on the heading marker. Move the yellow square down to target 6 and across to the Rnge Column. Set this target 9.5 miles away (A0950). The own ships are heading 298° so the target should be on that bearing. Move to the Brg Column and type A298. The co-ordinates of this target have been computed as 193.46 and 255.61. Set the size to 9 (A09) and move to the Course Column. Set the course on the reciprocal of 298° (ie 118°) at a speed of 15.0 knots (A118→A150).

The CPA of target 6 is now 0.00 miles in 21 minutes. Check that target 5 and target 6 are not going to have a close quarters situation by making target 5 the *reference vessel* (F5 - Function Key 5). The CPA of target 6 to target 5 should indicate 1.94 miles in 19 minutes.
Press F1 to make *own ship 1* the *reference vessel* again.

We will position the last target from the map screen. Press M to change to the map screen.
Assuming the the picture looks similar to that printed here and the crosshair is on the own ships. A target will be placed approximately two points on the starboard quarter at a range of approximately 3 miles. Use the numeric keypad and press 6 will cause the crosshair to move Eastwards. The black table at the lower left will show the position of the crosshair from the *reference vessel* (in this case *own ship 1*). Move the crosshair till it is approximately 3 miles due East of *own ship 1*. Press the INSERT key on the keyboard and the first unassigned vessel (in this case *target 7*) will be positioned at the crosshair.

Increase this vessel's speed by moving the mouse pointer to the Sp↑ button and depress the left mouse button. The table above will show the speed increasing and the vector on the screen will extend. Increase the speed to about 16.0 knots.

Move the mouse to the ← Co button and alter the course to 297°. The CPA should indicate a CPA of around 1 mile in around 40 minutes. Increase the size by clicking either mouse button till the Size is indicated as 10 000 GRT.

While on the MAP SCREEN press the + key extend the VECTOR TIME. These TRUE VECTORS indicate where all the vessels will be minute by minute in the future. At about the time the end on vessel is due to collide with the own ships, target 7 should have caught up and would now be about 4 points on the starboard quarter. In practise when running this exercise, the controller should alter target 6 25° to starboard about 6 minutes after the exercise begins so as to avoid a collision with the own ships. Target 7 is used to discourage an alteration to starboard by the own ships as this would necessitate that the students *alter towards a vessel abeam or abaft the beam.* At the same time it is clear that the students should take evasive action for target 5. (*Avoid altering to port for a vessel forward of the beam other than for a vessel being overtaken)*

Return to the MAIN SCREEN and type E for Exercise Save. A directory of previously created exercises will appear. The exercise name may consist of up to 8 alphanumeric characters.
Type PRACTISE and ENTER.

You have now created an exercise called PRACTISE.EX which may be found in the directory SEINEBAY. This exercise may be loaded at any time and run or even used as a template for creating another exercise.

UTILITY

This program is an optional module and provides an additional features for ship building, printing exercise data, plotting an exercise as well as creating briefing sheets and navtext information. Routes may also be set up from this module.

From the DOS prompt type UTILITY [ENTER].

EDIT A SHIP/BUILD A SHIP

This first two options on this utility include editting a ship's data as well as creating a vessel from scratch. This option allows the following characteristics to be selected.

Period of Yaw (in centiseconds) for the vessel - time input is for a half cycle ie from maximum port yaw to max starboard yaw.
Standard rudder to be used with the Auto Pilot.
Speed delay is the time before there is a reaction to speed changes.
Engine acceleration (centiseconds/rev) - when power is increased the revs climb until desired RPM is reached at a rate determined by this figure.
Maxiumum RPM
Maximum ahead speed in knots
Maximum astern speed in knots
Rudder rate in degrees per second
Ship size - Press Enter and a table of ship sizes will appear.
Draft in metres
Speed increase control affects the acceleration/deceleration of the vessel.
Loss of speed affects speed loss due to turning.
Advance control affects the amount of advance of the vessel.
Diameter control affects the turning circle of the vessel.
Drift control determines the lag between ships head and direction of movement.
Two shadow sectors (start angle and sector size for each).

NB it should be noted that many of these variables inter-react and that the final results should be checked by pressing S for speed graph and T for the turn graph. The turn graph can be scaled by the +/- keys on the numeric keypad.

NB Note that if the turning circle of the vessel is relatively small (particularly with respect to computer speed) that this may cause steering to be very erratic as the auto pilot will not be able to handle these dynamics. Generally if a problem occurs edit the vessel with a larger turning circle.

Alter the values until satisfied and then **ESC**APE. A list of names will be displayed. Type in a name for the vessel to be saved under.

SHIP GRAPHS

A shiptype can be selected and first a speed graph is shown. This graph can be scaled to display the important part of the graph. Pressing P will plot this graph, provided a HP laserjet printer is connected. ESCape will allow you to print a turning circle graph in a similar manner.
These graphs are useful for student handouts before running an exercise.

PRINT AN EXERCISE

The details of the own ships and positions of all vessels may be printed in a hard copy form for maintaining information of various exercises. The computer will request an output device (Screen, Laser Printer and Dot Matrix printers are supported) as well as Coastname and exercise name.

BRIEFING SHEETS

A briefing sheet for each own ship with data useful for student handout can be created. The objectives of the exercise can be clearly indicated along with ship name etc. These briefing sheets may be called up on the second screen display (INSTRUCTIONS) if connected or alternatively printed (both Laser and Dot Matrix supported). File name has extention .BRF

NAV WARNINGS

The second screen system has a static Navtex receiver so that weather and nav warnings applicable to the exercise may be loaded and displayed. File name has extention .WX. A block of 40 characters on 15 lines may be created . This is an ASCII file and can be editted from any text editor (such as EDIT in Dos 6 and above).

ROUTES

Up to 10 routes numbered 1 to 10 may be defined with up to 10 waypoints or alteration points each. These are stored under the Coast name and it is recommended that these are set up permanently. Once an exercise is running any *target* may be *routed* to any route and any leg.

The *target* will alter course to join the route at the required leg. The course alteration will not be instantaneous but will be determined by the target size. The speed of a *routed target* may be altered at any time. If however the *actual or desired course* is altered it will stop being a *routed vessel.*

When a *routed target* is within 2 cables of a leg it will alter course to the next leg if there is one. If there are no more legs then that target will be deleted and will be removed from the tote automatically. It will now be available for re use as a new target.

On loading a selected coastline, the coastline and map will be displayed along with any routes (if any) displayed in grey. The current route will be displayed in red and is selected by pressing F1 through F10. The crosshair may be moved using the numeric keypad and zooming, unzooming and panning is possible in the same manner as the rest of the suite of programs.

< > changes the currently selected waypoint and by pressing L causes the selected waypoint to be placed at the crosshair.
Up to 10 routes may be placed and used while running a simulation.
Escape allows you to exit this routine.

NB Route files for adjoining areas must be identical (ie DOVER.RTE must be duplicated and renamed IOFWGT.RTE, SANDETTE.RTE, SEINEBAY.RTE, and FLUSHING.RTE) otherwise panning out of the current area will cause new routes to be loaded.

Radsim v 17 uses a series of interconnected charts to make up an area (eg SEINEBAY, IOFWGT, DOVER, SANDETTE and FLUSHING are all interconnected in an area which may be referred to as CHANNEL) and exercises can proceed from one area to the next smoothly. It is possible to in fact store an IOFWGT exercise in the DOVER directory and this will in fact work quite happily. I suggest storing exercises on a day/coastline basis for easy management.

PLOT AN EXERCISE

This option allows a previously created exercise to be recalled. The Map Screen is shown and this may be Zoomed, Unzoomed, Panned and the Vector Length may altered by pressing + or -. When all the vessels and adequate coastline is displayed in the window, typing D will sends this data to a printer. Provided the printer is compatable with the Hewlett Packard plotter commands, an image of the screen will be printed out.

```
                                UTILITY FLOWCHART

EDIT AT A SHIP       →   SELECT   →     VESSEL        →   SHIPTYPE
                         VESSEL         CHARACTERISTIC    SAVE NAME
                                        SCREEN

BUILD A SHIP         →   VESSEL   →     SHIPTYPE
                         CHARACT        SAVE NAME
                         SCREEN
SHIP GRAPHS          →   SELECT
                         VESSEL

PRINT AN EXERCISE    →   SELECT   →     SELECT        →   SELECT
                         OUTPUT DEVICE  COASTLINE         EXERCISE

BRIEFING SHEETS      →   SELECT   →     SELECT        →   BRIEFING   →   AUTOSAVE
                         COASTLINE      EXERCISE          SHEETS
                                                          MENU

NAV WARNINGS         →   SELECT   →     SELECT        →   NAVTEXT    →   AUTOSAVE
                         COASTLINE      EXERCISE          EDITTER

ROUTES               →   SELECT     →   EDIT          →   AUTOSAVE
                         COASTLINE      ROUTE

PLOT AN EXERCISE     →   SELECT   →     SELECT        →   ZOOM/UNZOOM
                         COASTLINE      EXERCISE          TILL WINDOW
                                                          CORRECT

QUIT
```

QUICK REFERENCE (EXPREP)

F1..F10	- select *vessel* 1 to vessel 10 *as reference vessel.*
SHIFT + F1..F10	- select *vessel* 11 to vessel 20 *as reference vessel.*
CTRL + F1..F10	- select *vessel* 21 to vessel 30 *as reference vessel.*
R	- currently *selected vessel* becomes *reference vessel.*
TAB	- changes the cursor and numeric keypad rate.
U	- Unzoom with the screen centred on the crosshair.
Z	- Zoom with the screen centred on the crosshair.
P	- Pan with screen centred on the crosshair.
+	- Increase Vector Time by 1 minute (max 99 mins)
-	- Decrease Vector Time by 1 minute.
Cursor keys	- Used to set the *selected vessel's* course and speed.
Numeric keypad	- Used to position the *selected vessel.*
<	- Decreases the selected *vessel's* size if it vessel number 9 or greater.
>	- Increases the selected vessel's size if it vessel number 9 or greater.

NB *Own ships ie normally 1 to 8 cannot have the sizes altered in EXPREP but their sizes can be changed at run time.*

REPLAY AN OLD EXERCISE

Type REPLAY [ENTER] on the control terminal.

A directory will appear. The last save directory will be opened and the last exercise run highlighted. To debrief this exercise simply press ENTER or click the mouse on Accept. Alternatively select the COASTLINE as used in the desired exercise by highlighting the appropriate Coast. Either double click the mouse on this directory or click on Accept to open this directory. The highlight bar may be moved by mouse or cursor key. Thereafter a list of files containing replay exercise data contained in the specified COAST directory will appear. Select the particular file for replaying as indicated above. All exercise data is stored in a coast directory with extention .RPL. Manoeuves carried out by *own ships* during the exercise is stored with the same name but with the extention .MAN.

LOAD	- Load another exercise
PAN	- Centre on the Crosshair
ZOOM	- Zoom in on Crosshair
UNZOOM	- Unzoom at Crosshair.
<	- Step forward one minute
>	- Set back one minute
REF	- *Vessel* nearest Crosshair becomes *reference* and crosshair range and bearing from this vessel is displayed.
FIRST	- Stepping forward to a particular time and pressing this button will cause tracks prior to this time to be erased for purposes of clarity. By backstepping before FIRST and repressing this button will cause this step to be undone.
PRINT	- Print a list of own ship manoeuvres to screen or printer.
QUIT	- Quit this program - **ESC**ape can also be used.

The cursor keys can move the Crosshair. This program is mouse compatible.

The two windows on the side panel below the buttons display first range and bearing of crosshair from the *reference vessel.*

The second window shows the *own ships* course and speed alterations as they take place. Colours of the writing is consistent with ship colours used thoughout the suite of programs.

TECHNICAL SPECIFICATIONS

This program cycles through a number of functions on a Round Robin time slot allocation. Each cycle the computer checks the keyboard, checks time since targets were last moved, applies clutter, updates the time and computes range and bearings of a section of the coast. This time cycle is typically in the order of 10 centiseconds on average on a 486 running at 40 MHz. On the Navaids program the time period is around 4 centiseconds. Pressing various keys will slow the cycle down slightly. Time is kept to a precision of 1 centisecond for all high speed requirements. Each cycle is also used to draw a two sweeps of targets and land from the centre of the screen on an incrementing bearing basis ½° apart.

Certain functions obtain priority over the round robin time allocation to allow smoother operation. These are EBL, VRM, parallel index, course and speed alterations.

- Targets and land are stored in integer values (LongInt in Turbo Pascal) in centimetres. Likewise speed is computed in metres per minute and these are converted internally to other forms.
- All manoeuvres and updates are unaffected by delays caused due to keypresses or different speed machines as real time is used to measure distances covered etc.
- Maximum number of targets is 29 in any mode.
- Land is updated at 3 lines per time cycle (typically 10 centi-seconds) and the map may contain up to 1000 elements. All targets including own ship are updated every complete rotation (when sweep is at 180°).
- Yaw is in 10 steps including off. Maximum yaw is 1 degree greater than the yaw value. This yaw is cycled according to ship characteristics.
- The sStudent terminals attempt to transfer and read data every 5 seconds. If the network is occupied, it will rotate another 10° before attempting to gain access of the network.

Up to 3 targets may be painted in any particular bearing. These targets may be land or vessels or a combination of both. Ships will not shadow other vessels but will shadow land. High land will obscure low lying objects.

Up to 1000 echo soundings are recorded per chart area. The depth of water at the vessel is computed by measuring the nearest depth in each quadrant (NE, NW, SE, SW) and averaging them based on range from the vessel. The vessel's draft is subtracted, the selected tide added and a random value (up to 1 metre) is applied for display. The actual depth is computed by the Navaids display, (or radar computer if no navaids computer is used) and relayed back to the control terminal for display. The coastline points are assumed to have a depth of zero and also used. Small objects such as buoys are ignored by the algorithm.

The coastline may contain up to 1000 elements and each element has a byte associated with that element which is split into two variables - namely height and depth of slope. 16 values of height are possible as well as 16 different depths of slope.

Up to 100 ship types, 100 exercises per coastline are accepted by the system. Higher numbers may be catered for by creating a new map that is identical to the old one but with a different name.

Data transfer from Control Terminal to Ramdrive takes on average 5 centiseconds (both reading and writing of data - Ramdrive on Control Terminal). Data transfer from student computer to the network takes somewhat longer (35 centisceonds for a 386 running at 40 Mhhz).

NETWORK CONNECTION

Each slave system dumps information every rotation of the sweep to a ramdrive (generally on the control computer). Thereafter it reads a file (MAIN) containing the positions of all other vessels in the exercise as well as a status file containing the ship status and exercise status. The control terminal reads ship data and writes the file MAIN every 5 seconds. Communication of data takes typically less than a tenth of a second.

CO-ORDINATE SYSTEM

All points of land are initially stored in in Latitude and longitude format, converted to RADSIM format and when necessary returned using a reverse algorithm to lat/long. RADSIM format converts difference in latitude (dlat) from reference point (converted to centimetres at 185200cm to a minute of latitude) and departure (based on latitude of the point) from the reference longitude using a similar measure.

This modified Transverse Mercator system results in slight inaccuracies particularly in bearings at the edges of the playing area (maximum on North/South bearings). Also due to the simplified formula distances measured East/West are also compromised. It is felt that the errors so caused are acceptable and the producer recommends using the co-ordinate system whenever high precision of target placement is required. If the x co-ordinate is identical to the own vessel, then the target will appear due North/South even though the longitudes of the two vessels may differ. The latitude/longitude co-ordinates should be seen as a guide rather that being absolute.

For the purpose of evaluating these discrepencies, an arbitrary point (close to Map reference) was selected for Dover. This position was taken as 50°48,00' N, 001°16,30' E.
Using the RADSIM program targets were placed 100 miles North and West, North and East, South and West, South and East of this point thereby forming a 200 mile (RADSIM co-ordinates) square encompassing the exercise area (as required by specification).

Position 1	52°28,00' N	001°27,85' W
Position 2	52°28,00' N	004°00,43' E
Position 3	49°08,00' N	001°16,53' W
Position 4	49°08,00' N	003°49,08' E

	RADSIM	**ACTUAL (Mercator Clarke 1880)**
1 to 3	180° x 200,0	177,9° x 200,1 miles
2 to 4	180° x 200,0	182,0° x 200,1 miles
3 to 2	045° x 282,84	045,1° x 283,4 miles
4 to 1	315° x 282,84	314,9° x 283,4 miles

From the above it is apparent that the error is maximum on North/South bearings at the extreme sides of the required exercise area with a maximum error of 2,1° irrespective of range (ie this error will be almost consistent from 1 mile up to 200 miles). For this reason high precision placing should be down using xy co-ordinates when far from the map centre and using areas in relatively high latitudes. It should be noted that for angle approaching 45° this error (less than 0,1°) becomes negligible and may for practical purposes be ignored. Ranges start to deteriorate above 45° but at this angle are within 0,2% which is well within radar specifications. Distances are based on simple departure formula so at 90° the error is identical to the difference between parallel sailing and corrected parallel sailing.

It is believed that the above inaccuracies will have little effect on practical training provided that the lecturer in control of the simulation exercises due care when positioning targets with high precision in mind. Results of student's computations should be compared with the RADSIM data within these limitations.

DETECTION RANGE

The maximum detection range of objects is based on a fixed distance dependent on target height nybble, added to the radar horizon for the ownship size as determined on the table on the right minus 6 miles. This range is then affected by a percentage of tuning and gain as set by the student as well as STC for shorter ranges. The 6 mile subtraction is in order to take account of weak objects such as liferafts. Assuming that a liferaft may have a height of 1 metre (radar horizon 2.21 miles) and the Own Ship antenna height may be 9 metres, a pure computation would determine that theoretical detection range is 8.84 miles which the producer feels is excessive. Allowance is therefore made by using a different method of computation. A liferaft is assumed to have an effective detection range of 4.5 miles *less* than the radar horizon of the own ship (2.13 miles for a 9 metre high antenna).

```
Case TgtSize of   {value1 in miles- 6 miles is subtracted later}
   0 : value1 := 0;   { invisible }
   1 : value1 := 1.5; { liferaft }
   2 : value1 := 3;   { lifeboat }
   3 : value1 := 4.8; { 15 metre }
   4 : value1 := 7;   { 100 GRT }
   5 : value1 := 10;  { 500 GRT }
   6 : value1 := 14;  { 1000 GRT }
   7 : value1 := 18;  { 5000 GRT }
   8 : value1 := 21;  { 10 000 GRT }
   9 : value1 := 24;  { 50 000 GRT }
  10 : value1 := 28;
  11 : value1 := 32;
  12 : value1 := 36;
  13 : value1 := 40;
  14 : value1 := 44;
  15 : value1 := 48;
 end;
{height of antenna in metres}
Case OwnSize of  {value2 in metres}
   0 : value2 := 0;   { invisible }
   1 : value2 := 3;   { liferaft }
   2 : value2 := 3;   { lifeboat }
   3 : value2 := 6;   { 15 metre }
   4 : value2 := 8;   { 100 GRT }
   5 : value2 := 10;  { 500 GRT }
   6 : value2 := 12;  { 1000 GRT }
   7 : value2 := 15;  { 5000 GRT }
   8 : value2 := 21;  { 10 000 GRT }
   9 : value2 := 24;  { 50 000 GRT }
 end;
Value1 := value1 - 6 + 2.21 * sqrt(value2);  {6 used to be an 8}
```

SPURIOUS ECHOES

Three types of spurious echoes are displayed by *Radsim*.

Mutual Radar Interference

From the Control panel (Status Screen) a level of interference on a scale of 0 to 7 may be selected which causes a number of psuedo random spirals to occur on the radar screen.

Indirect Echoes

When shadow sectors are selected from the Control panel (Status Screen) and these have been defined for a vessel type, not only will all targets in the shadow sector be blanked, but objects on the reciprocal bearing will be displayed also be shown in the shadow sector.

Multiple echoes

When a vessel is within 1 mile of an own ship, and its course is within 10° of own ship's course (or its reciprocal) and the bearing of the vessel is within 10° of being on the beam two addition fasle echoes will be displayed at double and treble the real distance.

OWN SHIP CHARACTERISTICS

The own ship type may be selected by the user.
A period for the vessel is required and recommended to be above 100 centiseconds. Larger values should be used for larger vessels.
Maximum ahead and astern speed may be selected to the nearest knot. Actual speed is computed to 0,03 of a knot and displayed to the nearest 0,1 of a knot.
Speed increase follows the formula

$$S = (V - v)(1 - e^{-t/k}) + v$$

Speed reduction

$$S = (V - v)(e^{-t/k}) + v$$

where

S = new speed
V = higher speed
v = lower speed
t = time in seconds
k = constant between 120 and 1500

(in compliance with 1980 radar simulator specs)
Course is used precise terms but displayed to the nearest degree.

Alteration of course includes a number of variables which affect speed loss, advance, diameter or turn and drift angle. Rate of turn varies according to Standard rudder angle as well as the current velocity of the vessel.

Rotation is set at zero and increments by change in rotation every second.

Change in rotation =
AdvanceControl * (DiameterControl *(DesiredSpeed + 2*ActualSpeed) * sin(Rudder) - rotation) *per second*

change of course = rotation /180 *in degrees*
Heading = heading + change of course *In degrees*
Drift direction = heading - change of course * drift constant *in degrees*
Speed loss = Speedloss constant * ActualSpeed * rotation *knots per scond.*

Actual speed, rudder position, course and drift direction are typically computed every 100 to 150 centi seconds.

These formulae allow a reasonable representation of a wide variety of vessels and both turning circles as well as as inertial and crash stops can be plotted on a HP laser jet printer provided one is available.

TARGET CHARACTERISTICS

Targets have a simplified alteration pattern based on the following predetermined formulas.

Size	Rate of Turn	Change of speed
0	600	26
1	600	20
2	150	13
3	120	6.5
4	100	5.2
5	85	4.5
6	75	3.9
7	60	3.2
8	50	2.6
9	30	1.9

Rate of turn is indicated in degrees per minute at 20 knots. This reduces at slower speeds.
Every 3 seconds while the vessel is turning its speed will decrease by 1% of actual speed.
Acceleration/decelleration for targets is assumed as linear and the values indicated show approximate speed change in knots per minute.

ARPA TRACKING ROUTINE

When the acquire window is clicked on the radar screen, the following process takes place. The area within the window (as shown by the square brackets) is searched for the mean point of all radar return. An attempt is made to open an empty tracking record (if no empty records exist - maximum of 20) an alarm indication (TARGET OVERFLOW) is given.
If no radar return is found, the system will cointinue to search for 10 scans and indicate an alarm situation LOST TARGET.
Assuming that radar return is found, the mean point is stored in the tracking record. At this point the program compares this position with its database of actual simulator targets to determine whether it is a movable target or whether it is land/clutter. If the target should no longer appear on the radar screen (changing rangescale) or the rangescale is changed to 24 or 48 mile range scale then tracking as such of the screen is stopped and target position is obtained from the simulation data. If it is determined that it is not an actual vessel, the position of the tracking window will remain geographically fixed.
It is stressed that this only occurs if the tracking window is off screen or long ranges are used.

Provided the tracking window is on screen and the rangescale is 12 miles or less then the tracking window of each tracking record is checked every rotation of the 'scanner'. On each cyle the current position is updated in the tracking record. An array of 18 positions (30 seconds apart) is maintained in a FIFO arrangement with a pointer maintaing current position. In addition timelapse since last pointer adjustment is maintained. This 9 minute period is used to display the past positions of the targets when requested.

The tracking period for determining course and speed, cpa, tcpa etc is gradually increased and maintained between 2½ and 3 minutes until CANCELLED etc.

The above arrangement ensures that the data obtained from the tracking system is realistic and conforms with the outer limits of the IMO specifications of ARPA. Targets can be acquired more than once (similar to the Krupp 8600), that target swop can and does occur, that targets may lose the tracking window in clutter and that attempting to track coastline will result in 'hunting' up and down the coast in a random manner.

NAVAID DATA TRANSFER

One byte of data is sent to pass errors etc to student terminals. The byte for each contains the following data.

DECCA

MSB							LSB
0=No Lock 1=Lock	Range			Direction			0=N/A 1=Avail

GPS

MSB							LSB
0=No Lock 1=Lock	Range			Direction			0=N/A 1=Avail

RDF

MSB							LSB
Distress vessel							0=NA 1=Avail

ECHO SOUNDER

MSB							LSB
Tide height in decimetres starting from -1.0 metres to 11.7 metres							0= N/A 1=Avail

RADAR

MSB							LSB
SART vessel					0=All controls 1=Restrict	0=Zero 1=Preset	0=N/A 1=Avail

MSB - Most Significent Bit
LSB - Least Significent Bit
N/A - Not available
All controls - Student has acces to all radar controls
Restrict - Student access to radar controls is limited to operational controls only.

SOUND SIGNALS (OPTIONAL)

The optional sound signal system may be used provided the twin screen system has been purchased. It is only available on the Navaids computer of each *own ship.* This option is required by the South African authorities although is optional under British requirements.

Sound signals can be initiated by any *vessel.* These may be under *targets* or *own ships.* When an *own ship* initiates a signal it is given priority over all other signals. Next priority are one time signals sent by *targets*. These signals include the following characters: E, I, S, 5, C, G, and Z. Once these signals have been made they will be removed from the tote page.

Other signals made by *targets* (T, M, H, D, B and R) are assumed to be automatic and will be at a lower priority than the signals mentioned above. The system will wait at least 100 seconds between sending a particular target's signal on successive occasions. The time period may be longer depending on the number of active signals being used.

Every 5 seconds, the Control Computer will check if there is a signal that is ready to be sent. The vessel of origin is checked against each *own ship,* the signal, relative bearing and range (if less than 2 miles) is then sent to each *own ship* and the appropriate sound signal as well as a alphanumeric display of relative bearing and range will be displayed on the Navaids second screen display. The signal will be emitted by the navaids computer at constant pitch and amplitude.

The Control Terminal will display on the tote page just below target 30 (when in SVGA mode) that a particular vessel is making a signal.

Eg 'Ship number 5 is sounding C'

FILES ON DISC

CONTROL COMPUTER

These files are found in the main directory (RADSIM17).

NB It is essential that *all* the coastline files for a given area appear in the directory. For example if DOVER.CHT is in the directory then SANDETTE.CHT, SEINEBAY.CHT, FLUSHING.CHT and IOFWGT .CHT must also appear. In the Cape area the files are COLUMBIN.CHT, SALDANHA.CHT, CAPETOWN.CHT and FALSEBAY.CHT. WALVIS.CHT and LUDERITZ.CHT are stand alone areas and can exist without any other coastlines. This applies to all computers within the system.

C:\RADSIM17

TX**	.EXE	-	Program for Simulation Control Terminal.
NAV**	.EXE	-	Program for navaids simulation for students.
RADSIM	.CFG	-	Text file containing serial port number and baud rate .
RADSIM	.NET	-	Text file containing Ramdrive (and ship number on student computers).
PREP***	.EXE	-	The program for setting up various exercises.
REPLA***	.EXE	-	This program allows for replaying a previous exercise.
DOVER	.CHT	-	Various coastlines that are available.
DOVER	.NAV	-	Information for Navlines if available for a coast.
DOVER	.ES	-	Echo sounding data if available.
DOVER	.RTE	-	Route data for Dover straits.
VLCC	.VSL	-	Ship characteristics for own vessel (any name may be used)

The stars after the various TX, RX etc are version numbers within Radsim17
The following are stored in subdirectories named for the coastlines used in RADSIM ie
C:\RADSIM17\DOVER

EX001	.EX	-	Exercises created by the user that are available in the selected map area.
EX001	.TID	-	Additional exercise data with respect to tide and current. If this file is not found default values are presumed.
EX001	.BRF	-	Briefing information for an exercise called EX001.
EX001	.WX	-	Navtex data in text form for an exercise called EX001.
FIRST	.RPL	-	Exercise replay data run under a particular coastline directory for debriefing.
FIRST	.MAN	-	Replay manoeuvering data attached to a previous exercise saved as FIRST.

The network version creates a number of files on the Ramdrive

COAST		-	Name of the coast file to load
MAIN		-	Data as to the position of all 30 vessels including course speed and size.
EXSTATUS	.000	-	Exercise status - paused, finished.
RADAR	.00ϕ	-	Own ship ϕ radar status
SHIP	.00ϕ	-	Own ship ϕ position, course and speed.
START	.00ϕ	-	Own ship ϕ characteristcs and start status.
STATUS	.00ϕ	-	Own ship ϕ equipment status.
FOG	.00ϕ	-	Own ship ϕ incoming fog signal.
BRIEFS	.BRF	-	Briefing information for downloading to second screen
WEATHER	.WX	-	Navtext data for downloading to second screen

STUDENT COMPUTER

These files are found in the main directory (Normally RADSIM17).
C:\RADSIM17

RX**	.EXE	-	Program to run Radar simulation for students.
NAV**	.EXE	-	Program to run Navaids simulation.
DOVER	.CHT	-	Various coastlines that are available.
DOVER	.NAV	-	Information for Navlines if available for a coast.
DOVER	.ES	-	Echo sounding data if available.
RADSIM	.CFG	-	Text file containing serial port number and baud rate .
RADSIM	.NET	-	Text file containing Ramdrive and ship number for Radar.
NAVSIM	.NET	-	Text file containing Ramdrive and ship number for Navaids.

BATCH FILES

A batch file (R.BAT) must be created in the root directory.

RADAR TERMINAL

On the Radar Terminals this consists of the following lines:-

CD RADSIM17	Change to the directory where the RADSIM files are found.
RX** N S	Run the radar program with parameters N (Network), A (No Navaids on radar), S (Super VGA hi resolution).
CD..	Return to root directory on exitting the program.

CONTROL TERMINAL

On the Control Terminal there should be three batch files.

R.BAT which consists of the following lines:-

CD RADSIM17	Change to the directory where the RADSIM files are found.
TX** N S	Run the control terminal program with parameters N (Network) and S (Super VGA hi resolution).
CD..	Return to root directory on exitting the program.

REPLAY.BAT which consists of the following lines:-

CD RADSIM17	Change to the directory where the RADSIM files are found.
REPLA**	Runs the replay exercise for debrioefing students.
CD..	Return to root directory on exitting the program.

PREP.BAT which consists of the following lines:-

CD RADSIM17	Change to the directory where the RADSIM files are found.
PREP***	Runs the exercise preparation program.
CD..	Return to root directory on exitting the program.

PARAMETER SUMMARY

Summary of parameters - these may also be used in any order

M - serial connected interactive (no navaids panel possible)

N - Network connected interactive

A - Second computer being used for navaids and ship control

S - Super VGA system with higher resolution applicable to CONTROL and student RADAR terminals only

B - Toggles a button mode. When used the left button on the trackball/mouse will down the selected control down, the rght hand button turns it up. This is the preferred method by students although Simulation approval lays down that only one button may be used and the position of the arrow determines up/down action.

W - Special version for the South African Navy (Own ships are designated by letters)

C - This code is for future expansion and for sending NMEA data out on a serial port so that ECDIS may be added at a later stage. This option is not fully implemented.

*** refers to a numbered version of the software and must correspond with the values in the appropriate EXE files. This allows the producer to ensure that all users are using precisely the same software version.

RADSIM.NET

This file is used if a network is connected but must appear in the RADSIM directory. This standard ASCII text file contains the identification of the ramdrive accessed by the computer for storing exercise data being transferred between machines. Each machine may have a different drive letter allocated depending on the configuration. The second line contains a number determining which vessel is allocated to that computer.
It is important that no two computers are allocated the same ship number otherwise there will be unpredictable results.

In this system this file has D in the first line (the Ramdrive on the control terminal is marked as drive D and when this resource is shared the other computers are configured to access this drive as drive D as well).
This designation could be altered if changes are made to the hardware and another drive letter is allocated to the ramdrive of the control terminal.

```
D
1
```

The above file means that D drive will access the Ramdrive on the Control Terminal and that the vessel represented by this computer is Own Ship 1.

The numbering system of the own ships is indicated in the cubicle layout in the appendix.

RECOMMENDATIONS

The actual *own ships* that are to be allocated to students can be altered at any stage by modifying RADSIM.NET although I do not recommend doing this. It would generally be easier to EDIT AN EXERCISE and swap vessels at this point. In the *Network System* the *own ships* can be set at any value from 1 to 8.

If the dual system feature is to be utilised (allowing 4 own ships - twin screen as well as 8 own ships - single screen), I recommend numbering the computers in the first cubicle as 1 and 5 in RADSIM.NET and as 1 in NAVSIM.NET. The second cubicle would be numbered 2 and 6 etc.

In the *twin screen system* the first 4 *own ships* would normally be used by the students and *vessels* 5 through 8 would be allocated as *targets*. If the system is used in the single screen sytem then obviously all 8 *vessels* would be allocated as *own ships.* In this case I recommend setting vessels 1 through 4 in one part of the exercise area and vessels 5 though 8 in another area. In this way the students in each cubicle would not be interacting with other students in the same cubicle.

NETWORK INSTALLATION

The selected network software needs to be installed according to the suppliers recommendations and instructions.

The computers themselves have the normal connections of monitor, keyboard and trackball (mouse) generic to most computers. In addtion a network card is installed in each computer and configured using software supplied by the manufacturers of these cards. Each computer is connected to the next computer using a coaxial cable plugged into a T piece at the back of each network card. There are therefore 9 computers (placed in any order) strung together so that 7 of the computers are connected to two other computers. The remaining two computers are at the ech end of the chain and the second leg of the T piece has a terminator resister plugged in.

The control computer (for that matter any computer) could be placed anywhere within this string.

In the Granger Bay layout, the string starts with the Control Computer which is connected to OS1 (Own Ship One) Radar to OS1 Navaids to OS2 radar to OS2 navaids to OS3 radar to OS3 navaids to OS 4 radar to OS4 navaids. The control computer and OS4 navaids are fitted with terminators as mentioned above. (See APPENDIX for actual lauout)

The following instructions are suitable for WorkGroups Add-On for Ms-Dos which needs to be installed on all computers in the system. Refer to these manuals for further details.

Only one computer needs to share its resources. This is the control computer and has been allocated a Ramdrive which will is allocated the drive letter D. In the CONFIG.SYS file ensure that this line is included

    DEVICE=C:\DOS\RAMDRIVE.SYS 500 /E

The contollers computer has been assumed to be called *Control* and the students computers *OS1, OS2, ..etc.*

On all computers the command SHARE must be included in the AUTOEXEC.BAT file to prevent sharing violations (ie two computers trying to access the same data at the same time) and after installation of the network software the instruction NET START must also appear.

    C:\DOS\SHARE.EXE
    C:\NET\NET START

(this line will be placed in the AUTOEXEC.BAT file by the Workgroup installation program)

I recommend using Dos 6.0 or later and running MEMMAKER to optimise space allocation. Generally use all default options when offered.

On the control station type

    NET SHARE RAMDRIVE=D: /FULL

(this will share D drive named as Ramdrive with full access allocated to all computers)

    NET SHARE C=C: /FULL

(this will share C drive named as C with full access allocated to all computers)

On each slave station type NET and a window will appear on screen
The first drive offered will normally be D. (Press ALT V to select this field and change if necessary)
In shared resource type (ALT P to select this field)

    \\CONTROL\RAMDRIVE

and ensure that the box RECONNECT AT STARTUP is crossed (ALT R) before typing ALT C to connect
Next type

    \\CONTROL\C

to connect this resource to E drive.
Finally ESC or ALT X will return you to dos.

Changing to drive D: or drive E: should allow you to now copy files to and from the host computer. Note that the host computer (control terminal) cannot access the slave computers in the manner described above. A printer connected to the control computer can also be accessed by any slave. Please

contact the author or a Network supplier if any difficulties arise in these connections.
Test that connections are made by storing a temporary file on D drive from the control computer.

D: [ENTER]	Screen should now show D:>
EDIT TEST.BAT	The screen editter of DOS will appear.
Type any sentence	
ALT F	Select FILE pull down menu
X	Exit
Y	Save the file.

Typing DIR [ENTER] should show a fairlry small file called TEST.BAT in D drive.
On the Student Computers type

D:[ENTER]	Screen should now show D:>
DIR[ENTER]	Screen should show TEST.BAT (which is saved on the control computer.)

If you fail to obtain the results shown above, contact a network specialist to ensure that the connections are as above and that there are no faults in either the cable interconnections or or network cards.

Thereafter the system should reconnect automatically each time provided the control computer is started first and offers its resources before the student computers attempt to claim them.

INSTALLING THE SOFTWARE

One disc is supplied.

Provided that the computers boot up correctly and the slave computers can access the RAMDRIVE on the control computer as indicated on the previous page, the software may now be installed on each of the computers.
The disk will be used to install software on all computers.

INSTALLATION

Insert the disk in the each computer after it has switched on and has completed booting up (showing C:>).
Type A: INSTALL [ENTER]
The program wil automatically create a directory called RADSIM17 and install all files that are required and that are indicated on page 28 as well as certain files required by the student computers.

CONTROL CONFIGURATION

Type cd RADSIM17 [ENTER] to change directory to Radsim17.
Type EDIT RADSIM.NET [ENTER]
Ensure that the first line shows the network drive letter of the Ramdrive - allocated as Drive D (the second line is not used on the Control Terminal)
Type ALT F (File Pulldown Menu)
X (Exit)
Y(es) to save the corrected file.

RADAR CONFIGURATION

Type cd RADSIM17 [ENTER] to change directory to Radsim17.
Type EDIT RADSIM.NET [ENTER]
Ensure that the first line shows the network drive letter of the Ramdrive
Ensure that the second line contains the Own Ship number.
Type ALT F (File Pulldown Menu)
X (Exit)
Y(es) to save the corrected file.

NAVAID CONFIGURATION (only applicable if this option is included)

Type cd RADSIM17 [ENTER] to change directory to Radsim17.
Type EDIT NAVSIM.NET[ENTER]
Ensure that the first line shows the network drive letter of the Ramdrive
Ensure that the second line contains the Own Ship number.
Type ALT F (File Pulldown Menu)
X (Exit)
Y(es) to save the corrected file.

Note that both computers in each cubicle must have the same ship number and that no two cubicles use the same ship number.

Create Batch files as indicated on page 28 so that these programs can be started simply.

TESTING THE SYSTEM

Ensure that all computers are on and that all are showing the C:> prompt.
On the Control Terminal type R [ENTER] to start the simulation at the control terminal only.
Start the exercise called PATTERN in coastline SEINEBAY (any exercise can in fact be run)
When the data page appears type **P** to start the program running.

In cubicle One type D:DIR [ENTER] on both computers.
A number of files should appear including the following

COAST
MAIN
EXSTATUS.000
START.001 through to START.008
STATUS.001 through to STATUS.008

This indicates that the network is operational. If these files do not appear, the network is not operating correctly and you are referred to the information on network installation, *Workgroup Add-on for MsDos Manual* or a Network Technician.

Assuming that the files are displayed correctly type N [ENTER] to start these two computers.

The radar and navaids should appear and begin running immediately. The radar may start, change, to headup and return to its original picture. This is normal and is purely the various computers determining which is in control of the ship's position (which is initiated by the control computer but in fact determined thereafter by the appropriate Navaid Computer).

Note the course and speed output on the ship control panel of the navaid terminal and confirm that the heading of the radar agrees with gyro (the exercise should not have yaw or current set in if an exercise other than pattern is used).

Check on the control terminal that the course and speed conforms with OS 1 and that there is green writing in the last three colums of the data page for this vessel. These green numbers indicate that the navaid computer and radar computer are responding. Changing course/speed on the navaid computer or rangescale on the radar computer will cause these numbers to alter.

If this appears to be working correctly close down the program from the control terminal by typing ALT Q. The computers in cubicle one should return to the Dos prompt within a short period of time (10 seconds).

Restart the simulation from the control terminal with the same exercise and proceed to cubicle two.
Check that cubicle two is able to read D drive by typing D:DIR [ENTER].
Run up both computers by typing N [ENTER].
Check that the second vessel on the control terminal has become active. If another vessel other than 2 has become active it indicates that the NAVSIM.NET (and possibly RADSIM.NET) have not been set correctly as indicated on page 29.

Do the same with cubicle three through eight.

Provided each computer operates correctly and is communicating with the correct ship number, all the computers may now be started by typing R [ENTER] on each of the student computers and by typing R [ENTER] on the control terminal. This may be done in any order whatsoever and will have no effect. Normally the control program will be run up last in practise although it is essential that the control computer is switched on first and allowed to share its resources before switching on the student computers. Failure to do this will result in an error message during the boot up procedure of the student machines. Simply ensure that the control computer is on and reset the student terminals.

If this error message continues it indicates that the student computers cannot connect to the control computer which indicates that the network installation section should be referred to. Network diagnostics are fully explained in the *Workgroup Add-On for Ms-Dos* as well as in the literature supplied with the network interface card.

QUICK REFERENCE

↑, ↓	-	Own ship speed increase, decrease.
←, →	-	Altering Auto pilot or Rudder to port, starboard.
C	-	Centres the Screen.
D	-	Decca receiver displaying position in LOPs.
E	-	Electronic bearing line on/off toggle.
M	-	Head Up Relative Motion/North Up Relative Motion/North Up True Motion toggle (only operates if exercise is set for North Up).
I	-	Parallel Index on/off toggle.
R	-	Fixed Range rings on/off toggle.
G	-	GPS receiver displaying Lat/long.
F	-	Automatic Radio Direction Finder displaying relative bearings. Tuning is done using Up/Down Cursor Keys and can be switched Off by pressing O.
T	-	Target Trails on/off toggle.
V	-	Variable Range Marker on/off toggle.
+, -	-	Range decrease, increase.
P	-	Toggle autopilot on/off - status indicated by green light.
F3, F4	-	Turn EBL to the left, right.
F5, F6	-	Turn VRM inwards, outwards.
F7, F8	-	Turn Parallel Index to the left, right.
Esc	-	Turn POWER to left, and quit
Enter	-	Turn POWER to right
[,]	-	Turn Brilliance down, up
SHIFT [	-	Map brilliance down
SHIFT]	-	Map brilliance up
<, >	-	Tuning left, right
Q W	-	Gain decrease, increase.
A S	-	STC decrease, increase.
Z X	-	FTC decrease, increase.
; '	-	Vector brilliance decrease, increase
?	-	Ground / Sea stabilize toggle

ARPA CONTROLS

7	-	Selects function of the marker - either **Acquire target** (start tracking) **Designate target** (show information) or **Cancel target** (Delete selected Target), **Offset Centre** for off setting the screen centre, or **Map move** to align the predrawn maps.
8	-	Guard zone - allows a banana shaped zone to be selected. EBL selects start angle, Vector Time for guard angle (maximum 40°) and VRM selects inner boundary. Depth is always ½ mile.
9	-	Dangerous Targets - allows the user to select CPA and TCPA that is regarded as dangerous (defaults to 1 mile in 10 minutes). VRM and Vector Time are used to select these values.
4	-	Toggles between **True Vectors, Relative Vectors** and **Vectors off.**
5	-	Past tracks on/off toggle - 4 past positions 2 minutes apart can be displayed.
6	-	Alarm - silences alarm caused by dangerous target, guard zone or lost target.
1	-	Trial manoeuvre - selects relative vectors and activates EBL. Altering EBL shows course change and vector time changes Trial speed. Press again to cancel.
2	-	Decreases Vector time (used for other functions as well)
3	-	Increases Vector Time (maximum 99 minutes) and used for other functions as well.

USING THE TRACKBALL

The supplied Trackballs have 4 buttons. The buttons on either side have been set to be identical results. If you wish to tune the GAIN down for example, place the mouse pointer on the screen button GAIN. Presss either of the left trackball buttons and the left side of the screen button will also depress and decrease the applied gain. Pressing either of the right hand trackball buttons will depress the right half of the screen button and increase the gain.

ERRORS

The software for Radsim is designed to fail gracefully if some software bug should occur. In most cases it will also record the fault and where this occured so that the supplier can eliminate this problem in the future. The Student's terminal may go blank or fill with a single colour in this case. If the twin screen system is in use, the following steps are recommended.

From the control terminal, return to the MAIN PAGE and press E for Exercise save (give it a temporary name so that if the exercise needs to be interrupted, you have an opportunity to start off from the same point).

Check whether the navaids screen linked to the radar screen is still operative. If not reboot this computer by pressing the reset button on the computer casing.
On the radar terminal press ESC and then simply reset both computers in the cubicle forming this single ship.

In most cases this short technique may be the only delay that is incurred. It will be necessary to pause the control terminal for about 30 seconds so as to synchronise the clock times.

In an extreme case, the same bug may terminate the program again.
In this case stop the simulation and restart from scratch using the saved exercise name.
If it fails again, try rebooting the system with an different exercise that has been used successfully recently.

If it still fails after this, then the network software (not part of the RADSIM software) or some part of the hardware is not operational or certain files may have been corrupted. I recommend checking that the system is virus free.

On any error (successfully or unsuccessfully restarted), after the simulation is terminated, proceed to the failed terminal and do the following.

Ensure that you are in the Radsim17 directory.
Type TYPE EXITERR.DTA
Record the last line and send this data to the supplier by fax or telephone.

A typical readout is as follows

22:26:24, 30/05/96 - Exit code 255 at 3543:3499 (decimal)

and means that the program terminated at 22:26:24 on the 30th May, 1996 with error code 255 at address 3543:32499. From this data the programmer can idenrify to an extent the cause of ther failure of the program. In this case the user typed CTRL BREAK which causes an error 255.

Certain error codes that may allow an operator to identify the cause of the problem

1	Invalid Function Name	Dos version in use is not Dos 5.0 or newer
2	File not found	Check that all files particularly RADSIM.NET, RADSIM.CFG and NAVSIM.NET are available. Ensure that all ****.CHT files are available on all computers
3	Path not found	Possibly due to RADSIM.NET referring to a non existent disk drive such as D drive when there is no network connection.
4	Too many open files	This should not occur unless CONFIG.SYS has been corrupted. A line herein should state FILES=10 (or more)
5	File access denied	The files must not be hidden or protected.
100-106	I/O errors	A file has become corrupted during the simulation.
150-162	Network errors	This is caused by possible sharing violations which are partly controlled by Radsim software and partly by the dos program SHARE.EXE which must be run as part of the AUTOEXEC.BAT file
200-202	Overflow errors	Caused by computations within Radsim that exceed maximum limits of Turbo Pascal.
203	Heap overflow error	Insufficient RAM memory available to run the program fully. 2 MegaBytes or RAM are normally needed to run Radsim although 1 Mbyte can be used in extreme cases (depending on Dos Versions). Ensure that there are no unnecessary TSR (Terminate Stay

		Resident) programs running.
205-206	Overflow errors	Caused by computations within Radsim that exceed maximum limits of Turbo Pascal
215	Overflow errors	Caused by computations within Radsim that exceed maximum limits of Turbo Pascal
255	CRTL BREAK	Program terminated by operator.

Capt Ken Lark

Compass Adjuster

Standard/Steering

COMPASS DEVIATION CARD

Vessel ____________________________

Ship's	Head	Deviation	Ship's	Head	Deviation
000°	N	2° W	180°	S	2° E
022½°	NNE	0°	202½°	SSW	1½°E
045°	NE	3° E	225°	SW	1° E
067½°	ENE	3½°E	247½°	WSW	2° W
090°	E	4° E	270	W	4° W
112½°	ESE	3½°E	292½	WNW	5° W
135°	SE	3° E	315	NW	6° W
157½°	SSE	2½°E	337½	NNW	4° W

Fore & Aft Magnets ____________________________

____

Athwartships Magnets ____________________________

____

Flinders Bar ____________________________

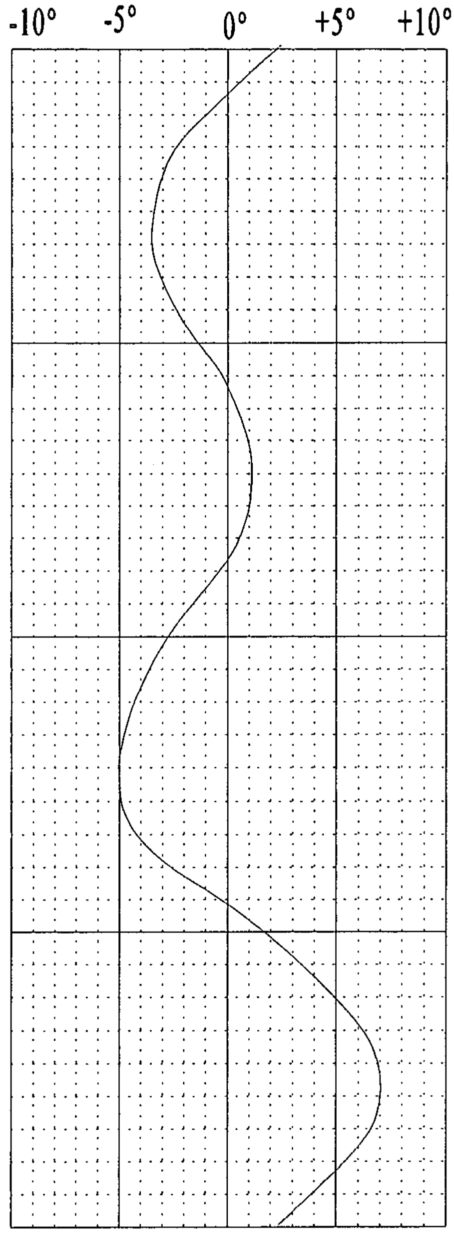
Spheres ____________________________

Captain K.R.Lark
P.O.Box 26397
Hout Bay
7872
Tel 790-1310
Fax 790-5670

Signed

Date ______________

R.D.F.Calibration Curve



Vessel		
DF Receiver	Analogue type	2/O
Serial number	C479432	
Date	11th March, 1995	
Beacon	Minto Light, Robben Island	R/O
Derricks	N/A	
Antenna	Normal	