A DISCUSSION ON FUTURE MACHINERY CONTROLS AND SURVEILLANCE TRAINING IN THE ROYAL NAVY

BY

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ABSTRACT

The aim of the article is to promulgate some thoughts on and to generate discussion of the future of shipboard Machinery Controls and Surveillance (MCAS) training in the Royal Navy. The objectives of MCAS systems and the training of personnel associated with them are to promote safety and efficiency. A brief exposition of the perceived Platform Management Systems (PMSs), and a description of the staff composition of an envisaged Unified Warship Engineering Department (UWED) with technical responsibility for all ship borne systems are given. The requirements for such future MCAS systems training are outlined; this commentary is then extended by hypothesising about the training philosophy that might produce the optimum training environment. Some future MCAS systems training concepts are discussed. A possible procurement strategy that is compatible with such future training concepts is sketched out. The main conclusions drawn and recommendations made are:

1. Ship's engineering staff should be regarded as an integral part of the plant
2. The design and operation of PMSs is at the heart of the safe and efficient warship
3. The feasibility of concepts such as the UWED and the utilization of novel technologies should be thoroughly explored
4. The design and development of MCAS systems parent equipments and the associated teaching aids/training equipments should be simultaneous and integrated.

Introduction

Safety and efficiency are both essential ingredients of an effective warship. SHANKARARAMAN and LEE[1] identified direct correlations between operational safety and performance with training; and BICHAT-GOBARD[2] quantitatively demonstrated the importance of good quality practical training to watchkeeping safety.

The nature of this subject matter of Machinery Controls and Surveillance (MCAS) systems training involves a wide range of topics, such as vessel purposes, ship design, operational procedures, training philosophy, operator performance monitoring, procurement considerations, etc.

Safety and efficiency do seem to have strong positive correlations, thus:

- Unsafe plant can be prone to higher risks of adverse operation
- Consequent damage could well reduce availability (for repairs, etc.) and/or de-optimize the plant, therefore impairing performance
- Hence, poor safety can manifest itself as inefficiency, which leads to:

=> safe design ≡ efficient operation.

However, these two concepts are arguably opposed to each other. For example, efficiency often implies the reduction of resources (both financial and personnel, which are linked in ship design); this could well degrade safety, especially if proven supporting technologies are not installed in the plant to suitably compensate, and this clearly requires the finance for necessary procurement. Therefore, it follows that

=> efficient design ≡ operating with minimal <u>acceptable</u> safety.

The personnel who operate and maintain the constituent equipments should be regarded as an integral part of the parent plant; the Man/Machine Interfaces (MMIs) can be considered as the engineering joints between the ship systems and the humans. Therefore, striving for safety and efficiency in both fundamental design and operation for the optimum performance is applicable to both machinery and personnel. Such optimization is achieved through:

(*a*) Setting to Work (STW) and 'tuning' processes for equipments and systems (usually executed by humans and machinery); and

(*b*) The training of ships' staffs (which fulfils the analogous role) for the human elements of the plant.

Platform Management Systems (PMSs)

Interpretation

PMS is commonly perceived as the hardware and software associated with the MCAS of the Marine Engineering (ME) equipments and systems. In RN warships this function is concentrated in the Ship's Control Centre (SCC) from where a Cruising Watch (of approximately 5 Watchkeepers) is coordinated to interact with either Remote Control Panels in the SCC or Local Control Panels (LCPs) in the machinery spaces to:

- Oversee plant safety
- Operate machinery
- Conduct running maintenance
- Monitor plant performance
- Execute 'first aid' action to emergencies (e.g. fires and floods, etc.).

However, the definition of PMS should ideally encompass:

- Navigational systems
- Weapons systems
- Logistical support
- The ship's company.

Goals of PMSs

The ultimate PMS could perhaps yield unmanned ships, although this seems to be some way off from the present. However, the general trend in both the Merchant Navy and RN is to significantly reduce the size of ships' staffs due to the implementation of automatic controls systems. (This phenomenon is discussed in detail by SMITH and BURNOP.[3]) Although economics is often the governing consideration here, its full effects are tempered by other factors in warship design and operation, such as:

(*a*) Availability, Reliability and Maintainability (ARM).

(*b*) 'fightability'—personnel are required to make immediate repairs during action in order to sustain operational capability.

(*c*) Survivability—ships' companies must conduct fire fighting, leak stopping and shoring operations as required.

(*d*) Safety—unmanned vessels carrying weapons may well be considered environmentally and politically unacceptable.

It is reasonable to assume that future PMSs will be more sophisticated with significantly larger spheres of influence over on-board activities. Such developments will change ship designs, manning levels and the type of people who will become seafarers.

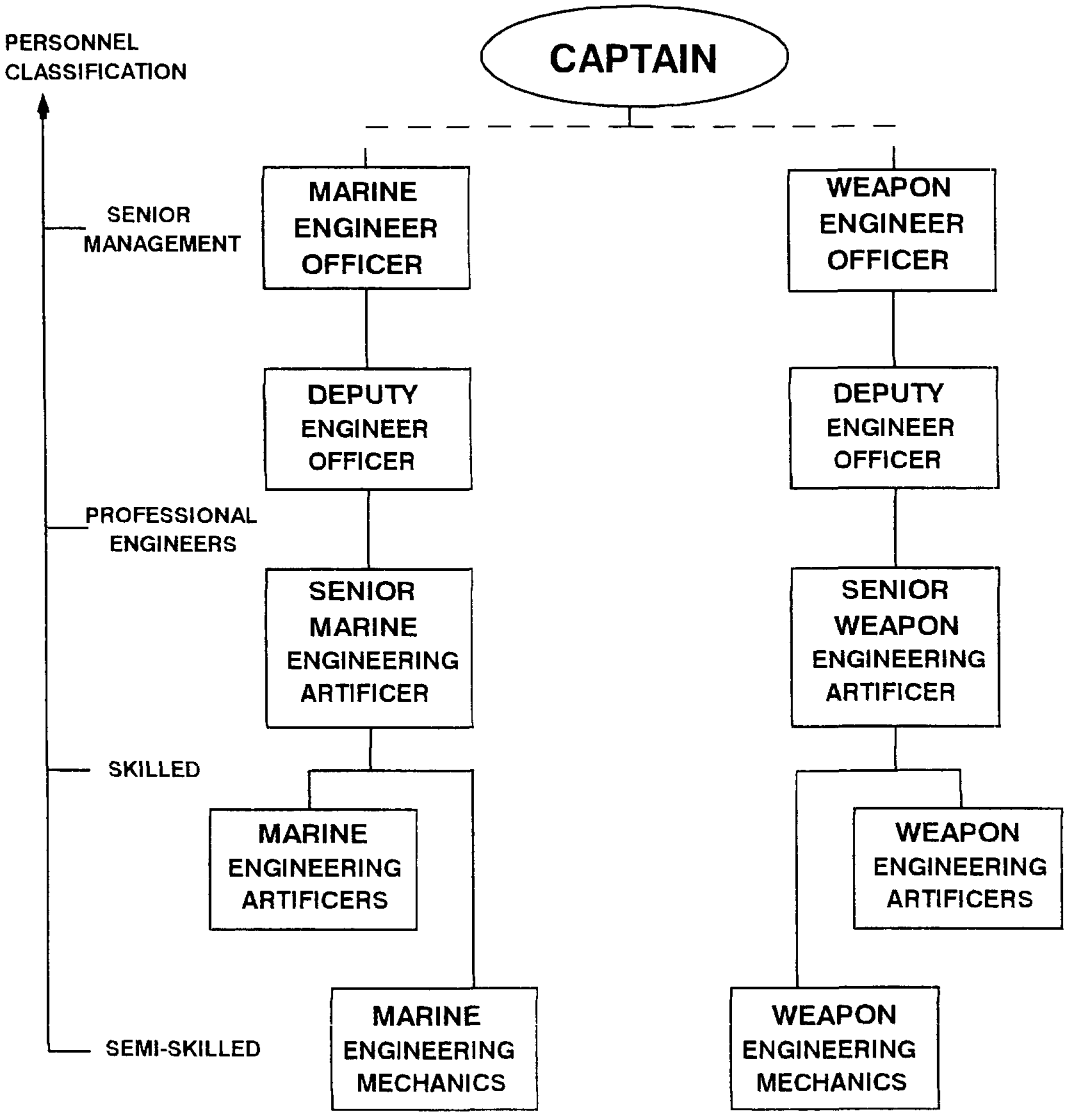

FIG. 1 — THE CURRENT STRUCTURE OF ENGINEERING DEPARTMENTS ON BOARD FRIGATES AND DESTROYERS

The Unified Warship Engineering Department (UWED)

(FIG. 1) illustrates the current structure of the Engineering Departments (EDs) onboard typical RN major warships (such as frigates and destroyers). (FIG. 2) shows a possible future Ship Engineering Department that could be the result of PMS developments in the medium to long term.

For this UWED to be workable, safe and efficient, the associated PMS must be sufficiently:

- Intelligible
- Manageable
- Reliable
- Adaptable/flexible
- Maintainable
- Modifiable

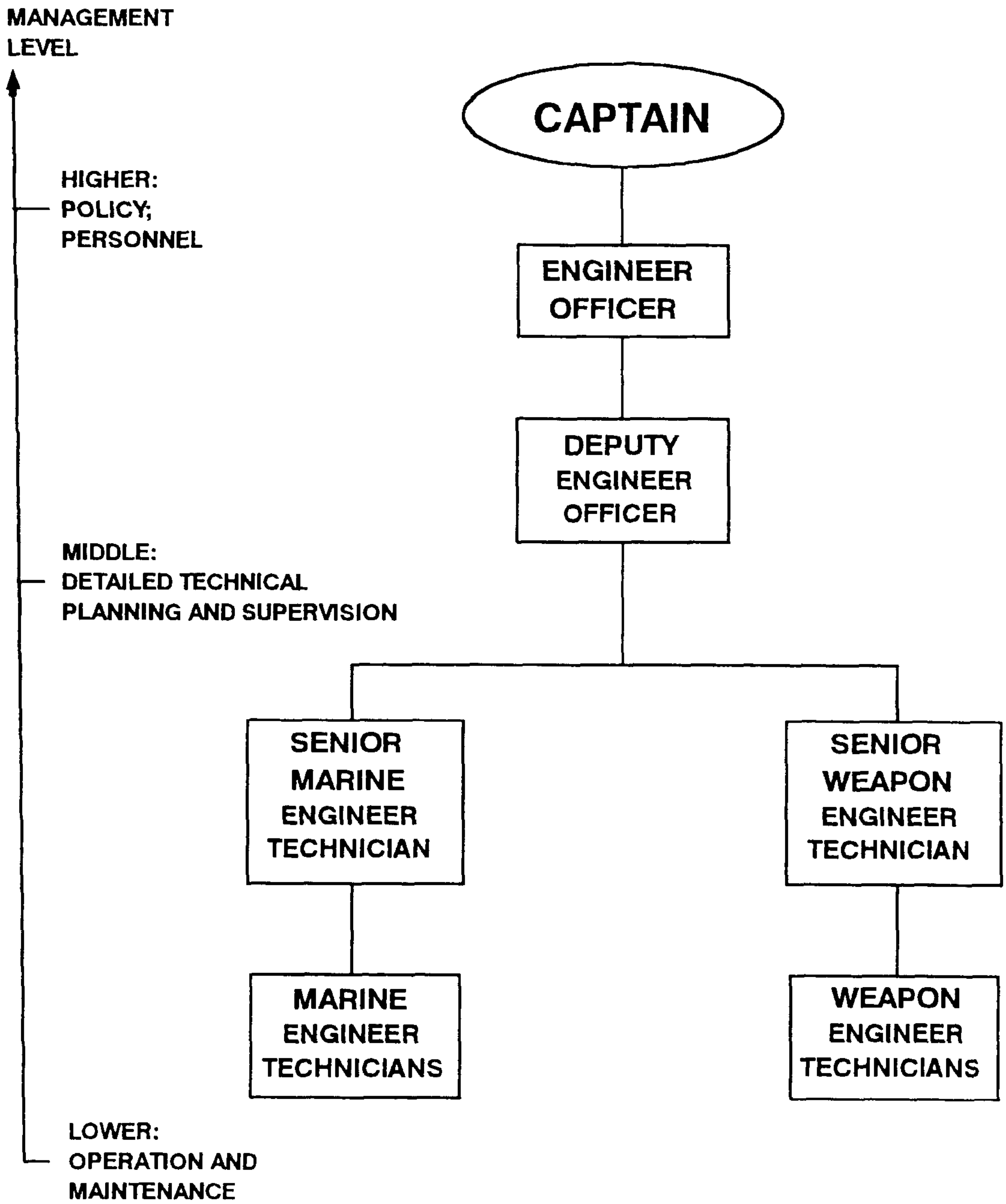

FIG. 2 — A POSSIBLE FUTURE SHIP ENGINEERING DEPARTMENT STRUCTURE

Thus enabling the Engineer Officers (EOs) to have the confidence to concentrate on the higher level management tasks (such as ED/Command liaisons, policy making, personnel, etc.) without being overly burdened with 'nuts and bolts' engineering with only a small supporting staff.

The implementation of such PMSs will have a profound influence on the type of training that ships' companies will need. Perhaps the biggest change will be the fundamental engineering education of EOs. A good understanding of mechanical, electrical and electronics engineering will be necessary by **all** EOs so that they can operate as effective systems engineers. In fact, this type of education is required for the practical development, application and intelligent acceptance of PMSs.

Training Requirements

This discussion will now concentrate on ME type MCAS systems. RN personnel will require theoretical and practical training in MCAS procedures and maintenance, and a relatively small population will need to acquire a good appreciation of the associated design and development methodologies. Procedural training must give watchkeepers practice at:

- Operating switches, buttons, levers, dials, etc. in the correct sequence with sufficient dexterity and speed.
- Reacting to warnings and alarms.
- Reading and interpreting data displays.
- Communications (particularly voice procedures).
- Directing watchkeepers.

These functions must be executed safely and efficiently in normal, emergency and action (i.e. battle) situations and should therefore be practised to the extent that gives the Command a high degree of confidence in its ME watchkeepers.

MCAS systems maintenance training must offer personnel practice at:

- STW procedures.
- Routine calibrations and performance checks.
- Very importantly, diagnostic information interpretation for fault finding/trouble shooting.

This type of training should include the cognitive aspects of maintenance and the facilities to acquire the skill of hand required for effective use of test equipments, repair apparatus and the handling of delicate and/or sensitive equipments.

Academic and vocational courses can give engineers the basic intellectual skills required to understand MCAS systems design and development philosophies. However, only by actually designing or being directly involved in design and development processes can a full appreciation be gained (and therefore effective MCAS systems design and development training be considered to have been achieved). This aspect of training is particularly important in procurement work since it underpins intelligent and fair engineering judgements. Seconding suitably qualified and experienced EOs to industry as part of their career development is a way of achieving this with mutual benefits to the RN, industry and the EOs.

Training Philosophy

Boundaries

Broadly speaking, two extremes in training philosophy can be identified:

1. Verbal descriptions supported by basic visual aids (e.g. blackboard and chalk).
2. Executing operations in the real environment (i.e. gaining experience, On the Job Training (OJT), etc.).

The latter extreme implies that personnel never actually cease to be in 'training environments', and that the operational and training scenarios merge. However, a noteworthy difference between these two types of situations is not so much their levels of realism (which may be very similar) but the degree of control over events (independent of circumstances) that can be exercised. The optimum training environment will be a mixture of these two extremes, (FIG. 3).

Poorly designed training programmes can produce undesirable differences between training and operational procedures which might drive a philosophi-

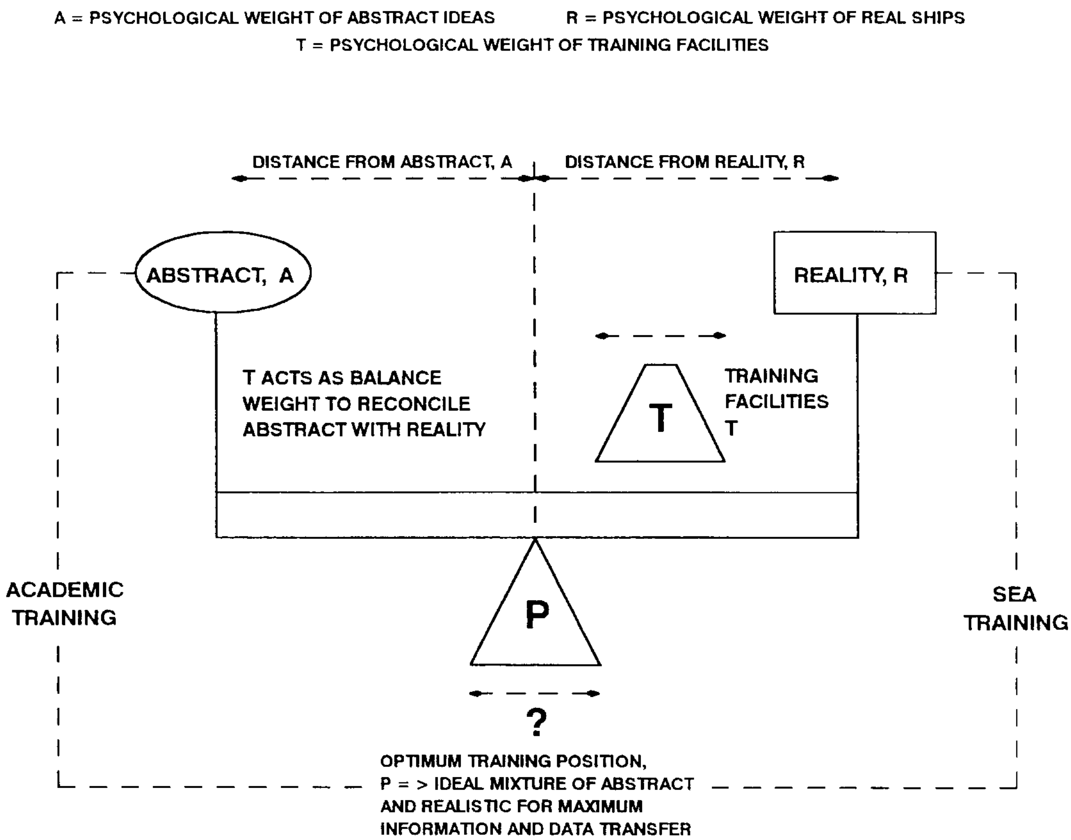

FIG. 3 — A SCHEMATIC FOR A TRAINING DESIGN PHILOSOPHY ANALOGY

cal wedge between the training and operational environments. This can manifest itself as experienced operators doubting training validity and despising the trainees and their trainers. Considering the training of ships' companies as an integral part of the operational environment should eliminate many such prejudices providing due care is taken to safeguard the operational effectiveness at all times.

Application to MCAS systems training

Dedicated training ships in which personnel can practise all procedural and maintenance operations on specially adapted hardware and software to enhance training value is an ideal. However, economic and safety considerations preclude this. Therefore, alternatives must be sought to ensure that the RN has well prepared personnel on board its vessels in order to guarantee the highest levels of safety and efficiency which are commensurate with the required operation capability. Some of the possibilities for achieving and improving these states of readiness are explored in the proceeding discussions.

FUTURE TRAINING

Computer Based Teaching/Training (CBT)

CBT offers significant advantages over more conventional media, such as textbooks, etc. For example:

(*a*) Improved levels of sophistication, i.e. interactiveness and consequent stimulation through high quality graphics (which also encourages students to study).

(*b*) Increased efficiency of self-tutoring and automatic performance monitoring.[4]

(*c*) More effective use of space (particularly important on board warships).

(*d*) Ease of updating information and data.

Such benefits are likely to promote more extensive use of CBT. Personal Computers (PCs) are commonly used to implement CBT (for example, see KLUJ[5]). However, policy-makers should appreciate that this style of training is normally restricted to so called 'Part-Task Trainers', i.e. the full scope of training required for engineering jobs cannot usually be accommodated by these sorts of equipments. Furthermore, even very good MMI design is unlikely to replace all the advantages of information transfer from human to human.

Simulators

General

RAY[6] gives an interesting discourse on the effective use of simulators in marine engineering against the backdrop of reduced manning and increased automation on board ships. Simulators have applications in training:

- Procedures
- Maintenance
- Management[7]
- Design and development investigations.[8]

Simulators can be designed and built to yield attributes such as:

(*a*) Good comparisons with reality at acceptable costs.

(*b*) Enhance training value by introducing greater flexibility, freedom and safety compared to practising on unadapted equipments and systems.

(*c*) Automatic performace evaluations as an aid to assessments of watchkeepers' operational abilities.[9]

Some Design Considerations:

(*a*) Boundaries

The training objectives must be prioritized, and the spheres of influence of the various tasks need to be scoped.

(*b*) Scale

The physical dimensions and the simulation time bases should be chosen to optimize training value.

(*c*) Fidelity

The accuracy of emulation in terms of functionality and physical similarity acceptable to meet training objectives should be established as early as possible.

(*d*) Economics

Availability of funds and time, simulator life expectancy and usage rates, and capabilities to accommodate future modifications have to be accounted for.

Fidelity

The effects of simulator fidelity on training and the validity of consequent performance assessments are discussed by Barnett.[10] Exact behavioural, physical and environmental replication of reality is not necessarily required (or perhaps desirable) in order to produce effective training facilities.[11]

However, there must be sufficient similarity between the simulator and reality such that students can:

(*a*) Easily recognize the relevance of their training.

(*b*) Simply translate between the training environment to shipboard scenarios.

(*c*) Apply the acquired knowledge and skills with no confusions arising from the imparted training.

Trainees become part of this simulation environment and will naturally react to the physical stimulus surrounding them. (The Danish Maritime Authority have put great emphasis on the emulation of machinery space ambient noise, temperature and humidity.[12] This approach familiarizes students with the seagoing marine engineering environment, and thereby induces the required stress levels, but it is perhaps extravagant for pure procedural and maintenance training.) Simulated noise could be useful as representative symptoms of correct or incorrect machinery operations; however, general background noise is unlikely to significantly improve the training effectiveness of simulators. Computer generated graphical representations often have significant advantages in terms of versatility and economy, however, their perceived attractiveness should be moderated by consideration of skill of hand training requirements commonly associated with maintenance operations; this might lead to hybrid hardware and software training facilities.[13]

High fidelity simulations (that is, emulations yielding true reflections of behaviour and very close physical resemblances to the associated controls devices) are required for training safe and efficient human interactions with controls devices which:

(*a*) Involve complex-interdependent-sequential operations.

(*b*) Include operators in the feedback loops (i.e. acting as moderators).

(*c*) The touch and feel affect time, magnitude and direction of output functions.

(*d*) Skill of hand directly influences the successful execution of operations.

(*e*) There are certain safety critical implications.

Some examples of these so called 'critical tactile' training areas for RN warships' MCAS systems are:

- Electrical switchboards
- Remote propulsion controls
- Some LCPs, especially for emergency operations
- Certain maintenance and calibration operations.

The Generic Simulator Concept (Fig. 4)

Historically the RN has procured traditional simulators specific to each class of ship.[14,15,16,17] These essentially consist of simulation environments constituting:

- Machinery control room or SCC
- Outstations, i.e. representations of machinery spaces
- Instructors' station and observation room.

This class-dedicated design approach has the advantage of relatively straightforward optimization of the simulation environment for a particular ship type; however, its main drawback is high expense in terms of initial procurement and through life support costs.

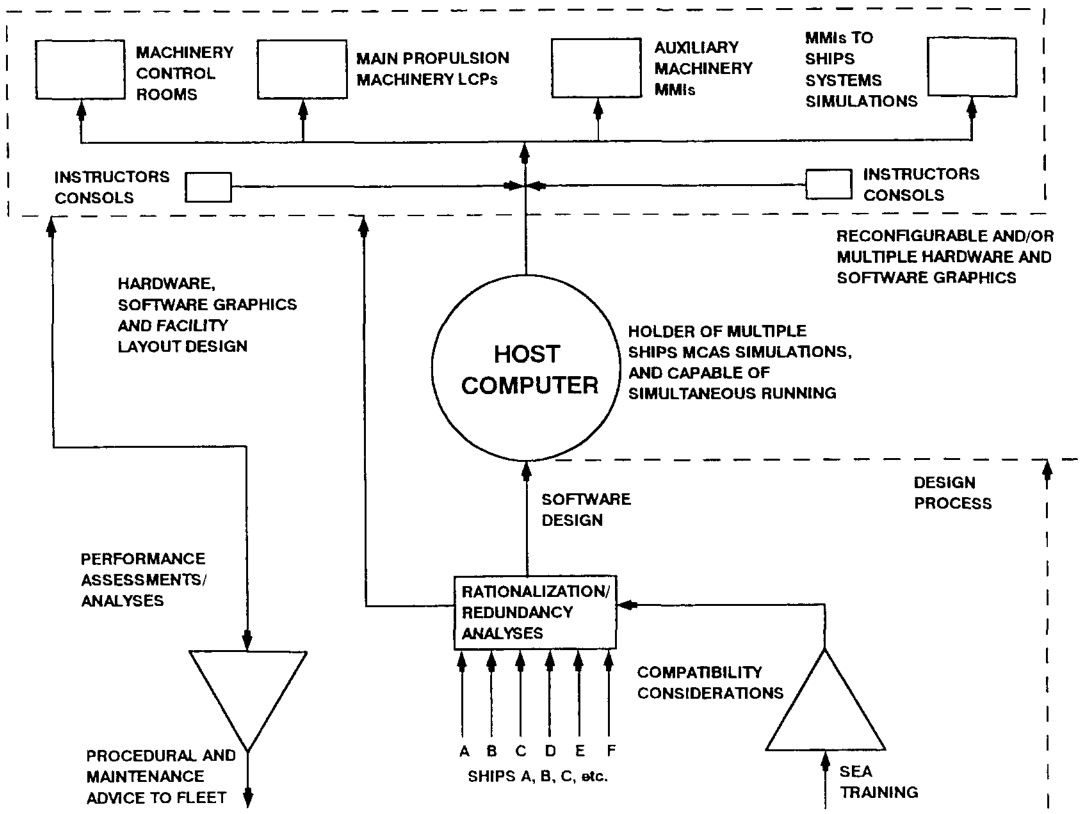

FIG. 4 — THE GENERIC SIMULATOR CONCEPT AS A SHORE BASED TRAINING FACILITY

In view of the fiscal constraints imposed on the modern RN, it is perhaps worthwhile considering implementing shore-based simulators with greater degrees of generic design, as illustrated in FIG. 4. Common aspects of plant operation and maintenance for various ship types could be analysed to yield acceptable generic physical similarities to the real controls MMIs. (Complicated reconfiguration of simulator hardware is undesirable due to the likely associated time consumption and degradation of ARM characteristics.) Modern software should enable a host computer to store a number of detailed class-specific mathematical models, thereby lessening the need for rationalization of behavioural characteristics of different plant configurations; the design process must ensure compatibility of particular computational models with the generic physical aspects of the simulator.

The PMS/Onboard Training (OBT) system concept (Fig. 5)

The integration of OBT with the PMS is discussed by Young,[18] and Shoben and Kasturi.[19] Fig. 5 schematically describes a proposed concept for integrating OBT with the PMS. (Table I summarizes some of the perceived advantages and disadvantages.)

Table I—*Some perceived advantages and disadvantages of the PMS/OBT system concept*

Advantages	Disadvantages
Optimize use of ships' systems.	Risks of ineffective or incorrect operation due to adverse mode switching, i.e. operational/ training signal data corruption.
Promotes greater familiarity with real systems.	Potential reduction of operational capability.
Training relates directly to ship environment.	Imperfect teaching environment
Operational staff train their own subordinates: —clearer communications —greater team cohesion.	Ships' staffs might not have aptitude for teaching/training
Improved continuity training.	Possible redundancy requirements could take up valuable space.
Command have more visibility of their staffs' training.	Potential conflicts between maintenance and training commitments could adversely affect training programmes.
Training design and supporting equipments more compatible with requirements of vessels.	Increased workload for ships' engineering staffs: —teaching —maintenance —training to train.
Effects of PMS design changes can be explored in actual shipboard surroundings	Reduced flexibility of Fleet in terms of training strength directly dependent on number of vessels
Minimizes logistical problems of transferring training, i.e. personnel travelling, etc.	Potentially higher ship initial procurement costs
Potential for reducing shoreside training costs	

Structure

The MCAS central computing facility deals with all aspects of running the plant, including training functions via the Training Interpreter that ensures controls signals are:

- Recognized as training directives
- Instructionally embellished
- Safe.

Operationally interpreted signals relate to the real control of the plant. The PMS MCAS sub-system is accessed by dual purpose MMIs which have operational and training functional modes. In the training mode, information, data and operator interactions form part of the plant simulation environment. Global and local safety interlocks safeguard the propulsion plant against reacting to the wrong type of signal by individually or collectively designating MMIs to the desired mode.

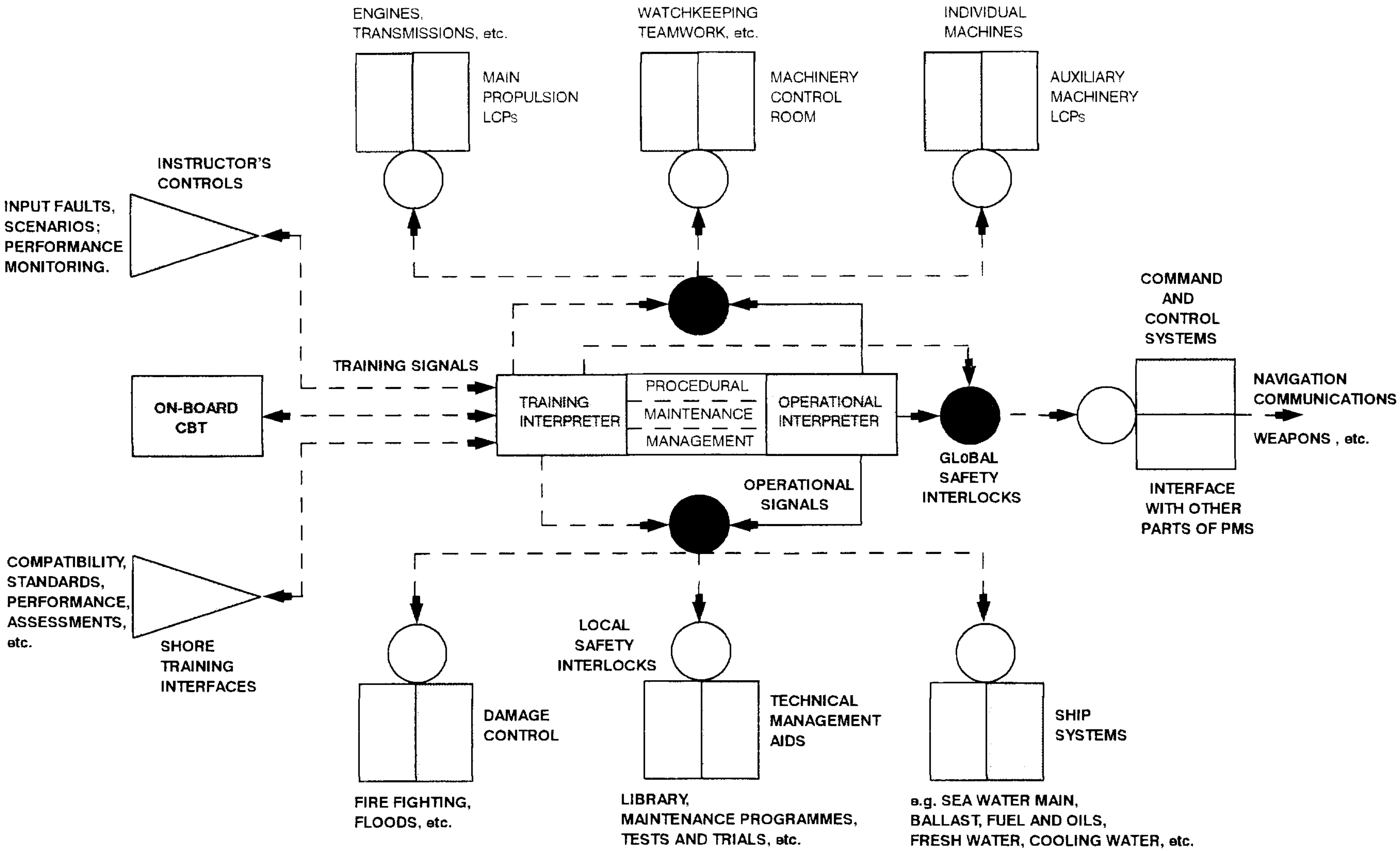

FIG. 5 — A SCHEMATIC OF THE PLATFORM MANAGEMENT SYSTEM/ONBOARD TRAINING SYSTEM CONCEPT

Perceived capabilities

This System will cope with operational and training signals simultaneously. The MMIs can function in training mode in the foreground (apparent at MMIs) whilst executing operational controls and surveillance in the background (unnoticeable at MMIs). Safety considerations demand clear promulgation of the active mode for MMIs, and that MMIs involved in training sessions whilst their associated machinery is still actually running can:

- Flag up real alarms and warnings
- Almost instantaneously mode switch enabling appropriate action to be taken in real emergencies.

Unwanted interruptions to training can be avoided by:

- Intelligent filtering of real warnings and alarms (i.e. incorporating decision-making algorithms to either activate awareness at a MMI or redirect them).

and/or

- Introducing some redundancy of MMIs.

Maintenance

This integration could possibly increase the maintenance loading on ships' staffs. However, promotion of commonality between operational and training systems will minimize any extra work and additional maintenance training required for the upkeep of the overall system. Also, training systems modifications will be done automatically and simultaneously with PMS revisions, thereby eliminating potential phase lags in training applicability.

Management

A reduction of Fleet running costs through the introduction of this style of training can only be realized by an associated restructuring of shoreside training philosophy. OBT could accommodate staff familiarization with PMSs and practice in essential procedures prior to novel ship classes, new builds or refitted ships becoming operational; however, non-operational periods associated with such activities would lengthen. The design of integrated PMS/OBT systems and programming of vessels utilizing them must enable ships' companies to undergo intensive work-ups and deploy to operational theatres quickly, and arrive fully prepared for action.

Staffing

This extension of OBT will influence ship manning philosophy: necessary allowances for fully trained personnel, new trainees and training staff could reduce the manpower saving that would be realized by consideration of the PMSs technological capabilities alone. Furthermore, rationalization or elimination of Pre Joining Training Courses would result in significant changes to hand-over periods between joiners and leavers, for examples, increased details, theoretical discussions and practical demonstrations, etc. Consequent modifications to Naval drafting policy would be required to match staff turnover to these new types of ships. Successful implementation of PMS/OBT systems requires support by training staff of appropriate rank, qualifications, experience and teaching ability who could be sourced from:

(*a*) The existing ships' companies.

(*b*) Drafting training specialists permanently to specific ships.

or

(*c*) Forming a mobile training task force to serve the Fleet.

Optimization of this OBT leads to a combination of (a) and (c) such that normal ships' companies are not over(committed and the Fleet benefits from specialist training units (with wide visibility and experience of standards and a good understanding of common weaknesses).

Virtual Reality (VR)

This modern technique effectively places trainees in three dimensional software models which will interact with their physical actions and reactions to graphical representations of machinery, equipments and systems. VR can offer significant advantages in terms of physical space saving, adaptability to specific modelling requirements, ease of modifications and possibly associated cost benefits. However, this tool is currently perhaps too immature to directly apply to MCAS systems procedural and maintenance training due to the types of problems discussed by Kooi and Werkhoven,[20] such as:

- Relatively poor dynamic definition and accuracy
- Noticeable image lag behind input physical movements (this can cause nausea)
- Significant familiarization times required to benefit from VR.

Possible procurement strategy

MCAS systems and associated teaching aids and training equipments should be designed and developed simultaneously. The design of training programmes and necessary supporting hardware and software, and traditional documentation should ideally evolve with the development of the operational systems. Failure to consider training at an early stage of warship design could result in:

- Ill-conceived training programme designs
- Poorly designed and manufactured training equipments
- Insufficient completion time before the ships are complemented
- Shortage of funds for training facilities procurement.

This paralleling of the development of the parent MCAS systems and their associated training facilities should begin at the conceptual design stage. The benefits of research and development (from, say, the pure, engineering and psychological sciences) can then be equally well applied to the training facilities as to the parent machines, equipments and systems.

In order to avoid these potential hazards previously mentioned, the prime contracts awarded to shipbuilders could perhaps include the design, development, production and commissioning of appropriate training facilities necessary to support the safe and efficient operation of the associated ships, that is, the MCAS systems simulators, etc. Such facilities normally require special design considerations, and therefore the temptation to provide 'bits and pieces' of inadequately or inappropriately modified real machines, equipments and systems to fulfil the training requirements must be avoided. The main aims of broadening the scope of the prime contracts for shipbuilding in this manner would be to ensure timely consideration of the necessary supporting training facilities for the vessels, and to maximize the efficiency of information and data transfer to the relevant personnel.

In order to promote well designed training facilities, contractors and the buyers must utilize suitably qualified personnel. The ideal qualifications are relevant experience in:

- Watchkeeping
- Training (as a student and instructor)
- Project engineering.

For large projects such as the procurement of a new class of ships, or implementation of novel propulsion systems, etc. such suitably qualified personnel should be in ship operators' project teams with specific responsibilities for the MCAS systems training facilities; leading representation in terms of project management from out of these project teams could present unnecessary communications obstacles, thereby reducing effectiveness and possibly prolonging time requirements. Nevertheless, expedient procurement of the training facilities must involve consultations with relevant in-service support and procurement specialists.

For well prepared ships' companies, teaching and training programmes and their supporting equipments should ideally be available before the introduction of the ships and/or machines, equipments and systems into the Fleet; the drawback here is that these facilities will inevitably require at least some fine tuning to optimize training effectiveness. Design, contractual arrangements and funding of projects must allow for appropriate post design support activities in order to avoid the awkward tasks of initializing remedial actions to achieve satisfactory apparatus for accomplishing the necessary safety and efficiency training.

Conclusions and recommendations

Ship's engineering staff should be regarded as an integral part of the plant, and their training considered as: 'fine tuning' of the human elements of this man/machine system; and a normal feature of the operational environment.

The design and operation of the PMS is at the heart of the safe and efficient ship. Its full implementation will have profound effects on the training requirements of ships' companies. Future MCAS systems training will continue to exploit CBT, simulators and OBT. Significant extension of OBT will force considerable revisions of shoreside training philosophy and Fleet programming strategy.

It is judged to be worthwhile to thoroughly explore the feasibility and implications of implementing the concepts of:

- A single, unified warship ED
- Generic simulators
- Substantial extension of OBT
- The utilization of novel techniques (such as VR).

Simultaneous and integrated design and development of the parent MCAS systems and their associated teaching aids and training equipments could yield significant technological and procurement advantages.

Author's Note

This article expresses the opinions of the author, which are not necessarily coincident with those of the Ministry of Defence/Her Britannic Majesty's Government.

References

1. SHANKARARAMAN, V.; LEE, B.S. 'An Integrated Approach to Offshore Safety Training', *Transactions of the Institute of Marine Engineers*, (1994) Vol 106, Part 3, pp. 137–150.
2. BICHAT-GOBART, D. 'Ongoing Research into the Use of Simulators as an Assessment Tool to Check an Applicant's Competency as an Engineer', *Proceedings of the Second International Conference on Engine Room Simulators (ICERS 2)* (1995), pp. 1/7–17/7.
3. SMITH, B.S.; BURNOP P.J. 'Conjecture on the Continuing Development of Machinery Control', *Proceedings of the 10th Ship Control Systems Symposium*, (1993) Vol 1, pp. 33–46.
4. NIERI, D.S. 'Certification and Licencing of Mariners Based on Performance Assessment', *Proceedings of the Second International Conference on Engine Room Simulators (ICERS 2)* (1995), pp. 1/9–9/9.

5. Kluj, S. 'The Role and Mission of a PC Based Diesel Engine Simulator', *Proceedings of the Second International Conference on Engine Room Simulators (ICERS 2)* (1995), pp. 1/11–11/11.
6. Ray, A. 'Use of Marine Machinery Simulators in Education and Training', *Proceedings of the Second International Conference on Engine Room Simulators (ICERS 2)* (1995), pp. 1/12–16/12.
7. Bolton, H. 'The Role of Management Simulation in Improving Shipboard Engine Room Operations', *Proceedings of the Second International Conference on Engine Room Simulators (ICERS 2)* (1995), pp. 1/9–9/9.
8. Sallabank, P.H.; Whitehead, A.J. 'The Practical Application of Modern Simulation Tools Throughout the Design and Trials of a Diesel Electric Propulsion System', *Transactions of the Institute of Marine Engineers*, (1995). Vol 107, Part 2, pp. 101–117.
9. Nakamura, T.; Ikenishi, K. 'A Methodology for Training and Assessment Using an Engine Room Simulator', *Proceedings of the Second International Conference on Engine Room Simulators (ICERS 2)* (1995), Pages 1/9–9/9.
10. Barnett, M.L. 'Workshop on the Use of Simulators for Assessment', *Supplement to the Proceedings of the Second International Conference on Engine Room Simulators (ICERS 2)* (1995).
11. Sommer, H.; Wimmel A. 'PartTask Trainers: Are They Only Simulators for Small Budgets or Even a Cornerstone of Every Training Concept ?', *Proceedings of the International Training Equipment Conference and Exhibition (ITEC 95)*, pp. 469–477.
12. Lem, S.E. 'The Danish Simulator Project', *Proceedings of the Second International Conference on Engine Room Simulators (ICERS 2)* (1995), pp. 1/9–14/9.
13. Burger, J.J. 'Effective Training of Maintenance Technicians by Integrating Simulation and Original Hardware', *Proceedings of the International Training Equipment Conference and Exhibition (ITEC 95)*, pp. 281–287.
14. Molloy, J.; Beeson, H.A.R. 'COSAG and COGOG Machinery Control Room Simulators at HMS 'Sultan'', *Proceedings of the Conference on Simulator Training for Seagoing Engineers* (held at HMS *Sultan*), The Institute of Marine Engineers, (1976).
15. Locke, N.J. 'Machinery Controls Training Facilities for Type 22 Frigate and Command Cruiser', *Journal of Naval Engineering*. Vol.24. No.2. pp.205-211.
16. Trotter, S. 'Type 23 Machinery Controls and Surveillance Shore Training Facilities', *Journal of Naval Engineering*. Vol.34. No.1. pp.184-193..
17. Young, S.S. 'Single Role Mine Hunter (SRMH) Procedural and Maintenance Trainer', *Journal of Naval Engineering*. Vol.33. No.2. pp.454-464.
18. Young, S.S. 'Machinery Control Procedural Training in the Royal Navy—Future Trends', *Proceedings of the International Training Equipment Conference and Exhibition (ITEC 91)*..
19. Shoben, S.; Kasturi, R. 'On Board Team Training: Leveraging Integrated Shipboard Controls Capability', *Proceedings of the 10th Ship Control Systems Symposium*, (1993) Vol 4, pp. 1–9.
20. Kooi, F.L.; Werkhoven, P. 'Quantifying the Quality of Space Perception in Real and Virtual Environments' *Proceedings of the International Training Equipment Conference and Exhibition (ITEC 95)*, pp. 225–230.