'WHAT TO DO' IN SHIP SYSTEMS AUTOMATION

THE SURFACE WARSHIP MACHINERY CONTROL AND SURVEILLANCE RESEARCH PROGRAMME

BY

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Summary

This article outlines the research programme that has been initiated within the Ship Department to establish the way ahead for control and surveillance of machinery systems in the light of the need for the best use of manpower and automation in future warship designs. The wide ranging studies now under way are described and the potential solution that may be adopted is indicated.

Background

The use of digital technology and microprocessors in the field of automation for machinery control and surveillance was investigated within the Ship Department some four years ago and Ref. 1 outlined a possible system of the future using these techniques. These Ship Department investigations resulted in a realization that the problem was not one of hardware alone. If an optimum balance between man and hardware was to be realized in future ships, the traditional machinery orientated design process needed to be complemented with a design process to include the overall ship and manning considerations as well.

Ref. 2 described the critical factors in the manpower and automation balance in warship design, and placed the control and surveillance philosophy to be adopted for machinery systems into a 'total ship' concept. It also argued the need to establish 'a technical strategy for the future development and implementation of automated systems in the warship application, based equally on the trends in control and surveillance technology and upon the operational requirements of the warships themselves'. The Machinery Control and Surveillance Research Programme, described in this article, is the means for developing this strategy.

Programme Formulation

In formulating the content of the programme, the experience of the first generation of electronically-based propulsion control systems now at sea in Type 21/42 ships was taken into account. These systems have generally been well received at sea but there have been a number of problems, notably:

(*a*) the systems have been expensive to put into service, both in initial design and support costs;

(*b*) the design has not proved flexible and modifications of the machinery control system, as a result of first of class trials, have been difficult to implement;

(*c*) although designed from a system point of view, no clear philosophy in all areas of technical and operational design was adopted. Thus, inadequacies were found in such areas as earthing policy, system power supplies and data presentation;

(*d*) insufficient attention was paid to the role of the man both in the detailed ergonomics of the display panels and of the ship control centre, and to the concept of the tasks he was required to fulfil.

The major lesson that has been learnt is that the definition of what is to be achieved, and why, is of prime importance. Only when this (the 'What to do') has been decided should the means of doing it (the 'How to do it') be investigated. With the great potential capability that is now offered by technology, this vital thread runs right through the research programme that has

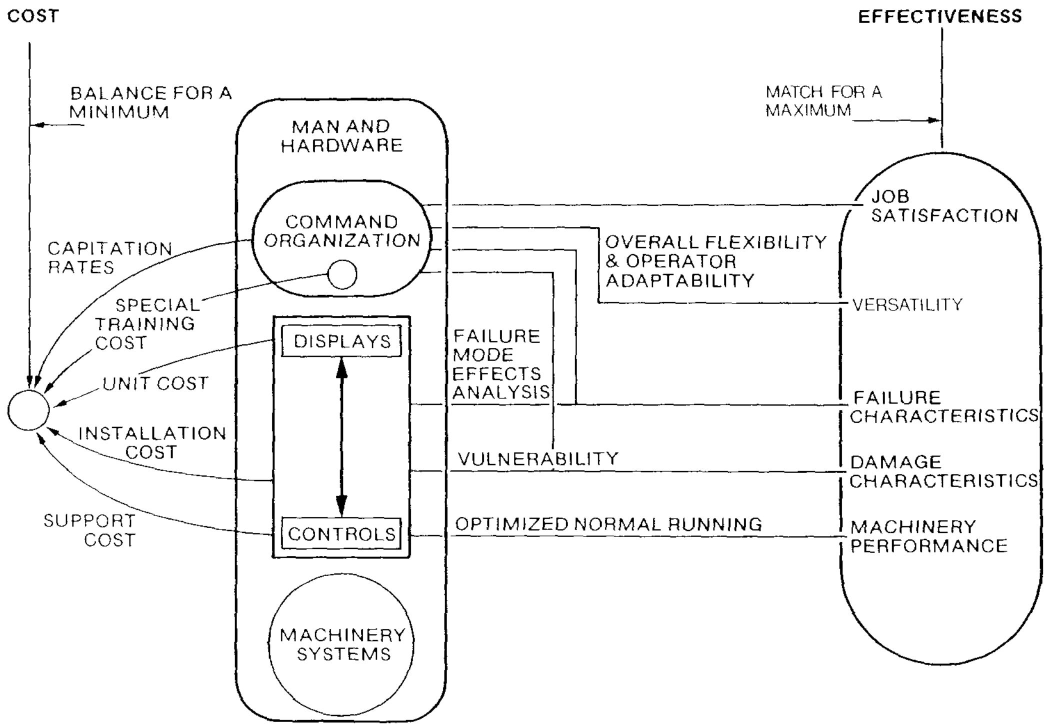


FIG. 1—MAN/MACHINE BALANCE CHARACTERISTICS

been established, and is the key to achieving the optimum balance between men and hardware to meet the functions laid down for a ship in its Naval Staff Requirement. In general terms, man has flexibility, but is expensive in terms of life cycle costs, (e.g. pay, food, built-in-hotel services, training, etc.). Automation, though low in life-cycle cost terms, can only fulfil those functions which the designer has built into the ship initially, and is therefore inflexible. Thus, if the functions of a ship are limited in number and well defined, say as in a merchant ship, a higher degree of automation and fewer men are more justifiable than in a ship where the functions are much more numerous, e.g. a warship. The degree of automation therefore involves a cost-effectiveness trade off and this is illustrated qualitatively in FIG. 1, which lists on the left hand side the costs and on the right hand side the criteria of effectiveness associated with men and hardware.

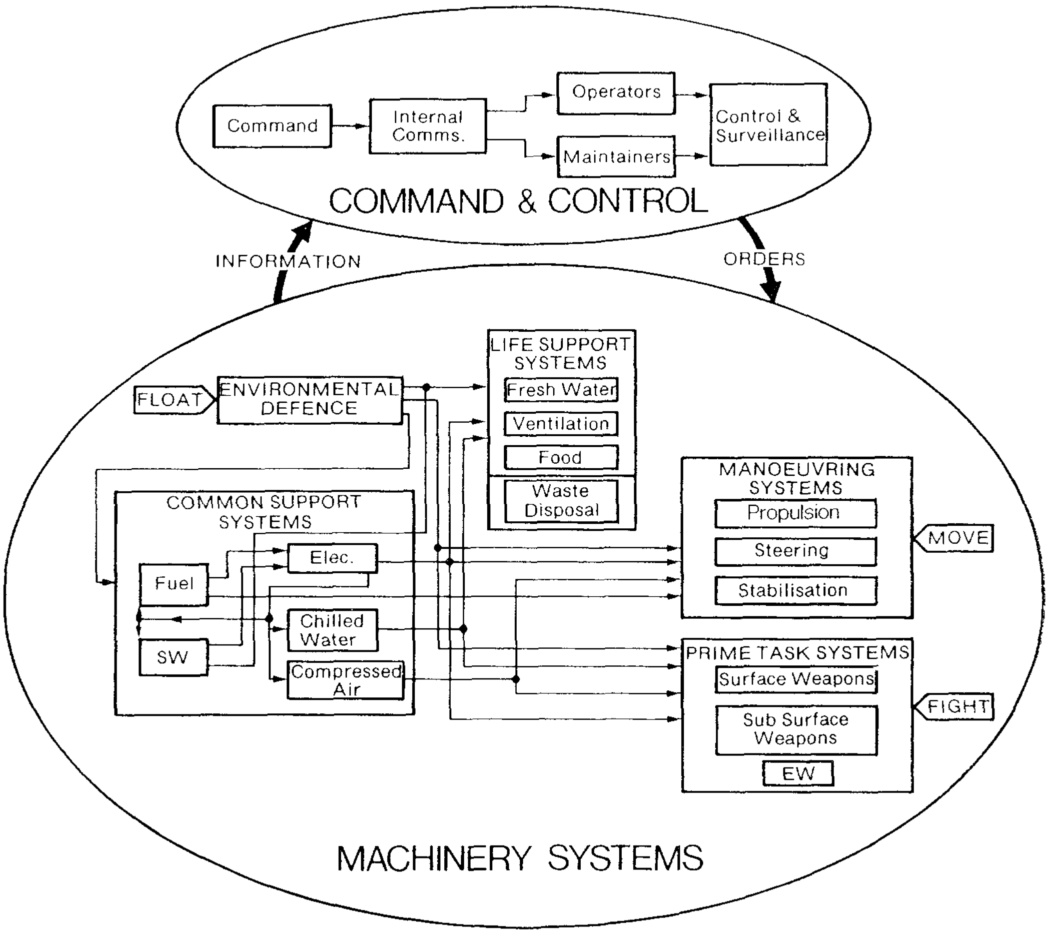


FIG. 2—SYSTEM SCOPE

FIG. 2 illustrates the scope of the problem. The various machinery systems including weapons and their various interdependencies have been grouped together on the basis of the ship functions they perform or support, i.e. fight, move, and float. The interrelationship between systems to execute these ship functions has largely been ignored during the conceptual stage of past ship designs. This has given rise, for instance, to incompatibilities between the integrity of electrical power supplies and chilled-water supplies to the same weapon system. There are many ways of restoring the former after damage but none for the latter.

At the top of the FIG. 2 is shown the human element which commands and controls the machinery systems in the performance of the necessary ship functions. The interface between the human element and the machinery element is another area which the traditionally machinery-orientated approach of the past has largely neglected. As an example, the problems of keeping the Captain informed of the state of his ship and her weapons in order that he can carry out his role as Captain have proved almost insurmountable in present ships because the information he needs to have to fulfil this role either is not presented to him or is contained within a host of information he does not need to have. This problem manifests itself each time a ship arrives at Portland for work-up. Temporary modifications to internal communications and organization are made on the instruction of FOST to alleviate the effects of such deficiencies. Clearly this should not be necessary. Though the role of the Captain is given in the above example, it is true to a greater or lesser extent in all instances where the man interfaces with the machine, though the problem appears to be worse the higher a man appears in the hierarchy of the ship command structure. As manpower is reduced in ships, this aspect of design becomes even more critical. It is essential for the ship designer to have a clear understanding of the role of each operator in the ship. Only then can he provide the necessary machine interface, e.g. displays, gauges, communications, etc. for the operator to fulfil his allotted role.

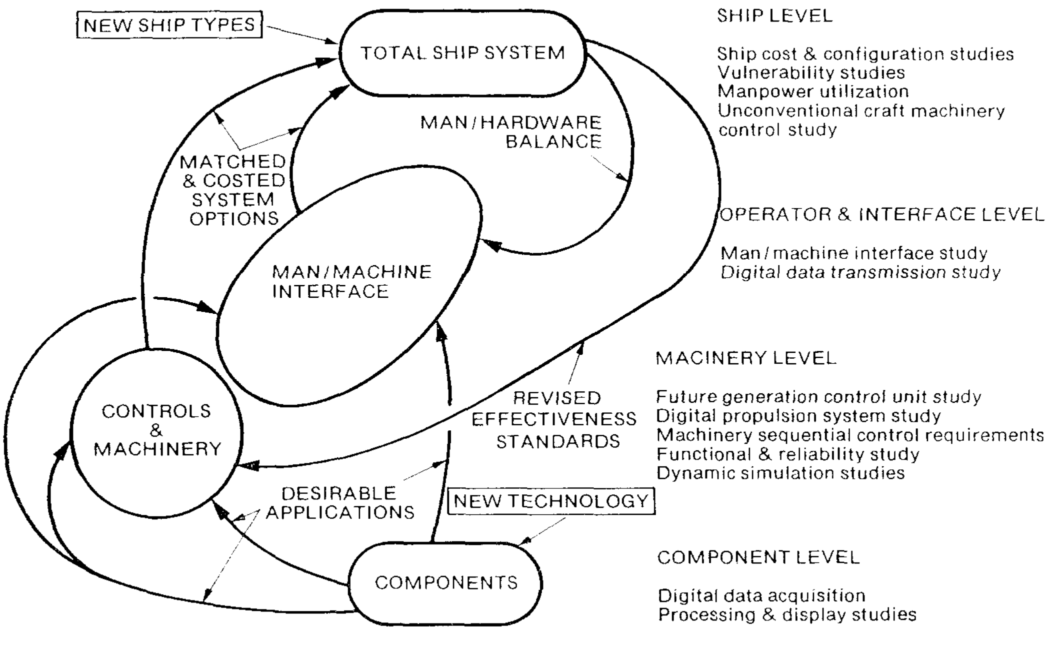


FIG. 3—PROGRAMME STRUCTURE

The Research Programme

To analyse fully all the problems discussed above, the Machinery Control and Surveillance Research Programme was authorized to commence in June 1975. The programme has three important features from an administrative point of view:

(*a*) it is a research commitment and is funded from research sources;

(*b*) it is not tied to any particular ship class or ship programme;

(*c*) it is organized within the existing Ship Department organization such that the normal points of contact with outside authorities remain undisturbed.

The programme comprises a number of work packages divided into four groups or levels — Ship, Operator and Interface, Machinery, and Component. FIG. 3 illustrates the interaction and relationships between the four levels, and the particular features that will emerge from the various level packages. For instance, studies at the ship level, such as the vulnerability study, could result in different effectiveness criteria for machinery systems (e.g. degree of redundancy to be fitted), and hence will affect the machinery level studies.

Two external factors will affect the course of the programme. New technology, as it becomes available, will naturally provide new and perhaps better methods of achieving good design; whilst a new ship design when it comes into being will naturally bias the programme in order to meet its particular requirements.

The majority of the individual work packages are now under way and their titles, most of which are self-explanatory, are shown on FIG. 3 under the level headings. These studies are being carried out by a wide range of industrial and naval organizations. This provides a good cross-section of expertise, much of which has not been traditionally associated with the marine field. The individual studies are managed by project officers in the most appropriate section of the Ship Department for the task and this again ensures a wide spread of involvement within the Ship Department itself.

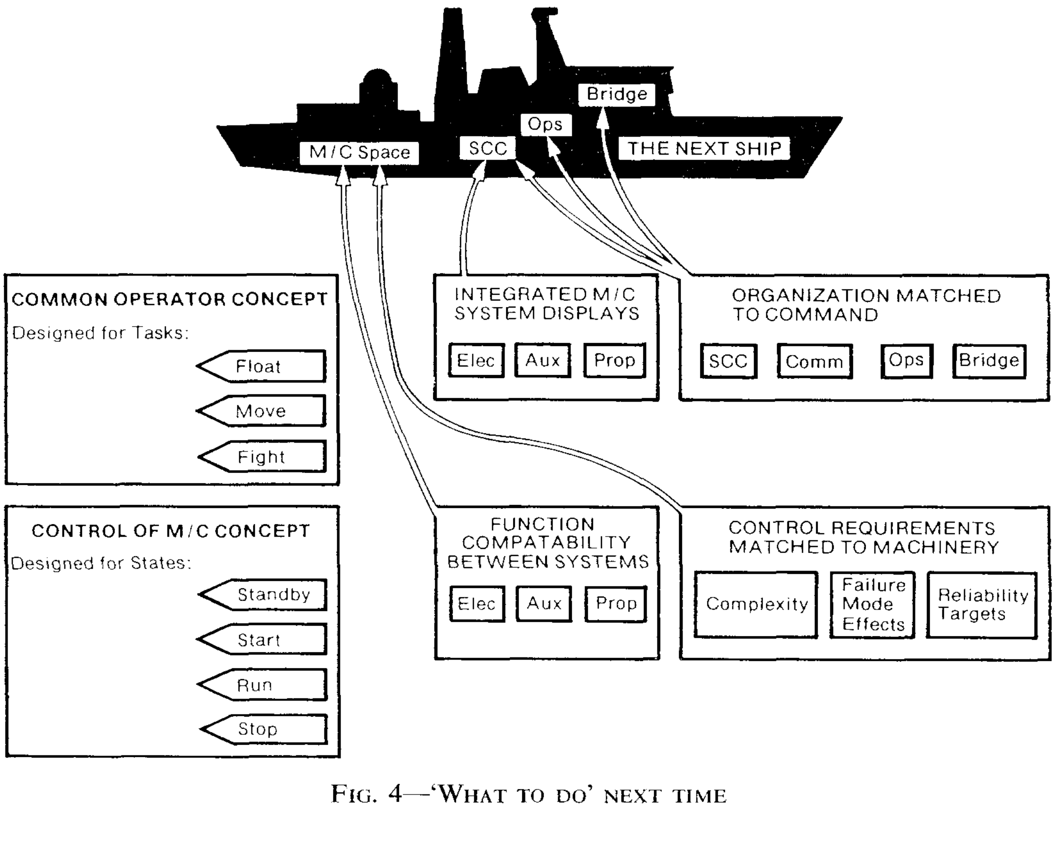


FIG. 4—'WHAT TO DO' NEXT TIME

The Emerging Hardware

Although the programme has only just got under way, it is already becoming clear what the future system philosophy and technology might look like, though it will be some time yet before the outcome can be fully documented and justified. In FIG. 4 the future philosophy is displayed as ' "What to Do" Next Time'. The major features have been implied in the background section of this article namely:

Operator concept

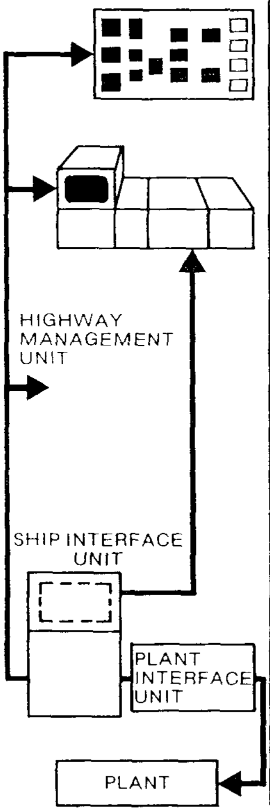
Analysis of the tasks to be performed by a particular system in fulfilling its contribution to the ship functions of *float, move* and *fight,* and allocation of these tasks either to automation or man, depending on which is most suited. By considering the role of the man as part of the system, his effectiveness will be increased and a consistent operation policy across the ship matched to the command structure can be adopted.

Machinery concept

Systems need to be designed to provide compatible integrity one with another, with special emphasis on the engineering support systems such as electrical power distribution, chilled water and compressed air.

Some of the other aspects in developing a future philosophy are also shown in FIG. 4.

Having decided ' "What to Do" Next Time', FIG. 5 shows some of the features that might be adopted when considering ' "How to Do It" Next Time'. The particular improvements and their characteristics are summarized in the figure but it is emphasized that these, more than the philosophy changes, will be much influenced by the in-depth studies now in hand.



CONFIGURATION	TECHNICAL FEATURES	DEGREE OF STANDARDISATION	CHARACTERISTICS
Primary Surveillance Display	Mimic panels. Colour-coded indicators.	Substantially standard concept for all classes of ships	a) Reduced Size & Unit Cost b) Increase in Operator Effectiveness
Secondary Surveillance Display	Shared alpha / numerical displays & keyboard	Standard Hardware. Ship Specific Software	
Multiplexed	Highway Management Scheme. Signal type & data format to match display & control technology		Reduced cabling cost & installation time
PLANT CONTROL TWO UNIT CONCEPT			
Ship Interface Unit, Incorporating System Control if possible	Processor based?	Standard Units? within ship	Reduced cost & improved reliability
Plant interface Unit	Electric/Fluid Power	Selective Standardisation on plant type	

FIG. 5—'HOW TO DO IT' NEXT TIME

A possible 'Ultimate System' is shown in FIG. 6—the question mark indicates its still hypothetical nature. The heart of the system would be a data multiplex ring, i.e. a single pair of wires in the form of a ring, to which are connected sources of data (e.g. machinery) and receivers of data (e.g. operator displays). By appropriate electronic hardware, the correct sources and receivers can be connected as required to transfer information and orders, one from the other. The advantages of such a system over dedicated wiring between source and receiver are:

(*a*) less ship installed wiring required;

(*b*) the reliability of the data received can be increased by various automatic checking procedures;

(*c*) overall redundancy can be achieved without additional wiring, as two separate paths exist between any source and any receiver.

Though, theoretically, communications and weapon systems could be included in the data multiplex ring, the studies indicate that this would not be economical as the nature of the data is so different from that of normal machinery control. The former requires, for instance, a wide band width system. Each ship system, i.e. propulsion, electrical generation and distribution, would have its own dedicated controls at the centroid of the system concerned. The system controller could be a microprocessor or, if not exactly that, a programmable device using digital techniques. These system controllers would be of common hardware design whilst their function would be altered by means of programming, or software. The advantages over centralized control systems (such as the existing propulsion machinery controls in the Type 42 and 21 ships) are a reduction of cost of equipment and installation, and the greater survivability to damage inherent in having the controls close to the parent plant. In addition modifications during the development and setting-to-work phase are much easier and cheaper to implement due to the ease with which the controller can be reprogrammed.

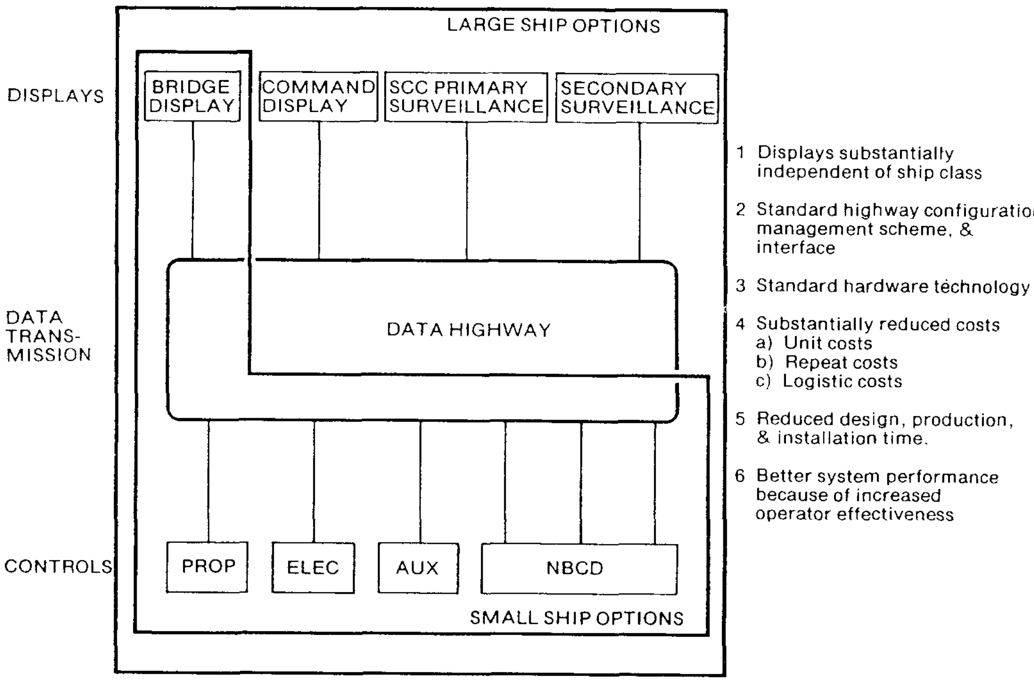


FIG. 6—THE ULTIMATE SYSTEM?

The operator displays fitted at the operator positions would be in the form of mimic diagrams for primary surveillance, which is defined as information needed by an operator at all times, such as equipment states. For secondary surveillance, which is defined as information needed at longer notice (e.g. for maintenance), visual display units in the form of television screens would be used and data would be called up by the operator on a keyboard as and when required. System alarms when they occur would also be displayed on these units and would override any other display activity in progress at the time. By using such a 'management by exception approach', the amount of data displayed at any one time would be minimal. The controls at the operator position would depend on ergonomic studies. For example, levers could be used as at present for the propulsion systems, keyboard entry for bringing a chilled-water plant into operation, and push-button control for NBCD flap operation.

Whatever ship is envisaged for the future, whether she be small or large, a much greater degree of standardization can be achieved than at present both in terms of hardware and man/machinery interfaces. The hardware, as stated previously, can in many cases be standardized with its functions being changed by programming. This is true across different systems within a ship and between different ships. In the area of operator facilities, standardization of display formats and controls will increase operator effectiveness and cut down pre-joining training.

FIG. 6 shows a large and small ship configuration. In the latter, no SCC is shown as being required, whereas in a large ship various additional control positions are shown. The former concept was based on the Future Light Frigate case for which the 'Small Ship Cost and Configuration' study was initially instigated. This showed that, if initial cost was a primary factor, the cost-effective solution was to have only one control position (the bridge and no SCC), minimal machinery surveillance and roving watchkeepers. Such a concept would not apply in a larger ship but there is no reason why largely standard hardware should not be used nor common display format employed in both ships.

Summing up, the hoped-for advantages to be realized by such an approach are:

(*a*) reduction in cost due to:
- (*i*) standardization of hardware,
- (*ii*) reduction in ship wiring,
- (*iii*) flexibility in introducing modifications in the development phase,
- (*iv*) greater reliability,
- (*v*) reduced training costs,
- (*vi*) reduction in size of display and control consoles;

(*b*) increase in operator effectiveness due to:
- (*i*) better integration of men with machinery,
- (*ii*) common display and control facilities between ships.

The Future

It is obvious that these concepts cannot be introduced into the design of the next generation of ships purely as a result of paper studies of a research nature such as comprise the present Machinery Control and Surveillance Programme. Some selected hardware evaluation is needed to give confidence that the new concepts will be realized in practice. To this end, a co-ordinated work package, called in this context a technical strategy, is currently being devised within the Ship Department, financed from development funds rather than research. The evaluation will include trials at manufacturers works, e.g. Rolls-Royce on running gas turbines, work at research establishments, and trials in ships. For the latter, plans are well advanced to use H.M.S. *Bristol* for the testing of a data multiplex system together with selected displays.

For the traditional controls manufacturer, the new concepts represent a shift of emphasis from the production of hardware to one of producing software. Visual display units, microprocessors and analogue digital converters are all standard items which are produced by specialist electronic firms and hence would be bought out by the controls manufacturer. In addition, the new concept implies a greater need for the system approach and indeed a greater co-ordination between systems. The hardware/software balance is primarily a problem for the controls industry itself and is not peculiar to naval work and hence it is for the controls industry to adapt themselves to the advancing technology. The system co-ordination is largely the concern of the MOD and consideration is at present being given to the greater use of and selection of system contractors. The result will be the formulation of an industrial strategy.

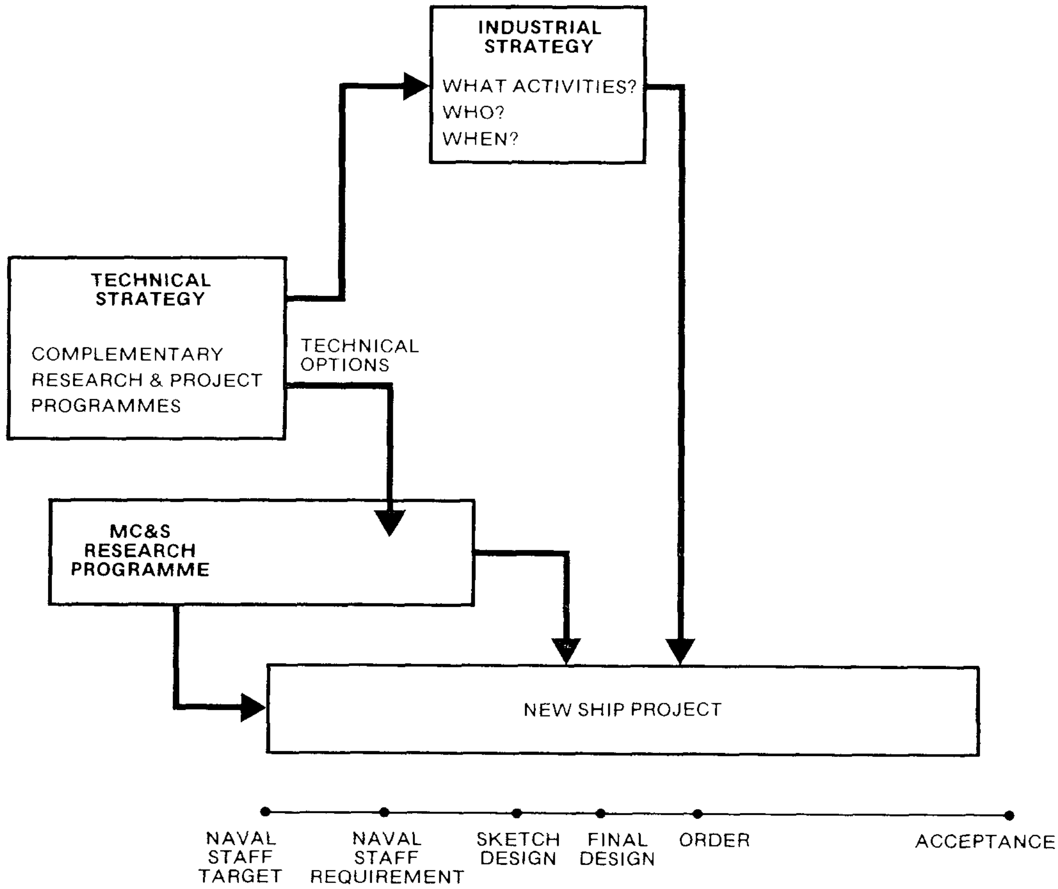


FIG. 7—THE OUTLOOK?

FIG. 7 represents in block-diagram form the MC and S programme, technical strategy and industrial strategy aspects in relation to the programme for a new ship design. In the formulation of the naval staff requirement, normal discussions between D.G. Ships (Forward Design Group) and the Naval Staff would take place and the work of the MC and S programme will influence these discussions. The results of the technical strategy and industrial strategy work are required later in the design process and this is shown in FIG. 7.

Spin Off to Date

Though the programme has largely been discussed in terms of a new ship design, various projects have been undertaken since its inception which have been influenced by the programme. Thus a new universal electronic controller for gas turbines and the training equipment for the Type 22 frigates and the CAH machinery systems are projects which are using the results of studies from the programme. This is expected to continue for other new projects as they arise.

Interaction with Authorities outside the Ship Department

Whilst much of the work involved in the studies can be progressed independently of other authorities, there are certain essential interactions that are required to take place to ensure that the research programme is soundly based and acceptable. One or two of the studies are very much involved in areas of mutual interest of other authorities, notably those related to manpower and manning, whilst the training requirements of the new systems are important and must not be overlooked. All the studies need a good data base on which to develop the new ideas and against which the projected improvements can be compared. The establishment of this data base will be a lengthy task involving visits as well as the recovery of data from authorities, such as the Ship Maintenance Authority.

It is hoped that this article will have given those who become involved in such liaison a broad idea of the aims and scope of the programme.

Conclusion

The aim of the Machinery Control and Surveillance Research Programme is to achieve the optimum balance between man and automation to meet the specific functions of ships as laid down in the Naval Staff Requirements and thereby to define the hardware to match this balance. In so doing the programme is not intended as a means of reducing manpower in itself unless that is a prime aim of the Naval Staff.

References:

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