DIGITAL CONTROLS TRAINING IN THE ROYAL NAVY

ARE THERE PROBLEMS AHEAD?

BY

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An analysis of the effects recent changes in the naval procurement process are having on digital systems maintenance training in the R.N. Marine Engineering Branch, and recommended steps to cope with these changes.

Introduction

The introduction of microprocessor technology in the ME Branch of the Royal Navy is relatively recent. The first of the digital propulsion control systems will be fitted in the Type 23 frigate, expected to be in service by 1989. Other 'digital' platforms will include the Single Role Mine Hunter (SRMH), the Type 2400 (UPHOLDER Class) SSK, and the TRIDENT Class SSBN. Electronic control systems have been in use since the early 1970s, using the discrete component technology of the day.[1] These systems have proved to be quite complex and are a significant training load.[2] The addition of another technology has not been catered for in resource and manning terms at the training establishments, so difficult choices are being made by the R.N. training authorities concerning training priorities.

The R.N. is familiar with microprocessors. They have been used in weapons systems for many years. The WE Branch experience, especially in training, may be directly transferable to the MEs. Organizations being what they are, it is unlikely that a complete transfer of experience will be possible. It must be stressed that there are at least two main training requirements; operator and maintainer. The ME Branch historically has used a 'dual role' man to tackle the difficult operator-maintainer interface. For instance, a specialist maintainer for a control system would also be a system operator. This had the definite advantage of simplifying the task of diagnosing faults, in that the maintainer could quickly and competently separate 'plant' faults from control system ones. This is the major factor which makes it more difficult for a non-ME to maintain the control system electronic hardware . . . the non-ME has difficulties with system fault diagnosis due to the lack of 'plant' understanding. To be fair, the training task is different between the two branches, but is it possible that much of the problem is due to R.N. organizational 'trade demarcations'?

The prime reason for a re-evaluation of the present R.N. training methods is the commonality of digital hardware in all the platforms under consideration (see FIG. 1). Not by design, but by accident, a single controls hardware manufacturer has been chosen by all of the shipbuilders to provide the various control and/or surveillance systems. In addition, this manufacturer uses a single software firm to prepare the application software. There is therefore an opportunity to take advantage of this commonality by consolidating the training task. The digital systems under consideration are all part of a proprietary system called 'D86', which is the common (hardware) denominator in all these ships. The traditional controls training by class of ship needs to be reviewed for the future digital ships, especially when applied to maintenance training.

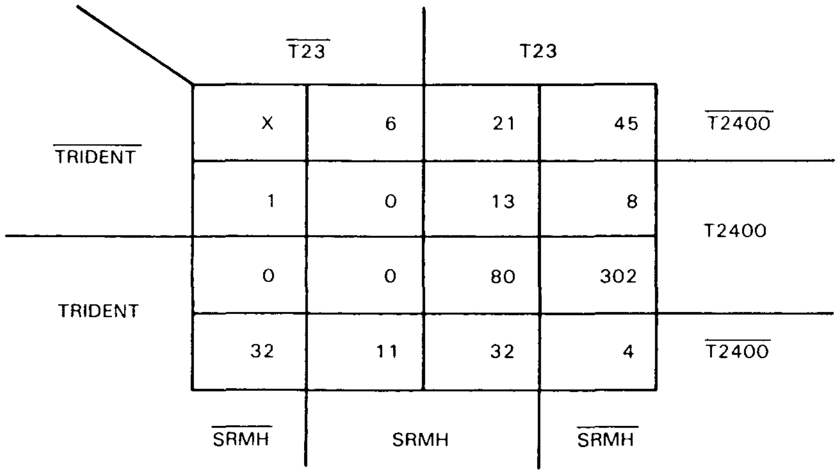
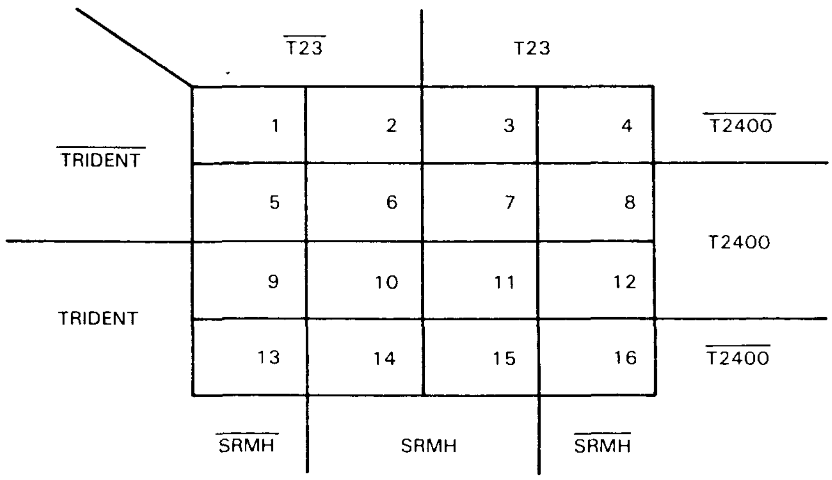


FIG. 1—KARNAUGH MAP SHOWING THE PRINTED CIRCUIT BOARD COUNT FOR THE D86 SYSTEMS TO BE FITTED (TOTAL 555 BOARDS)

Note 1: Weapons boards not included
2: figures improve when downwards compatibility is considered
3: single platforms only; these figures need to be scaled by the number of platforms.



EXPLANATION OF FIG. 1

The lines over 'TRIDENT', 'T2400', 'T23', etc. mean not. (Do you recall your Boolean terminology?)
Examples:

a. Box 3 means *not* TRIDENT, *not* T2400, but *including* T23 and SRMH (in Fig. 1 there are 21 PCBs in this category).
b. Box 4 means *not* TRIDENT, *not* T2400, *not* SRMH, but *including* T23 (in Fig. 1 there are 45 PCBs in this category).
c. Box 11 shows all platforms included (in Fig. 1 there are 80 PCBs in this category).

Background

The training of officers and ratings of the R.N. in ships' control systems has historically been done using two types of courses, the Pre-Joining Training course (PJT) and the ADditional QUALification course (ADQUAL). In addition, career courses exist for each of the sub-specialist trades within the ME Branch.

The PJT is attended by all officers and ratings before joining a particular class of ship. It is designed to give a broad overview of the capabilities of the particular control system under consideration, an appreciation of its strengths and limitations, some 'hands-on' experience in operation, and limited maintenance training. The PJTs tend to be segregated by rank. Typically, a single course for each rank is available in each term. An officers' course lasts approximately four weeks, whereas a ratings' course lasts six weeks. Each course culminates in a week of simulator training in an MCR or SCC mock-up. Facilities exist in H.M.S. *Sultan*, the ME training school, for each of the major classes of ship in the R.N. inventory.

ADQUALs are given to a select few of the electrical and mechanical ratings to give them an in-depth diagnostic and maintenance capability for the particular control system under consideration. Historically, the analogue electronic control systems, although complex, are repairable. Plant ageing can be catered for by judicious changes in potentiometer settings. Control system drift can be similarly catered for. The ADQUALs train the specialist controls man to make these changes as necessary.

The nub of the problem in digital systems training is that the changes necessary to cater for many sorts of defects must be realized in software, often software that will be inaccessible to the shipborne maintainer. The naval maintainer must be aware of this limitation in his repair capability. Does this imply a reduced training requirement, since the maintainer does not need to be taught to repair many of the faults he previously would be expected to, or is the training requirement increased because he must be taught to get around the system limitations? Only detailed analyses of the digital systems can resolve this training problem, but as will be made clear later, the revised procurement process does not give sufficient design visibility to make such fundamental decisions without an unacceptable degree of risk.

The Applications

Four quite different platforms will be fitted with a common digital machinery control and/or surveillance systems hardware:

(*a*) *Type 23*. The Type 23 frigate will have digital control for most of the major systems. Electrical power system, propulsion system, local control positions, engine telegraphs—all will use D86 digital hardware for control and surveillance.[3]

(*b*) *SRMH*. The SRMH uses the D86 system for propulsion machinery control and surveillance, as well as in its Ship Position Control System (SPCS) (for dynamic positioning and track-keeping). The SPCS system has the added complexity of interfacing with the Action Information Organization (AIO), hence any diagnosis must take into account AIO problems as well as the traditional ME concerns.[4]

(*c*) *Type 2400*. This class of SSK uses D86 in its surveillance mode only. The submarine service only begrudgingly uses analogue electronics in the control system. The 'radical' step of introducing unproven digital systems was deemed to have too high a risk factor in the control task. Nevertheless, due to very restrictive manpower limitations, an extensive D86 surveillance system will be installed, suitably backed up by the traditional local gauges. Although the D86 system is perceived as not critical to the operation of the submarine, the ME complement takes into account this added facility, so by default the system will be critical to the Type 2400 operation.[5]

(*d*) *Trident*. The SSBN will have the most comprehensive D86 system of all, with over 2000 sensed parameters. In keeping with the submarine policy, none of the propulsion system controls will be digital and the

D86 will be used in surveillance mode only. Much of the sensing instrumentation on the boat will be available only through the digital system, so D86 will be critical (no pun intended) to the functioning of the vessel.

Incorrect digital training can have a considerable impact on ship availability. Digital training is vital to the operational success of all future ships. Even in the earliest stages of a control system design, careful consideration must be given to the extent and type of the features necessary to ensure that the naval maintainer has the ability to diagnose and repair all critical faults. Self-diagnosis and test, self-checking, adequate documentation; all these must be shaped to take into account the man's capabilities and limitations. The MOD(PE) procurement policy has given design responsibility to the shipbuilders. Do they know what these manpower and training limitation are?

Although the shipbuilders have assured the MOD that training factors have been taken into consideration, there remains a critical shortage of information in the detail necessary to allow training authorities to have confidence in the 'correctness' of their decisions. The danger here is not that insufficient training takes place, since any instructor worthy of the name will err on the side of safety. Over-training will more likely result, which will stretch not only the already limited resources of the training system but also the capability of the man (with all the usual penalties in morale and self-esteem). Further, the shipbuilder is only aware of his own ship. Who is aware of the wider issues? Even the MOD Platform Project officers cannot be expected to be aware of all of them. In the given D86 example, how can credible training decisions be made in the absence of detailed design information?

Organizational Problems

The duplication of hardware across various platforms seems to imply potential savings in training. It is likely, at least for maintenance training, that a single facility can be provided for a cross-section of R.N. ratings. The traditional courses dedicated only to a particular class of ship may become unnecessary, making combined training possible and avoiding duplication. The driving force here is cost minimization, made possible by taking advantage of the flexibility of digital systems. As an added bonus, the education (as opposed to training) of the ME in digital systems can be facilitated on D86 maintenance hardware as well.

How can training quality be maintained when each platform has different training requirements and standards? For instance, the SRMH is expected to operate in local waters only and hence will only need to get home on failure of the control system. Contrast this with the TRIDENT which cannot tolerate an unrepairable failure because of the strategic nature of its deployment. Can this dichotomy be resolved without running the risk of either over- or under-training a significant proportion of trainees? The training solution is not as straightforward and single dimensional as presented so far!

Typically, the answer to this problem lies more in the organizational aspects of the R.N. than in any technical realization of a solution. A strong case exists to advocate the use of WE ratings, already trained in the general application of digital systems, to undertake the sophisticated maintenance of the propulsion control system, especially since some weapons systems will ultimately contain the same D86 hardware as used in the ME application. This seems to contradict an earlier statement concerning the use of WEs in control system maintenance, but do recall that it is only the present training system that perpetuates this perceived weakness. This radical proposal will likely be unacceptable to the R.N., more for emotional than technical (or financial) reasons. These emotional reasons are often disguised as 'leadership' decisions, not subject to analysis by the cost-conscious pen pushers of headquarters. Yet the potential for more efficient use of scarce resources must be coldly assessed. If the WE option is more cost-effective, then defence of the *status quo* is difficult.

Even the (rather blurred) split between the electrical and mechanical sub-specializations within the ME Branch creates some potential for friction. The further split between submarines and surface navies is yet another factor. In the surface navy there is a definite break between 'large ships' (frigates) and 'small ships' (mine hunters). What about the split between conventional and nuclear submarines? (The D86 system cuts across all these boundaries, hence is an ideal test case.) It is clear that the 'organization' has much to answer for in perceived inefficiencies, including those of the training system(s). Any proposals for combined training must remain aware of the internal conflicts for genuine cost saving to take place without incurring an unacceptable loss of training value. Can co-operation be enforced? Is it still co-operation if it is enforced?

Yet the R.N. must remain aware of the danger of becoming too involved with D86 at the expense of teaching digital techniques in general. It must be stated that training establishments deal not only with 'training' but also with 'education'. For instance, H.M.S. *Sultan* is now responsible for the education of naval ME apprentices of both mechanical and electrical backgrounds. The R.N. is committed to providing this education to 'Guild Standard', which in essence means that they must remain aware of educational issues outside the parochial R.N. concerns. Similarly, the Royal Naval Engineering College provides degrees in various engineering disciplines which must meet the standards of the professional institutes. A 'digital techniques' awareness has been forced into the young officers and ratings in the R.N., but the great majority of the senior officers are new to the concept. Sadly, the senior 'decision making level' is almost technically illiterate in this vast and complex engineering discipline. This is yet another factor to consider before devising a training scheme—the extreme variation of technical backgrounds.

The Effect of Changes in Platform Procurement Processes on Training Options

The procurement of naval vessels in the U.K. has been completely revamped in the last five years. Until the late 1970s the MOD would do the initial ship design in-house, with judicious use of consultancies where required. This meant that there was complete design visibility which in turn meant that the Navy was able to keep track of the design process by using on-site officers. Due to the pressures on the Defence budget, a policy decision was made in the early 1980s to no longer design ships in-house, but instead go to the marketplace for less expensive alternatives. The theory was that the competitive tendering environment would produce more 'bang for the buck'.[6] In anticipation of the success of this policy change, the MOD(PE) reorganized (became smaller) and is no longer capable of assuming the traditional role as ship designers.[7]

One of the penalties paid for this policy change was design visibility. It is no longer possible to get design information of the required quality and detail necessary to minimize the risk of making the wrong training decisions . . . at least not free. The new decentralized ship design system also does not easily allow for a combined support system for 'common' items, since the extent of commonality is not often apparent at an early stage. This problem is especially evident in the D86 systems, since the applications are so widely different; are the WEs aware that some of their equipment will use the same hardware as the machinery control systems? The various 'navies' within the R.N. also make the potential training advantages due to equipment commonality difficult to realize. Hence a golden opportunity to consolidate training may be lost as a result.

The Naval Staff responsible for all training policy try to take account of all the above issues,[8] but they cannot work in isolation. Decentralization has made the potential for common support difficult to recognize. A common support policy is the cornerstone of a common repair policy. It is the repair policy that affects the extent of the maintenance task. It is the maintenance task that will decide the best training method. Much like a house of cards, all will collapse without an infrastructure that ensures a common fleet-wide support policy.

(*a*) Does the changed procurement policy account for this?

(*b*) Is it possible to generate such a common policy in the present climate of decentralized ship design?

(*c*) Who is accountable for the wider support and training issues which are significantly affected by decentralization?

(*d*) Will the penalty be paid at sea with unrepairable equipment?

(*e*) Will the training establishments be blamed for inadequately preparing naval technicians?

(*f*) Must the 'design authority' share the blame for these potential problems? If so,

(*g*) How can this be enforced, especially in the face of a contract between the MOD(PE) and one shipbuilder which, as an up-front cost-saving measure, deliberately excluded training from the requirement?

MOD policy decisions made in order to streamline the procurement process will undoubtedly meet the objective of more value for money. Unless the MOD takes an active part in the more parochial R.N. concerns such as training, the net effect of this streamlining will be negative as far as the training establishments are concerned. The effect of procurement policy on the R.N. is significant and needs to be understood in order to take full advantage of the change to digital technology and avoid the pitfalls outlined above.

The Future: Short and Long Term

There is approval in principle to proceed with a combined D86 maintenance facility at H.M.S. *Sultan*. The understanding is that 'core' maintenance training will be taught at this central facility, and the trainees will then go on to specialized training (if necessary) at their own facilities/training establishments upon completion. This approval was based on the assumed hardware commonality, an assumption which has proved to be correct (in terms of board count, 85% are common; in terms of board types, taking advantage of downward compatibility, 80% are common). The problems have therefore shifted to the release of information by the shipbuilders, since design responsibility implies design ownership. The MOD(PE) may be forced to buy the same information several times due to the (present) poorly defined Intellectual Property Rights (IPR). The shipbuilders' tough stance on IPR may be hard to justify when one considers the considerable input from the

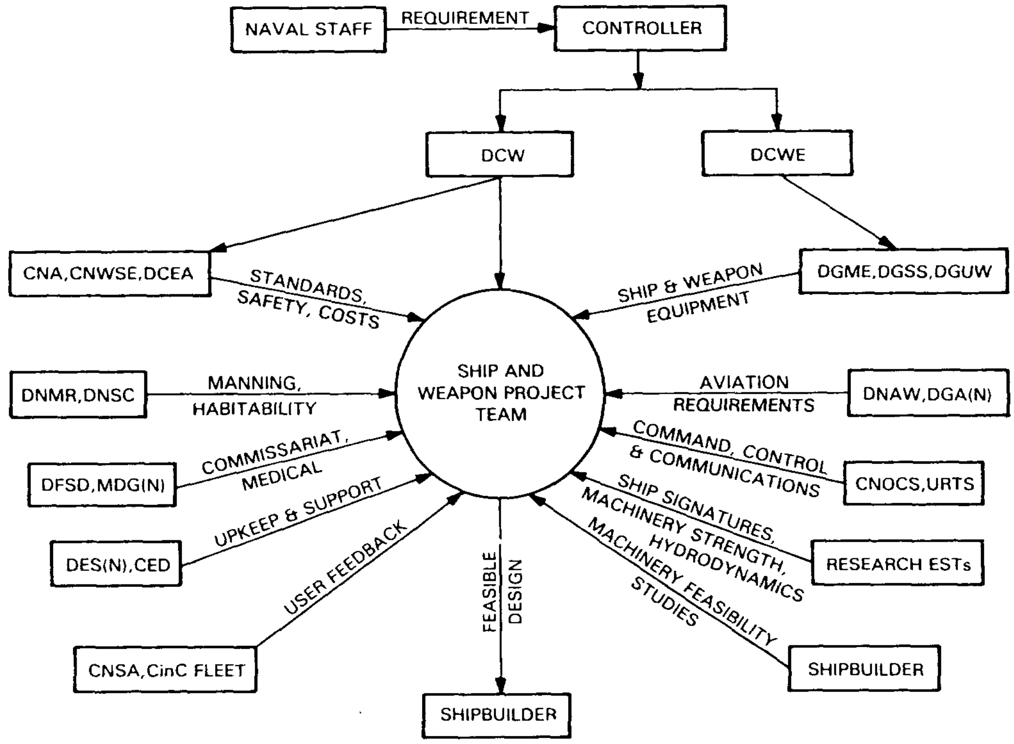


FIG. 2—SOME OF THE AUTHORITIES INVOLVED IN SHIP DESIGN

CED:	Chief Executive Dockyards
CNA:	Chief Naval Architect
CNOCS:	Captain Naval Operational Command Systems
CNSA:	Commodore Naval Ship Acceptance
CNWSE:	Chief Naval Weapons Systems Engineer
DCEA:	Director Cost Estimating & Analysis
DCW:	Deputy Controller Warships
DCWE:	Deputy Controller Warship Equipments
DES(N):	Directorate of Engineering Support (Naval)
DFSD:	Directorate of Fleet Supply Duties
DGA(N):	Directorate of Air Engineering (Naval)
DGME:	Director General Marine Engineering
DGSS:	Director General Surface Ships
DGUW:	Director General Underwater Weapons
DNAW:	Directorate of Naval Air Warfare
DNMR:	Directorate of Naval Manpower Requirements
DNSC:	Directorate of Naval Service Conditions
MDG(N):	Medical Director General (Naval)
URTS:	User Requirements & Trials Section

MOD (see FIG. 2), but it is a major factor at present. Eventually the lawyers will sort the problem out, but this is no comfort to the training authorities who need information now.

It is certain that the use of microprocessors will continue to increase in the R.N. The future may include the introduction of ship-wide data busses (including WE systems) and the adoption of the latest techniques in fault analysis and system redundancy.[9] Improvements in self-diagnosis may make the training task for the R.N. relatively straightforward. Will it be acceptable in the future to train the ME in control system operation only, with the diagnosis of faults being done by computer-driven 'expert systems' or even a WE technician? This would reduce the ME training task to teaching a man to change printed circuit boards and, as always, the completion of paperwork. If this is the navy of the near future, the R.N. may be placing too much emphasis on the digital training 'problem', whereas in fact there is no real problem, just a lack of understanding of the capabilities of the digital systems themselves.

The way ahead is first to recognize the changed procurement environment in which the R.N. operates. In order to take advantage of the potential savings and simplification of the training task that should accrue due to the adoption of digital systems, more attention must be paid to the new role of the shipbuilder. The MOD(PE) in the past, as a routine part of the ship design process, took account of the naval training requirements. If a shipbuilder has now taken on this design responsibility, surely he must be expected to be responsible for the training task. Foreign navies, who have made similar procurement policy changes already, do recognize training as a shared, but mostly shipbuilder, responsibility (the Canadian Patrol Frigate[10] is a prime example).

Ship contracts must be written in such a way that, when equipments such as D86 are identified as having fleet-wide applicability, design information will be made available as necessary in sufficient quantity and quality to enable the R.N. training authorities to make the necessary decisions in a timely manner. The problem of poorly defined IPR boundaries delaying information transfer must be addressed. At present this is not the case, and as a result the R.N. has inadequate data and may be in danger of making the wrong training (and even support) choices.

Training is not a separate issue which can be isolated from ship design. The requirements are a direct result of the ship design decisions which today are not solely in MOD hands. A case can be made for whole ship design responsibility to include training. Is it too late to make this so? Is the increased 'first cost' of a ship as a result of this inclusion of training a small price to pay? More to the point, how can it be justified to not include it?

The R.N. must consider changing the maintenance training for controls systems by consolidating, for digital systems at least, all of its internal navies. The combined D86 maintainer facility is a step in the right direction (assuming it will be approved). In addition, R.N. branch 'demarcations' must be minimized. Some recognition must be made of the potential role of the WE as a source of on-board expertise, if only as a back-up. In this time of restricted manning and reduced ship complements, it is unrealistic to continue as if there is still sufficient manpower to justify the traditional separate internal naval training systems. Even the branch boundaries must become more blurred for the mutual benefit of all. The introduction of digital systems should provide an opportunity to make better use of scarce naval resources, an opportunity that the Navy cannot afford to miss.

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