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Future Engineering Systems for Naval Ships

L. D. Dymoke

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Future engineering systems for naval ships

By L. D. Dymoke
Ship Department, Ministry of Defence (Navy Department), Bath

This paper concerns engineering systems in naval ships, i.e. propulsion, auxiliary, hull and hotel services. It is not concerned with the engineering of weapons systems themselves. An attempt is made to forecast the requirements and constraints which these engineering systems will have to meet in the 1980s, including operational and functional requirements, technical developments and economic and environmental influences.

1. Introduction

The statements and conjectures in this paper are those of the author alone and must not be construed as representing official policy in the Ministry of Defence. Some constraint is imposed by security considerations on the depth to which subjects are covered, particularly in relation to submarines.

The engineering systems discussed are those whose function is to deploy and support weapon systems (as distinct from the weapons systems themselves) i.e. propulsion, auxiliary, hull and hotel services.

New naval ship concepts take on average 7 to 10 years to materialize and thereafter a class will be in operational service for at least 20 years. Although it is conceivable that these long cycles could shorten it seems unlikely because on a through-cost basis a shorter cycle shows less return – i.e. we do not know how to make short-life ships significantly cheaper than long-life ships. Modernization during service life has so far mainly applied to weapon systems but may extend to some engineering systems if judged effective on through-cost or military-worth criteria.

Thus an engineering system may 'last' from concept to scrap for over 30 years on present time cycles. We are currently designing and building, and will soon start bringing into service, the new generation of surface ships of the post-big-carrier Navy. They were conceived in the 1960s and some will probably still be operating at the end of the century. We are already contemplating the concepts of the next generations which will be being built in the 1980s and may still be in service in 2010. In the 1980s we shall be concerned with the conception and selection of systems (and the planning of their development) to last until 2020.

Most of this paper is concerned with what we shall actually be building into ships in the 1980s; but some important guesses have to be made about what constraints on further concepts will then be emerging.

2. Requirements and constraints

Operational and functional requirements

One can only assume that the development of the 'doctrine of flexible response' for the deterrence of major conflict, and the strategic withdrawal to a generally European/Atlantic theatre, will continue. By and large (together with economic considerations) this appears likely *inter alia*, to maintain for Britain two trends now apparent in most navies of the world, i.e.

(*a*) surface ships are getting smaller, and
(*b*) submarines are of increasing importance.

High weapon punch and sophistication, excellent sea-keeping qualities, ability to withstand damage and shock, and reduced underwater noise are significant military features which heavily influence engineering design and will continue to be required. It seems unlikely that major surface ship endurance of less than 5500 km (3000 n. miles) will be acceptable. We will not be able to limit ourselves to a short-range coastal navy concept, which could otherwise ease many technical problems. The major engineering problems in submarines will continue to be those connected with noise and deeper diving depth.

Finance

It is hard to see any early reversal occurring in the present trend whereby defence takes a falling share of the g.n.p. This means an undiminished pressure to achieve increased availability from fewer hulls and to achieve reduced through-cost in ships' life cycles. It also means that adventurous engineering development will be hard to justify unless some over-riding economic or military advantage can be offered, or some overwhelming constraint avoided, thereby.

Manpower

It seems possible that the absolute shortage of men suffered for some time will disappear in the next ten years, but it is certain that the pressure to reduce the number of men carried on board (whether for operation or maintenence or both) will increase because men are costly to accommodate at sea, and to train. Thus automation and repair-by-replacement will both continue to advance to the extent that they show a through-cost advantage, and the shift from on-board maintenance to shore-based support will continue.

Morale

High standards of accommodation and victualling will continue; but more important, engineering systems which tend to debase men by requiring unceasing menial work will have to be avoided.

Industrial connexions

In-house Government resources in the engineering field may be expected to continue to decline in favour of industry, placing upon the latter increased responsibilities in design initiative, line repair and quality assurance. The position whereby the Navy often requires special features in low-volume orders but at the same time wishes to take advantage of commercially based developments will continue to be a problem.

Pollution

The Navy will have increasingly to ape Caesar's wife in regard to atmospheric pollution, air-borne noise in harbours, and waste and sewage disposal.

3. Aims

From the above it may be deduced that the main aims in the development of naval engineering systems and equipment will continue to be:

(*a*) increased performance/through-cost ratio,

(*b*) increased ship availability,

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(*c*) reduced on-board manpower, and
(*d*) proper man-machine relationship
and these would not, presumably, be much different for any other ship operating concern once allowance is made for the different meaning of the word 'performance'.

4. General technical and contractual requirements

Some general trends which are expected to intensify in development, in selection of equipment for standardization, or in industrial contracting, are:

(*a*) Automated surveillance and data analysis for engineering systems.

(*b*) Modular design in equipments and systems to facilitate rapid unit and sub-unit replacement.

(*c*) Built-in machinery health monitoring and defect diagnosis features, and provision in design for non-destructive testing examination to gauge life-expectency in service as well as to help quality assurance in manufacture.

(*d*) Emphasis on low maintenance needs *per se*, coupled with quantified reliability and maintenance data.

(*e*) Emphasis on total through-cost (i.e. development plus procurement plus running plus maintenance) as a criterion of technical choice.

(*f*) Emphasis on 'systems approach' in equipment design.

(*g*) Increased need to adapt commercial designs to naval use rather than develop from scratch.

(*h*) Increasing proportional use of research and development funds to improve availability and through-cheapness rather than specific performance alone.

5. Technical problems for the next decade

Hull forms for surface ships

Some believe an issue here lies between displacement and foil-borne systems. Although the latter may offer some tempting performance advantages, two general points will perhaps be obvious to the thoughtful observer:

(*a*) The feasibility of hydrofoil vessels large enough to mount an adequate weapon fit and rugged enough for ocean service (i.e. for roles beyond that of coastal-waters craft) will require full scale experimental verification.

(*b*) It is difficult to think of any engineering system that gets easier (and therefore cheaper) to provide in a foil-borne rather than in an equivalent displacement vessel, and easy to think of many that will get more difficult (and therefore more costly).

Propulsion prime movers

The prime task of the next decade will be to consolidate the quiet revolution which has taken place already in major surface ships, namely, the abandonment of steam in favour of marinized aero gas turbines, so that the great advantages of these integrated, automatable and replaceable units may be fully realized, and their weaknesses probed and eliminated. In particular, life between overhauls must be extended. Some gaps in our presently available power ranges need to be filled, but it seems unlikely that major ships requiring installed shaft powers in the 4 to

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40 MW (5000 to 50000 horsepower) range will be propelled other than by gas turbines, and any moves to exotic hull forms seem certain to involve their use.

For patrol craft, and the like, of modest military performance and essentially shore-based, diesels are likely to continue to show a through-cost advantage despite high maintenance loads. For very fast coastal craft, however, gas turbines will continue in favour.

The most difficult problem, perhaps, will be to choose the best propulsion system for really small but fully ocean-going warships with significant weaponry if, for reasons of cost, such concepts are required. For example, if a single-shaft ship is desired, how best can a correct cruise-endurance/full-power relationship be achieved with a cheap plant which will ensure survivability against damage or breakdown in ocean operation? The permutations of plant are endless, particularly if unconventional transmissions become cheap enough to be contemplated.

Propulsion transmissions

The extension of controllable-pitch propellers to higher powers than are now entrusted to them may be expected, and hopefully some objectionable features such as high cost and difficulty in silencing will diminish. High power epicyclic gears (capable of reversing) are an increasingly attractive proposition likely to be closely evaluated as an extension of the major advances in transmission gears made under naval auspices since World War II.

Many serious overall warship design problems in relation to the siting of propulsion prime movers and their uptakes would be eased, however, if a high performance electric transmission could be produced at low enough cost. Homopolar machines with superconducting field coils show promise and the problems associated with such systems are currently being actively evaluated. It is possible that such systems (despite their complexity) will be being built into naval ships ten years from now, but cost will figure heavily in the necessary decisions.

Electric power generation and distribution

If ships remain generally of modest size it is unlikely that the electrical system will change from generation and main distribution at 440 V 60 Hz, with generator unit size limited to about 2 MW. A new large ship design would probably force a change to, say, 3.3 kV through considerations of short circuit ratings in switch gear and sizes of cabling.

As regards prime movers, the issue is likely to be whether gas turbines (which in this size at the moment are not economic) will displace diesels on overall availability and through-cost criteria, coupled with design considerations of intakes and uptakes at widely dispersed points in the ship. This is a case where decisions will be greatly influenced by the availability (and extent of usage in non-naval applications) of smaller gas turbines suitable for marinization.

Exploitation of advances in electrical equipment, notably in solid state devices for conversion, control and protection systems, will continue.

Auxiliary systems

The current first-generation all-gas-turbine-propulsion ships still have auxiliary boilers to provide some services, notably desalination. The total non-propulsion *connected* load in all forms is currently between 10 and 15 % of the total propulsion power installed, and although this may rise somewhat the rate of increase in successive designs is easing. In ships of less than about 3000 tons it seems likely that it will be most economical to use the electrical power systems to supply all services; but in larger ships auxiliary boilers will still be needed. In 'all-electric'

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ship concepts, desalination and winterization (de-icing) services present problems. Desalination by reverse-osmosis is under development and looks promising.

Naval operating patterns differ fundamentally from mercantile usage and are such that very little is gained by arranging interdependent energy systems such as waste heat boilers in prime mover uptakes. Thus our policy may be expected to continue whereby interdependence of systems (which brings complex problems of overall reliability and maintenance) will be avoided as far as possible.

Hotel services

Accommodation standards specified already present very serious problems of cost due to space consumption. In this our problems are probably many times more severe than in merchant ships. Design and engineering ingenuity in the more efficient use of accommodation space will continue to be at a premium. The catering system may undergo radical changes, in the interests of saving space, men and equipment; but this would depend on the achivement by the frozen-food industry of considerably higher standards in food taste and appearance than apply today, since excellent quality and variety of food (from a single galley in new ships) are nowadays consistently achieved, and rightly expected, for all on board.

Waste disposal

Sewage treatment plants are specified in new ships, and their efficacy will have to be increasingly assured. In addition plant for treating *all* waste to non-polluting forms will probably soon become mandatory even in small ships. It can further be argued that within ten years there will be a requirement to salvage all logistic supply containers for recycling.

Materials

The over-riding problem will remain that of corrosion, and effort to improve life-cycle value will have to continue. Perhaps inert plastics with better mechanical properties for the marine engineer, and easier to form and work, than those now available will emerge, although it seems unlikely. A really great advance would be a protective paint for steel structures which would be efficient although applied to wet or oily surfaces, but that seems unlikely too.

Nuclear propulsion for surface ships

Any observer could deduce that the application of nuclear power to British surface warships has so far not been considered cost-effective; and that while existing petroleum economics obtain it is unlikely to prove so unless by some major technical advance, should such be feasible, it becomes potentially very much cheaper. Since major development investment is in general necessary to achieve any significant technical advance in nuclear engineering this impasse seems likely to exist for some time. The analogy with the mercantile position will be noted.

Direct energy conversion systems

This phrase is meant to comprehend those systems which have been put forward in the past as offering great advantage through the elimination of mechanical heat engines. They include:

(*a*) magneto-hydrodynamics and electro-gas dynamics,
(*b*) thermionic conversion,
(*c*) thermo-electric conversion, and
(*d*) fuel cells,

and these have been repeatedly considered for our purposes, in company with other nove devices. In some cases we have funded studies and modest experimental work in industry.

It seems improbable that any of these systems (with the possible exception of fuel cells) will be applied to naval ships in the next fifteen years, because they will not offer sufficient military advantage to justify purely naval development and seem unlikely to be developed in mobile forms for other applications. Their supporters often overlook the fact that elaborate ancillary plant, especially that associated with waste energy removal even if reasonable efficiencies are achieved, will make them as bulky as conventional systems. Mechanical equipment like pumps and heat-exchangers will still be needed, even if the central device does convert energy directly, together with large d.c. motors.

6. The further future

Thus far it may appear that naval engineering systems actually materializing in the 1980s will not be dramatically different from those being built today. For those being *conceived* at that time, however, I believe it will be a different matter – at any rate as far as prime movers are concerned.

Bearing in mind that such conceptions will be in service as late as the year 2020 the question of fuel resources must, in my opinion, be considered. If the phrase 'easy liquid fuel' (or e.l.f. for short) is acceptable to describe what we enjoy now, then all the indications are that before the 1980s are out we will have to think very hard about how to do without it; and will have at least to be planning the necessary research and development. Public debate in the world of science on this, and wider issues, is now fortunately getting under way. Re-emphasizing that I speak only for myself, I feel the following points (which require no special or official knowledge as their basis) are relevant without being either profound or alarmist:

(*a*) Calm thought, early enough, can only be helpful and may save nugatory development effort on systems which in the event will not have an established future.

(*b*) It cannot be assumed that the armed services would receive favoured treatment in competition with civilian needs for dwindling e.l.f. resources – one might even guess that the reverse could occur, because the armed services are under direct government control.

(*c*) Any development work required, being based within the existing fuel infrastructure, will get more expensive as e.l.f. prices rise.

(*d*) The desired characteristics of future naval surface ships indicate that satisfactory non-e.l.f. solutions may be difficult.

The last point arises by the following route. If on the basis of present technology one supposes for argument's sake that:

(i) industry, the home and railways can be powered wholly by coal- or fission-fired electricity;

(ii) civilian automotive transport (and even, for example, pleasure craft) can be powered by short-range energy storage systems developed to an endurance of a few hundred kilometres;

(iii) large ships can be powered by coal (with anti-pollution equipment) or fission reactors, as an interim measure;

then the real problem areas appear to be heavier-than-air aviation, free-ranging military land vehicles, and small ships (especially high-powered small ships) with ranges up to a few thousand kilometres. Fission reactors (which may, in my opinion, be regarded paradoxically as dangerous enough to ensure sufficient discipline in licensing and usage to avoid a pollution problem) cannot be readily accommodated in small ships because of bulk and weight; and integrated, non-polluting, low-maintenance, automatable, coal-fired steam- or gas-turbine plants of high specific performance would appear to present some harsh design problems – and furthermore will probably not be required for any other application.

One must hope, perhaps, that in the 1980s either cheap practical mobile fusion reactors, or some novel short-term major energy-storage system, will be in sight – capable too of being engineered cheaply with reducing resources of certain important materials! By and large it seems unlikely that ship technology in the 1980s will be dull.

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