DEVELOPMENT OF AN INTEGRATED ELECTRONIC SYSTEM AND THE HUMAN MACHINE INTERFACE IN A NEW CLASS OF LIFEBOAT

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SUMMARY

Until recently control and monitoring of systems on board RNLI vessels has required a collection of stand alone systems. With the increasing complexity of lifeboat designs, this presents inherent difficulties and the requirement has arisen for a more efficient solution.

The novel RNLI defined Systems and Information Management System (SIMS) is a true integrated system, centralising electronics in a single rack. It combines remote operation and monitoring of the various systems on board (from radar to bilge), and allows crew to share information and workload via a number of flat screens in the wheelhouse. Through the careful presentation of only necessary data, the RNLI can ensure that valuable crew training resources can be maximised.

NOMENCLATURE

C	Centigrade
CCTV	Closed Circuit Television
DF	Direction Finder
EMM	Environmental Management Module
FMEA	Failure Modes and Effect Analysis
GPS	Global Positioning System
HMI	Human Machine Interface
IP	Ingress Protection
LCD	Liquid Crystal Display
LOA	Length Overall
MF/HF	Medium Frequency / High Frequency
MHz	Mega Hertz
mm	Millimetres
RNLI	Royal National Lifeboat Institution
SAR	Search and Rescue
SIMS	Systems and Information Management System
VHF	Very High Frequency

1 INTRODUCTION

Electronic navigation and communications equipment has increasingly been provided in RNLI lifeboats over the last 50 years. The earliest electronics were radios, including direction finders, followed by radar, echo sounders and speed logs. The major advance in navigation aids was the introduction of the compact Decca Navigator in the late 1960’s. In more recent times the introduction of the Global Positioning System (GPS) and electronic chart systems have given the lifeboat crews very sophisticated aids to navigation.
As the electronics fit increased, space was found, normally in the wheelhouse adjacent to the nominated seat for the operator. This has led to clutter in some areas of the boat and often a reduction in the field of view out of windows. These dedicated seating arrangements also mean that crew have to physically change seats to carry out different roles.

During this period the RNLI fleet has undergone a dramatic increase in capability, from 8 knot boats to a commitment to a fleet of 25 knot all weather lifeboats operating up to 50 miles offshore. A corresponding increase in the machinery power and complexity of mechanical and electrical systems necessary to achieve such capability has also brought crew safety and training considerations to the fore.

These issues were key in the formulation of a requirement to develop an integrated electronic system for the new Tamar class slipway launched lifeboat, which the RNLI saw as having the potential to provide the following benefits:

- Improved situational awareness
- Sharing task loading between crew.
- Improved safety through remote systems monitoring and control.
- Greater redundancy.
- Simplified training through a common user interface.

2 INITIAL DEVELOPMENT

Following initial design work on the Tamar by the RNLI, a competitive tender process resulted in the RNLI awarding a contract for the detailed design and build of the Tamar to Devonport Management Ltd (DML) in 1998.

The RNLI procurement specification included a detailed set of requirements for an integrated electronics system, to be known as the Systems and Information

Management System (SIMS). Technical development of the SIMS concept between DML and RNLI Engineers produced a more detailed SIMS specification. Since 2000, SIMS has been developed in conjunction with Servowatch Systems Ltd (SSL).

3 TAMAR PROJECT

The Tamar class, due to enter service in 2005, has the following particulars:

- LOA: 16 metres
- Beam: 5.25 metres
- Displacement: 31.5 tonnes
- Speed: 25 knots
- Crew: 7
- Endurance: 10 hours at 25 knots.

The RNLI built a prototype boat (see figure 1) to evaluate the fundamental aspects of the design such as speed, sea keeping and manoeuvrability.

Following these initial trials, the boat was fitted with the prototype version of SIMS and used to assess the system at sea, before committing to the final design and ultimate build of the Tamar fleet (around 30 boats).

Figure 1. Prototype Tamar class lifeboat

4 SYSTEM REQUIREMENTS

To ensure the success of SIMS, each of the following elements would need to be addressed fully:

- Systems definition
- Environmental considerations
- Weight management
- Safety
- Human machine interface (HMI)
- End user involvement
- Support and training
- Obsolescence and upgrade planning

4.1 SYSTEMS DEFINITION

The variety of systems to integrate into SIMS, coupled with the range of protocols and standards adopted by the various equipment manufacturers required a flexible, but very capable system architecture. The systems to be integrated into SIMS were as follows:

- Helm instrumentation
- Radio communications (VHF & HF/MF)
- VHF direction finder
- Intercom
- Radar
- Chart plotter
- Main machinery monitoring
- CCTV
- Door and hatch monitoring
- Hydraulic systems
- Bilge system
- Sea water system
- Fire fighting systems monitoring
- Fuel system monitoring
- Electrical distribution
- Data / mission logging

4.2 ENVIRONMENTAL CONSIDERATIONS

The shock loads to be expected on board all weather lifeboats are considerable, and the salt laden marine atmosphere is harsh. As such robustness and reliability are critical to the design of SIMS.

The requirement to shock mount the major components of the system was identified early in the design stage and a review of high shock capable processors was carried out.

The need to exclude moist air from electronic enclosures resulted in the specification of IP65 standards for all internal components. Therefore all processor enclosures must be sealed, however this could raise a converse problem with heat dissipation.

4.3 WEIGHT

Weight management is critical to the final performance of any high speed craft. As the scope for weight growth in the development of novel systems is great, a clear weight budget and weight control measures were implemented as part of the SIMS design process.

4.4 SAFETY

As with all RNLI equipment developments, a safety assessment was undertaken on the outline proposal to identify hazards and associated risks. The Failure Modes and Effect Analysis (FMEA) identified specific issues for re-appraisal, particularly any single point failures.

4.5 HUMAN MACHINE INTERFACE (HMI).

Since the inception of the project, it was always recognised that the development of a common, effective and simple HMI would be fundamental to the success of SIMS.

The plethora of different HMI's assembled in a typical SAR vessel presents organisations with usability and training challenges, not to mention the potential for misinterpretation and misunderstanding by users.

An early review of systems employed on the RNLI's own and other similar vessels failed to reveal a suitable HMI for adaptation across other applications. The advantages for the RNLI in seeking a bespoke solution were:

- The HMI only had to be applicable to RNLI.
- The RNLI has a relatively large fleet, which would benefit from standardisation.
- RNLI crews have considerable knowledge of many marine systems.

The RNLI retains all intellectual property rights (IPR) associated with the development of SIMS and its HMI.

4.6 END USER INVOLVEMENT

The success of SIMS will ultimately be judged by the end users, therefore crew involvement is essential. RNLI crews would expect the following from any such system:

- Simplicity of use.
- Clarity of presentation of information.
- Robustness and reliability.
- Redundancy in the event of failure.

Representatives from the Tamar project user group, consisting of RNLI Coxswains and mechanics from stations nominated to receive Tamar class boats, were to be fully involved throughout the development of SIMS.

4.7 SUPPORT AND TRAINING

The need to lessen the RNLI's training burden, partly due to the complexity and variety of modern lifeboat systems, was a major issue in the development of SIMS.

Additionally, the costs associated with the repair and replacement of such systems throughout the life of an all weather lifeboat can be considerable. If possible a simple repair by replacement policy was to be implemented for SIMS.

4.8 OBSOLESCENCE AND UPGRADE PLANNING

Continuous technological advances in the field of microprocessors, networks, software and displays mean that such equipment is constantly in the process of development, and equipment fitted in year one of a five-year project will not necessarily be the same as that fitted in year five, although similar principles and techniques would be employed. However, this should be considered a strength of such a system, since it allows easy update paths in the face of inevitable obsolescence and technological advance.

5 SIMS TECHNICAL DESCRIPTION

5.1 OVERVIEW

SIMS is a distributed network based arrangement of computers and data input/output devices designed to assist in the management, operation, control and data recording (mission logging) of this highly advanced rescue vessel.

There are 6 workstations, each comprising of a single rugged processor mounted in a 19 inch (wide) rack and connected to a high resolution 15 inch LCD screen and seat mounted control interface (trackball pod). Each workstation has the facility to run all or any of the on-board systems.

5.2 CENTRAL RACK

The majority of the SIMS hardware is located in a central rack sited below the main deck within the survivors space (see figure 2). The rack has the following dimensions.

- Height: 1200mm
- Depth: 600mm
- Width: 483mm

The rack is custom fabricated from marine grade aluminium; deep etched, anodized and mounted on shock mounts.

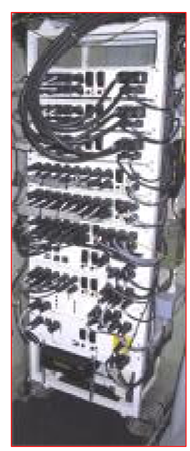

Figure 2. SIMS rack on the Prototype Tamar

5.3 SYSTEM PROCESSORS AND ENCLOSURES

The processors for the 6 workstations are housed in three IP65 rated enclosures in the rack. Each processor has an independent power supply and Environmental Management Module (EMM). Internal electronics are housed in a shock mount cradle.

Flash drives are used for mass storage in place of conventional hard drives, to mitigate the probability of failure due to shock. Heat dissipation issues restrict processor capability to around 800MHz.

The EMM is used for housekeeping functions such as maintaining the unit in the operational temperature range of –20 to 55°C. The EMM will also perform a controlled processor shutdown if main power is lost for more than 10 minutes. A controlled shutdown prevents corruption of the flashdrive.

In addition to the workstation processors, the rack also houses enclosures for the network hubs, radar processor, communications controller and the video digitizer.

5.4 OPERATING SYSTEM

The six workstations use Windows NT Version 4 for the primary operating system. The main perceived advantages being that Windows NT supports most software packages required for systems integration, such as Electronic Chart System software and PC radar systems, and it offers suitable protection for storing secure data. It is also relatively easy to set-up, maintain and use.

5.5 NETWORK ARRANGEMENTS

Interconnection between PC's is via dual redundant Arcnet networks, primarily for data and control exchange, and a dual fibre-optic Ethernet link, primarily for radar, video and navigational data exchange.

The two Arcnet networks are run in parallel, rather than as a master / slave relationship. All information is passed on both networks simultaneously. This provides comprehensive redundancy in the event of one or more network nodes failing.

The two Arcnet networks are Star-configured to two independent central hubs. Failure of any node or hub will be indicated by an alarm on the operator workstations but will not result in any degradation in performance.

The second network is a dual Ethernet network, implemented on two parallel fiber-optic networks. This network transfers high-data content elements around the system, such as digitized radar, video and file transfers.

The SIMS specification defines the requirement for all processors to be available in the case of failure. Therefore, SIMS employs a keyboard, video and mouse (KVM) switch to allow processors to be swapped to alternative displays (therefore if one processor fails, the signal from another less critical processor could be diverted to the desired screen, along with the input from the relevant trackball pod).

5.6 POWER CONSIDERATIONS

The System is powered from a dedicated set of electronics batteries, which are charged from an alternator driven by one of the main engines.

In an event where SIMS battery power is lost, the EMM will provide a period of backup power to allow the crew to cross connect power from any of the 3 alternative battery sources, without processors shutting down.

5.7 RADAR

The radar fitted to the TAMAR class is based on a type approved IMO compliant processor, developed and supplied by SML Technologies (SML). The radar does not have a dedicated display. Radar images and data are relayed to the SIMS workstations by means of the dual Ethernet network.

A single SIMS workstation is nominated as the Master Radar Control (initially Navigator 1). All other workstations are radar slaves. The master radar function can be taken by other workstations given secondary control privileges.

5.8 COMMUNICATIONS SYSTEM

The vessels communication system integrates the Intercom System, the SIMS VHF Radio, the SIMS MF Radio, the USP VHF Radio, the DF System and the Wireless headsets into a single multi-user system. All communications are all routed through the Communications Controller housed in the rack in the Survivor space.

5.9 REMOTE SYSTEMS OPERATION

A number of the boats mechanical and electrical systems have been provided with remote operability from the wheelhouse. This represents a considerable step forward in the RNLIs desire to reduce the need to move around the boat at sea, thus reducing the probability of accidents.

SIMS allows crews to actuate valves on the bilge, sea water and hydraulic systems as well as electrical breakers from their workstations. As with other systems, only one user can control any one system.

5.10 SYSTEMS MONITORING

SIMS provides remote monitoring of many systems such as main machinery, fire fighting systems, CCTV (internal and external) and hatches from the wheelhouse. These systems are not controlled through the workstations, but they do allow more users to view this information than has previously been possible on other lifeboats. The RNLI believe that greater access to information on all systems will improve the efficiency and situational awareness of the crews.

5.11 REDUNDANCY

The system is designed such that no single unit failure will affect the rest of the system. The functionality of that unit may be lost, but it will not impact on additional non-dependent functions.

The system features two fully independent dual redundant networks, the technologies being implemented both proven and mature. If any single node or single hub fails, then the data integrity of the system is not affected. The fault will be reported on the workstation alarm summary.

5.12 SOFTWARE SECURITY

To avoid software viruses and or accidental software damage, users cannot access any operating system files.

Additionally, SIMS is not currently provided with telemetry to access the internet etc.. All access to the system must be made via a dedicated SIMS support laptop issued to each station.

6 CONTROLLING SIMS

6.1 DEFAULT SIMS SETTINGS

SIMS has been designed such that only one user may control any one system at any particular time (although all users are able to view all systems at any time). Therefore to match usage to the layout of the boat, SIMS has been programmed with a set of user privileges. SIMS has also been programmed to allow users to take control of a function over which they have 'secondary' control privileges. This means that at start up they do not have control of a system, but they have the functionality to be able to take control of it. The matrix of control privileges does not grant automatic secondary users rights for all systems to all users.

SIMS employs a 'take' control methodology rather than a 'pass' control arrangement. This is because if a user's screen fails whilst he has primary control of a system, he would not be able to undertake a pass operation.

6.2 CHANGING USER LOG ON

Each user position in the boat is matched with the appropriate user log on at start up. However, either by preference or necessity, the user log on can be changed.

No interlocks have been implemented, because in the event of partial system failures, the system must be quick and simple to re-configure.

7 SIMS USER INTERFACE

7.1 OVERVIEW

The user interface consists of three elements (see fig 3).

- Screen
- Trackball pod
- Headset

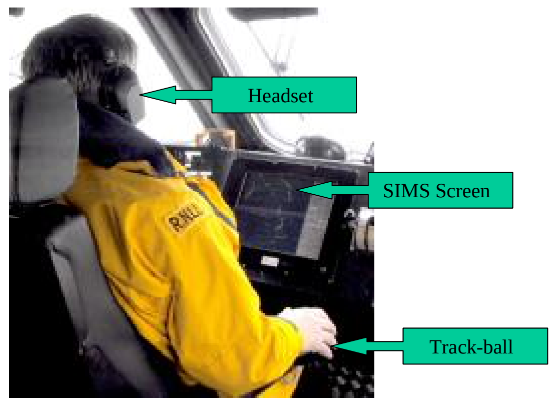

Fig 3. The 3 elements of the user interface on board the Prototype boat

No keyboards are used on board, with all screen interaction via the track-ball pod. The rationale for this being:

- Keyboards are difficult to use in heavy weather.
- A keyboard could be used to inadvertently access, delete or rename important system files – leading to software problems.
- Keyboards take up space and require stowage.

7.2 SCREENS

Each of the 5 wheelhouse workstations has a ruggedised IP65 flat screen display. The screens are backlit to permit daylight viewing, whilst also being dimmable to night-time conditions.

None of the screens are 'touch' screens. The reasons for this are:

- Accuracy problems in rough seas.
- Users may damage either the screen or themselves in a large impact.
- Touch screens can be adversely affected by environmental conditions (temperature, moisture, dirt etc.).

The Upper Steering Position (USP) has a display with a similar specification to the Internal Display, but it is sunlight readable and has an IP68 waterproof rating.

7.3 TRACKBALL POD

Each workstation is provided with a trackball pod on the right hand seat arm. The whole pod is waterproof and is a bespoke ergonomic design for the project (see figure 4). The hand should rest comfortably, with easy use of the track ball and buttons even in rough sea conditions.

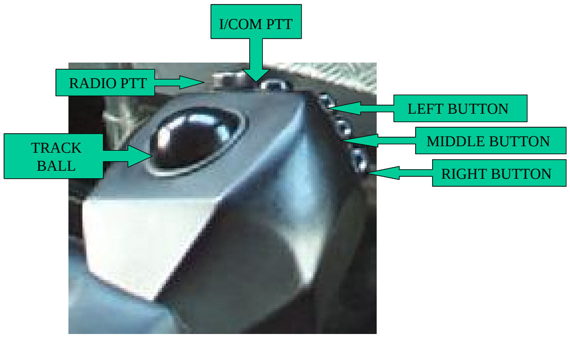

Fig 4. Trackball pod functions

The motion of the 2 inch trackball is damped to avoid the curser moving too rapidly around the screen.

The radio PTT button allows the user to 'Push to talk' over the VHF and MF radios. The button is shrouded to denote its importance and to avoid inadvertent use of the radio. Only the user in control of the radio will actually transmit over the radio on pressing this. The Intercom PTT is always live at all stations, and any crew may talk on the intercom through the headset.

Like typical computer mouse operations, the left button is used to select an item or to operate a function on screen. The middle button is used to toggle between the full screen image of the chart or radar and the normal SIMS view. The right button is only used as the first step in taking control of a particular function, or for accessing properties in the chart package.

A sealed (IP68) pointing device is used at the Upper Steering Position that will survive exposure to saltwater.

7.4 HEADSET

Each station on board is fitted with a waterproof headset with two earpieces and a boom microphone.
The headset earpieces may be independently set up via the SIMS screen.

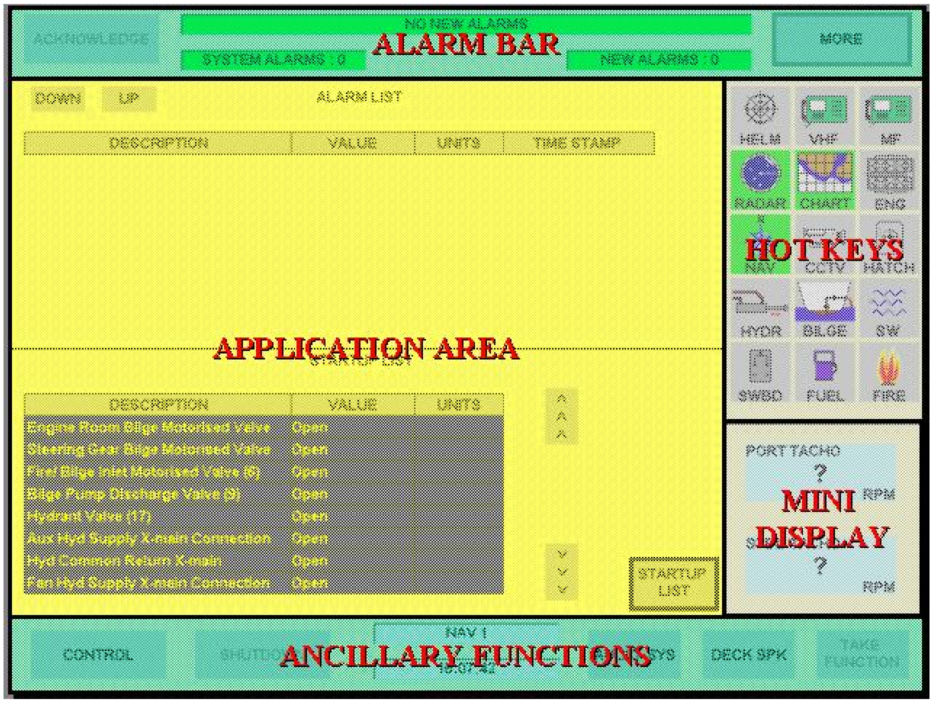

Figure 5. Screen area definitions laid over a SIMS screen shot

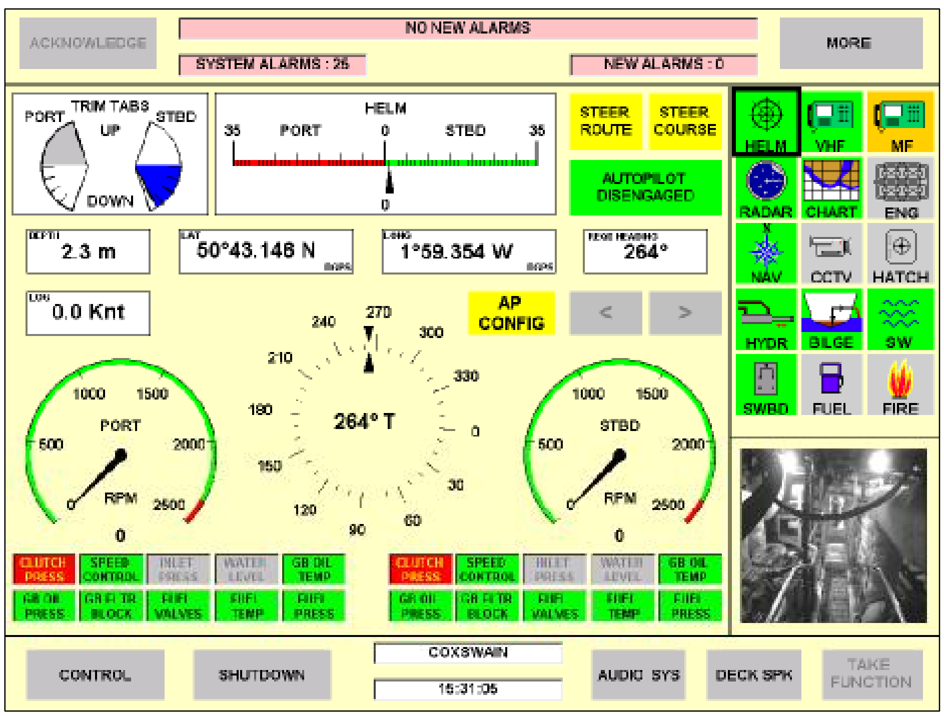

Figure 6. Sample SIMS screen shot (Helm screen)

8 HUMAN MACHINE INTERFACE (HMI)

8.1 CONTROL SHELL

An overall control program called the Control Shell is used to control the environment for each crewmember. When the workstation starts up, the shell program is automatically started.

The Shell is a key part of the HMI and is the basis of the SIMS system. When a particular function or application is required it is launched through the HMI. The HMI is

always running even when applications such as Radar or Electronic Charts are using the full screen. In this way essential information such as alarms can be relayed to the crewmember at any time.

8.2 INDEPENDENT ASSESSMENT / VERFICATION

Although a number of skills were represented in the development of SIMS, the project team did not include personnel with particular ergonomic expertise. For this and other reasons, it was decided to have the HMI independently assessed against industry best practice.

In June 2000, the Centre for Human Sciences department at DERA (Farnborough) were requested to review the HMI specification. Their report [Ref' 1] contained some recommendations for modifications to the HMI specification.

8.3 SCREEN LAYOUT

The research into the HMI, has resulted in a common screen layout across SIMS, as shown in figure 5.

- Alarm bar – top of screen – present in all functions (radar and chart excepted). Most recent alarm displayed.
- Hot keys (Menu Button Application Bar) – the 15 hot keys give access to most systems - left click on the required hot key.
- Application area – the area into which the systems represented by the selected hot key will appear.
- Mini display – a small area of screen with 4 toggle options which are independently selectable in addition to the hot key functions.
- Ancillary functions – Access to various ancillary functions and information.

8.4 FONTS AND COLOUR

Since good colour vision is a medical requirement for RNLI crew, extensive use has been made of colour throughout the HMI, such as yellow for live controls, cyan for signal faults and red for alarm conditions.

By combining colours and symbols, the application of an individual colour can be extended across a range of meanings without leading to ambiguity or confusion.

All display panels have a pale yellow background as this has been found to be restful on the eyes and provides good contrast for the HMI colours used.

All text is shown in 12-point Arial bold font as shown:

12 POINT ARIAL BOLD FONT

The majority of text labels are in capitals, whereas longer text strings (such as alarm reports) utilise sentence case for easier reading.

A sample screen shot (of the helm screen) is illustrated at figure 6 on the previous page.

9 STARTING SIMS

For a SAR vessel getting to the scene quickly is essential. Therefore a single push button (located in the deckhead to the Port side of the wheelhouse doorway) is used to start SIMS. The start up procedure currently takes around two minutes to complete.

All screens show an initial list of start up alarms that list any default actions (opening valves, making breakers etc.) that have failed to complete. SIMS will not, however, stop the boat going to sea – that decision always lies with the crew.

10 TESTING AND INSTALLATION

In order to assure that a system as complex as SIMS will perform as required, a standard approach to testing was adopted, comprising the standard 3 elements of acceptance testing:

- Factory Acceptance Trials (FAT)
- Harbour Acceptance Trials (HAT)
- Sea Acceptance Trials (SAT)

The system was delivered to DML for fitting to the Prototype boat during 2002.

Following the successful FAT of all systems, another user group review was held in September 2001.

11 SIMS FINAL DESIGN

The RNLI plan identified that following trials of the system, inevitable changes would be required – to either correct defects or to make desired improvements. The plan also identified that another Formal safety assessment and a series of extensive User evaluation trials would be pre-requisites for any re-engineering

The second FMEA undertaken in July 2003, benefited greatly from the experience gained by trialing the prototype system at sea.

11.1 INDEPENDENT EVALUATION

As with the HMI, the RNLI believed it was prudent to involve an external body in the evaluation phase of the project, to provide further independent assessment / validation of the trials.

The development of SIMS is only a part of the RNLI's efforts to provide safer and more efficient craft for its crews, Other aspects include seat design (the subject of another paper at this conference) and ergonomic layout.

Therefore to provide a coherent review of these issues the RNLI approached the Ergonomics and Safety Research Institute (ESRI) at Loughborough University. Amongst other services, ESRI provide consultancy services in the assessment of driver workload and performance as well as ergonomic design matters.

11.2 SIMS USER EVALUATION TRIALS

The trials, developed by the RNLI and ESRI, had the following aims:

- To identify issues for remedial action prior to introduction into service.
- To provide a measure of the effectiveness and appropriateness of SIMS, and specifically, the HMI.
- To gain user approval of SIMS prior to introduction into service.

The trials were constructed taking into account the following points:

- 50 users were required to facilitate a significant statistical analysis (whilst keeping the trials to a manageable duration).
- The layout of the boat suited 3 users per trial
- Trial duration of 2 days.
- All users to be either current serving lifeboat crew, or RNLI Operations department staff.
- No computer literacy required.

Each user undertook the roles of Coxswain, Mechanic and Navigator in turn, answering questions and completing tasks appropriate to the role (during the trials, the safety of the boat was the responsibility of the RNLI Trials Officer and Trials Technician who remained outside of the SIMS trial).

These roles were then broken down into a series of specific tasks. Each task was communicated to the users via the intercom (headset). Tasks were of two types.

The first type required users to find information from within SIMS and relaying the information to the staff member (who could verify the answer at another SIMS screen). The second type required users to perform a specific function within SIMS, completion of which could be verified by the staff member at another SIMS screen

Each task was assessed with the following metrics, which were recorded on the trials form by the trials supervisor:

- Task completed correctly - Y/N.
- Time to complete task.
- Ease of undertaking task (on a 1:5 scale) – confirmed verbally by user.
- Ease of interpretation of information (on a 1:5 scale) – confirmed verbally by user.
- Number of clicks (of the trackball buttons) required to complete task – confirmed verbally by user.

At the time of writing this paper, assessment of the results of these trials was ongoing and currently no quantitative results have been produced, but initial assessments are favourable.

11.3 USER FEEDBACK ANALYSIS

The Trials were attended by 40 crew from 18 RNLI lifeboat stations around the coast of the UK and Eire.

Following the trial, each user was given a feedback questionnaire to take away and complete. Completed forms (of which 31 were received) were returned to the RNLI Engineering Office where an assessment of the data was undertaken

Users were asked to compare the features of the SIMS system compared to the systems they use on their current lifeboats. The results are summarised in figures 7 & 8.

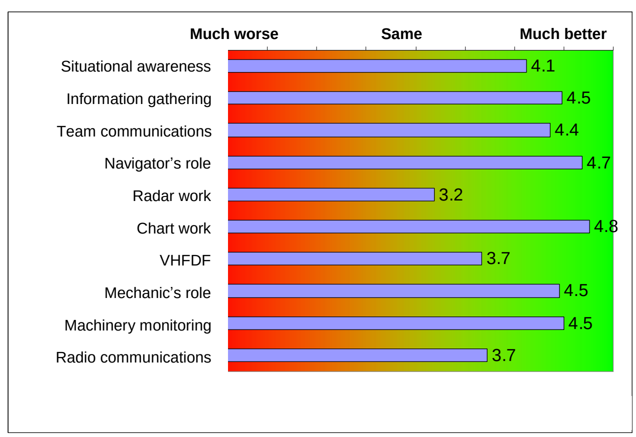

Fig 7. User responses (average scores out of 5)

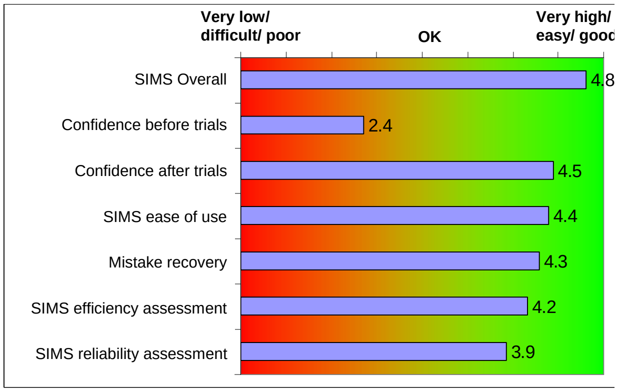

Fig 8. User responses (average scores out of 5)

Apart from identifying specific issues for further attention, perhaps the most significant figures from this data are the notable measures of crew 'confidence' in SIMS before and after the trials (2.4 to 4.5).

12 SUPPORT SERVICES

As with any system support services will be required to ensure successful use in service.

Currently, the RNLI are developing both maintenance and training requirements for SIMS. These will ensure that:

- Trainers are trained to provide training to crews.
- Training facilities are in place to train crews.
- Maintainers are trained to support SIMS
- Spares are in place to keep the boats on service.

13 CONCLUSIONS

This paper covers the design and development of the SIMS system and has identified the need for a bespoke HMI. The regular involvement of end users and external bodies has contributed to a user interface that has been well received throughout a period of extensive sea trials.

The facility to operate systems remotely, coupled with the multiple levels of redundancy inherent in the design have produced an effective and robust product that should deliver the improvements in crew safety and simpler training regimes that the RNLI seek.

As this paper is written during the latter stages of the development of the SIMS system, some design and production issues still require final resolution, however the RNLI are confident not only in resolving these issues before the system enters service in 2005, but also in developing a system that will produce enhancements to the performance levels already achieved.

14 ACKNOWLEDGEMENTS

Devonport Management Ltd
DERA (now QinetiQ) Centre for Human Sciences
ESRI – Loughborough University
Servowatch Systems Ltd
Safe Marine Ltd

15 REFERENCES

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16 AUTHORS

John Nurser is the Principal Electronics Design Engineer in the RNLI Engineering Office. In addition to the design and development of SIMS and other new electronics equipment, he is responsible for the through life support for legacy systems. Previously served in the Royal Navy for 35 years as a Weapons Engineering Officer, serving in both sea and shore appointments, until retirement in 1997.

Neil Chaplin is a Principal Naval Architect in the RNLI Engineering Office where he has been employed for 6 years. Project manager for the Tamar class lifeboat. The integration of SIMS into the Tamar has required in depth involvement throughout the project including extensive sea trials. Previously Naval Architect with Ministry of Defence procurement.