INFLUENCES ON FRIGATE DESIGN 1950 TO 1990 AND BEYOND

by

M. B. Hawke, CEng, FRINA, RCNC
(*Sea Systems Controllerate, Bath*)

ABSTRACT

The nature of the design of weapons and the demands they make on warships in which they are carried, particularly destroyers and frigates, has changed. It is argued that, if the trends seen over the last forty years continue, radical design solutions will have to be sought by the naval architect.

THE PROBLEMS

The Payload

Ships are primarily designed to carry a payload; warships are no exception, the payload being weapons. These have to be carried in an environment in which they can operate to their full potential, this being provided by the ship. In the case of frigates the style of weapon to be carried has changed, not only due to changes in weapons themselves but also because the ambitions of the Naval Staff have changed. From the point of view of the ship designer, weapons have changed from heavy, high density items such as guns and shell hoists to equipments of low density and of light weight like missiles and electronic accessories.

This is emphasized because even the few guns we do have have become smaller and of lighter construction with features such as grp gunhouses.

Coupled with this has been an increase in demand for weather deck space. Missiles are now stowed in silos, not in deep magazines. The helicopter is a voracious demander of upper deck space and becoming hungrier with each new type. The number and variety of electronic devices increases and each requires aerials and separation from other aerials to reduce or avoid mutual interference.

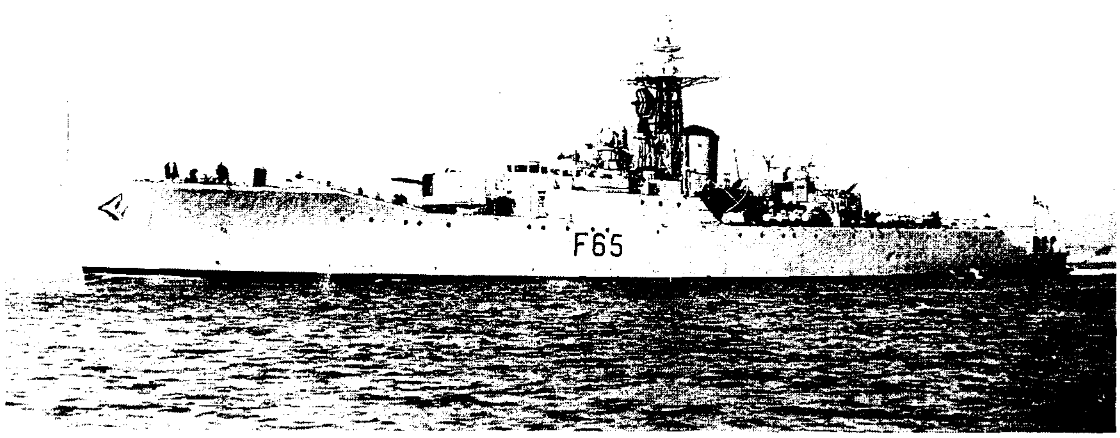

FIG. 1—HMS 'TENBY' (EARLY 'FIFTIES)—THE GROWTH OF UPPER DECK DEMAND HAS STARTED. COMPARED TO THE TRADITIONAL DESTROYER, NO. 1 DECK IS EXTENDED ALMOST TO THE STERN. TORPEDO TUBES AND OTHER WEIGHTS ARE RAISED BY ONE DECK HEIGHT. YET THERE IS SPACE TO PUT 'A' GUN TURRET WELL AFT OF THE BOW, KEEPING IT OUT OF SPRAY AND GREEN SEAS AS MUCH AS POSSIBLE, AND THE EXTENT OF SUPERSTRUCTURE ABOVE NO. 1 DECK IS MODEST

The trend of increasing topweight, demand for upper deck area and surrounding space and volume has been steady since at least World War II. It does not seem likely to stop. The 'extras' in Yarrow's Super Type 23, details of which were recently published in the technical press[1], were all demanders of weather deck space calling for a lengthening of the ship. The Naval Staff response to the threat in respect of the future follows the same trend.

The Ship

This change in weapon demand would not matter, indeed it might not even be noticed, if there were other influences at work which increased the size of the hull in at least the same proportions, thus causing it to be automatically large enough to support all the requirements of the payload. But this is not the case. Trends in ship design have been, if anything, in the opposite direction.

Changes to the nature of weapons have pushed the centre of gravity of the ship upwards, bringing stability and seaworthiness problems. Changes in hull and machinery design have accentuated that rise. Heavy boilers and steam turbines have been replaced by gas turbines of aero industry derivation, lighter in weight but demanding in space, including prime space amidships on the upper deck for uptakes, downtakes and removal routes. Structural engineers have devoted their talents to designing lighter and more efficient hull structures with almost depressing success. There is a demand to place

FIG. 2—HMS 'GALATEA' (EARLY 'SIXTIES)—THE SUPERSTRUCTURE HAS NOW EXTENDED AND NO. 1 DECK EXTENDS ALL THE WAY TO THE TRANSOM. A 'CLEAN-UP CAMPAIGN' HAS RESULTED IN A NEAT APPEARANCE BUT NOTE THE EXTRA TOPWEIGHT OF TWO PLATED MASTS AND 965 'BEDSTEAD' AERIAL; THE 40 mm BOFORS HAVE RISEN BY ONE DECK. THE VISUALLY PLEASING WHOLE HAS DISGUISED THESE CHANGES AND THE RELATIVELY SHELTERED POSITION OF THE 4.5 INCH GUN HAS BEEN RETAINED

auxiliary machinery high on the upper deck where the length of the noise path to the sea is longer and the underwater radiated noise signature will be minimized. With the advent of the towed array sonar, the major sonar set moved from the keel (where it at least provided weight in its demand for structural support) to the upper deck. In the Type 23 two of the diesel generators migrated with it.

The designer of a modern frigate might be forgiven for expressing the opinion that there is no longer anything respectably heavy to put low down in the ship. Now, his last hope, the one thing which could be used to demand space in the main body of the hull and has been a major influence in determining the enclosed volume of the hull is under attack. I refer to the man. From a complement of well over two hundred in the LEANDER and Type 22 Classes we are reduced to a complement of under one hundred and fifty in the Type 23. There is a debate on both sides of the Atlantic about the prospects of the 'fifty-man frigate'.

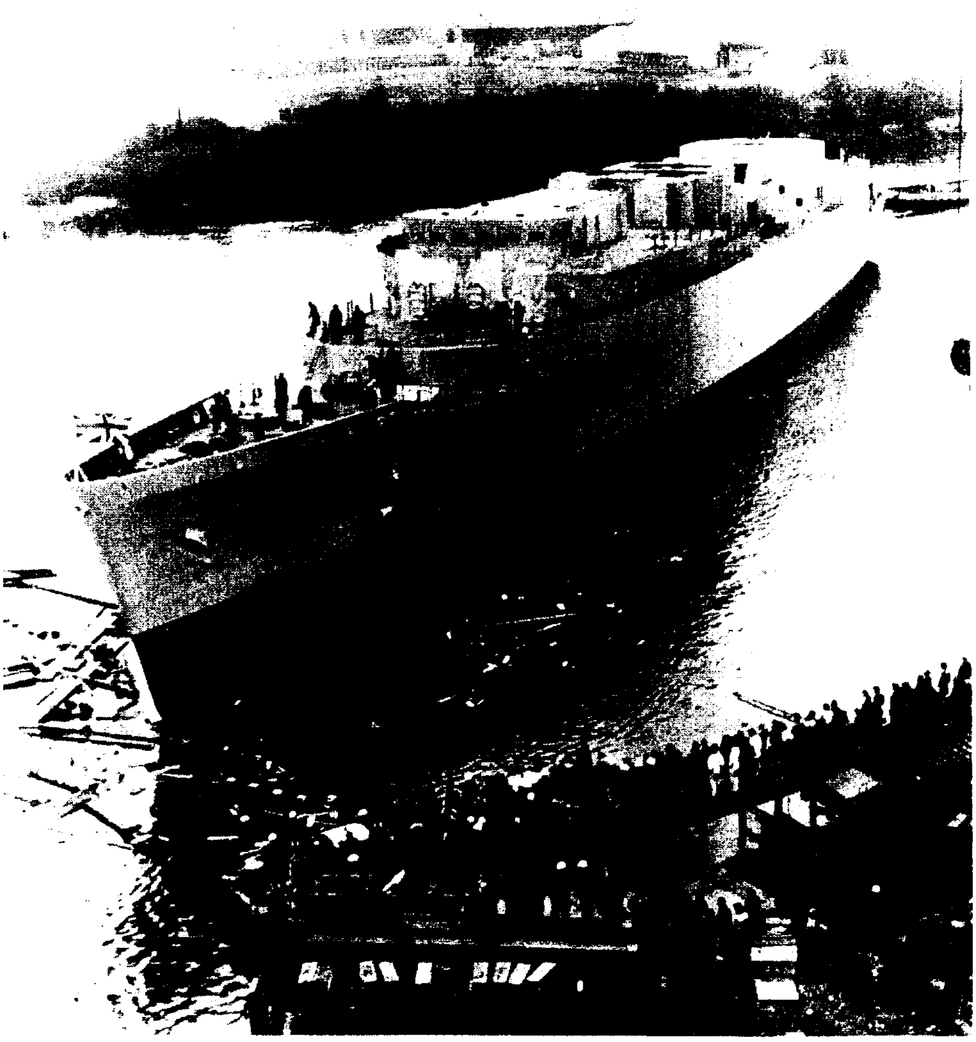

FIG. 3—HMS 'BRAZEN' (DESIGN FROM THE EARLY 'SEVENTIES)— 01 DECK (YES, 01 DECK) NOW RUNS FOR ABOUT TWO-THIRDS OF THE SHIP'S LENGTH. THE BRIDGE HAS BEEN RAISED AND THE EXPANDED COLLECTION OF DECK-HOUSES ASTERN OF IT IS PLAIN TO SEE

FIG. 4—HMS 'NORFOLK' (DESIGNED IN THE EARLY 'EIGHTIES)— THIS DESIGN STARTED LIFE AS A SIMPLE, CHEAP TOWED ARRAY CORVETTE AND GAVE THE DESIGNER A CHANCE TO TRY TO RETURN TO THE LONG LOW LOOK OF THE TRADITIONAL DESTROYER. IN PRACTICE, THE CHANGES DURING THE FORMULATION OF THE STAFF REQUIREMENT CALLING FOR A MORE GENERALLY CAPABLE SHIP RESULTED IN A VERY CROWDED UPPER DECK. THE BRIDGE STAYS IN ABOUT THE SAME FORE-AND-AFT POSITION BUT THERE ARE NO LESS THAN THREE WEAPON SYSTEMS SITED FORWARD OF IT. THE GUN LOOKS PARTICULARLY EXPOSED COMPARED TO PREVIOUS PRACTICE. AFT OF THE BRIDGE THE TOWER BLOCKS RISE IN PROFUSION

The increase in demand for equipment on the upper deck and topsides of ships is being complemented in effect by a decrease in heavy items low down in the hull, accentuating these effects. A reduction in hull volume needs simply makes matters yet worse. Any ship designer needs to keep his centre of gravity low to provide a stable, seaworthy hull—and the lower the better. In the case of the modern frigate, all the cards are stacked against this aim.

The Naval Staff

The Naval Staff composes the Staff Requirement and, for practical purposes, is the customer. The way in which customer demand and perception influences warship design in general and frigate design in particular is a major topic in itself. For the purposes of this article it is worth mentioning just one milestone in the story of frigate design since World War II, 1966, the year of the cancellation of the replacement aircraft carrier project.

From 1945 until then naval tactics and ship design requirements were centred on the Carrier Task Group, an aircraft carrier (or carriers) surrounded by an escorting screen of destroyers and frigates, backed up by replenishment ships. The background assumption was that the air space over the CTG was under friendly control. Attendant frigates and destroyers were equipped to do their specialist tasks be they anti-submarine work, surface engagement, torpedo attacks, radar picket or air-sea rescue chaser. Self-defence against the air threat was provided by the aircraft carrier(s). We recall the Types 12, 41 and 61 frigate classes, introduced in the 1950s, which were products of this scenario and thinking.

The removal of the aircraft carrier and with it the ability to control air space changed all that. Henceforth, as one wag put it, the frigate's task was to defend a patch of ocean which would not need defending if she (the ship) were not there. An anti-air defence capability was now needed and Naval Staff Requirements reflected this.

Whilst aircraft are swift-moving and need rapid-reacting and agile weapons to shoot them down, the problem of killing the missiles they launch is even more difficult. Knocking out a target with a cross-section about the size of a football, travelling at supersonic speeds a nominal height above the waves is a high-tech problem. The present solution is called Sea Wolf, a point defence missile system which is hugely demanding of upper deck space and electronic sophistication. Its inclusion in ships like the Types 22 and 23 has had a major influence on the design and balance of demands on the ship.

This is but one example of how the changing shape of the fleet has changed the Naval Staff's perception of what they need. Compared to twenty years ago they seek more capable ships in both range and depth of duties and, in a smaller fleet, there is less room if any at all for more specialized or single-role ships. Frigates which were once small, almost expendable, units of the fleet are now looked upon as major warships. The resulting demands and aspirations of the Naval Staff add more equipment to the upper works of such ships—and little if anything down below. This provides yet another push in the same direction as the change of technology and reduction of complements. The designer's lot becomes even more demanding.

Future Trends

He who predicts the future is often made to look foolish. However, there is no reason why the three influences which have been discussed so far should not continue to exert increasing pressure. Equipments needing more and more volume topsides will be introduced, further reductions in complement will be sought and each future class of ship will be expected to be yet more capable as windows of opportunity to introduce new classes become fewer.

THE DESIGNER'S RESPONSE

The Response So Far

First it may be appropriate to look at ships in general. Nearly all ship designs have some feature which controls their size. As a simple example, in oil tankers it is the amount of oil to be carried. In passenger ships it is not quite so obvious for it is not dependant only on the number of passengers to be carried. First class passengers who demand a cabin with a scuttle and upper deck space for recreation are probably the key, lesser passengers whose cabins can be hidden out of daylight and who can be restricted to a less liberal amount of upper deck might be carried in some numbers without necessarily increasing the size of the ship very much. For warships there are so many inter-relating factors that identifying the key issue may be very difficult. The key feature may change as the Naval Staff clarify their ideas. It certainly did in the case of the Type 23.

Looking at warships of the past, some instances of controlling features are interesting to consider. In battleships of eighty years ago it was weight. The weight of armour plate, big guns and turrets, heavy steam machinery, etc. meant that, by the time a watertight hull big enough to keep it all afloat had been provided, the volume inside was quite big enough to accommodate men, stores and so on. In aircraft carriers it was flight deck layout, size of catapults, etc. It is interesting to speculate that for destroyers up to 1945, which were the direct ancestors of the ships we are considering, it was the size of the boiler to be fitted. Boilers often spread over the whole beam of the ship and in height from keel to upper deck. Further, the length of the ship was determined largely by the speed required and provided by the steam from that boiler. Certainly the pressure hull diameter and hence most of the other major dimensions of nuclear submarines prior to Trident has been settled by the size of the reactor.

The trends described in this essay were not perceived initially as an upper deck space problem. In the beginning they were viewed as a topweight problem. That there is now a space problem is self-evident. Compare the views of the upper deck from the bow of a Type 12 and a Type 23. It is the contention of this essay that we now have a clear controlling feature of frigate design which has emerged; upper deck space.

The designer's reaction to this trend has been to see that the stability of the ship remains acceptable by increasing the beam a little when required and by continuing to do what good designers have always done, keep weight as low as possible in the ship, oppose topweight where possible and, where additions during service have caused problems, use solid or liquid ballast to keep stability satisfactory. This response has often seemed to be obstructive and unhelpful to the operators. It has certainly had some unhelpful effects. For instance, designers have made great efforts to produce lightweight hulls to keep displacement to a minimum and then added solid ballast to keep them upright! The alternative of water-displaced fuel systems has proved to be neither the MEO's nor the environmentalist's best friend. A more subtle result has been the changing proportions of ships' hulls. The beam/draught ratio of destroyers and frigates has steadily increased from 2.8 in the CA Class to 3.2 in the Type 23.

One may not think this represents a major change over forty years. But, if the trend continues for another forty or even longer, our ships will begin to look like Mississippi paddle steamers and become floating tin trays. This may be acceptable in a river gun boat, designed to operate in shallow water, but ships operating in the deep ocean need draught. They need draught to reduce slamming when steaming into head seas, to reduce bow dome emergence, and to provide good rudder and propeller immersion. For any operational requirement there must be a draught below which the sea performance of the ship in a heavy seaway begins to suffer. When the beam of a ship is increased, if the length and displacement are not changed, then the draught is reduced. So, there comes a point in the design where further increases in beam to counteract the effects of topweight must result in increases in displacement or compromises in operability in rough weather.

Yet an increase in displacement is often looked upon as undesirable. The NFR 90 requirement even contained a statement to the effect that the finished design was to be of minimum displacement. There could be several reasons for this from the political to the practical, via pride. It is a false constraint.

Other Design Influences

Most rules of thumb for costing new warship proposals are based on displacement. Thus, the lower the displacement of any new warship proposal, the lower the expected cost and the greater the perceived chance of getting the ship approved. The fact that such a rule of thumb may be at least misleading and at worst quite unrealistic is not acknowledged. Naval staffs (and nearly everyone else) tend to have a mental picture of what capabilities and range of armament to expect in any given size of ship. If they are presented with a ship which is quoted as being of 5000 tonnes displacement and it possesses a range of weapons which they consider to be more appropriate to a ship of 3000 tonnes they do not think much of it and tend to be very critical. All this is complemented by the designer himself who, quite understandably, takes a pride in producing a ship which can be described as a 'compact package' or a 'powerful weapon platform for its size' or 'much more capable than some other class of similar size'.

This is another set of reasons why the designer, whilst well aware that the laws of physics cannot be circumvented and such things as stability must not be treated lightly, will do his best to lay out a restricted upper deck and topsides using all the compromises available. Design ingenuity has concentrated in producing a compact package in as small a hull as possible. As long as the major challenge to producing an acceptable design was seen as controlling topweight, this was a common sense approach which gave the best chance of presenting any new designs as 'good value'. If the real problem is something else, then this treatment will be of limited value only in its early stages. Once the 'space-up-top' demand outstrips all others the shoehorning option becomes less and less credible and will not be sustainable.

The Future Response

If there is to be a radical approach to frigate design, the designer must take the initiative. That is the easy bit. The difficulty is to take along the user, the customer, the politician and the man holding the money bags. There are at least three possible courses of action, not necessarily mutually exclusive: seek and exploit requirements which will increase hull size; develop methods to demonstrate that big is best for hulls; and seek alternative hull configurations which provide a much larger upper deck area for a given displacement compared to the conventional monohull. Let us examine these possibilities.

Requirements which will Increase Hull Size

One current trend is that ships are expected to spend less of their lives under refit and repair. Ships of the LEANDER Class tended to have much of their hull structure replaced at their mid-life modernizations. The Type 23 has no such luxury specified in her life cycle, the mid-life refit being much shorter, and the Staff may be even more frugal when specifying the pit stops of the Future Frigate. It is also more than likely that frigate type ships may have to serve more than the twenty or so years which has been a typical life span in the past. Both these changes should cause the thoughtful designer to revise his ideas on such things as corrosion allowances, reduction of field stresses to increase fatigue life and provision of accessible spaces around machinery to give easy sight of structure for survey. Finally the weapon engineers would welcome stiffer hulls, particularly in torsion to improve the tolerance in alignment of weapon and sensor. All these four factors will tend to produce bigger and heavier hulls. But, if it is some other design consideration which is driving the size of the hull, the advantages that they give will come as a free gift. Can the designer demonstrate that this is so?

These are opportunities which are waiting to be taken. The Staff might be persuaded to play a similar game. For instance, what is the cheapest ingredient of a ship? The steel. What can we provide in a ship, using steel alone? Tanks. Fuel tanks? Perhaps the specifying of a greater endurance in distance terms rather than time might add very little to the cost of a ship if it resulted only in larger fuel tanks and victualling stores. There might be a long-term spin-off in a reduction in RFA requirements. What can the designer actively do to get others to increase the size of his hull for him?

Big is Best for Hulls

This has led us well into the second possibility of developing methods to demonstrate that big is best for hulls. The time has come to return to reality. Sure, for any given weapon payload, a bigger hull will have the advantages of better seakeeping, wider arcs of fire for weapons, more space for upper deck evolutions and routine maintenance and many other advantages. On the debit side, it will cost more (even if it is only a bit more); it may, but not always, cost more to drive it through the water; and further disadvantages may include practical considerations such as being too big to fit into the Frigate Complex at Devonport. The costing of the advantages is vague and hedged with assumptions. The disadvantages are plain for all to see and might be costed with precision. The presumption that big is best gets short shrift in today's financial climate.

Alternative Hull Configurations

Finally there is the possibility of hull configurations which give more upper deck space for a given displacement. Three might have promise, SWATH, catamaran and trimaran.

All three of these hulls have disadvantages which must be declared at the outset. All will be wider than the monohull carrying the same payload. This could bring docking and berthing problems with present facilities and may call for investment in shore installations. Also all, and particularly the SWATH, are sensitive to changes in displacement. In the case of the monohull, increases in displacement degrade performance at a graceful rate. We have LEANDER Class and Type 21 ships in service which are more than 25% deeper than they were designed to be. Yet their hulls still perform tolerably well in terms of seaworthiness and propulsion, albeit with much restriction on the working of fluids in order to maintain stability. Such tolerance of change of displacement could not be expected of SWATHs and catamarans. Prospects for the trimaran are much better in this respect, especially if the centre hull is large compared to the side hulls and the properties of the vessel tend toward those of a monohull in this respect.

The SWATH is topical because the US Navy is building some for towed array sonar duties. The particular property which is attractive for this work is good seakeeping at slow speeds when the active stabilizers are not effective. This is because its small waterplane area causes only small forces to be exerted on the vessel when the waterline changes, e.g. in waves. This US Navy design has an upper deck area of over 2000 square meters on a displacement of 3500 tonnes. This compares with the Type 23 which has about 1600 square meters with a displacement of just over 4000 tonnes. It is a debatable point as to the comparative usefulness of the two decks. The SWATH deck has a circumference of about 180 meters compared to about 270 meters for the Type 23s. But the point is clear; you get more topside space for a given displacement on a SWATH than on a monohull.

The catamaran is topical because of the recent publicity received by the wave-piercing catamaran *Hoverspeed Great Britain* which has been awarded the Blue Riband of the Atlantic and The Hales Trophy. Subsequently she entered cross-channel passenger service and gained a reputation for making her passengers seasick. In some respects the problems of the frigate designer and his passenger ferry colleague are the same. They both have to accommodate a high-volume, low-density payload which likes to be high up in the ship. International Catamarans of Hobart have tackled the problem boldly, going for an in-service speed of 39 knots and using aluminium alloys extensively. For this latter choice, we would be reluctant to follow their path. But, whilst the catamaran does not have the slow-speed seakeeping advantages of the SWATH, it does have its upper deck area advantages. If it had 'warship conditions' placed on its design, it might not prove to be attractive.

And so to *the trimaran*. There are many possibilities here; the ratio of displacements of the centre and outrigger hulls; whether they are the same or of different lengths; how far apart we place them, and so on. If we play on the advantages we want to gain, we are likely to home in on a design in which the greatest part of the bouyancy is in the centre hull. If this could be arranged to have a length/beam ratio of at least 14:1, wavemaking resistance would be much reduced and propulsive efficiency increased. Placing the propulsion units in the side hulls may also have some propulsion and radiated noise benefits. It should be possible to design a ship of this configuration with the capability to carry a frigate-style payload having some advantages over the normal monohull.

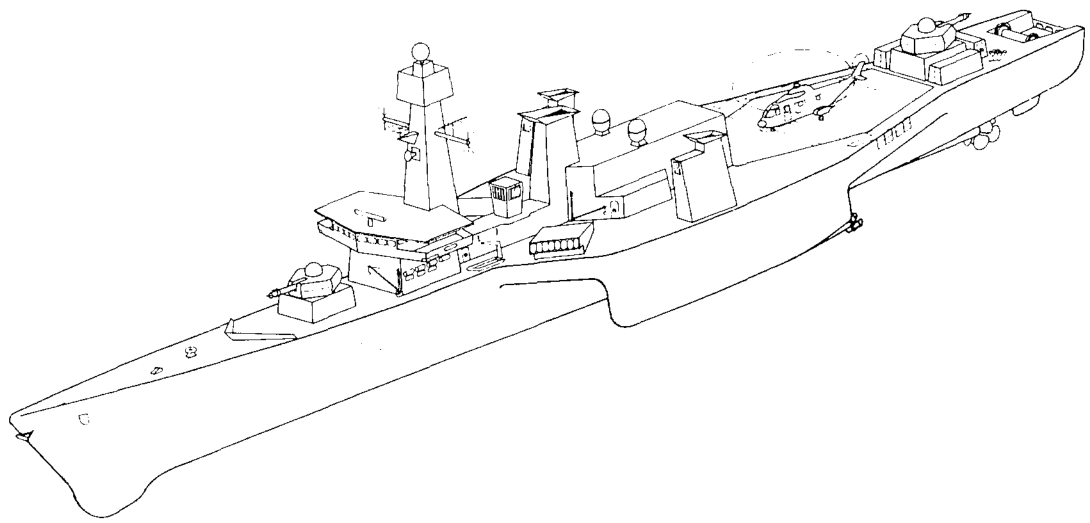

FIG. 5—'F 2000' (?2000 AD)—THIS DESIGN ILLUSTRATES A POSSIBLE APPROACH TO OBTAINING SHIPS WHICH NEED A LARGE UPPER DECK SPACE FOR A SMALL (BY COMPARISON) DISPLACEMENT. THE POSSIBILITIES WHICH SUCH A DESIGN COULD OPEN UP ARE HINTED AT BY THE SITING OF THE FLIGHT DECK NEARER AMIDSHIPS AND THE CENTRE OF PITCH, GIVING A CHANCE OF BETTER OPERABILITY IN HIGHER SEA STATES

In the 1990 MSc ship design exercise at University College London, where the Sea System Controllerate warship designers are trained, a team of students produced such a design[2]. Whilst it cannot be claimed that this is a workable solution to an existing Staff Requirement, the proportions of the vessel which emerged are significant (FIG. 5). A ship of about the same displacement as the Type 23 has a 20% greater length between perpendiculars, giving much better opportunities for a good upper deck layout, separation of electronic devices and clear arcs for sensors and weapons. In addition the centre part of the ship for about one third of its length is of double the width of the Type 23. This affords much larger deck space in the areas where evolutions such as RAS are conducted. The potential advantages and opportunities offered by this hull configuration are worthy of serious consideration.

SUMMARY

It was during the 1939–1945 war that the trend of weapons to demand more and more topside space started. The initial reaction of the ship designer was to treat the needs of ever-heavier and more numerous radar sets as a topweight problem. This was a sensible reaction as long as the ship turned out to be big enough for other reasons. As soon as the demand for upper deck space begins to be the driving force in the requirement, the naval architect must seek unconventional means to produce a balanced and workable design. Trends in ship design are slow, because the timescale between concept and genuine in-service feedback is about half a career lifetime, and are difficult to see clearly, even in retrospect. It is, however believed that frigate and destroyer design has reached the point where new solutions must be sought to the problems which the requirements present.

References

1. Preston, A.: Naval news; *Naval Architect*, Apr. 1990, p. E162.
2. Bastisch, C.: An advanced technology ASW frigate for the year 2000; *Journal of Naval Engineering*, vol. 33, no. 1, June 1991, pp. 43-57.