THE ADVANCED TECHNOLOGY FRIGATE

BY

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This article is based on a paper presented by the author at "Warship '90", the Royal Institution of Naval Architects International Symposium on The Future for Surface Warships, on June 4th, 1990. It is printed here with the agreement of the Institution.

ABSTRACT

This article discusses the roles and problems of surface warships, concentrating on the frigate category. Though conventional frigates are versatile, effective and relatively cheap, they could be improved in all these aspects by the introduction of new technology and design. The key to effectiveness with economy is innovative design and the rapid introduction of new technology.

Roles and Tasks

The principal roles of the Royal Navy's surface fleet are to ensure the safe arrival of military reinforcements to NATO's Central and Northern Fronts and to protect supplies of raw materials on which the economy depends. To carry out these duties the ships must be effective in both Anti-Submarine Warfare (ASW) and in Anti-Aircraft Warfare (AAW). It is assumed that any major threat from enemy surface forces will be removed by SSN, assisted by shore-based aircraft[1].

However, recent and continuing experience since the war has shown that the R.N. is also required to support government policy outside the NATO area in operations ranging from the Falklands war to Armilla, the Beira patrol and cod wars. In retrospect, it is clear that 20th century designs seen as 'successful' were versatile as built and adaptable for new tasks, unforseen at design, during their service life.

A few years ago doubt was expressed over the continuing value and viability of surface ships[2]. It was thought that aircraft and submarines were so superior in ASW that the surface ship, though cheaper, was not cost-effective and that it was too vulnerable to modern weapons.

More recently, the success of Soviet designers in reducing the noise radiated from their submarines has degraded the effectiveness of passive sonars used by all ASW vehicles—submarines, aircraft and surface ships. This does not mean that passive sonars are not needed; for many years the Soviet Navy will deploy numbers of older, noisy submarines and even the new ones can be heard, though at much reduced range.

Increasingly, big active sonars will be needed which cannot be used by aircraft or, in most circumstances, by submarines. It is very likely that such active sonars will be used in towed bodies, behind the ship and well below the surface.

The modern frigate can use controlled force. Its power to influence ranges from cocktail party diplomacy, through limited force—the traditional shot across the bows—to a considerable capability in major war. Such graduated force is under close control of government through the excellent communication fit of a frigate, a capability which is not available in submarines. The very visibility of a frigate is important in giving the impression of power and protection and it can remain on station for a long while.

Survivability of the Frigate Force

Weapon firing trials against frigates more than 20 years old have shown how difficult such ships are to sink using airflight missiles or shells, though a correctly functioning non-contact torpedo is lethal. Computer simulation, backed by trials, has shown that it is possible to give a high probability of retaining mobility after a non-lethal hit[3].

On the other hand, current ships are relatively easily put out of action by damage to cables, electronic spaces etc., but modern micro-electronics, multiplexing and data highways offer a good prospect, in new designs, of sufficient redundancy to provide some fighting capability after a missile hit. The non-contact torpedo is harder to counter but countermeasures combined with a tough structure can do much to reduce the threat.

The designer's aim must be to make the enemy's task more difficult. The number of missiles and torpedoes deployed is quite limited with respect to the number of NATO frigates and destroyers. If the number of enemy missiles arriving can be reduced using weapons and decoys and ships are tough enough to take the occasional hit, the enemy will run out of missiles before NATO runs out of ships; a thought which implies safety in numbers.

These preliminary ideas lead to some basic principles for the design of frigates. Resources will not increase and are all too likely to diminish while the tasks are unlikely to reduce in either number or variety.

- Ships should be cheap enough to be built in sufficient numbers both to carry out all the tasks and as the best form of defence.
- Men are another scarce resource and ships should be designed to work with small crews.
- Ships must be effective in defending merchant ships against a variety of threats. In particular, the ability to operate a big helicopter is important.
- They must be able to communicate and to use controlled force.
- Their availability to fight must be high; it should not be unduly degraded by bad weather, nor should they spend long periods off station for replenishment, maintenance or rest.
- They should be 'battleworthy', able to fight after damage.

(*There can be no perfect solution and the ideas which follow are intended to provoke discussion rather than pretend to a universal revelation.*)

Innovation

Before World War II, a new class of destroyers was ordered each year, usually with only small changes from the previous class. This rapid design cycle and the evolutionary style of design meant that new technology could be brought into service quite quickly and with little risk.

TABLE I—*Introduction of new classes or batches of frigates*

Class			*Date First Laid Down*
Type 22	Batch I	Broadsword	1975
	Batch II	Boxer	1979
	Batch II	Cornwall	1983
Type 23	Batch I	Norfolk	1985

In recent years, the interval between new classes has increased very considerably and is now approaching 10 years, though some changes can be introduced in later batches (see TABLE I). Changes in batch II and III tend to be limited to equipment, with very little alteration to the naval architecture or marine engineering. This lengthy design cycle much reduces the experience of design teams, reducing their ability to innovate successfully.

One of the reasons for the increased interval between new classes is the magnitude of the 'First of Class' costs[4] which include the cost of all the detail drawing work, mock-ups, models, test beds and tools, etc. Such costs have recently been of the same order as the cost of one ship.

The full introduction of computer-aided design (CAD) and draughting, combined with computer scheduling of the production process should lead to a dramatic reduction in such costs and in the time required to develop production drawings from the design. CAD has already greatly reduced the need for mock-ups and models and these should be eliminated by walk-through graphics in the next generation[5].

CAD has reduced the drudgery involved in design and led to a considerable reduction in the number of technicians needed. It has not reduced—may even have increased—the number of qualified designers needed. Even so, the numbers needed are very small and an increase in their numbers and salary will cost very little and would lead to a considerable reduction in building costs and an increase in effectiveness. Such men, naval architects, marine, electrical and weapon engineers *with design experience* are very rare both in industry and in the Ministry and must be offered an attractive career.

Controlled innovation can improve operational effectiveness or reduce cost (occasionally both).Too often, new technology has proved unreliable, with a long period of 'teething troubles' and perhaps, even when these have been overcome, failing to achieve the expected benefit.

For these reasons, Baker[6], himself a great innovator, proposed in 1950 that new design percentages should be 25% novelty and 75% well-tried practise since greater novelty would lead to unreliability whilst less would cause pre-natal obsolescence. At that time the design interval was about three years[7] which would have led to a total change in about 12 years. To match this today, with a 10 year design cycle, would mean changing almost every aspect in each new class. Though the *Norfolk* (Type 23) is a far more revolutionary ship than is generally realized, she falls well short of 100% novelty.

The U.S. Navy Admiral Metcalf drew attention to the problem in a series of talks and papers under the heading of 'The Revolution at Sea'[8]. His theme was that dramatic changes in aircraft and weapons had not been matched by changes in ships. An essential aspect of his revolution was covered by the slogan 'Ordnance on Target' emphasizing that the overriding task of a warship is to fight. This was recognized in a different sense by the slogan 'Fight Hurt', accepting that ships would be hit and must still be able to fight.

Within the Sea Systems Controllerate a similar appreciation led to a less formal—and less sensational—approach known as the Advanced Technology Warship programme. Initially this was conceived as a shopping catalogue, setting out information on new, proven technology which could then be readily utilized in a new design. It is a strange fact that, even though there is such a long interval between designs, an actual design is always rushed. In this paper an attempt is made to show how a large number of individual technology packets can be used together in an 'Advanced Technology Frigate', based loosely on the Type 23.

Beaucoup de préjugé, de doutes raisonnables et des difficultés réelles

(Dupuy de Lôme, 1840, of iron ships)

Even today, the introduction of new technology gives rise to prejudice, reasonable doubts and real difficulties. Many of these arise from lack of appreciation of the contribution made by 'ship' characteristics such as seakeeping, stealth, etc. to fighting capability. Other problems arise from

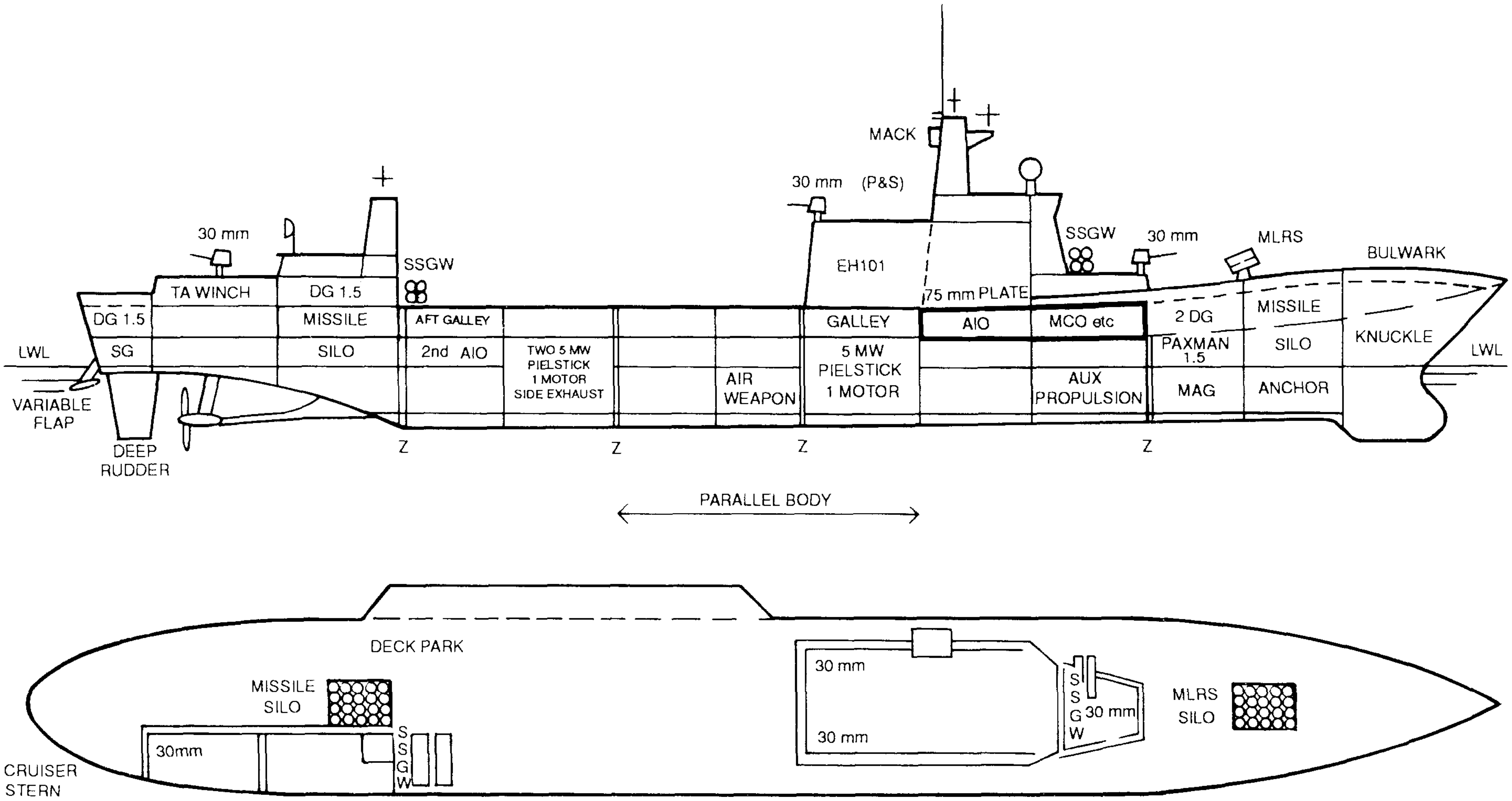

FIG. 1—ADVANCED TECHNOLOGY FRIGATE
Z denotes zone boundary

failure to use investment appraisal to balance increased first cost against savings in life cost. Inevitably, R & D resources are limited and time is short, increasing the risks inherent in new ideas. There may, too, be real difficulties in operating a novel craft, e.g. a 65 knot hovercraft, in a conventional fleet. Most problems can be overcome given the will and authority.

Cost Benefit

The proposals can be grouped under improved operability, reduced vulnerability and reduction in cost (usually running cost). Many involve some increase in first cost and their real value can only be determined by a full investment appraisal. The difficulty lies in allocating a 'Value' to an operational day. It has been suggested[4] that the cost of a day at sea be used as a notational value, since if the ship is at all effective, value must at least be equal to cost.

The cost of providing one frigate at sea for a day is about £100 000 and, if this figure is accepted as the value base for investment appraisal, at least the ranking of the proposed innovations should be correct. It will still be impossible to quantify the value of reducing vulnerability, though computer modelling is making rapid advances in evaluating the effectiveness of various measures[9].

The Advanced Technology Frigate

This study is intended to illustrate the value of a number of innovations in a frigate designed for the same role as the Type 23 and with much the same weapon fit (FIG. 1)

Improved Operability

Many of these improvements are aimed at reducing the effect of motions, so increasing the number of days per year in which weapons and their crews can operate without degradation. The first step is to bring the helicopter spot close to amidships. Lloyd[10] has shown that this will significantly increase helicopter availability. Since pilots, understandably, do not like a superstructure behind them when landing, the deck is sponsoned to port (the normal direction of approach) and a small after superstructure, carrier style, is arranged on the starboard side.

The draught has been considerably increased compared with current practise, to reduce slamming, and the freeboard increased to keep the vessel dry. Some of this increase is achieved using bulwarks which need much less maintenance than rails and can hide the clutter which contributes to radar cross-section. Wetness is reduced and appearance enhanced by a knuckle[11,12] and the anchor is keel-mounted to reduce spray and make damage to the bow sonar less likely.

A cruiser stern is adopted to reduce the risk of broaching though the evidence for the risk is not very strong*. For the same reason, very deep rudders are fitted.

Vulnerability—duplicate, separate, concentrate

The objective is to have at least two of any vital item of equipment, widely separated, so that the ship can move and fight to some extent even after severe damage to one part of the ship. The components of any one system must be concentrated, reducing the profile exposed to damage[3].

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* During the design of the survey ship H.M.S. *Vidal* in 1945, the Hydrographer asked for a cruiser stern as less likely to broach at low speed than a frigate with a broad transom. Papers by Bishop, Price and others also suggest that transoms make broaching more likely.

Diesel-electric propulsion has been chosen since this permits widely distributed prime movers with uptakes and downtakes smaller and hence less difficult to arrange than those of gas turbines. Some are shown with underwater, side exhausts, partly for ease of arrangement and partly to offer a reduction of infra-red signature as an alternative to noise reduction. The bigger diesels are sited in the motor rooms but if these are disabled, power can be drawn from remote generators. A retractable auxiliary propulsor is shown forward, though studies will be needed to see if it is cost-effective. So far, no secondary steering system has been proved. A possible solution is the use of a Voith Schneider unit for the auxiliary propulsor*.

The main operations room complex is forward under the main mast and is protected with 75 mm plate which will keep out most splinters and small arms fire. A secondary operations room is arranged aft (possibly linked to a commercial air surveillance radar). Vertically launched missiles are arranged in two silos at opposite ends of the ship.

The ship is divided into five battle zones, each with its own power supply. Zone bulkheads are of double sandwich material to resist blast and splinters. Accommodation for each rank is divided fore and aft.

Subdivision is considerably improved aft by raising the towed array to the upper deck. The hull is stiffened to resist whipping damage.

Cost of Ownership

A variable incidence transom flap (possibly between the shaft brackets) will give a worthwhile reduction in fuel consumption at all speeds and some increase in top speed[13]. The single set of shaft brackets is angled and twisted to optimize flow into the propeller and a short bossing obviates the need for a second set. The shafts are of spiral wound carbon reinforced plastic, light, stiff in torsion and flexible in bending to accept distortion from whipping.

General Aspects

The ship is designed for a minimum superstructure[14] with little more than the hangar, sensor supports (Macks) and the compass platform forward, and a generator and towed array winch aft. It is essential that good access lobbies and upper deck stores are provided to reduce the clutter on the upper deck which adds to both maintenance and radar cross-section (now known as radar echoing area).

The ship has a parallel middle body slightly reducing first cost and allowing major changes to be made by inserting a new section either instead of or in addition to the existing body (strength margins are allowed). For example, a big Variable Depth Sonar (VDS) could be added amidships working through a moon pool. Endurance could be increased by adding a vast fuel tank (see later in this article).

Helicopter Operation

The principal AS weapon is the big helicopter able to use sono buoys and launch lightweight torpedoes. In practice, this means the EH101 Merlin, which is a big aircraft (TABLE II).

TABLE II—*The EH 101 Merlin*

Weight	14.2 tonnes
Length	22.9 m
Width, folded	6.0 m
Aircraft crew	6
Maintenance crew	13

Such helicopters using Sea

* The German aircraft carrier *Graf Zeppelin* of World War II was designed with two Voith Schneider units well forward.

Skua missiles provide a powerful anti-surface-ship capability, particularly against fast attack craft. Alternatively the helicopter can be used as an early warning aircraft. It is suggested that the R.N. role of protection is best satisfied by maximizing the number of big helicopters at sea and ensuring the maximum operational availability. A force of 50 frigates can, at best, deploy 50 big helicopters. In most current ships the landing deck is right aft, where the vertical velocity is high, limiting availability.

Cost

The ship described would cost more than *Norfolk* but, with one possible exception, the cost need not be great. The apparent exception is the second operations room but it is suggested that the real cost and difficulty of a command system lies in the development. The marginal cost of a duplicate set of hardware and software should not be very large (though there would be some cost in setting to work) and the value in 'fighting hurt' would be considerable.

The ship will be a bit bigger but steelwork is not expensive. With current modular outfitting methods, zoning should not add to the cost; indeed if carefully planned to reduce through services it could even reduce cost. The diesels will be commercial units but the saving on prime movers will be offset by the cost of big motors and elaborate switchboards.

Overall, a slight increase in cost, a few per cent., is likely, offset by reduced operating cost, by improved operability, and by greatly reduced vulnerability.

The British government has reiterated its determination to keep a frigate force of 'about 50'*. Since the U.K. is among the higher spenders on defence in NATO there can be no thought of increased spending. Since the ecomonic life of a frigate is about 20 years[15] this programme implies about two and a half ships a year. The cost of a Type 23 is about £115 million so that there is around £290 million per year for the escort force. Note that the U.K. commitment to the NATO frigate programme, now dropped, was for a more expensive ship than the Type 23, corresponding to a larger total spend.

One of the biggest problems in allocating limited resources is the conflict between quality and quantity. A Soviet writer, Khudyakov[16] expresses this dilemma rather neatly, suggesting that the two most common objectives for optimization are:

(*a*) maximum effectiveness for constant cost;

(*b*) minimum cost at constant effectiveness.

Carried to extremes, the former leads to the 'super battleship' paradox, a single, infinitely powerful ship, whilst the second can lead to the 'Chinese junk'.

In recent years, Admiral Zumwalt, U.S.N., proposed a possible way out in the HILO mix with a small number of fully capable ships backed by a larger number of more limited ships. Earlier, in the 1950s, the R.N. used this approach with the WHITBY/BLACKWOOD classes in the ratio 1/2. The BLACKWOODS were half the cost of the WHITBYS but had virtually the same ASW capability, sacrificing all other roles.

This is the right approach for a low cost, second rate. It must be fully capable in its primary role, saving cost by eliminating other roles. At very low cost, a limited capability in other tasks, at least in peacetime, can be added. The BLACKWOODS might have been more highly regarded if they had been given a simple four inch gun for police duties, adding little to the cost.

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* From July 1990 the official figure is 40. The arguments which follow, though not the arithmetic, remain valid.

The Mix of Ship Types

On a tonnage basis the official building plan of two and a half ships a year corresponds to about 10,000 tonnes of warship. On the basis of constant cost per tonne, it should be possible to buy one destroyer of 6000 tonnes carrying four helicopters leaving 4000 tonnes for simple corvettes. If these are 1500–2000 tonnes some two to two and a half can be built each year.

Big helicopters are not cheap either to buy or run and money must be found to support the bigger fleet of some 6 per year. This will be found by omitting the occasional corvette from the programme.

There is one major objection to a HILO mix, given by the House of Commons Defence Committee[17]:

> We find yet more compelling the more cynical argument that once a cheaper alternative to a fully capable frigate began to be ordered, such ships would not be ordered in greater numbers, but would take the place of frigates, changing the nature and capability of the whole fleet.

The other argument is that the corvette is below the threshold of effectiveness; a point which will be discussed in the context of possible ship options.

The 6000 tonne Destroyer—1st generation

The primary role of the 6000 tonne destroyer is to lead ASW operations with four big helicopters embarked and able to command and control a force including older frigates and corvettes as well as maritime patrol aircraft (MPA) and SSN. It should have the capability to defend itself and ships in company against air attack. Ideally, this implies AEGIS but, unless this is available on very favourable terms, it will have to accept the local air defence system developed for the NATO frigate (FAAMS, NAAWS, etc.). At 6000 tonnes, it can be designed as a 'double ended' ship, able to move and fight, at least to some extent, after a single hit.

The design is dominated by the big hangar. The cheapest solution is the *Engadine* arrangement, with the hangar forward and a rear door giving access to a flight deck aft. This is awkward in practice, involving a lot of helicopter movements, and the flight deck tends to move aft into the high motion zone.

The preferred arrangement is the mini-carrier, shown in FIG. 2. Aircraft operators rightly object to arrangements dependent on a single lift whose failure puts all the aircraft out of action. The sketch is a compromise; there is one lift but rear doors to the hangar give access to an alternative landing spot on the quarter deck which can be used in moderate weather.

Admiral Metcalf, in his *Revolution at Sea*[8], called for a bridge 'no larger than a 747 cockpit' and this has been provided as a crow's nest on the forward mack. Both masts are to starboard leaving an unobstructed flight deck. Since this is long enough for Harrier take-offs, a Ski Jump is provided. It is not intended that the destroyer should be capable of operating Harriers but there may be occasions when a refuelling platform, some considerable distance from the carrier, is valuable.

The big hangar re-opens the old arguments as to which deck is the strength deck. More detailed analysis is needed to settle the question. If the hangar and flight deck are load-bearing structure there will be a major discontinuity at the after end, in the region of maximum sheer stress which could lead to failure under whipping loads. On the other hand, the deeper section amidships could be of value under the same loading. The alternative would be to support a flight deck on steel portal frames with GRP cladding on the sides. The hangar, flight deck and quarterdeck are open spaces, making the ship very adaptable to other roles such as troop carrying, disaster relief, etc.

The machinery is diesel-electric, and all 'advanced' features are included.

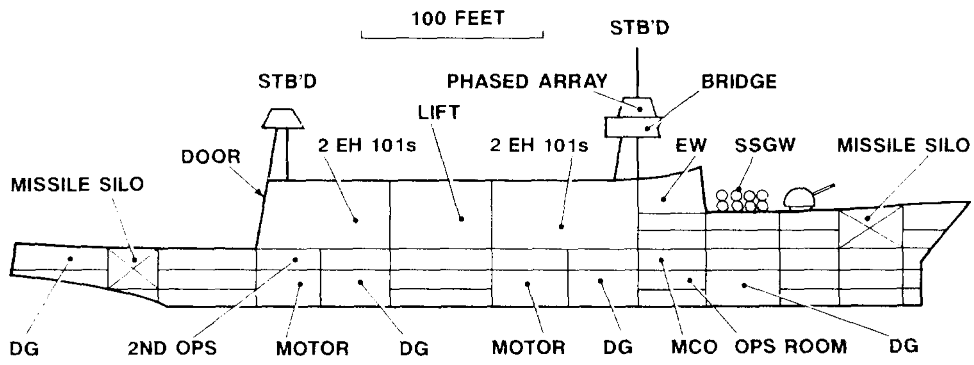

FIG. 2—6000 TONNE DESTROYER

The Baseline Corvette

This corvette is a development of the CASTLE Class with the same excellent seakeeping and small superstructure (FIG. 3). Its primary role would be to deploy a towed array and to provide a landing deck for a big helicopter. For this role it has to be quiet and would have diesel electric propulsion.

A speed of about 25 knots seems desirable to keep up with container ships and it is necessary to use lighter structure than the CASTLE (OPV 2) to obtain a satisfactory Ⓜ*. The power curve (FIG. 4) shows that even at 20 knots the CASTLE needs nearly 50% more power than the BLACKWOOD of the same displacement, and the differences will be much greater at 25 knots. Both noise reduction and speed add to cost but are affordable since costing is on the basis of frigate cost per ton.

These corvettes would have a peacetime role in offshore protection for which they need a gun that will destroy a terrorist or pirate launch and that can be guaranteed to miss when used for a shot across the bow. A modern 30 mm will have some anti-helicopter capability but a larger gun such as the ROF 105 mm may be preferred. These relatively simple weapons may be containerized and changed to suit the task.

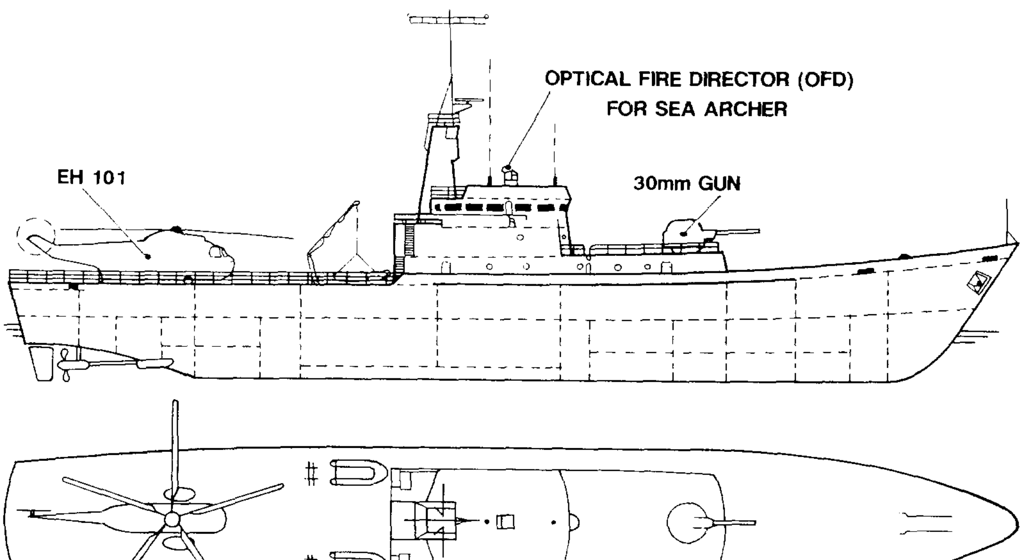

FIG. 3—BASELINE CORVETTE

* Ⓜ = length divided by cube root of immersed volume.

In a major war the corvette would operate as a towed array ship, up to 160 km from a destroyer or carrier, and the corvette's helicopter would rotate through the bigger ship for full maintenance and to avoid the worst consequences of being kept in the open. For many peacetime tasks the helicopter would not be embarked.

The corvette would have simple defensive measures, two engine rooms, and at least two zones but would not be operational after major damage.

The corvette has other advantages; as a small ship it would give young officers early experience of command. Being simple, frequent design changes can be introduced at low cost, on the one hand proving new technology and on the other helping designers to gain experience.

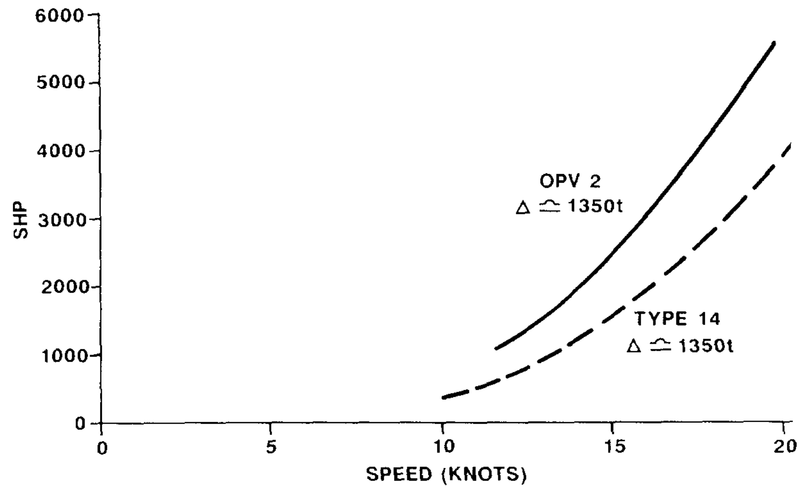

FIG. 4—POWER/SPEED CURVES FOR CORVETTES

Very Long Endurance (VLR) Escorts

Since World War II, warships have relied on replenishment at sea to keep their fuel tanks, store rooms and magazines topped up. This is a demanding and expensive operation which takes the ship off station for a considerable time, particularly in the case of a towed array ship, some 160 km from the main body, and is demanding in manpower. The replenishment ship (AOR) requires escort and its own defence such as point defence missile systems (PDMS) and decoys and should be quiet if it is to operate near towed array ships, all making it a very expensive vessel.

This suggests that there is a considerable advantage in giving escort ships sufficient fuel, etc, for any mission without replenishment. In practice, 30 days at sea is likely to be the longest operational period. Simple calculations show that this could be achieved for a 50% increase in deep displacement. The increase in cost would be very much less; the increase in structural weight would be about 25% which at £10,000/tonne is not much. The ship would be larger, increasing the run of a few systems but pipes and wires are not expensive; system costs rise when additional pumps, etc, are needed. The ship may be a little slower as an alternative to providing more powerful machinery.

There would be considerable overall savings by eliminating not only the AOR but also *the need for its escorts*. It must be realized that these savings will not occur until a complete squadron of very long range ships are in service; the savings are real but future, a fairly extreme spend-to-save measure.

The very long range ships, being bigger, would be better sea boats and would have other technical advantages. The corvette (FIG. 5) at some 2200 tonnes would be large enough to accommodate a hangar for its helicopter and some of the savings from the AOR could be used to give it basic maintenance facilities.

It is bound to be argued that a 2200 tonne ship with one small gun and a helicopter is grossly under armed and there will be strong pressure to add more equipment. Similar criticism will be levelled at the equivalent VLR destroyer of 9000 tonnes. However, cost lies in equipment, not in steel, and will escalate rapidly if more weapons are fitted. In turn, with a limited budget, this will mean fewer ships.

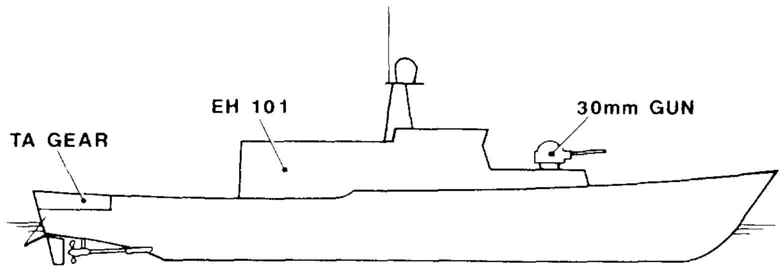

FIG. 5—2200 TONNE VLR CORVETTE

Unstable Designs

There are combinations of size and cost which are philosophically unstable with almost intolerable pressures to increase equipment and hence cost. The corvette is in one such zone; it must be kept cheap enough to be seen as expendible—safety in numbers; attempts to give it an adequate self defence raise the price to a level at which numbers become inadequate. Another example of the unstable design is the cheap helicopter carrier which is always likely, for very good reasons, to turn into an expensive CVS.

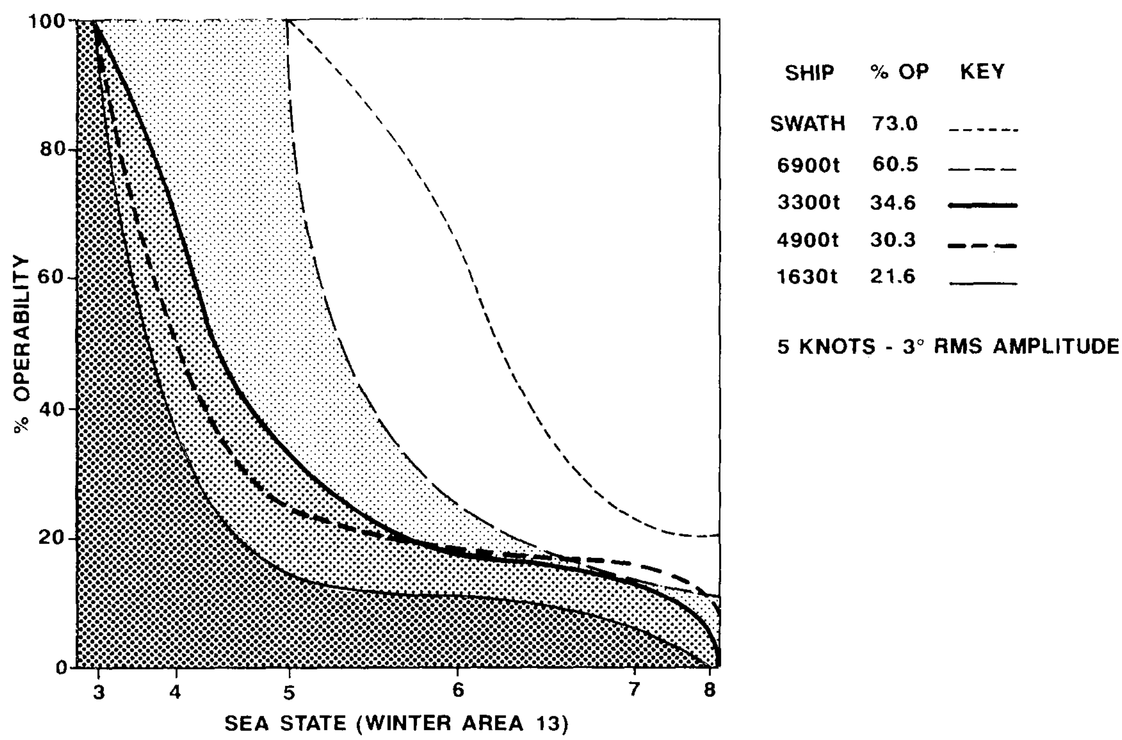

FIG. 6—OPERABILITY V. SEA STATE FOR SWATH AND VARIOUS MONOHULLS

SWATH

The case for SWATH has been argued energetically before and need only be summarized here. The SWATH offers a very great reduction in vertical motions in return for a small increase in structural weight and cost (FIG. 6). It may also require some additional systems for ballasting and for active fin stabilization.

The value of the increased operability given by reduction in motions is hard to quantify. In particular, there are limits on helicopter operation imposed by wind speed, independent of motions[10], a limit usually ignored by the more enthusiastic advocates of SWATH[18].

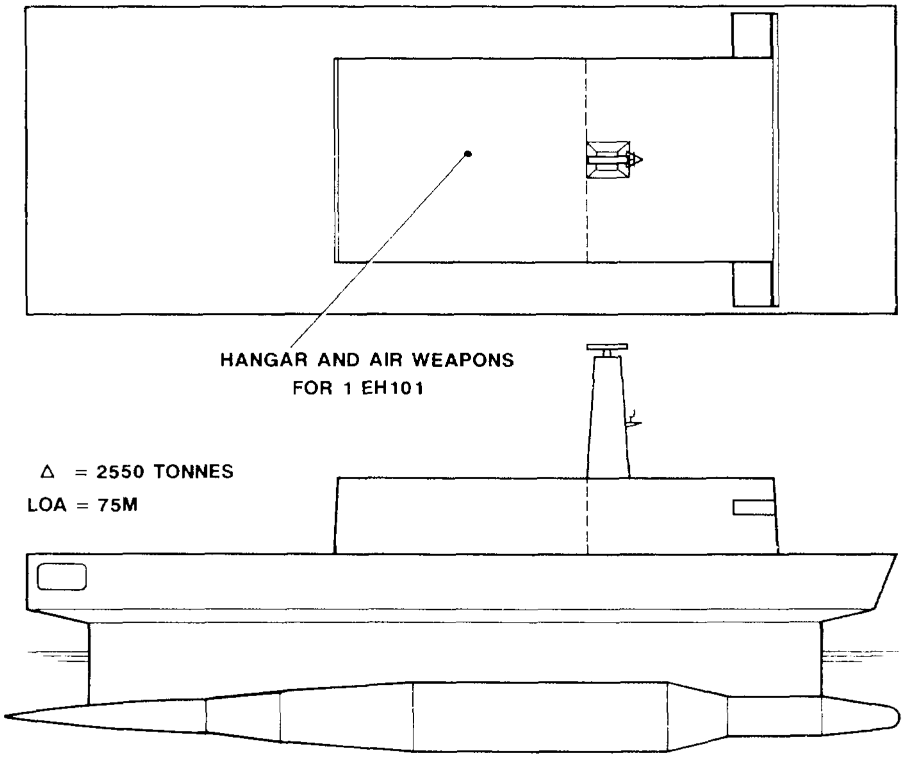

FIG. 7—SWATH CORVETTE

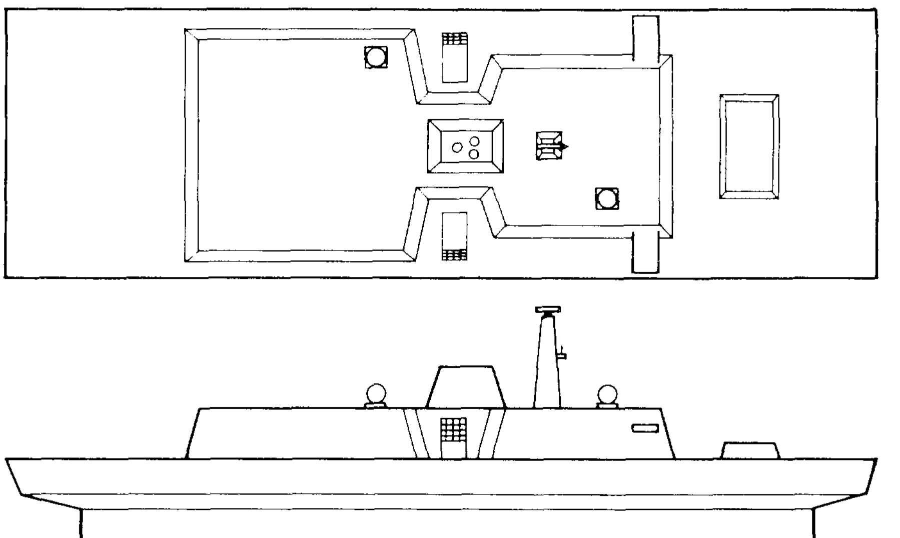

FIG. 8—SWATH DESTROYER

SWATH must operate at almost constant displacement and hence very long range variants, at least, will require ballasting as fuel is used. The SWATH configuration (FIG. 7) is convenient for helicopter operation and hence it should be possible to design the destroyer without a lift (FIG. 8), saving some cost.

The benefits of reduced motion will be more significant in the smaller corvette. The low cost and uncomplicated corvette is an ideal choice for a prototype SWATH with a high probability of a reliable and convincing demonstration of its advantages. In some roles the greater draft of the SWATH can be a drawback and it may be desirable to continue the building of a few monohulls.

SWATH advantages are less apparent in operations in the latitude of the Azores than off Greenland but it does get rough there, too, and for a fleet which must operate anywhere the SWATH still seems the right choice.

Reduced Manning

The declining birth rate means that there are fewer young men[4], and a smaller proportion of them seem to want to go to sea. It is essential that warships operate with smaller crews. The tasks which are most demanding in manpower are:

- Action Information Organization (AIO)
- Damage Control
- Replenishment at Sea
- Ship Husbandry
- Catering and hotel services

Reduced manning in any of these tasks is almost bound to cause some penalty, but if reduction is essential, as it seems to be, the penalty can be minimized.

The manpower demands of the AIO are, to a considerable extent, the result of the requirement to operate in a manual mode following damage or breakdown. The provision of a second AIO reduces the need and the performance of modern weapons makes a manual mode of little value. Since the AIO must operate continuously, manned in three watches, any reduction in operators is trebly welcome.

The Falklands War showed the advantage of big crews, particularly of technical ratings, in damage control and there can be no doubt that this function will be impaired if crew numbers are reduced. Increased redundancy can do much to reduce the penalty; a damaged—or even burning—compartment will be isolated and abandoned.

The need for replenishment is eliminated in very long endurance ships.

The Ship Husbandry task of day-to-day cleaning, painting and low level maintenance is demanding and cannot be eliminated. Major cleaning can be done by contractors on return to port. By avoiding dirt traps in the design and using 'easy clean' surfaces the task can be reduced, though many such 'easy clean' materials are fire and smoke hazards. All the crew, including officers, must play a part in keeping their living and working areas reasonably clean and tidy at sea—as do most bachelors ashore. 'Airline' style meals do not offer any overall advantage but may be helpful in reducing the need for catering staff to feed watch keepers at unusual hours. Larger crews may mean larger ships and if the ship has to be enlarged the cost is about £100,000/man. It is likely that upper deck layout will fix the minimum size of a monohull frigate and that there will be room below for about 100 men.

On cost, as opposed to demographic grounds, there will be little point in going below this number. Different considerations apply to a SWATH and the full cost/man may be incurred.

Virtually all paper work can be carried out ashore. There may be special operations for which a larger crew is needed. Some permanent spare accommodation can be provided, using recreation rooms, etc. In addition, bolt-on containerized accommodation can be added on the upper deck of the spacious VLR ships. It might still be cheaper to pay a seakeeping bonus so that young men want to go to sea.

Arms Limitation

Between the wars there were several treaties aimed at limiting the power and cost of navies. Categories (battleship, aircraft carrier, cruiser and destroyer) were clearly defined and the capability of units limited by simple rules on displacement and size of gun. For each category the number of ships or the total displacement was set. Despite some blatant cheating, mainly on displacement, these treaties were fairly successful[19].

Today, categories are unclear with frigate and destroyer almost indistinguishable and ranging from 1500–10000 tonnes; capability depends as much on computers and their software as on the number of missile launchers.

The need for navies differs widely. NATO is almost totally dependent to sea communications whilst the Soviet Navy is primarily an extended coast defence force but with a very considerable capability for submarine warfare on the high seas.

Western governments have found that a cash limit is the only way of restraining the ambitions of their own Service chiefs and this may be the key to naval arms limitation. Any such limits must recognize that NATO is dependent on sea transport. A limit on long range missiles, particular those with nuclear warheads, which could attack the enemy homeland may be welcome to both sides.

Such an agreed cash limit must be a long-term objective and will depend on much more open accounting. It is not long since a British government concealed the very expensive Chevaline programme from both Parliament and press and it seems likely that the Soviet government does not even know how much it spends on defence.

It is most likely that pressure in all countries, East and West, to reduce arms spending will limit navies to the minimum level seen as essential. Even more than in the past, it will be up to the naval architect to see that the taxpayer gets the best value for his money and the Navy continues to get the finest ships.

Conclusions—Innovate or Die

The design concepts outlined in earlier sections are illustrative; a personal view on how a more effective fleet can be created within a limited budget. Others may have alternative and better ideas. However, for any improvement some attitudes must change and some difficult and increasing problems must be tackled.

A warship is the largest, most expensive and most complex single artifact in the defence budget and it is the only one for which there is no prototype. Since the warship is unique, there is no need for its procurement procedures to be identical to those of other military hardware and, indeed, attempts to force ships into a straight jacket are harmful, leading to vessels which are unnecessarily expensive to build, costly to run and less effective than they could be.

The present system by which the customer, the Fleet, makes known its needs is too formal, too detailed and too often pre-supposes a particular solution. The initial statement (Staff Target) should be brief, in general terms, and 'fuzzy'. The even more detailed Staff Requirement, produced at a later stage, should be replaced by a Technical Response which the customer is invited to accept or modify.

Because there is no prototype, the design must work first time and yet designers are few and diminishing in numbers, losing experience and lacking authority. Lack of experience is almost inevitable with the smaller number of ships in the Fleet and the long interval between classes. The problem can be reduced by measures such as reducing First of Class costs and building smaller corvettes, so reducing the design interval. Improved data retrieval can reduce the rate at which corporate experience is lost.

Best use of the designers that are available comes from concentrating them in a single office within the Ministry (or under MoD control). There are too few for effective competition at the design stage. The work of the designer is very different from the equally important task of the project manager: in fact, since so much of the cost is committed at an early stage in the design, it may well be that the designer is pre-eminent in value for money terms. The authority of the designer should be restored by the creation of a Chief Designer post at very high rank[20].

It is clear that the applied research into ships and their systems works best when directed by designers rather than pure scientists. The Chief Designer should own his own research establishments for hydrodynamics, structures, materials and survivability[21]. A major function of the Chief Designer would be to carry out investment appraisals and he should have the authority to invest extra cost in building where worthwhile savings in running costs can be demonstrated.

With a limited budget, only technically advanced ships can offer the right combination of economy and effectiveness.

Acknowledgement

This article is a personal view but I am grateful for many valuable comments from, and discussions with, my former colleagues.

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H.M.S. 2010

A GLIMPSE OF THE FUTURE

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ABSTRACT

The engineer in the year 2010 will have quite a different ship to run and this article provides a lighthearted look at what he may be faced with. Although it is ME orientated, many aspects have a whole ship implication.

Introduction

You have just been appointed as the MEO of H.M.S. *2010* (FIG. 1). What can you expect?

This dissertation, whilst purely hypothetical, is intended to give you a taste of the future. Some aspects are based on current developments and initiatives whereas others have not yet emerged from the crystal ball. I do not believe that the weapon system RASTUS exists, for instance, but reduced manning, progressive upkeep and A.C. gas-electric main propulsion are less than figments of the imagination. Some of the ideas put forward in the article 'Engineering in the Royal Navy—Towards the Automatic Warship'[1] have been incorporated in your ship, H.M.S. *2010*.