CONTROL SYSTEM PERFORMANCE ASSESSMENT USING REAL TIME SIMULATION

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ABSTRACT

As part of the procurement of the Single Role Mine Hunter a performance assessment of the ship's position keeping and propulsion control system was carried out. The assessment used duplicates of the control consoles destined for shipboard use. These consoles were interfaced to a real time simulation of the ship, its machinery and environment. A simplified simulation of the ship's data system formed an essential part of the simulation. The assessment was performed over a trials programme that included all aspects of operational requirements. This article describes the steps involved in setting up this assessment in both management and technical aspects. The structure and facilities of the simulation system are described. The information gathered by the assessment programme is surveyed, together with comments on the value of the work.

Introduction

The use of real time simulation as a tool in the assessment of control and surveillance systems is not revolutionary. Its use in independent assessment, and the reasons for this method's acceptance were documented in an earlier *Journal* article[1].

The independent assessment of equipment procured by MOD in the past has been completed at MOD controlled establishments. Although subject to various management procedures, the pressures to meet cost and programme targets were not governed by contract conditions.

The assessment of the Single Role Mine Hunter (SRMH) equipment was therefore a step into the unknown in that the task was to be carried out by a independent contractor on MOD's behalf. The objective to be achieved did not change by going to a contractor. The MOD Project Group would, as a result of a successful assessment, be able to endorse the SRMH Ship Manoeuvring System (SMS) and Machinery Control and Surveillance (MCAS) system design. In addition, confidence would be gained in the systems' performance before integration and use in the ship. The place of the simulator in the design of the SRMH Ship Position and Control System (SPCS) has been discussed by Burt[2].

An essential part of a successful assessment is well-structured and thorough preparation. A clear and unambiguous objective must be defined and supported by definitions, and/or detailed assumptions of trials, standards and procedures.

In order to coordinate and to obtain input from all parties during the work programme, a Joint Trials Team (JTT) was established. Membership of the

JTT included MOD interests as the procurer and user, the equipment contractor, and the assessment contractor. This body provided the forum through which the work was planned and reported.

Preparation

It is essential to prepare for a project thoroughly and in such a way to ensure success. The preparation started with a clear Statement of Requirements supported by a detailed response from a contractor. In their response the company was asked to provide a description of the procedures for:

- project management
- quality control
- trial programme and content
- simulation model, structure and management
- system architecture.

These statements then formed the basis for two documents:

- the Assessment Programme Management Specification
- the Requirements Specification for the SRMH Simulator.

In the early days, the full nature of the assessment had been difficult to gauge. This could not be allowed to continue if costs and programme were to be maintained. The production of these two documents ensured that clear boundaries were defined for the work.

In order that progress could be maintained it was inevitable that assumptions would be made. These assumptions were recorded in some detail to ensure that their impact on the results could be judged. This approach also allowed some flexibility to be introduced into the programme. Many of the assumptions concerned operating limits. Provided that these were set at realistic levels, it was recognized that changes would be minimal if and when the correct information became available.

Considerable time and effort was put into the preparation of both the Assessment Programme Management Specification and the Requirements Specification for the SRMH Simulator, leading to full agreement from those involved.

Quality control procedures were introduced into the Project from day one, for both hardware and software. Quality audits, particularly concerned with software, provided confidence in the simulation software produced. Periodic checks by independent auditors provided further confirmation that adequate documentation and testing was being completed.

The benefits of this preparation became apparent as work on the simulator and trials documentation began with clear objectives and guidelines.

Simulation of the SRMH

The Simulator System

The SRMH simulator consisted of the following major elements shown in FIG. 1:

(*a*) The 'user system' provided a powerful interactive user interface for the control and monitoring of the real time simulation. The commands available allowed full control over the data and conditions within the simulator from the keyboard, or from command files, and made extensive use of 'windows' to allow different data to be displayed simultaneously. In addition, the user system provided analysis and display facilities to deal with the display and interpretation of data logged after each trial had been completed.

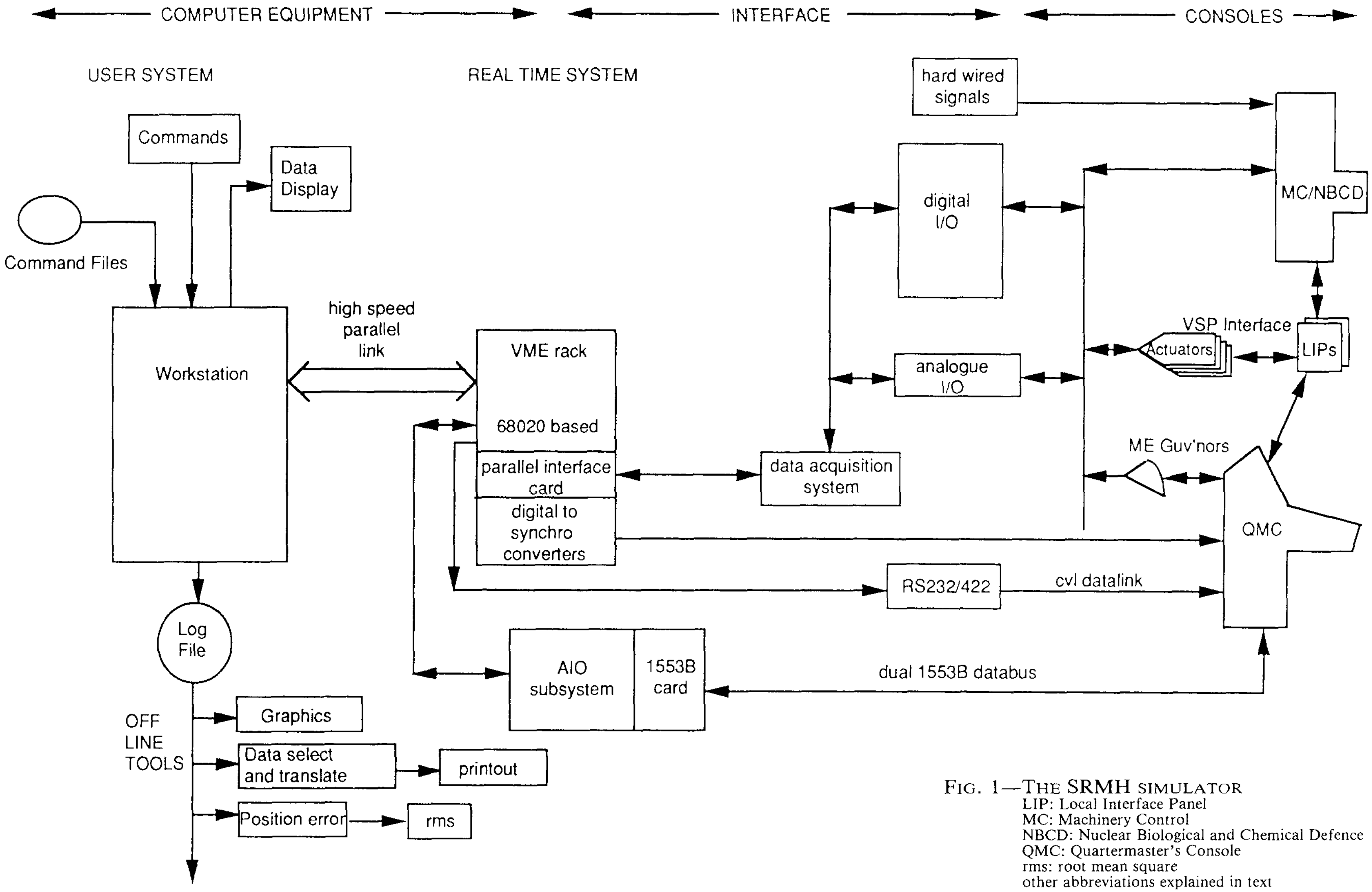

FIG. 1—THE SRMH SIMULATOR
LIP: Local Interface Panel
MC: Machinery Control
NBCD: Nuclear Biological and Chemical Defence
QMC: Quartermaster's Console
rms: root mean square
other abbreviations explained in text

(*b*) The 'real time system' housed the simulation model within a commercially available 68020-based single board microcomputer using the VME (Versa Module Europe) bus standard. All communication with the model was via the User System, or directly with the 'ship' via the I/O (input/output) interface. The dynamic model of the SRMH was defined by the various sections of the SRMH Database detailing the primary machinery equipment dynamics, the ship dynamics and the environment.

The Ship Manoeuvring System (SMS) exchanges various items of command and navigation data with the Action Information Organization (AIO) to issue propulsion demands. The AIO interfaces with the SMS via the Weapons System Data Bus (WSDB). Simulation of this interface contained only those functions relevant to the operation of either the SMS or the WSDB. This part of the model used a separate processor, with a serial data link to the rest of the real time system.

(*c*) The I/O interface to the control consoles consisted of:

(*i*) The WSDB interface was a Mil Std 1553B databus implemented using commercially available boards.

(*ii*) The recently installed correlation velocity log interfaces to the SMS using an RS422 serial data link. A commercially available RS232/RS422 communications converter was used for part of this interface.

(*iii*) Most analogue and digital signals pass from the consoles to the simulation software via appropriate signal conditioning circuits, and a proprietary data acquisition system. The channel count was small, with a total of around 20 analogues and 400 digitals for both input and output.

(*iv*) Several navaids use synchro signals for transmission, and for these VME-based digital to synchro converter boards were used.

(*v*) Some functions, notably the main engine governors were simulated in hardware using stepper motors. This was done to maximize compatibility with the equipment fitted to the SRMH, and to optimize simulator design.

(*vi*) Some status functions had no effect in the simulation; thus it was appropriate to simulate these functions in hardware using toggle switches, and potentiometers. These functions were not available for data logging and analysis by the User System.

Simulation Model

(*e*) Simulation of navaid sensors was implemented to allow the simulated sensor values to be contaminated with noise.

(*f*) The simplified simulation of the ship's AIO system and WSDB interface.

Verification and Validation

Before embarking on the trials programme, the simulation model needed to be verified and validated. In the absence of the 'real' SRMH, the following paragraphs summarize the policy followed.

(*a*) *Verification of the Database Model.* The major task was to verify the simulation against the contents of the SRMH Database document. To perform this verification, comparison with alternative sources of performance data was required:

(*i*) Feasibility work on the SRMH control system design used a simulation model based upon the SRMH Database (although an earlier edition). This model implemented only the hull dynamics and a limited range of environmental conditions. This work served to establish that the new simulation's performance had reached a level of maturity to allow meaningful comparison with other data from outside.

(*ii*) The suppliers of the SRMH control system have also developed a simulation model in support of their design and manufacturing programme. As part of their support activity, simulation work was carried out in order to provide wide ranging data for comparison. A series of test and short manoeuvres exercised the major parts of the simulation model representing the propulsion machinery and the hull dynamics using constant environmental conditions.

Both models agreed over a wide range of conditions. The qualitative agreement obtained gave confidence that both simulations were accurate representations of the SRMH Database.

(*b*) *Verification of Other Functions.* A number of areas of the new simulation's functions were not covered by the Database, and hence verification proceeded as follows:

(*i*) Machinery State Control: for both main and auxiliary machinery the simulation provides state control using the start/stop signals. For these simple functions a functional check was sufficient.

(*ii*) Towed Body Dynamics: alternative data was not available. Verification was thus by inspection and acceptance of the simulation's results.

(*c*) *Comparison with SRMH 01*. After the Contractor's Sea Trials of HMS *Sandown*, some information on her behaviour became available and allowed some comparison to be made. This gave some view on the degree of agreement between the simulation model and the real thing, thus completing the validation process.

The Trials Programme

Planning the Trials

By testing and assessing performance in isolation from the actual ship, there is the potential to execute a wide variety of trials, involving extreme conditions. The wind and tide environment is controllable and repeatable, a feature not found in a seaborne trials programme.

The assessment criteria and the trials programme must reflect the requirements for the MCAS and the SPCS for the SRMH. As a result, the definition of the trials was built up using both the original requirements documents and a general appreciation of the needs. An important input was the knowledge of operational aspects provided by a Naval Trials Officer. Documents produced later than the original STRs were not used, either as a basis for planning the trials, or in assessing the results.

During the planning of the trials, an appropriate documentation system was set up to ensure that each trial's procedure was fully specified, and that all relevant data was recorded. This information was set out in the form of 'Trial Definition' documents which were formally approved following comment by JTT members.

Structure of the Trials Programme

It was recognized at the outset of the work that most, but not all, of the trials could be identified beforehand. As a result, 'Defined Trials' and 'Undefined Trials' were set up.

The *Defined Trials* exercised all aspects of the systems' functionality. This gave a broad view of the performance of the equipment in a operational setting. They were planned as a programme of exercises of increasing complexity, allowing familiarity and confidence to be accumulated. This 'bottom-up' approach resulted in two distinct campaigns, designated 'A' and 'B'.

- *Campaign A*, exercised subsystem performance, and assessed the equipment against purely functional requirements, where each is exercised in relative isolation from others.
- *Campaign B* built upon Campaign A by exercising the equipment under conditions that approached operational conditions as far as possible. This

in more depth and across a wider range of conditions than the Defined Trials.

This was the structure in which the trials programme was executed. After the completion of equipment setting to work and team familiarization, campaign A was completed in about four weeks. After a short pause, campaign B was completed in a further two weeks. It had been expected that a break of six to eight weeks before the start of Undefined Trials would be possible. This would have allowed the reporting of results, and further planning to be carried out. In the event, the pressure of time on the programme meant that the Undefined Trials started immediately, and ran through without a break until trials activity was curtailed when the equipment was removed for use elsewhere in the SRMH programme. Trial activity finished in early October 1989.

Defining and Reporting the Trials

Documentation was prepared in advance of the execution of every trial, in the form of a full definition, and each trial was the subject of a separate results report.

(*a*) *Trial Definitions*. The Trial Definitions for all the exercises made use of a set of Standard Operating Procedures (SOPs). These were set up before the trials based on standard orders as adapted for the SRMH's needs by the Trials Officer. The adaptation was based on an expectation of how the system would be operated.

(*b*) *Reporting*. During and following the Trials programme, the results, assessment and recommendations were reported as follows:

- (*i*) Trial Results: these reports contained the data and information gathered during the execution of each trial.
- (*ii*) Assessment Reports: summarized the assessor's view of the results obtained, and recommended further action or Undefined Trial proposals.
- (*iii*) Interim Report: summarized the results of the trials carried out, and included an early interpretation of the results and implications on system performance as a whole.
- (*iv*) Final Report: presented similar information as the Interim Report, but extended its scope to include all aspects of the work programme.

Execution of the Trials

For the execution of the trials, the roles set up within the trials team were:

Comments on the Trials Programme

The trial programme was made up of 22 trials defined during the course of the work, with a range of objectives. In this section, we survey each of the trials to provide an overview of the contribution made by each to the programme as a whole.

(*a*) *Campaign A*

A1: Machinery Control Functions—These exercises served to establish a baseline of functionality, and to act as a confidence measure confirming correct system integration. Few comments were made, and those that were, reflected the satisfactory nature of the system design.

A2: SMS Manual Control Functions—These exercises served as a similar 'benchmarking' function as A1. Additionally, they acted to confirm the familiarity of system operation on the part of the trials team.

A3: Indications, Alarms and Warnings—As with A1 and A2, the basic functionality of the equipment was confirmed in these exercises.

A4: Hoverplan Display—A 'static' review of the information presented by the hoverplan against the demands of the original Statement of Requirements (STRs). As with A1 to A3 the baseline functions were confirmed.

A5: Ergonomics—This trial produced much valuable information. This was largely the result of being one of the first occasions to use the new standard Def Stan 00-25 as an assessment tool. Although the Def Stan was not a contractual requirement on the designers, it was shown to be a useful benchmark with which to review the equipment ergonomics.

A6: SMS Automatic Control Performance—This trial, executed without the random effects of environmental dynamics, allowed a baseline of capability to be observed and gave confidence in the system's operation.

A7: SMS Response with Environmental Disturbances—This trial successfully achieved its objective of providing the first complete view of what the ship would be under automatic position control. As such it was rich in data.

(*b*) *Campaign B*

B1: Command Mode Transitions—Relatively little came out of this trial for two reasons. Firstly the requirements had been met by the system design, and secondly the transitions were so straightforward that system's response to variations in the quality of data provided by the CVL.

U2: Transition between DP and PCM—in Hover—The execution of this trial provided much valuable data of importance to the ship's capability.

U3: Performance of SPCS issue 2 software—This trial added a level of confidence to the conclusions obtained earlier. The exercises showed the good repeatability obtainable within the trials programme.

U4: Manoeuvring Between Closely Spaced Waypoints—This trial successfully explored an area of performance that had not been envisaged in the original requirements. The results obtained were rich in data for assessment purposes.

U6: SRMH Turning Data—The value of this trial is dependent on comparative data being obtained elsewhere from the ship's programme. By presenting data in a 'user-oriented' form, it provided a further focus on the model validation issue.

U7: Operating Mode Review—This activity was useful in allowing a further opportunity for the views of the user community to be fed into the assessment.

U8: Operational Manoeuvres—This trial was successful and the results rich in data to provide further coverage of the issues thrown up by trial B3. The information provided has value beyond the assessment programme, particularly for the ongoing development work of the designers.

U9: Additional Exercises—This trial was very rich in data, and provided a prime example of the 'Undefined Trial' concept. The exercises explored several specific observations made earlier, and were based on previous exercises. The experienced trials team used the command file libraries to define and execute the trials in a very short space of time. This was done without compromising the quality of the documentation or traceability established throughout the trials programme.

(*d*) *Campaign L*

The campaign L activities were recognized as essential across the board reviews in specific areas. Although only a limited amount of information emerged it is felt that they served their purpose well.

Conclusions

At the end of this assessment, the result was a positive answer to the initial objectives. However, more questions were raised for the respective Ministry Projects to ponder. The Undefined Trials programme provided the answer to some of these questions, but many were left open, and require investigation. These aspects could not be addressed due to equipment availability and other constraints placed upon this work.

The value of Assessment projects is not easily quantified in time and monetary terms. The confidence gained from the operation of new equipment during an assessment is invaluable experience to all concerned. Having assessed one particular system design, it is unlikely that a repeat assessment would be needed. Ship design and build programmes often being in the order of ten years duration, the chance of the same system design being used for follow-on ship designs is small.

Therefore, assessment should be used as a tool for design support. The justification and reasons for such an approach become stronger as the complexity of control and surveillance systems increase, and the move is made towards management systems.

Hawken[4] identifies the case, and makes the recommendation for a Shore Based Test Facility being established during system development, in order that assessment becomes an integral part of a design programme.

Specific points did come from other issues around the Assessment:

(*a*) The involvement of the 'user community', through the participation of the RN Trials Officer, proved most useful.

(*b*) The process of verifying and validating the simulation model showed the importance of alternative and independent data. The data from the trials, including that from the validation exercises, should be compared with 'ship data' when available. The result of this comparison should enable improvements to be made to the simulation model. Any further assessment trials should be defined with a greater recognition of the potential disagreement between the simulation model's behaviour, and that of the ship.

(*c*) The amount of data collected was awesome but, because of the documentation and user system structure, it was found to be controllable. This became important and most evident when carrying out the Undefined Trials. Trials were defined, executed and the results captured very quickly, typically in less than a week, without sacrificing quality, consistency or traceability.

(*d*) The user interface flexibility and effectiveness cannot be praised too highly. The time and effort spent in defining and implementing these facilities proved to be well worthwhile.

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