FUTURE DIRECTION FOR RN MACHINERY CONTROL AND SURVEILLANCE SYSTEMS

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ABSTRACT

Greater integration and automation of platform functions can be achieved with current and emerging technologies, which could radically improve ship control centre manpower utilization. The article looks ahead to the next generation of RN ships, discussing the requirement for greater platform integration and automation. It surveys some of issues which need to be resolved before this approach could confidently be adopted. These issues include the concept of an Integrated Platform Management System, safety, hardware and software standards, extension of system automation, flexible Man Machine Interfaces, improvements in system specificaton and changes in training policy.

Introduction

At a time when the latest RN ships are being accepted into service, it is appropriate to look ahead to the next generation warships to establish the broad requirements of the Platform Control and Surveillance Systems of these vessels. In doing so it is instructive to look at previous and current trends in Machinery Control and Surveillance (MCAS) System design to establish the impact of these trends on future systems.

These trends and the limitations of current systems help to determine the likely direction of future system design and the resulting procurement and design issues. These issues need to be resolved to reduce programme risk and ensure that future systems can be specified with confidence.

Current Design Trends

The evolutionary change in design of warship control and surveillance systems over the last 30 years or so appears to have followed broadly the same pattern in most NATO navies. Current RN new construction ships give a good indication of these trends and a pointer for the design of future systems. These trends can be seen by looking briefly at the design of the current major new construction vessels i.e. the Type 23 frigate[1], Single Role Minehunter (SRMH)[2] and Auxiliary Oiler Replenishment Vessel (AOR)[3]. These include the adoption of:

(*a*) *Distributed software based systems* which have to a large extent decentralized control to remote positions. Hard-wired control and surveillance signals have been retained for vital functions[1,2,3].

(*b*) *Integrated Ship Control Centre*, whereby all Damage Surveillance and Control (DSAC) and MCAS System functions have been integrated within a single large console to provide a more effective command centre. The MEO can from a single location have visibility of all functions[1].

(*c*) *Complex control systems*. The integrated nature of the Type 23 CODLAG propulsion plant has required greater integration of the control system with a consequential increase in the automation and complexity of the MCAS system[1].

(*d*) *Interface with Ship Combat System*. Where operationally required, a link has been provided between the Combat System and the Platform control system to enable automatic modes of control[2].

(*e*) *Reduced manning*. The Type 23 MCAS System has been designed to be operated by three watch-keepers in Defence State 3, which is a significant reduction from the numbers in the Type 22 Frigate. The AOR has achieved manning levels more associated with the merchant fleet, with the Machinery Control Room (MCR) capable of being unmanned whilst cruising and manoeuvring at sea[3].

(*f*) *Larger Systems*. A gradual increase in the size of MCAS Systems has been seen, that of the AOR[3] being the largest, with approximately 4000 control and monitoring input and ouput signals.

Development Constraints

The design of the current new construction ship MCAS Systems shows significant improvements over previous designs. These designs have been dominated by the need to adopt well-proven industrial technology to secure the high availability required of naval systems. Low risk technology has been adopted to secure the maximum benefits in development cost and programme timescales. In addition to technological constraints, procurement policy has had a dramatic effect. Whole ship procurement and the pressure to reduce costs, while undoubtedly reaping rewards in reducing ship procurement costs, has held down the scope of the MCAS Systems to the minimum. The main losers have been the operators who have not been provided with the many desirable facilities which would have improved operator efficiency.

As a consequence, within the wider context of the Ship and Platform System, interfaces with other systems or equipments have only been made on a strictly operational basis resulting in a largely piecemeal development of Platform Systems. In particular, the opportunity to transfer data between systems even at a most basic level has not been taken. Likewise, in the main, automation has been applied where required by the complexity of the plant under control rather than from a desire to reduce operator workload.

The current design philosophy for RN warships also seriously limits the further development of more intelligent systems. In particular it would be difficult to provide:

(*a*) *Integrated management systems*, which enable all platform data related to machinery operation and maintenance to be viewed, analysed and manipulated to enhance overall management.

(*b*) *Optimized ship control philosophy*, to provide optimized and adaptive ship and machinery control performance for various operational and environmental conditions.

(*c*) *Centralized knowledge based systems*, which provide enhanced decision aids for both operators and maintainers.

(*d*) *Further manpower reductions and/or improvements in efficiency*, due to the design limitations of current Man Machine Interfaces.

Further Design Pressures

In addition to current trends, other external pressures will motivate further change.

Demography

It has been suggested that the factor which will call for the greatest change in design philosophy is the so-called demographic trough. Warnings have been given in the UK of the effects of demographic trends resulting from the fall in birth rate during the 1970s. The UK is not unique in this respect, West Germany, Italy, France, and other European nations all recording sizable reductions in the number of school leavers by the year 2000. Further social changes and the expansion of the economy, with the consequent increased demand for talented and qualified young people will put additional strain on the recruitment of naval engineer officers, artificers and other ranks.

The likely effects of demographic trends on recruitment and retention have been studied and measures taken to reduce the effects of the trough. Even with these measures it is likely that there will be increasing pressure on recruitment and retention. Therefore further measures may need to be considered to reduce ship manning levels.

Putting aside demography, in strictly economic terms it makes sense to reduce complements to reduce through-life costs and ease the pressure on the defence expenditure. Further small reductions in Marine Engineering staff would be possible given the current state of technology but there would be a need to consider the wider consequences for ship operation. Radical reductions, whilst they may be feasible on paper, would require major changes in operating philosophies and manning structures.

The trend towards further reductions in complement is set to continue over the longer term, with a continuation of previous trends and a gradual reduction in complement in each succeeding class. In the short term, radical reductions are unlikely.

Integrated Ship Machinery

The adoption of more integrated ship machinery systems could have a major influence on the design of control systems. This and the desire to provide optimal control philosophies to improve ship performance would lead naturally in the future to more complex MCAS Systems, with greater levels of automation and integration.

Developments in Industrial Control Systems

Previous MCAS System designs have been dictated to some degree by the design philosophy and technology adopted by industry. Industry is already using or developing more Integrated Control systems in many forms, replacing hard-wired control systems with those based on data transmission systems. Several hardware advances are taking place which will remove the engineering restrictions encountered in the past with integrated computer control and monitoring systems. The most notable of these are the current improvements in data transmission design, the increasing power of microprocessors and the rapid advances in the design of efficient Man Machine Interfaces. Thus within a short time, the technology to significantly enhance platform control and surveillance could be readily available at reasonable cost.

Future Direction

Based on the broad analysis of the design pressures and current trends it is possible to determine the likely direction of future system design development. This review will be restricted to so-called near-term systems, for ships with an in-service date early in the next century.

Integrated Platform Management System (IPMS)

Further reductions in ME department manning and/or increase in efficiency and effectiveness can only be achieved by considering the platform on a 'system basis' at the earliest stage in project development. System functionality should be improved by automating relevant tasks, further improving MMIs and ensuring that sophisticated Engineering Management aids are provided. All these aspects can be provided if sufficient consideration is given at the concept stage and they survive the inevitable pressures to reduce Ship Unit Production Costs.

To provide a focus for these developments it is helpful to consider these design issues under the collective title of the Integrated Platform Management System (IPMS). There is perhaps no definitive definition of IPMS; however it is generally accepted to refer to the integration of the Platform control and surveillance functions into one system such that more efficient management of these functions can be advanced by marine engineering staff.

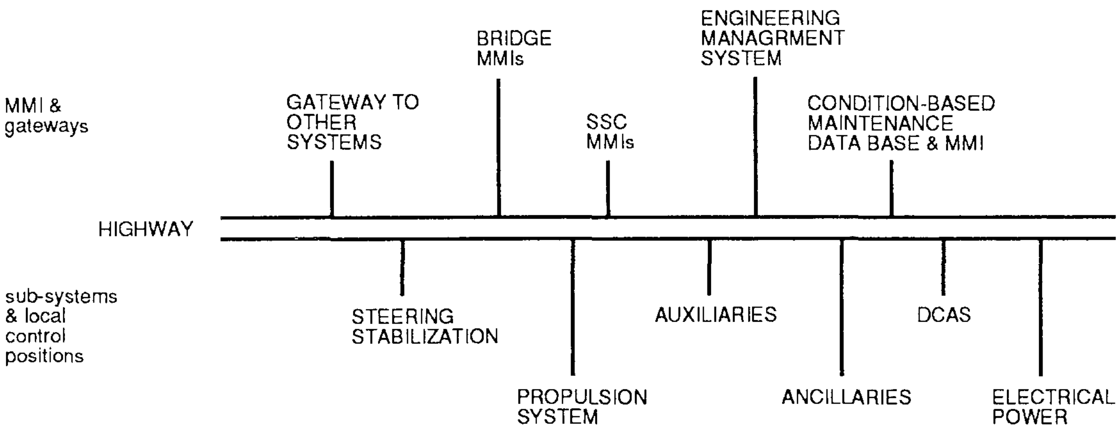

FIG. 1—INTEGRATED PLATFORM MANAGEMENT SYSTEM

DCAS: Damage Control and Surveillance
MMI: Man Machine Interface
SCC: Ship Control Centre

The real benefits of IPMS stem from the ability to transfer and manipulate data, i.e. the application of information technology to the marine engineering function. Central to this is the ability to transfer data automatically to other systems and the provision of intelligent displays or MMIs to enable storage and presentation of information in a user-friendly manner. Of primary importance is the interfacing or integration of platform control and surveillance with an Engineering Management System. The latter would encompass a maintenance management system, an Integrated Condition Monitoring System (providing on-line and manual data collection and handling facilities), OASIS (On-board Automatic Data Processing Support in Ships and Submarines), etc.

The degree of integration is a debatable point and at its fullest could include all Platform Systems and also the Engineering Management System. The scope of the system would be dependent upon the analysis undertaken during ship concept and feasibility studies.

To implement such a system would require systems or equipment to be interconnected by some form of data transmission system or highway. Individual systems and equipments would be connected to the highway through standardized local data collection units, operator access to the system being provided through flexible VDU-based MMIs (FIG. 1).

The move to an IPMS concept is seen as a logical evolution of current control and surveillance methodologies. The IPMS solution to platform control and surveillance, although possibly increasing development and production costs, will provide a more efficient and effective system. This will lead to the opportunity to reduce the man-hours involved in the operation and maintenance of the Platform, resulting in through-'`fe cost savings.

Man Machine Interface

To date, RN surface ship MCAS System information has been presented to the operator in a largely traditional manner. The use of discrete display devices and the general organization of information on purpose-built consoles has evolved from the Machinery Control Room (MCR) era to the current combined MCR and Damage Control Headquarters termed the Ship Control Centre (SCC).

The Type 23 has taken this a stage further by providing a large multifunction console and supervisors' console. Although much has been achieved with the Type 23 design it does not have the flexibility provided by a design based on multiple VDUs such as the Canadian SHINMACS (Ship Integrated Machinery Control System). Flexible MMIs are seen as one of the principal components of an IPMS design. It is therefore envisaged that future MMIs will rely more heavily on colour VDUs. This approach would provide a significant additional degree of flexibility, enabling the MMI to be more effectively designed to match the skill of the operator and filter out unwanted information. It would provide a firmer basis for the introduction of Intelligent Knowledge-Based Systems (IKBS) techniques if deemed necessary and would be more in tune with the general trends toward this approach in the control industry.

Issues to be Resolved

The concept of the Integrated Platform Management System raises a number of issues which need to be resolved before an IPMS approach could be confidently specified for future ships. The main issues are discussed in the following sections.

System Approach

Hitherto platform systems and equipments have largely been designed on a piecemeal basis. The advent of an IPMS concept will require a greater systems approach during specification, development, implementation and through-life support than has previously been the case. The design of individual sub-systems and equipments encompassed by IPMS must also be subject to this systems approach. This requires the development of a wide-ranging IPMS acquisition strategy to establish the policies and procedures to design, document and control all aspects of the IPMS design and implementation covering the total life of the project. It is possible that this will demand a change to current procurement policy and practices, the most significant change being made at the specification stage.

The initial (perhaps obvious) step is to recognize that IPMS involves a significant change in complexity and in the number of interfaces, which demands a change in management approach; further, it must be recognized that IPMS is yet another system within the overall warship design and cannot be developed in isolation from other systems. A top down systems approach needs to prevail in all aspects of ship and system design. This requires a more formal and therefore hopefully more complete method of specification to be undertaken.

A start has been made in this direction with the publication of Sea Systems Controllerate Publication (SSCP) 27, Machinery Control and Surveillance System Specification Guide, which, in addition to providing a framework for future specifications, recommends a top down approach and the use of structured analysis techniques[4].

IPMS will require much more consideration to be given to requirement elicitation at the early specification stage. While considerably less complex than a modern Combat System, IPMS has many similarities when attempting to define system capabilities. The techniques and tools being developed mainly for Combat Systems could be applied to the IPMS specification process.

The requirement specification for an IPMS needs to define in a complete and unambiguous manner the total functional requirements. Additionally it needs to define how well (in quantitative terms where possible) these functions are to be performed. Once specified, the systems approach needs to be followed during design, development and implementation. This requires careful consideration of the procurement strategy and the division of responsibility within the total warship procurement. The IPMS Systems Manager should be given total responsibility for the system which would include integration responsibility for all platform electrical and mechanical machinery.

Safety

The safety of the plant and personnel needs to be given the highest priority. The increasing use of computers within Platform Control and Surveillance in general, and within IPMS in particular, raises a number of safety issues.

In the design of MCAS Systems it is current practice to separate primary controls, primary surveillance, secondary control and secondary surveillance, in order to ensure the appropriate levels of ship, plant and personnel safety. This is in line with the general principle of avoiding common mode failures and is also in general agreement with the design principles exemplified by the registration requirements of the classification societies.

It was suggested earlier that IPMS could be assembled as one large system with control and surveillance signals passing along a common highway. As this is contrary to current design practice some rationalization of these conflicting concepts is required. This issue has been raised at a time when the subject of safety critical software is being given additional impetus with the issue of the Health and Safety Executive Guidelines for Programmable Electronic Systems[5] and Interim Defence Standard 00-55[6].

Ministry of Defence policy for the procurement and use of software in safety critical applications will be stated in Defence Standard 00-55. The main requirement of this standard is that all safety critical software is to be formally specified in a concise and unambiguous mathematical form. This standard is currently available as an Interim Defence Standard, which has been subject to much debate and comment, and it provides a yardstick in an area where few standards have previously existed.

A companion Defence Standard 00-56[7], which addresses the identification of safety critical components (not just software) has also been issued as an interim standard. This details the methods of hazard analysis to be used to identify and assess the safety critical features of a system. It details the hazard analysis activities that should be undertaken at each life cycle phase to ensure rigid documentation of the risks and measures taken to reduce them. It is beyond the scope of this article to cover the requirements of this standard and of Def Stan 00-55. However, it is clear that whether or not safety critical components are contained within an IPMS a Preliminary Hazard Analysis will be required. If this is undertaken, the analysis would be seen as the main vehicle for determining the safety of IPMS.

The presence of safety critical software within IPMS will invoke the rigorous standards of Def Stan 00-55 and would have a significant effect on system cost. At first sight a design strategy that eliminates the need for safety critical software may seem attractive. To achieve this could require reducing the level of automation, versatility or functionality of the system or alternatively requiring that additional supervisory safety systems (e.g. hardwired or non-programmable systems) are provided. A balance must therefore be struck as a result of the Preliminary Hazard Analysis, taking account of the cost, manning level and performance requirements of the system.

Undertaking a hazard analysis is not a small task, even at the preliminary stage. Although an IPMS would not in itself introduce many hazards, it has control over a number of potentially hazardous equipments. The preliminary hazard analysis must therefore be extended to include these equipments. This considerably increases the scope and complexity and hence the cost of the task. A balance must therefore be struck between the cost and scope of the analysis and the possible legal, safety and moral implications of not totally complying with the standard.

Software Standards

It has been a requirement for some time that all software in Platform Marine systems and equipments shall comply with Naval Engineering Standard (NES) 620[8] and that software development shall be carried out under approved quality assurance conditions.

It has been MOD policy from 1 July 1987 that Ada is the single preferred high level language for Defence equipment[9]. The design of current new construction warship MCAS systems was started before this date, so that the question of the use of Ada for MCAS systems has not yet been fully approached. Although issued as a policy statement applicable to all projects, it has tended in the intervening years to be left to individual project managers to determine the precise policy for their particular systems and equipments. This has arisen among other things because the Ada Programming Support Environment was slow to mature. It has also been suggested that part of the problem has been the doubt on the real-time system performance of Ada[10].

It is stated that the principal benefits of Ada will be realized over the longer term, where Ada will reduce system maintenance costs and reduce future system cost through reusable software modules. For IPMS and MCAS Systems, this raises the real possibility of re-useable software, as the functionality of these systems could be seen as being broadly constant for each succeeding system. However to be completely successful this will require the creation of a software module library over which the MOD would retain the necessary intellectual property rights.

This leaves the use of Ada in future IPMS still in doubt. As the policy has been set there will be increasing pressure to ensure that projects conform. Future IPMS Specifications will at least need to include the requirement for bidders to quote for an Ada solution, as well as for software to good commercial standards.

Data Transmission Standards

One of the major issues to be resolved for IPMS is that of data transmission and communications standards for the Platform highway or Local Area Network (LAN). It is beyond the scope of this article to discuss this in detail, but so far as possible these should be based on the International Standards Organisation's Open System Interconnection (OSI) Basic Reference Model[11].

The standards to be adopted need to be selected from the relevant commercial and military standards taking into account the required real time performance requirements, the need for high integrity and requirements for special functions. The LAN's physical layer should be selected from current proven systems supported by industry.

Data transmission rate, bandwidth and system response times for IPMS will be very much lower than that required for Combat Systems. However savings could be made by adopting a whole ship approach to data transmission standards particularly where the ship operational requirements call for a sophisticated interface between IPMS and the Combat System.

Automation

RN ships have achieved a high level of automation and remote control. The Type 23 and SRMH have extended this, as described above. Remote control and later extensive automation has mainly been motivated by:

(*a*) The need to control machinery from a central position within a gas-tight citadel with unmanned machinery spaces.

(*b*) The complexity and speed of response required for the control of modern ship machinery.

To a limited extent automation has been undertaken to reduce watch-keeping tasks, although the main thrust has been to provide more sophisticated remote surveillance systems. Indeed part of the on-going improvement of in-service ship MCAS Systems has been the upgrading of surveillance equipment with modern digital surveillance systems[12]. Further automation, other than that required by the introduction of more complex and integrated machinery systems, will only be undertaken as a result of the cost savings realized through real reductions in manpower.

It is evident that much more could be done to reduce operator workload. Simple, often manpower-intensive tasks have not been automated because they do not fall within the criteria set out above. Whilst a fully automated system of the sort adopted in the commercial fleet would not be appropriate for a warship, much more could be done given the necessary impetus. A sensible balance needs to be struck between automated and manual systems, so that the benefits of automation are achieved whilst maintaining the flexibility of manual systems. This inevitably will require an examination of cost-effectiveness (in terms of through-life costs), viability in all ship operating states, safety, flexibility and operational requirement. A blanket approach cannot be taken to automation. Each system or sub-system needs to be examined to determine the optimum level of automation.

Shore-Based Reference Facility (SBRF)

With the advent of software-based MCAS systems, the requirement for prototyping and Shore-Based Reference Facilities has become much greater. For the Type 23 MCAS systems and the SRMH Ship Positioning Control System (SPCS), it was agreed that independent assessment programmes should be undertaken[13,14]. Based on the success of these projects it is recommended that future MCAS systems development programmes should include the requirement for a Shore-Based Reference Facility (SBRF).

The case for an SBRF becomes stronger when an IPMS approach is considered. The size and complexity of IPMS with the larger number of interfaces to other systems will require comprehensive testing facilities to assist in the development, commissioning, acceptance and through-life support as part of an overall Integrated Logistic Support (ILS) strategy.

As with the Type 23 and SRMH Assessment projects the SBRF should be established using computer simulation at plant or data transmission level. Various options are open for its location and procurement.

Human Factors

Flexible MMIs using colour displays are not new to the RN. They are used in many weapon systems and are being provided as part of the Decca Isis

250 surveillance system and the AOR MCAS system. However it is a significant departure from previous design methods to require special attention to human factors during the specification and procurement phases of the future ship project.

A structured Human Factors programme should be undertaken starting at the concept stage and carried through each phase of procurement. This programme would need to be tailored to the specific requirements of the IPMS design but would be based largely on the structure provided in the MOD guidelines on this subject[15,16].

The design of the SCC and the IPMS MMIs would be heavily dependent on the agreed manning levels and assumed operator skills established by the Staff Target and Staff Requirement. Therefore it would be inappropriate to have fixed views on the design at this stage. However some broad principles can be set out as follows:

(*a*) The SCC should be optimized for action state operation.

(*b*) The benefits provided by large mimic panels in giving a quick overview of the total plant should not be lost. A mixed technology approach, part mimic part VDU, would provide an ideal solution.

(*c*) Particular attention needs to be given to the design of the Supervisor and MEO positions to ensure that they retain the necessary command overview.

Training

Another benefit of flexible MMIs is that they enable some form of on-board training to be conducted. It has become common for weapon systems to have training simulators built in to the MMI. This has not been possible in the Marine Engineering area, where the need to provide vital control and surveillance functions (even when alongside) and the use of inflexible MMIs have precluded this form of training.

On-board training could be provided during quiet periods using one of the unused MMIs, while vital control and surveillance functions are provided by one or other of the consoles. This training would form part of continuation training, reinforcing that provided during pre-joining training (PJT). It has been suggested that there is a greater need for this type of training where more automated systems are used. The concern is that with a more automated IPMS the operator will become too heavily reliant on the MMI and lose the mental model of the ship system currently required of more manual control methods, this knowledge being primarily required during reversionary modes of system operation. Therefore it is important that training reinforces System knowledge of the ME equipment. The types of training that need to be provided are:

(*a*) Training on Ship Marine Engineering Systems.

(*b*) Procedural training on machinery breakdown, including reversionary control.

Systems training would be the easiest to provide, being merely a form of Computer-Based Training (CBT). It may be possible to provide on board the same courseware provided by the shore CBT system. If on-board training were restricted to this type of training it would probably be more cost-effective to provide it on a separate PC outside the SCC. This could be used for a wide range of CBT packages applicable to training throughout the ship. Procedural training could only be covered effectively on the SCC Console and would require a means to isolate the console from the ship systems during training. This raises both personnel and system safety implications which need to be thoroughly examined before it could be implemented. It must be emphasized that an on-board simulator would not replace the need for shore-based facilities. This brings into question the cost-effectiveness of sophisticated on-board training. It is clear that a sensible balance needs to be struck. At a minimum, on-board CBT could be provided very cost-effectively on a separate PC.

Conclusion

Development of an IPMS concept for next generation surface ships is seen to be following previous and current trends towards more effective use of manpower for Platform Control and Surveillance. Progress towards this concept should be gradual in order to reduce programme risk to a minimum. Where possible, advantage should be taken of proven military and industrial experience and standards, to provide cost-effective, safe and reliable systems.

The form of IPMS has yet to be decided, it being a function of many factors including target manning levels, safety considerations, acquisition cost and through-life costs. The design of an IPMS cannot be isolated from that of the ship and other systems. Therefore a whole ship system approach needs to be taken throughout the procurement cycle.

Although the system can be designed within the constraints of current and emerging technology, it is the management of the system specification, development and integration that presents the greatest risk and challenge. To meet this challenge will require the adoption of more formal specification and design techniques by both the MOD and industry, and the recognition of the special nature of this approach.

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