MAN MACHINE INTERFACE DESIGN

EVALUATING THE CANADIAN SHINMACS STANDARD MACHINERY CONTROL CONSOLE

BY

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Introduction

Machinery control systems in Royal Navy warships have steadily evolved over the past three decades from rod gearing to microprocessors and serial data links. Control and surveillance of expensive machinery is moving away from the plates and into ever more sophisticated control rooms. Manning levels are being reduced to a degree that makes many engineers tear their hair out. A reduction in the number of mechanics and artificers available for watchkeeping places greater emphasis on the quality and reliability of transducers but this is not enough in itself. The presentation of decision-making information to the operator and the facilities to implement the decisions quickly and safely is just as important.

With this in mind, the Sea Systems Controllerate has embarked on a fundamental review of machinery control system design, and a significant part of this work is aimed at the optimization of the man machine interface or MMI as it is known.

The Canadian Forces have employed psychologists and specialist human factors engineers to design a state-of-the-art MMI for a microprocessor-based, distributed control system known as SHINMACS. As part of the U.K. review, the future concepts group of the machinery controls section arranged for eight ratings under my direction to carry out an operator assessment of the potential of the Canadian approach. This article will give a brief description of the MMI and its operation, and detail the results of the assessment.

What is SHINMACS?

SHINMACS is a SHipboard INtegrated MAchinery Control System using a triple redundant serial data highway for reasons of survivability. The MMI, or console, is a Standard Machinery Control Console (SMCC) (FIG. 1) which is specifically designed so as to be reconfigurable for different ship and submarine applications. The Canadians have plans to use it in all future Canadian warships, submarines, and AORs.

The MMI is a one man workstation housing three high resolution colour cathode ray tube (CRT) displays, their control panels, and a work surface. Operator inputs consist of pressure-sensitive joysticks, push button keys, and a touch tablet. The console on trial runs against a computer simulation of the COGOG powered Canadian DDH 280 destroyer.

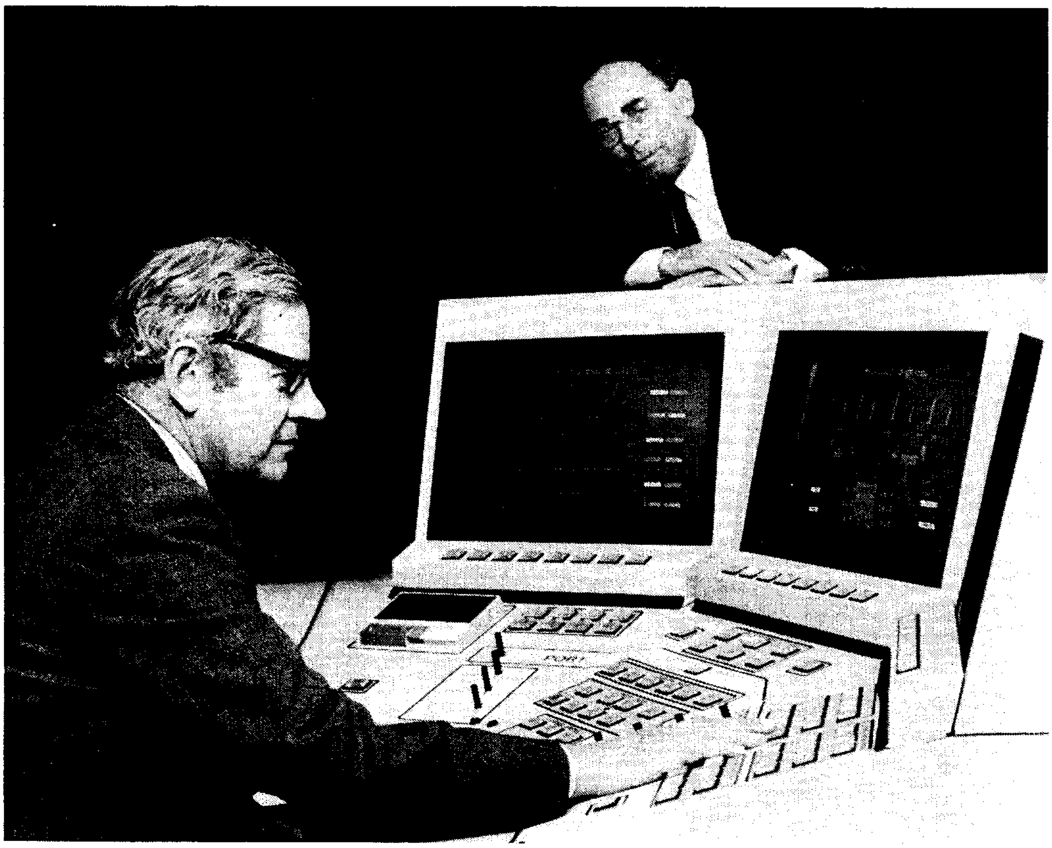

FIG. 1—REAR-ADMIRAL VALLIS OPERATING THE SHINMACS CONSOLE

Presentation of Information

All relevant machinery plant information is displayed using computer-generated graphics. Information is presented on the displays in such a way that the operator can perform each task expected of him in a straightforward and undemanding fashion. The static portion of each page is augmented by dynamic information consisting mainly of discrete digital parameters, bar graphs, and graphical status of individual components such as engines, pumps, and valves. There are 42 pages of information available to the watchkeeper, excluding up to three pages for the storage of additional alarm and warning information.

Primary information is accessed via dedicated keys grouped as follows:

(*a*) Overview pages module comprising:
- Propulsion overview (FIG. 2).
- Systems overview (FIG. 3).
- Alarms overview (FIG. 4).
- Shaft data.
- Operator monitor (FIG. 5).

(*b*) Engine pages module comprising:
- Engine control (FIG. 6)
- Engine data (FIG. 7).
- Engine log.
- Driving engines log.

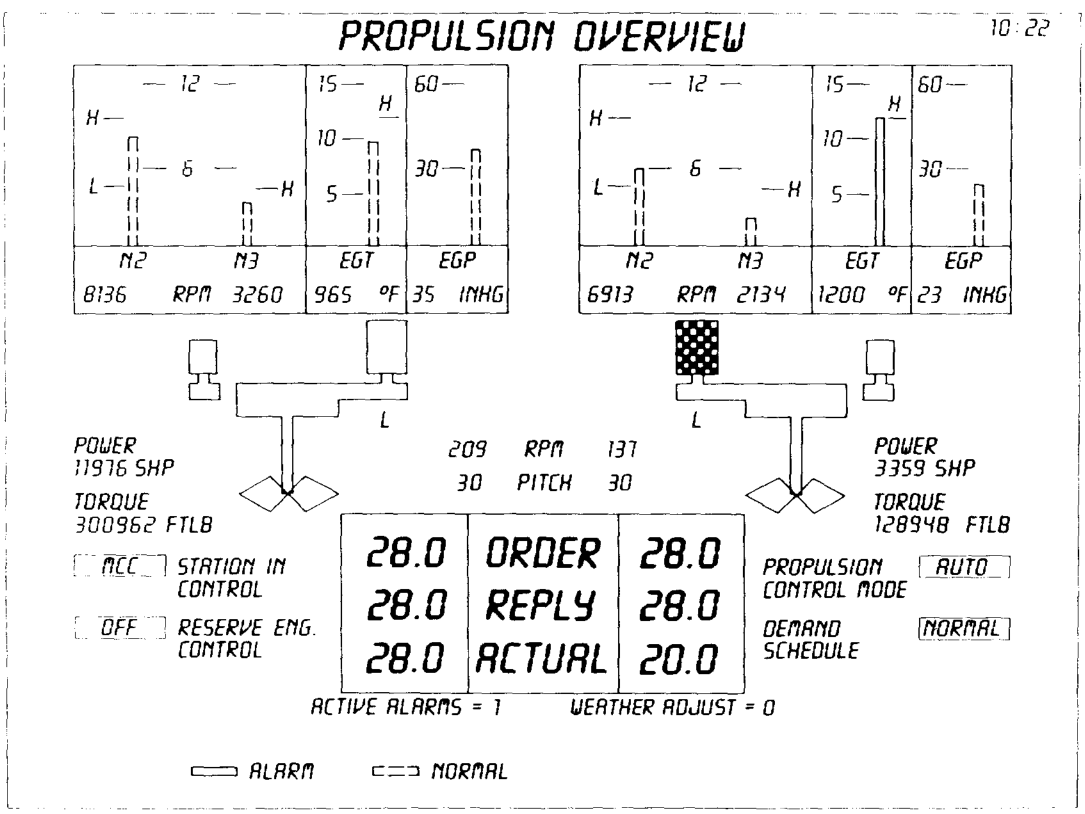

FIG. 2—PROPULSION OVERVIEW PAGE
Parameters at alarm level are shown in red on the console; others in blue

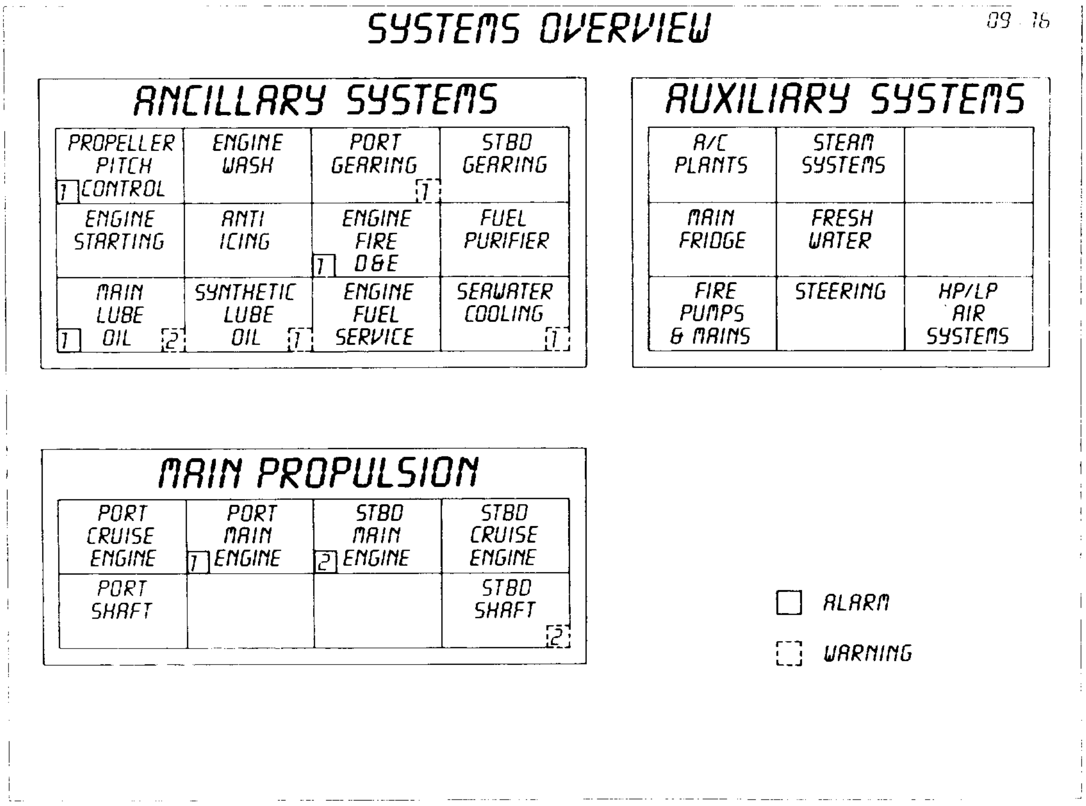

FIG. 3—SYSTEMS OVERVIEW PAGE
Alarms show red on the console, warnings amber. The numbers in the squares denote the numbers of each occurring at the time.

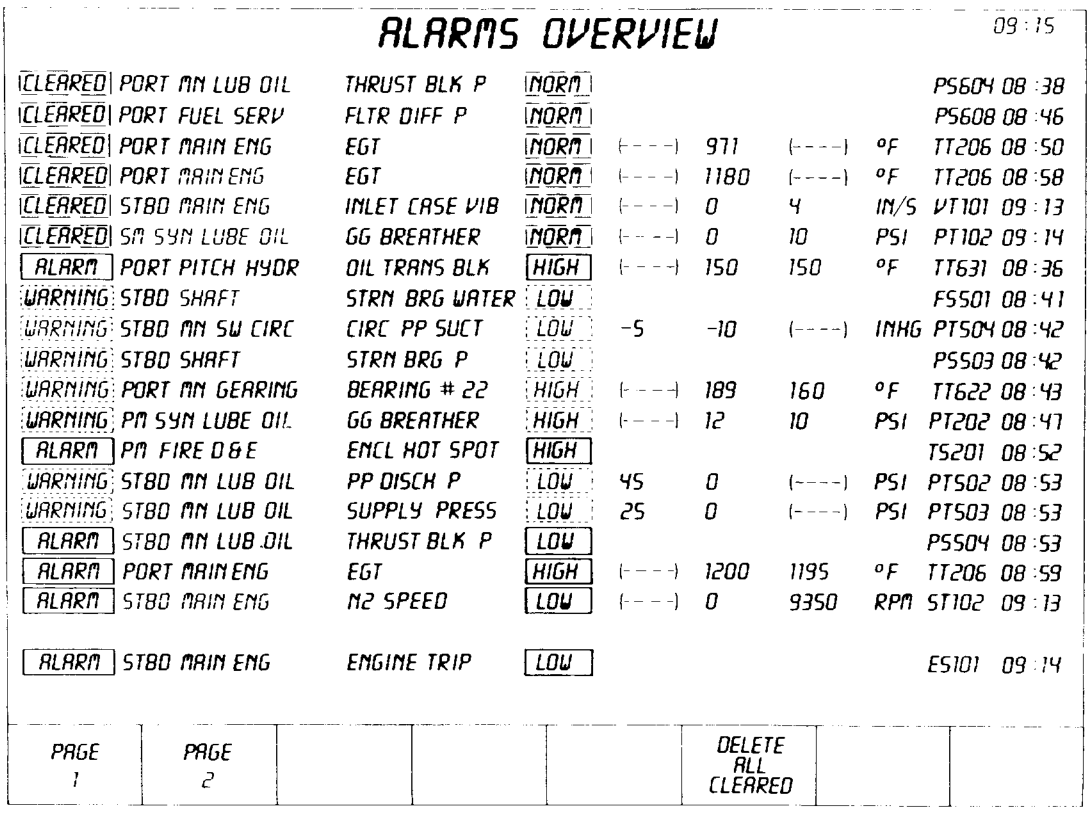

FIG. 4—ALARMS OVERVIEW PAGE (ONE MINUTE BEFORE FIGS. 3 AND 5)
Alarms show red, warnings amber. Parameters in normal state are indicated in blue.

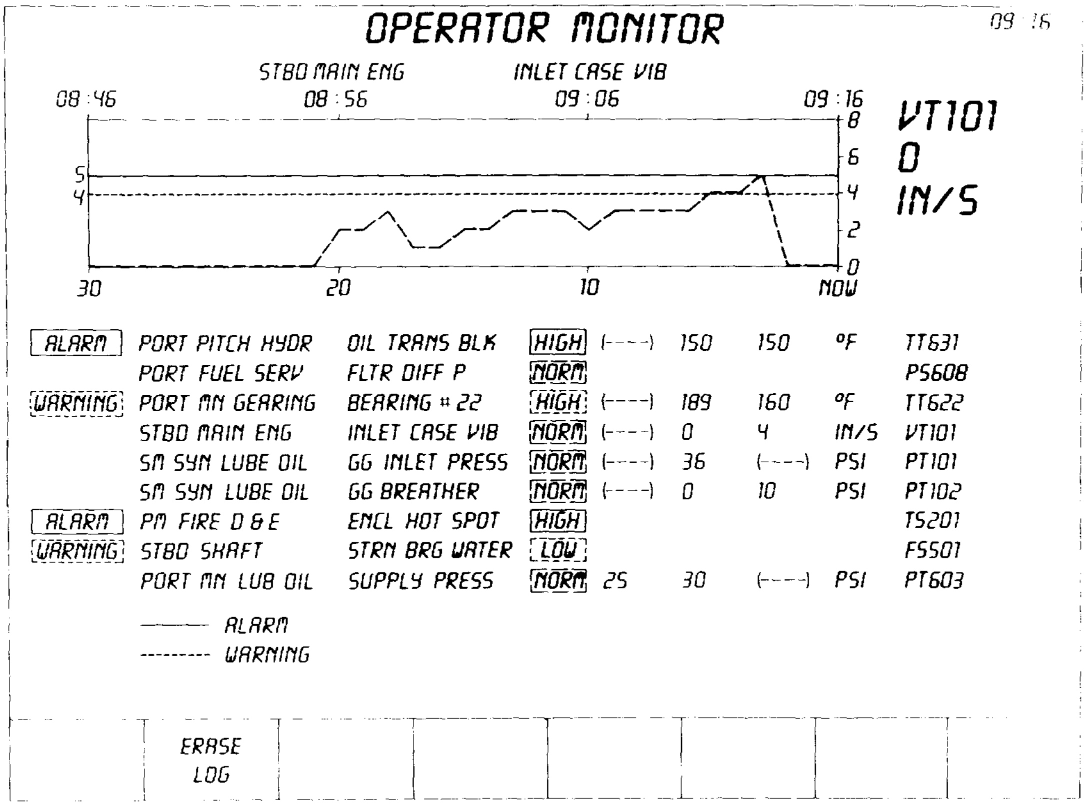

FIG. 5—OPERATOR MONITOR PAGE
The console uses the same colours as in FIG. 4.

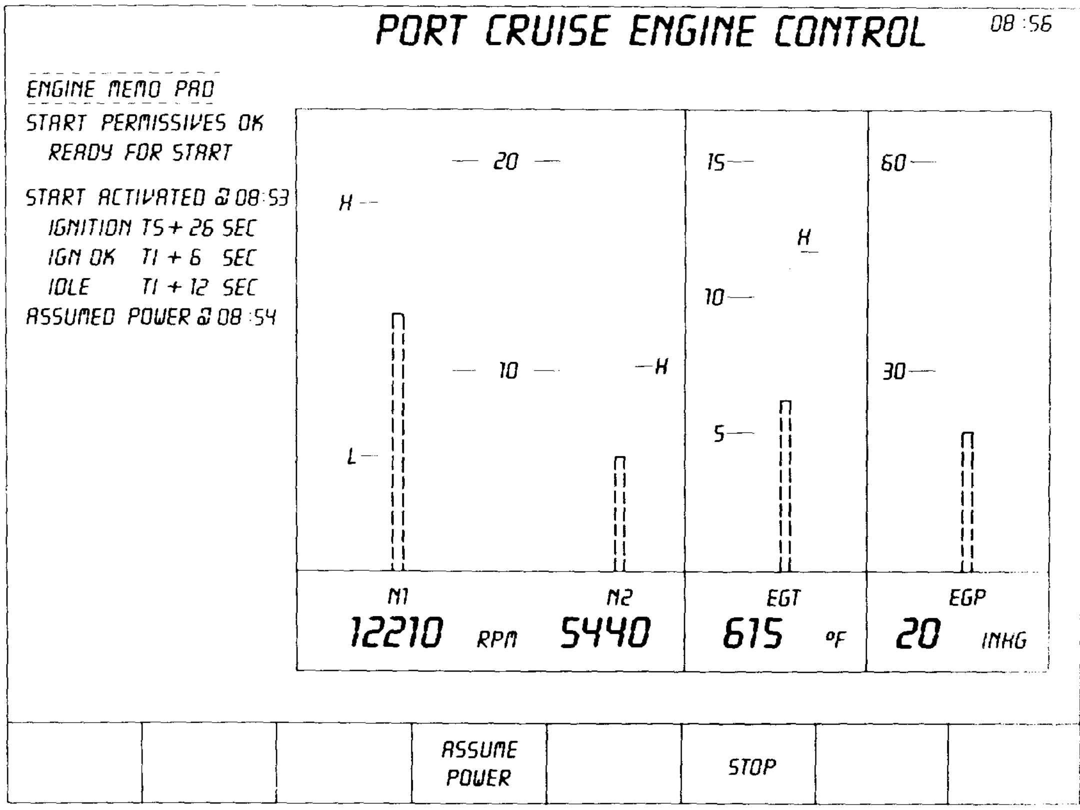

FIG. 6—PORT CRUISE ENGINE CONTROL PAGE. ALL PARAMETERS ARE NORMAL

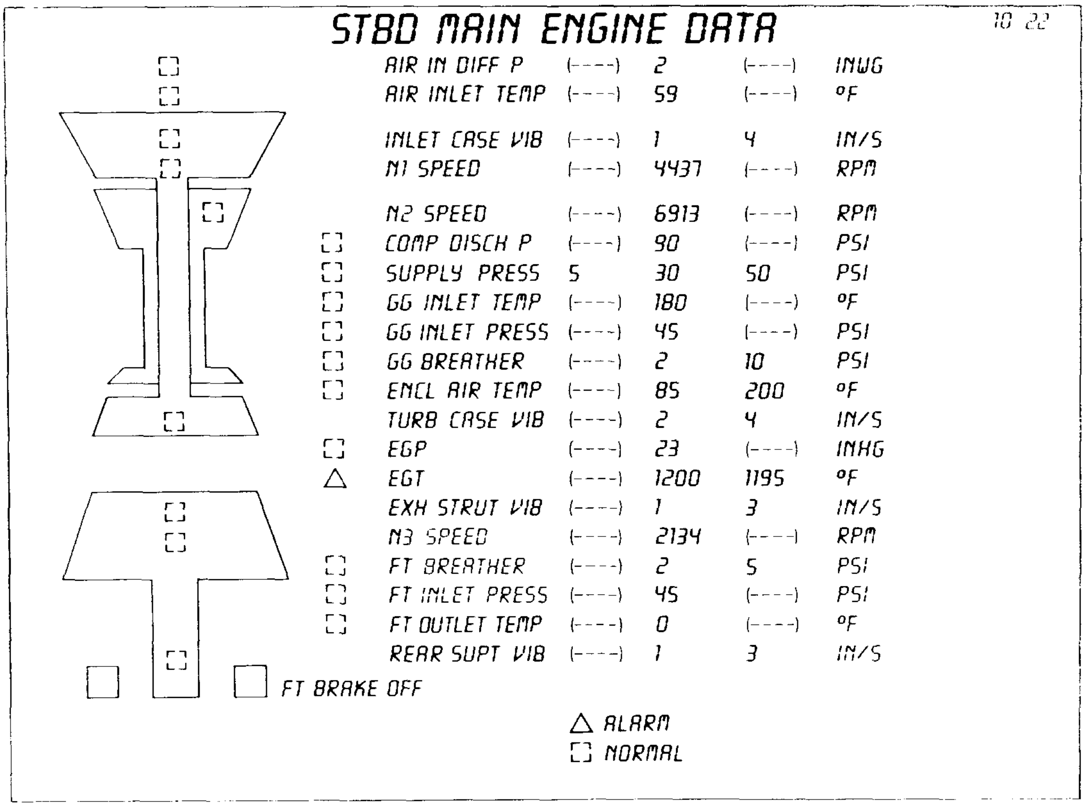

FIG. 7—STARBOARD MAIN ENGINE DATA PAGE

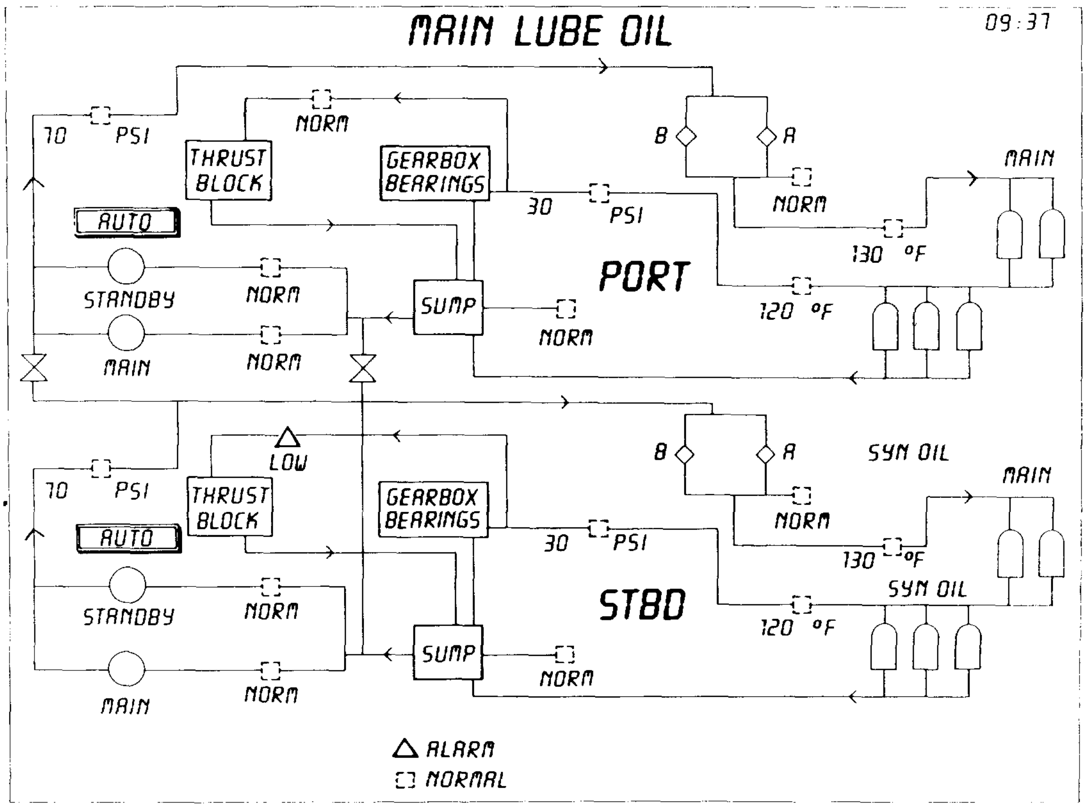

FIG. 8—MAIN LUBRICATING OIL SYSTEM PAGE

The secondary information, consisting mainly of active process flow diagrams, is accessed normally through dedicated keys grouped as follows:

(*a*) Ancillary systems module consisting of:

Anti-icing system page.
Engine fire detection and extinguishing page.
Fuel purifier page.
Engine fuel service system page.
Engine hydraulic start page.
Reduction gearing pages.
Main lub oil system page (FIG. 8)
CPP system page.
Synthetic lub oil system pages.
Seawater cooling system page.
Engine wash system page.

(*b*) Auxiliary systems module consisting of:

Air conditioning plant page.
Domestic steam system page.
Main refrigeration system page.
Fresh water system page.
Steering system page.
Fire pumps and firemain system page.
HP and LP air systems page.

Operator Interaction

The operator may direct the display of information to a screen of his choice. Alternatively, he may opt to allow the automatic screen selection protocol to direct the information to the oldest unprotected screen (the watchkeeper is given the facility to protect up to two displayed pages from being automatically overwritten on the screens).

The operator inputs to the system are in the form of eight pressure-sensitive joysticks, dedicated push-button keys, a touch tablet, and sets of eight non-dedicated option keys ('soft' keys) located below each CRT screen. A separate module of eight dedicated keys permits the operator to confirm the engines are ready for starting and, if necessary, trip the engines once the starting sequence has been initiated.

The operator can select either automatic or servo manual control. In the automatic propulsion mode, two force joysticks allow the operator to set the shaft power level according to a defined shaft r.p.m./propeller pitch schedule. Under certain circumstances, he may select a link feature and set both shaft power levels using either joystick. In the servo manual mode he has independent control of engine power and propeller pitch using four of the six servo manual joysticks.

Specific commands relating to pump and valve operation are input to the plant by means of the touch tablet and option keys. The touch tablet is used to position a screen-based cursor over the control block associated with a particular component. Selection of that control block generates a 'line menu' of options. Finally, depressing the associated soft key causes the command to be executed. It should be noted that only the valid options associated with the particular component are generated. For example, the watchkeeper is not permitted to start a pump if its suction valve is closed.

What did we learn?

The team of eight ratings employed in the assessment ranged from LMEM to FCMEA and included two submariners. They were subjected to a series of trials or scenarios over a two week period and their comments, suggestions and criticisms have been distilled into a summary of results which appears below.

Display of Information

All members of the evaluation team were impressed by the display of information. The use of colour was thought to be good and greatly enhanced the ability of the operator to understand what the MMI was telling him about the state of the machinery under his control. The various pages served to give a clear concise and helpful picture of the response of the plant to control inputs. There was no need to scan a large console to ascertain the state of the plant and the display of time histories was especially useful. However, some concern was expressed over the ability of the system to bring to the notice of the operator an abnormal rate of change in any particular parameter. All the operators have been trained to look at dials and gauges and the display of parameter values in digital form may cause problems unless some rate sensitive detection of parameter change is written into the software. On balance though, the SMCC approach to the display of information was thought to be much better than that currently used by the R.N. There is no reason to limit consideration of the use of this technique to remote MMIs alone. It could be of equal value in a local MMI or NBCD application, for example.

Control of Machinery

The SMCC was not designed as the primary position for control of engine power. This control would normally reside with the Bridge in the DDH 280. Notwithstanding this, few of the team thought that the telegraph arrangement fitted to the SMCC would be suitable for R.N. applications but they were all able to suggest workable alternatives. Apart from one operator, all were of the opinion that the joysticks fitted were difficult to use and inefficient but again, many acceptable alternatives were suggested. The difficulties experienced with both the telegraphs and the joysticks were largely symptomatic of the poor quality of the non real time simulation against which the console was operating. However, they should not be dismissed as areas for concern until the SMCC has been evaluated against a simulation which accurately reflects the response of the shipboard machinery. The operators found that the time and concentration required to answer the telegraphs by moving the joysticks was such that it was possible to miss other important events. Only two of the operators, for example, noticed an abnormal power turbine entry temperature on the upper part of the propulsion overview page whilst they were answering the telegraph order at the bottom of the same page. However, the speed with which the telegraphs could be answered when in servo manual control was thought to be more than adequate. This is important because this speed is more indicative of the projected speed of response for the ship system. If this proves to be the case, then the control of engine power afforded by the SMCC would be at least as good as that offered by current MMIs.

The use of a cursor on the CRT screen to gain access to control and surveillance did not prove to be difficult under normal operating conditions and the facility was generally liked. Operators became adept in its use after a short time and the only problem of note was the time taken to locate the cursor. The ability of the operator to use the cursor in a breakdown condition was questioned by many of the team. The team felt that recovery from a breakdown situation was much better and more quickly accomplished with the SMCC than with conventional MMIs because of the markedly better display of information. However, it was felt that first aid action cannot be carried out quite so efficiently with the console in its present form. The facility to carry out the serial and parallel actions required of the MCR crew when working as a team has not yet been incorporated in the prototype MMI. It will be incorporated in the next version, the Advanced Development Model. Nevertheless, initial analysis of the video recordings of all but the multi alarm scenario strongly suggests that the response times achieved by the operators were satisfactory when compared to those expected in an operational environment, despite the supposed handicaps of joysticks, telegraphs, and one man operation. There is every possibility therefore that the implementation of a comprehensive analysis of manning levels and tasks to be performed would further reduce the time taken to carry out the necessary first aid action in the event of a machinery breakdown. There is scope to redistribute control and surveillance functions to other workstations at the higher stage of readiness. NBCD control and surveillance, for example, could reside with the machinery operator in State 3 and be transferred to an NBCD workstation in State 1. Indeed, there is no technical reason why this information and control could not be made available at the section bases.

Multi Alarm Conditions

The final trial confirmed that this is the major area of concern with the MMI in its current form. A large amount of development work needs to be targetted at better presentation of alarms and warnings. None of the operators was able to determine the priority for action within an acceptable timescale when confronted with the alarms generated as in FIG. 4. They were all, however, able to see ways of making the task easier. The consensus of opinion was that the problem was far from insoluble, but that a lot more thought had to go into this most crucial aspect of the SMCC design. There is obviously scope for implementing automatic responses to warning and alarm conditions. The implications of such a solution in terms of reducing operator skills need to be carefully assessed. A reliance on the control system to respond to emergency situations might lead to an inability to operate the plant safely when that facility is not available.

Training Aspects

The speed with which the operators learned to use the MMI was remarkable. They all found it to be much more interactive and educational than the conventional consoles they were used to. The strength of the SMCC concept lies in the way that it continually reinforces the operators conceptual understanding of the plant. The team thought that the use of the console, fitted in a surface ship or submarine as a simulator whilst in harbour or as a procedural trainer whilst at sea, would serve greatly to improve the operational performance of the MCR crew. The concept of running the console against a simulation whilst at sea would have to be carefully thought out, but with the right degree of supervision and the ability to regain control instantly in the event of a breakdown, the time available for realistic training and fine tuning of the watch could be dramatically increased.

Operator Performance

All operators performed to a satisfactory operational standard in all the scenarios except for the multiple alarm condition. This was after only four or five hour's experience at a totally new MMI, and with no previous

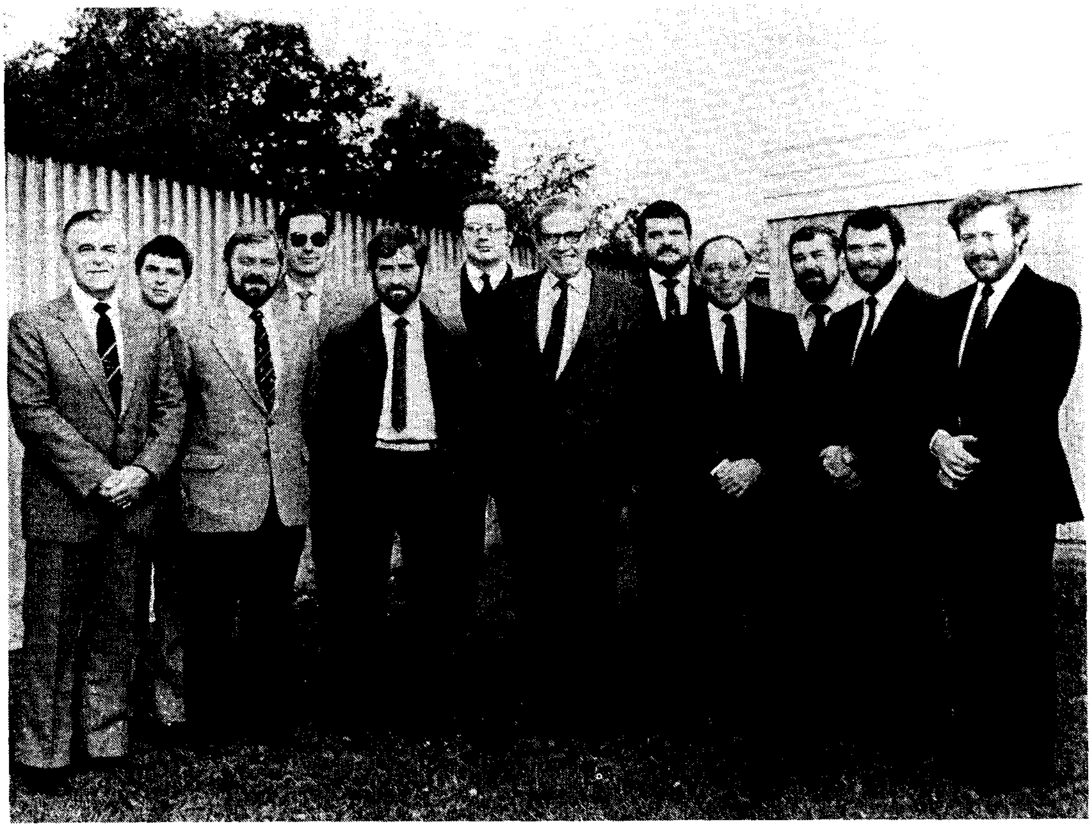

FIG. 9—THE EVALUATION TEAM, WITH SENIOR OFFICERS
(from left to right)
D.W. East, R.C.N.C.
LMEM B. Bingham
CPOMEA C. Matthews
CPOMEA J. Bower
POMEM S. Bishop
CPOMEA C. Nesbitt
Rear-Admiral M. A. Vallis
CPOMEA F. Davies
Captain T. J. Meadows
CCMEA M. Craddock
Lt-Cdr K. R. Doney
D. S. Knight, R.C.N.C.

knowledge or familiarity with the DDH 280 machinery plant modelled in the simulation. The two submariners showed a particularly high aptitude and ability for safe, quick, and effective operation, despite their total ignorance of the operation of COGOG machinery at the outset of the evaluation. There was no appreciable difference in the time taken to make the plant safe between one team member and the next, although those who adopted a more methodical approach and used the MMI to discover the cause of the breakdown before taking action generally achieved better results in the recovery phase. A more thorough analysis of the performance of the team would help to confirm the intuitive feel that their overall performance was at least as good as that achievable with conventional MMIs. This might best be done by psychologists and human factors engineers.

Where do we go from here?

We are now aware of many of the advantages and potential pitfalls of this type of approach to MMI design. The concepts incorporated in the development of the Canadian Standard Machinery Control console will be examined in detail to determine their applicability to primary and local reversionary control positions in the Machinery Control and Surveillance (MCAS), Main Electrical Power System (MEPS), and NBCD systems of future R.N. surface ships and submarines.

The results of this evaluation were presented to the Canadians in Ottawa in January 1985, and the lessons learned will be incorporated into the design of their Advanced Development Model (ADM). The assessment has acted as a springboard towards greater awareness of MMI design within the MOD(PE) and has realized significant savings in terms of time, effort, and capital investment. A MOD(PE) involvement in a follow-on evaluation of the Canadian ADM will serve to reinforce this awareness.

Almost without exception, the members of the evaluation team and those who witnessed the demonstrations agreed that the concept offers a highly attractive option to the MCAS system designer of any future R.N. warship.

Acknowledgements

I would wish to express my sincere thanks to Mr. John Griffin and Mr. Derek Knight, both R.C.N.C., of section ME121 in Bath, for their foresight and support in making this assessment possible. In addition, we all owe a debt of gratitude of the evaluation team members from H.M.S. *Edinburgh*, H.M.S. *Trafalgar*, and H.M.S. *Drake*—the end users. And finally thanks to the Canadian Department of National Defence for their co-operation in making the console available to the MOD.