FLIGHT DECK AND AVIATION FACILITY DESIGNS FOR FUTURE FRIGATES AND DESTROYERS

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ABSTRACT

The presentation aim is to review the design aspects of aviation facilities on frigates and destroyers that maximise aircraft availability and capability while minimising the impact on the other design aims of the ship. Some typical arrangements are presented that illustrate these aspects as well an under-deck hangar to assist exploring other concepts that could be adopted. In general mono hull solutions are considered although reference to trimaran types is made.

INTRODUCTION

Often the aviation facility on frigate or destroyer sized vessels is seen as a capability that is added to the aft end of the ship. Conventional practise is adopted without a full assessment of the effectiveness of the facility and consideration of optimisation of interfaces.

Yet when the ship is in service the helicopter provides arguably the most significant tactical system on the ship. Its roles include:

- electronic surveillance/and countermeasures;
- weapon launch platform;
- search and rescue capability;
- replenishment at sea;
- humanitarian and causality support.

The integration of a helicopter and or UAV into a frigate or destroyer involves almost every aspect of both the aircraft and the parent ship. The incorporation of the aircraft represents a significant proportion of the vessel's capability in terms of its 'Fight/Operational' function. The aircraft extends the range of detection and tactical capability to attack, and to supply and retrieve in the support/humanitarian role. Its effectiveness in the military role is dependent on the speed of deployment and the ability of the aircraft to take off and land safely in all but the severest weather conditions. Typically this means Sea State 5 as a minimum and preferably Sea State 6.

A ship that can only deploy its helicopter in Sea State 4 and below will become more vulnerable to attack particularly from submarines.

The inclusion of a helicopter into a frigate or smaller destroyer will influence the design of the ship more than any other weapon system, particularly if the helicopter is organic to the ship, i.e. has hangar facilities with a capability to:

- man;
- protect;
- handle;
- maintain;
- supply;
- arm.

The main disadvantage of UAV's as compared to a helicopter is smaller payload which impacts upon replenishment at sea, humanitarian and causality support, troop carrying etc.

The advantages of being able to deploy UAV's as compared with a helicopter are:

- speed of deployment;
- risks/redundancy associated with losing the aircraft;
- stealth being a smaller aircraft;
- the possibility of launch and recovery in more severe weather conditions;
- the possibility of carrying more than one aircraft in the same space on the ship and thus being able to address multiple threats.

These aspects all point towards the features of the ship that should be addressed in the concept/design process.

CONCEPT DESIGN ASPECTS

The designer rarely has the opportunity to alter or influence the User Requirement. However, the URD is usually worded in general terms defining a capability but often not specifying the capacity of the capability. Thus there is scope for the designer to interpret the requirement and to consult/collaborate with the 'User' on the development of a solution. The contracting of the design task leads to an agreed contract System Requirement (cSRD), or, depending on the project management/contracting arrangements towards a Contract Technical Specification (CTS) on which the contract with the customer is signed.

Figure 1 below indicates the design process for the aviation facilities.

The choices that affect the aviation and that are evaluated during the concept phase comprise the following:

- The type of hull (monohull, trimaran, etc);
- The general size of the ship (displacement, length);
- The size and number of helicopter(s);
- Layout of aviation facilities (e.g. position of flight deck, location of hangar, etc.);
- The number and size of UAV's;
- The capability of the ship (ship speed, seakeeping, complement, hangar size, flight deck size/height).

Once these parameters have been set, much of the capability regarding the aircraft and aviation facilities have also been set.

During the detail design phase, changes will only have minor impact on the performance and capability of the aircraft. These changes could include:

- minor changes of the hangar external shape;
- minor changes to flight deck dimensions/height;
- hangar arrangements;
- aircraft handling arrangements.

So it is clear that attention to decisions about aircraft capability must be addressed very early in the design.

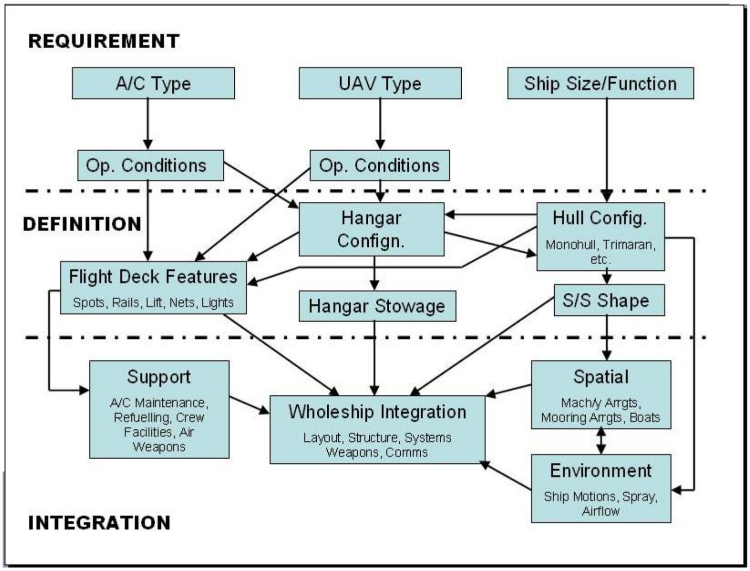

FIG.1 – AVIATION DESIGN PROCESS

The aviation facilities can be improved and optimised through careful consideration of a number design drivers.

The key design drivers are:

- Spatial;
- Environmental Conditions;
- Support;
- Whole Ship.

SPATIAL

The spatial aspects concern the relationship between Flight Deck and Hangar and Aviation Compartments. In particular we needed to consider the spatial impact of:

- Flight Deck;
- Hangar;
- Maintenance space;
- Magazine;
- Supporting compartments, crew, flight operations……;
- Fuel stowage and flight deck services.

Flight Deck

The primary influences that affect the space allocated to a Flight Deck are:

- The size and weight of the largest aircraft to be operated, and its undercarriage configuration;
- The number of operating spots to be provided;
- The handling system to be used for the aircraft;
- The presence of obstructions – superstructure, funnel, masts and the effect of Flight Deck location as it influences the impact of obstructions.

An excessively long Flight Deck will conflict with many other demands on space and is unlikely to be a feature of any design with a significant weapons and communications fit. It is more likely to be found in designs that tend towards the lower end of offensive/defensive capability.

The conventional location of the Flight Deck and Hangar at the aft end has been settled on for reasons that do not accord the priority to aviation concerns that objective assessment might suggest. In short, it has been located there and constrained to a minimum length because no better space of adequate length would be yielded by other design interests in competition for space along the ship length.

An aft Flight Deck location requires that mooring arrangements and weapons systems such as towed arrays have generally to be kept below the Flight Deck. The Quarterdeck housing these facilities can therefore be wet in following seas. Current practice requires these spaces to be enclosed or screened to reduce RCS which makes mooring and operation of a towed array more difficult but this is a design approach that would be adopted even if the Flight Deck was not located aft.

An aft Flight Deck and Hangar will generally limit the location aft of the after exhaust and, with it, the aftmost location of the after Machinery Room. If vulnerability considerations demand separation of main Machinery Rooms then there can be a conflict between Hangar, communications masts etc. and after exhausts.

The length of aft Flight Deck arranged in the majority of conventional frigates and destroyers does not permit a Merlin to be located fully inboard when on the grid because of structural clearance or air wake constraints.

This prevents a full pre-flight inspection unless the aircraft is brought forward. On smaller Flight Decks, such as that for the Type 23, the rotors would have to be folded to accomplish this. It is also possible that troop-carrying aircraft used in inter-service operations will require rear entry so this location will handicap such operations. There is also an increased risk of damage to the aircraft from the sea.

Hangar Requirements

The spatial requirements for hangars in future designs should include provision for any combination of:

- One large manned helicopter such as a Merlin;
- One or more UAVs or other items to be stowed in a protected location.

If fitted, a double hangar will not, in general, be used to embark an additional manned helicopter but will be used for:

- A mix of manned aircraft and UAVs;
- Additional accommodation for visiting aircraft;
- Vehicles or surface craft for Special Forces;
- Disaster relief equipment.

It is assumed that space provision will be made in the Hangar for a UAV and, possible, its ground station even if there is no dedicated spot for a UAV on the Flight Deck.

The maintenance level determines the size of the Hangar and, in particular, the height required if the main rotor head and gearbox are to be withdrawn. At the most basic level of first line maintenance and limited second line maintenance the space required for workshop facilities can be included in the Hangar size – adding up to $26m^2$ to the space required for the Merlin stowage, plus all-round access. Spares holdings are also determined by the level of maintenance provided and are now generally modularised for stowage within or close to the hangar. The modules in the Type 45 contain support equipment, tools and air stores.

A further aspect of support that impacts on space is the provision of maintenance platforms as permanent structure to increase safety and speed up maintenance work. A drawback of fixed arrangements is that they would usually be tailored to suit a particular aircraft and this conflicts with adaptable use of the Hangar, or with application to maintenance of aircraft other than that for which they are designed. Some flexibility for alternative uses of the Hangar or for application to different aircraft can be designed-in by use of sliding, hinged or removable portions of the platforms.

If shaping the end of the Hangar to reduce its air wake impact is considered. This inevitably reduces the internal space of the Hangar, or associated compartments, but possibly creates space on the deck outside that can be used for the storage of Special Forces' equipment and other items, provide that they do not impinge on the Flight Deck or block access to it.

FIG.2 – TYPE 22 AND TYPE 45 HANGARS

Above-Deck Hangar

The most common form of Hangar is on the same level as and adjacent to the Flight Deck (See Figure 2 and Drawing 1 in Annex A). This has the advantage of simplicity in that the aircraft can be moved directly between Flight Deck and Hangar and the principal cost item, apart from the Hangar structure and internal fittings is the Hangar door. In this location the Hangar can have a serious impact on superstructure space and systems mounted on the superstructure or on systems that require space within or through the superstructure. The large size of Hangar for a Merlin impacts on the height and width of the superstructure at the forward end of the Flight Deck, with adverse effects on air flow over the Flight Deck.

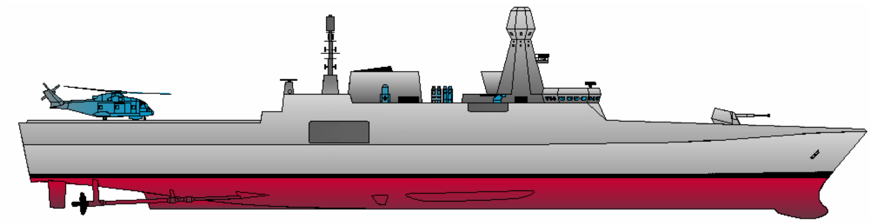

FIG.3 – UNDER DECK HANGAR FRIGATE

A way of reducing or obviating these impacts, assuming that a Hangar is required, is to provide an Under-Deck Hangar. This is normal for larger ships (LSDA, CVF, etc), but has not been adopted for frigate and destroyer size ships.

Under-Deck Hangar

A possible layout for an Under-Deck Hangar on a larger frigate/destroyer is shown in Figure 3 and Drawing 2 in Annex A.

The attractions of an under-deck Hangar are:

- To improve airflow over the Flight Deck;
- To raise the Flight Deck higher above the water level and thus avoid spray;
- The ability to use the lift to transfer other equipment to the Flight Deck from associated spaces such as a Mission Bay aft of the Hangar;
- The RCS signature of the ship can be reduced;
- The Air Weapons Magazine can be located lower down that can reduce vulnerability;
- The aircraft, stores and magazines are lower in the ship which is beneficial to stability. The fact that the heavy scantlings of the Flight deck are higher than for an above-deck hangar is offset by the loss of the hangar structure above deck, even though the scantlings are less. A comparison of the vertical moments concerned indicates that a reduction in the overall VCG can be achieved;
- The aircraft will be stowed lower in the ship and so ship motions will be less, inducing less load into the helo under carriage and lashing points. Structural cyclic fatigue is a consideration for stowed helicopters.

The issues that require consideration are as follows:

- The impact on subdivision and damaged stability. The height of the raised Flight Deck can be chosen to offset this;

- The costs of the aircraft lift and deck closure (if the lift is stowed in the down position). This is partly offset by the cost of the Hangar door;

- The large deck openings that impact on structural strength;

- A minor increase of ship roll motions due to the aircrafts greater height above the waterline. This can be offset by the use of stabilisers;

- The exhaust plume may impinge more directly on the Flight Deck unless the exhaust outlet is offset or raised.

The minimum maintenance height for a Merlin in a Hangar is 5.6m (excluding structure). It is estimated that the Flight Deck would need to be raised from 12.5m for a typical larger frigate/destroyer with above deck hangar, to 14.5m to provide sufficient depth for the Hangar with minimum impact on internal arrangements and to achieve an adequate damage control deck level.

The general arrangement in Figure 1 shows a Mission Bay aft of the Hangar with a watertight bulkhead in between. It would be very advantageous to provide a wide watertight door between the two to permit the transfer of equipment, such as containers, from the Mission Bay to the Flight Deck. The design of such a watertight door would require some ingenuity but is not impossible. The large deck openings can be compensated by fitting a substantial stringer through the half height of the Hangar. This could provide passageways/service galleries port and starboard.

By moving the ship's boat bay forward the effect on shear strength at the aft quarter point can be improved, and the operation of these boats would benefit from lower pitch motions.

Maintenance Space

In new designs it may be necessary to provide space to allow second line level maintenance. With the likelihood of fewer platforms in future, the level of autonomy will have to rise in order to make the maximum use of the asset. Hangar space should be accorded a high priority in the list of considerations for allocation of space. The aircraft is a primary weapon system. Merlin is an expensive aircraft that demands a high standard of maintenance. Deviation from this approach depends on the use of the future frigate or destroyer. History demonstrates that RN ships frequently have their standard roles stretched beyond the original intentions.

The modest savings in cost and space resulting from reduction in self-maintainability could seriously compromise the capability of a future frigate or destroyer to operate outside its standard role.

Air Weapons Magazine

The Air Weapons Magazine could be located below the waterline in the same way as other magazines, with a space adjacent to the Hangar for weapons preparation only, or it could be located adjacent to the Hangar. The deep magazine is preferable from the point of view of vulnerability and has particular advantages when a below deck hangar is also considered as the aircraft lift can also be used as the weapons lift. The installation and vertical access for the weapons lift is often the main argument against a deep magazine on frigate and destroyer sized vessels. However, it could be argued that although a flight deck level magazine increases the vulnerability of the magazine to all weapons other than torpedoes and mines, an above-decks explosion is less threatening to the ship than one below-decks.

The importance of access is directly influenced by Magazine location. Below-decks location will require provision of a lift large enough for transfer of weapons in their packaging assuming that it isn't fitted along with a below deck hangar.

It should be possible to transfer air weapons in their packaging between the Flight Deck and the Magazine/Preparation Space without requiring the aircraft, stores or support facilities to be removed from their stowed locations. This will increase the size of the Hangar, as access to the magazine/preparation space will be directly from the Hangar. Portable handling or maintenance equipment can be excluded from this requirement if minimum effort is required in their removal and there are safe alternative locations for them while weapons are being handled.

The need for air weapons preparation may be diminishing with changes in weapons and operational practice but, so long as the need remains, it is desirable to carry out this work in a dedicated space rather than combine it with some other function.

Supporting Compartments

If UAVs are carried then space provision will have to be made for one or more operators, if the Ground Station is ultimately fully integrated with the ship's weapon systems. While the Ground Station remains a separate control facility, the operator(s) could be located there and housed within the container in its stowage location.

Crew Facilities and Other Compartments

Facilities for aircrew include the significant amount of space required for survival equipment - clothing, parachutes, immersion suits, life rafts etc. The space required should cover stowage and repair of equipment, aircrew dressing/undressing and desirably some ready room facility for aircrew while waiting.

A Cleansing Station should be provided for aircrew returning to the ship. A Handling/Maintenance Crew Ready Room should have basic rest facilities, nearby toilet, etc. for aircrew on standby. The Ready Room should be close to the entrance into the ship from the Flight Deck. Access arrangements should take account of the clearances required for kitted aircrew and for Flight Deck crew wearing or carrying safety and damage control equipment.

Other space consuming compartments provided depend on the scale of the aviation facility and of aviation operations. These include; Air Office(s), FDO or FLYCO, Aviation Power Room, Sonobuoy Store with ready access to the Hangar and Flight Deck. In general, these compartments are of a size that permits them to be tucked into available space.

A FLYCO is required for simultaneous flying operations and a Flight Deck Officer's position (FDO) for single aircraft operation. It is likely that an FDO would suffice for the ships covered in this paper, on operational and minimum manning grounds.

The FDO requires a location that provides an overview of the Flight Deck. Inter-service co-operation suggests that a high central location for the FDO will provide an optimum view that meets the different operational needs of aircrew and aircraft outwith the RN.

Fuel Stowage

Aviation fuel stowage can be a major design driver in frigate and destroyer sized vessels if space for tankage is scarce or if exceptional range is required or if, at some future date, AVCAT had to be replaced by a more hazardous fuel. The latter is unlikely as aviation technology has developed and continues to develop to reduce the hazards associated with fuel although, provision should be made for AVTUR in tri-service or visiting aircraft. Fuel stowage impacts on the loading of the ship, its trim and stability. It need not affect the range of the ship because, in extremis, the engines can burn AVCAT in place of dieso. Clearly, a multi-aircraft ship will increase the fuel stowage required but it will not be pro rata. Aviation also requires a dedicated fuel system with its own pump room.

It is assumed that UAVs will use the same fuel as manned aircraft.

To allow for the possibility of tri-service aircraft being embarked, a facility for defueling AVTUR may be necessary and should be located on the Flight Deck outside the Hangar. Stowage arrangements for AVTUR will be as required in specific cases and will invoke the POL Class 2 precautions.

ENVIRONMENTAL CONDITIONS

- Ship Motion;
- Height of Flight Deck;
- Air Wake;
- Exhaust Plume Effect.

Ship Motion

The main environmental impact on Flight Decks is due to ship motion arising from the effects of wind and waves, but influenced by ship size, speed and heading.

The mono-hulls discussed here fall into a size range that is just beyond the effects of the commonest wave lengths that fall into the range of 50-100m where heavy pitching is likely in head seas and heavy rolling in following seas. Synchronous pitching is likely in head seas but unlikely in following seas.

Trimaran configurations potentially provide a larger Flight Deck with the possibility of multiple aircraft spots, but the motions outboard tend to be more severe. The main landing spot shown in Figure 4 is thus on the centreline. Trials on trimaran demonstrators have indicated that ship motions particularly in stern quartering seas tend to be more severe than for a monohull.

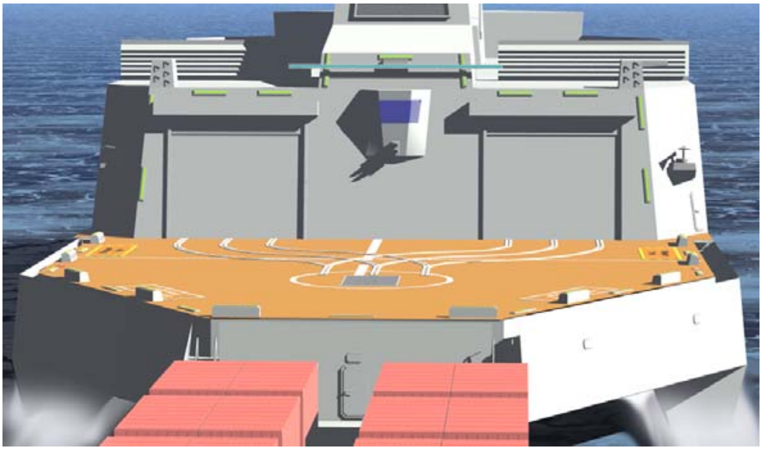

FIG.4 – TRIMARAN FLIGHT DECK

In general, pitching motion is most extreme at the bow and least at about 2/3 the length of the ship from the bow with motion at the stern still very significant but less than at the bow when the ship is proceeding directly into head seas. Astern seas can reverse this order of magnitude. The situation becomes complicated in quartering seas and when rolling and heave effects are included. There is no definitive design decision that can be universally applied to suit all ships under all conditions. Model testing can give an indication of ship motions in a seaway but only the experience of ship operation will determine the optimum manoeuvres for aviation to suit different conditions.

Up to Sea State 4, aircraft should have a time of operability at or close to 100%. At sea state 6 this can fall to around 60% at the upper end of the range of displacements under consideration and down to 30% at the bottom end of the range, even in competently designed ships.

Significant claims with respect to improved seakeeping are made on behalf of variants to monohull forms such as deep-vee bows and bow and stern bulbs.

In general, however, pitch reduction is best effected by length increase although a monohull form with the following characteristics is claimed to have pitch and heave performance similar to a vessel up to 15% shorter in length.

- V-shaped sections forward and aft;
- Wider waterplane forward;

- Harder bilge;
- High flare above the waterline forward.

Height of Flight Deck

The height of the Flight Deck is a critical design issue for aviation. Too low a height risks it being unusable in higher sea states or adds risk of damage to a parked aircraft from the sea or danger to aircraft handlers. This would favour an under-deck hangar arrangement, Figure 3 (and Drawing 2 in Annex A). Past and present frigate designs tend to be criticised for having the flight Deck too low for the reasons mentioned above. The combination of an increased height flight deck with an above deck hangar tends to increase top weight unacceptably. Thus a careful balance has to be applied.

Air Wake

Air wake is a key design driver and, although larger and more powerful helicopters can more readily cope with air wake effects, this is likely to remain a problem for smaller manned helicopters and UAVs.

Air wake effects over the Flight Deck are an inevitable result of ship speed and wind. High wind velocities need not in themselves be a problem although an operational limit is set. The main difficulties for aviators arise from abrupt differences in air flow created by the size and shape of the superstructure that compound the natural effects of most wind conditions. The accelerated air flow over and round the ship results in a wake created by the merging of eddies resulting from discontinuities in and on the superstructure. Over and alongside the Flight Deck the disturbance through which the aircraft must fly can take a variety of forms, depending on relative wind direction and strength and the local geometry of the ship and superstructure. This can be a shear layer between undisturbed flow and the wake, which has a significantly higher air speed than that of the wake, or strong vertical wind force components. The CAA claims that vertical components of airflow are more of a problem to pilots than the general turbulence. The criterion recommended by the Civil Aviation Authority is that the vertical component of air flows resulting from horizontal wind velocities up to 25m/s (48.6 knots) should not exceed + or – 0.9m/sec (1.75 knots) over the landing area at main rotor height. This criterion is generally applied to aviation facilities, offshore and research vessels that may not have the space driven constraints common to warships of frigate or destroyer size and no information is provided about how it is to be measured.

Ideally the flow should be turbulent over the whole wake but the need to penetrate a shear layer or cope with vertical wind components increases the pilot work load and can hazard the safe operation of the aircraft.

- The air wake problem has grown in recent designs that have introduced long, full width superstructures and moved away from earlier practice with side passages abreast the after superstructure/hangar. The reasons for this are RCS reduction and response to the spatial demands on the superstructure. The Navy has expressed a preference for a layout with side passages as in Type 23. This preference is driven by considerations in addition to air wake and on balance, and if the interests of aviation are given a higher priority than signature reduction in this respect, it is the better approach for new designs.

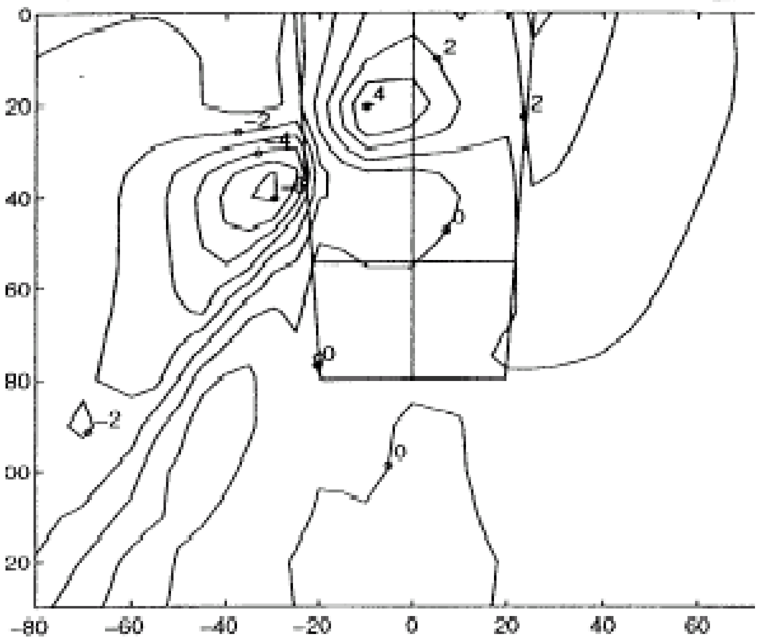

FIG.5 – FRIGATE AIRFLOW FOR 30 DEG GREEN RELATIVE WIND

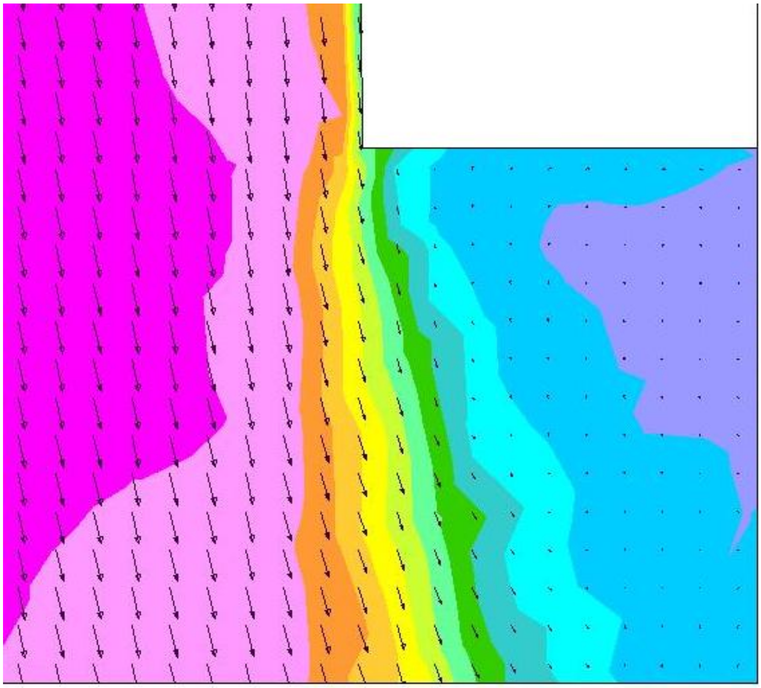

FIG.6 – AIRFLOW FROM CORNER OF FULL WIDTH HANGAR STRUCTURE

An assessment of present warship air flow predictions (see Figures 5 and 6) has led to a design rule that may be used to predict arrangements that avoid the shear-wall of turbulent air coming off the superstructure for aft flight deck arrangements. The procedure is outlined in Annex B. The worst case of a head wind is assumed. This would tend to penalise full width above-deck hangars, and special arrangements, such as tapering, or stepping, of the upper corners of the hangar may be required to achieve satisfactory pilot workloads. Some further validation of the formula provided would be beneficial.

Counters to air wake problems include:

- appropriate separation between superstructure and the forward-most spot;
- reduction in superstructure length, height and width, forward of the Flight Deck. Reduction in length will reduce the strength of the air flow and the associated eddies;
- tapering/stepping the superstructure as it approaches the Flight Deck;
- addition of flow modifiers to superstructure sides and end where it approaches the Flight Deck in order to promote general turbulent airflow.

Flow modification can take many forms from spoilers that break-up air flow to venture devices that redirect it but, in general the most desirable aim is to break up the air wake to minimise the shear layer and the formation of strong downward forces.

If design constraints limit the measures recommended elsewhere in this Report which generally result in increased length of Flight Deck and significant modification to superstructure size and shape, then serious consideration should be given to more drastic means of flow modification such as hinged sections of superstructure tops that can be raised/lowered to change the flow pattern under particular circumstances.

It has been proposed that an approach over the stern will bring the aircraft more gradually into the air wake and avoid the abrupt effects of penetrating a shear layer that could arise from the standard port side approach. This might also reduce the adverse impact of flying into the exhaust plume as described in the next section. Alterations to operating procedures like this have only a peripheral affect on Flight Deck/ship design, such as ensuring that lighting and landing cues are effective, whatever approach is taken.

Exhaust Plume Effect

The adverse effect of an exhaust plume arises from its temperature and gas content. Heated air reduces lift and aircraft engine performance. Depleted oxygen in the plume can result in variable engine performance. Even a 1°C rise in temperature will have a noticeable effect on lift and if the velocity of the exhaust is strong enough to generate a layer of heated air in the wake through which the aircraft must fly on take-off or landing then it can be a hazard. A gas turbine exhaust is much more significant than a DG exhaust owing to the volume of gases involved. The measures to limit the hazard are obvious but not always readily realisable in practice because of the conflict between funnels and other features (principally aerials and scanners for communications and surveillance) that demand space above decks but separation from the exhaust.

Exhaust cooling for IR signature reduction is a benefit but it cannot reduce the exhaust plume temperature to ambient in the immediate vicinity of the Flight Deck if the exhaust outlet is sited in an unsatisfactory location. It is prudent to separate the exhaust outlet as widely as possible from the Flight Deck and to direct the exhaust plume away from the deck. This can be done by raising the height of the funnel and ensuring by design of the exhaust system that the gas velocity carries the plume well clear of the aircraft flight path and of the air wake field.

There are three elements involved in designing to avoid exhaust problems:

- Funnel height based on boundary layer considerations. If the plume enters the turbulent flow regime around the superstructure it will descend to the deck;
- Selection of suitable ratio of plume velocity to wind velocity and funnel shape;
- Selection of suitable funnel shape.

The boundary layer conditions of the superstructure are the same as those that cause air wake problems. A guideline that has been used in the past is to keep the exhaust plume 10m or more above the deck. This is probably too crude to be trusted as it takes no account of the factors influencing the air flow pattern and depth in relation to the hull.

Funnel shape has a major impact on ameliorating exhaust problems. In essence, to keep exhaust clear of the deck:

- funnels should be a minimum size;
- increased length to breadth ratio of the funnel casing is good in head winds but severely increases eddying in other wind directions (yaw);
- improvement is achieved under yaw conditions if the exhaust discharge is as far aft as possible in the casing;
- a tapering casing is good under most circumstances if it has a reduction in breadth at the top;
- extending the exhaust outlet above the casing results in improvement, especially if it is streamlined;
- shaped tops in conjunction with a projecting exhaust can lead to further improvement;
- a horizontal top is best but downwards rake up to 1in 12 has no bad effect. Greater rake is bad.

Some of these guidelines conflict with modern practice for RCS reduction while measures to increase plume velocity as a means of avoiding problems can conflict with plume cooling for IR reduction.

The limitation of modelling on a case by case basis is that it can, at best, only identify specific problems and measures to combat them. The desirability of producing generic information to assist designers in producing acceptable superstructure, mast etc. arrangements is discussed in Section 6. There is a need for serious consideration of alternative arrangements of exhausts that minimise the impact of the plume on the Flight Deck. The CAA recommends that the increase in ambient temperature due to the exhaust plume should not exceed 2°C.

SUPPORT

- Aircraft Handling;
- Hangar Door;
- Support Equipment and Spares;
- Air Magazines and Stores;
- Air Weapons Handling;

- Flight Deck Fittings;
- Safety Nets.

Aircraft Handling

The handling systems for aircraft on the Flight Deck and in the Hangar comprise the following:

- A landing grid to capture the aircraft as soon as it lands using a harpoon, or in some cases is used to anchor the aircraft while in flight and then the aircraft is winched down onto the deck (see Figure 7);
- Fixed lashing points to restrain the aircraft on the deck to cope with ship motions, both when parked on the Flight Deck and also when in the Hangar;
- A handling system that ensures a safe transfer of the aircraft from the landing spot to the Hangar and vice versa;
- A lift that permits the transfer of the aircraft to a below-deck hangar or vice versa.

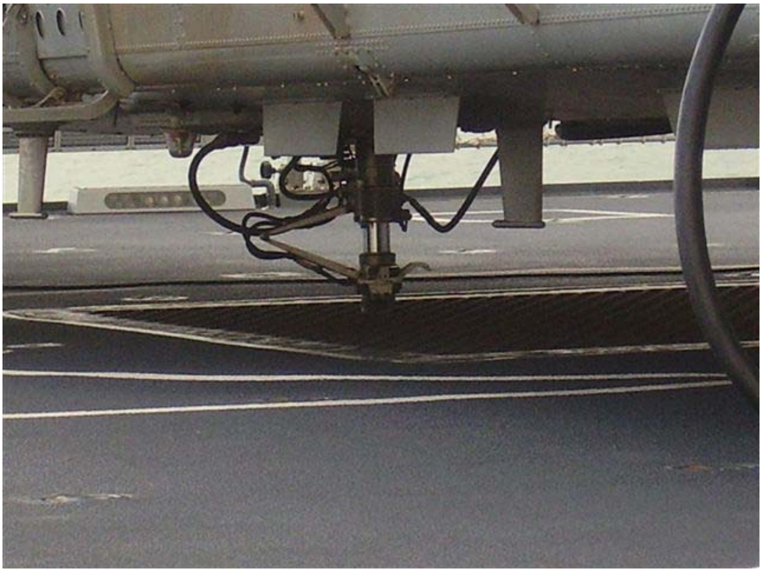

FIG.7 – LANDING GRID AND HARPOON

Handling systems for the aircraft vary from a towing trolley to a fully restraining rail system. The latter impacts significantly on the design of the Flight Deck and Hangar, and is not easily adaptable to different aircraft. However, the smaller the ship the more important it becomes to provide restraint as the Flight Deck is usually narrower, the motions more severe and the hangar, where provided, tends to be tighter on space.

The Navy commented that for larger platforms such as Type 45 and above, a mechanical handler is likely to be adequate. In high sea states a constraining device can be fitted to the handler, using deck link plates. In ships near the bottom end of the size range covered by this Study but which handle Seakings or Merlins, the Navy prefers a rail system. Rail systems can add significant cost, both initial purchase and through life. However, they can also significantly enhance the capability of the ship/aircraft, especially on ships that exhibit high ship motions and accelerations. As is often the case, there is a cost vs benefit trade-off to be undertaken which will be largely dependent upon the platform, but as a general rule, platforms such as Type 23 or smaller, operating large helicopters would expect to have a rail system. This would provide a fully constrained arrangement to take the helicopters from the flight deck into the hangar and back out to the flight deck. It also ensures that minimum clearances between the helicopter and hangar opening are maintained under all operating conditions.

A drawback of most handling systems (other than the mechanical handler) and of rail systems is that they are designed to suit a particular type of aircraft. The centre track could be used on the nose wheel of different aircraft in the same way as the mechanical handler but environmental conditions will determine the limits of this application in smaller ships.

Hangar Door

The Hangar door is an expensive feature and, like a lift requires a high standard of reliability as failure could prevent aviation operations or risk damage to the aircraft, as well as handicapping maintenance arrangements. There are considerations other than aircraft size in the size and design of the door. It has to be capable of withstanding large environmental loads as well as blast effects of an explosion on the Flight Deck.

In most cases the door is an up and over design that requires sufficient stowage headroom above the door opening. This suits the additional headroom required above the aircraft for a gantry and gearbox etc.

Aircraft Lift

It is recommended that the aircraft lift where fitted is stowed in the down position in order to provide maximum use of the hangar space. In this case a separate deck closure is required.

Under-Deck Hangar Lift Opening Closure Hatch

A segmented folding deck hatch can be designed and to ensure weather tightness, a trough and drain system should be provided to back up the sealing arrangement.

Support Equipment and Spares

Aviation spares in modules require readily accessible space adjacent to the Hangar or Aviation Workshop, both for use and for insertion/removal of the modules. This appears to be the way ahead for future maintenance practice and space provision has to be made. Current aircraft have their module requirements established and these will generally be embarked in port with a Flight at the start of a ship's mission but the normal exigencies of service will make it essential that they can be replaced at sea by VERTREP.

Air Magazines and Stores

Magazines and stores for air weapons and equipment etc. have necessarily to be located as conveniently as possible to the Hangar and Flight Deck. This either means at Flight Deck level to intrude on the superstructure where space might otherwise be used for accommodation, boats or uptakes/downtakes, or located below-decks. Below decks, the conflict with accommodation, offices and machinery is likely to be even more severe, compounded by the need for lift access. At the lower end of the displacement range it may not be possible to locate a Magazine below the waterline because of the presence of shafting and tankage.

Air Weapons Handling

There are two aspects to air weapons handling on a Flight Deck:

- VERTREP of ammunition and weapons. This could include most or all of the weapons deployed by the ship and air weapons for use with the helicopter;

- Arming the helicopter with air weapons. A dump is required in a safe location.

The process of arming the helicopter involves breaking weapons out of their stowages in the air weapons magazine, weapons assembly and securing weapons in or to the aircraft. If space is or can be made available, the weapons should be assembled in an annex to the Magazine. This can be the Hangar if it is clear of aircraft and, if so, the safety requirements for its use by aircraft have to be enhanced to comply with Magazine regulations. The alternative is assembly on deck and this is less desirable.

Weapons are generally loaded with the helicopter on its spot and not in the Hangar.

Flight Deck Fittings

Fittings on the Flight Deck itself are specially designed for that location with a low profile for minimum obstruction as a primary consideration. The move towards designs with plane decks and other surfaces unbroken by fittings to reduce RCS, maintenance etc. will primarily impact on:

- Service points, if located on the deck;

- Fire fighting equipment;

- Aircraft handling/transfer equipment;

- Lighting;

- Nets.

The proposal to replace safety nets by a catwalk, at least in larger ships, can provide a location for many flight deck fittings and equipment that takes them off the Flight Deck.

Alternative to Safety Nets

Safety nets are a maintenance burden and their deployment adds a safety risk for deck crew (see Figure 8). One of the most dangerous Flight Deck evolutions is the raising and lowering of the safety nets around the Flight Deck. This can be a very time consuming and risky operation so the nets are left down at all times when at sea and usually only lifted up when coming alongside. This often results in the bolts rusting up, making it much harder to release and re-secure them. There is also an RCS issue with the safety nets although this has been reduced since the change over from steel to GRP stanchions. The nets still have several metal components that add to the general clutter on the ship and to the signature. No alternative form of nets to enhance safety can be readily seen other than consideration of automated rather than manual deployment. Automated deployment will further increase maintenance requirements in an exposed position.

FIG.8 – FLIGHT DECK NETS

The solution adopted in aircraft carriers of a catwalk around the Flight Deck boundary at a lower level than the Flight Deck (see Figure 9 and Drawing 2 in Annex A) is only viable in ships with an adequate width of Flight Deck and a freeboard that does not risk the safety of personnel on the catwalk in higher sea states. It can certainly be applied to a trimaran where the extreme sides of the deck are of little value to aviation. The recommended minimum beam required by a Merlin for forward facing operation is 11m. Therefore the minimum beam required to fit the ship with a suppressed catwalk would be approximately 14.5m if a width of 1.5m on either side is assumed and the vertical sides have a 6° slope for

RCS. Type 45 is about the smallest size of monohull frigate/destroyer that this approach could comfortably be applied to if the standard helicopter is a Merlin.

The catwalk can be used to house Flight Deck equipment and life saving equipment etc. They can also provide an escape route from the Flight Deck under emergency conditions and house Flight Deck edge lights. These can be recessed into the catwalk sides to avoid RCS clutter and help keep the catwalk clear. Figure 2 shows an arrangement with the safety nets replaced by a catwalk.

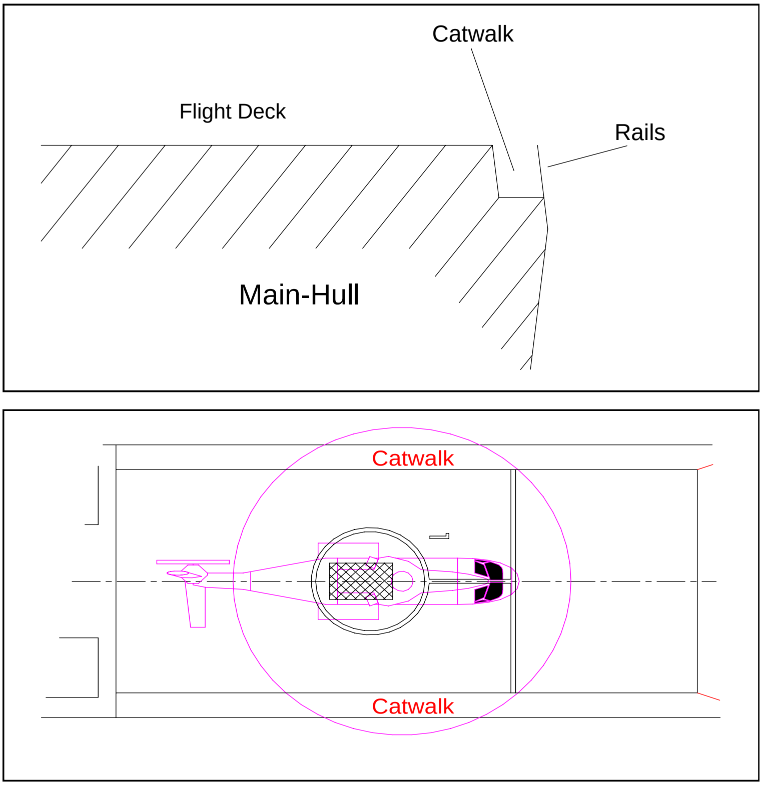

FIG.9 - ARRANGEMENT OF CATWALK

WHOLE SHIP

- Structure and Weight;
- General Arrangement;
- Machinery Spaces;
- Interoperability.

Structure and Weight

The Flight Deck is a major component of ship structure in most designs of frigates and destroyers as it is usually part of the strength deck. It follows therefore that any design variations involving change to Flight Deck location or arrangement have to take account of structural integrity.

Any measures incorporated with the Flight Deck to minimise weight have to take account of the fact that the flight deck is part of the main structural girder in the ship.

Weight as a problem may disappear or at least not grow beyond its present extent, if manned aircraft are wholly replaced in the future by UAVs.

Wheeled undercarriages have a significant effect on flight deck scantlings and thus weight. The obvious alternative is a skid. This is frequently found in small land based helicopters that operate where wheels could be a handicap and that either do not have to move often from their landing point or do so with assistance. The assistance can be retractable wheels or some sort of transporter. The benefit of the skid is that it spreads the load and thus could appreciably reduce the scantlings and weight of Flight Decks.

Some helicopters like the Merlin exist in single and twin wheel configurations. The current UK Navy Flight Decks are designed for the single wheel version. Thus some margin of strength is available if only the twin wheel version is used.

General Arrangement

The interaction between aviation arrangements and the General Arrangement of ships has been considered with respect to the effect on Flight Decks and Hangars of their location in particular parts of the ship. The broader General Arrangement issue is the impact on other features of the ship layout arising from Flight Deck and Hangar location. Some of these effects have been touched on in earlier discussion but principal elements of the layout are summarised here.

Machinery Spaces

The greatest interaction between aviation arrangements and other parts of the ship design arises from the machinery system because of the space and routes required to make provision for uptakes and downtakes. Uptakes carrying the exhausts have always been an issue in this respect but the shift from steam to gas turbines has greatly increased the temperature of exhaust gas and the quantity of airflow into and out of generator rooms. Between them, uptakes and downtakes have a dominant effect on above-deck arrangements, affecting the locations of sensors and weapons systems as well as aviation. A Flight Deck and Hangar, however, occupy a greater proportion of the ship length, wherever located, than any other single facility, so conflict with machinery arrangements is inevitable. If the ship has shaft driven propellers, there is a desire to keep machinery as far aft as practicable to reduce shaft length in order to minimise associated cost, vulnerability and the possibility of technical problems related to shaft length. A Flight Deck and Hangar extending forward from aft will often be in competition with machinery for contiguous space, resulting either in the Flight Deck being shorter or machinery located further forward than desired. The problem can be eased but not wholly overcome if a motor room is replaced by podded propulsion.

Weapons Systems

Weapons systems that fire projectiles have not been located on or close to the Flight Deck in past practice. In general the spatial impact on an aft Flight Deck is to shorten it or at least remove the possibility of lengthening it.

A concern for a Flight Deck/weapons system relationship is the risk of blast and debris from the firing system damaging or destroying an aircraft on the deck or in the air alongside. The risk of this occurring is small but real. A more significant risk and the principal reason for avoiding having weapons systems adjacent to a Flight Deck is the consequence of an aircraft crash on or near a silo.

Interoperability

A problem for warship design and outfit that affects aviation (and many other important aspects of ship operation as well) is interoperability between ships from different navies in combined operations or inter-service operation. Even within NATO countries there can be differences in operational practice that have to be allowed for but operations combining NATO and non-NATO forces will continue to increase.

Tri-service operation will involve aircrew with limited experience of flying operation from ships. As inexperienced aircrews are unlikely to fly if conditions are unfavourable, this may not be considered a problem. However, tri-service operation may be the commonest form of inter-operability involving aircraft at sea in future so Flight Deck design should take account of this.

Aspects of inter-operability that must be borne in mind are as follows:

- The impact of salt water on aircraft that are normally land based. Such aircraft will have to be got into the protection of the Hangar as quickly as possible. Provision for fresh water wash-down and protection of vulnerable parts of the aircraft should be available;
- The weapons systems carried by other aircraft. These may require different control and safety procedures from those normally applied to the ship's own air weapons;
- The safety of deck crew working with unfamiliar aircraft;
- The handling arrangements for aircraft other than those for which the Flight Deck was designed;
- The use of AVTUR rather than AVCAT.

The ultimate determinants of inter-operability are the size and strength of the Flight Deck. Tri-service operation may require the ship to handle troop-carrying helicopters such as the Chinook.

FUTURE AVIATION FACILITY/ CONCLUSIONS

It is argued that the Flight Deck and Hangar arrangements need to be optimised on any future frigate or destroyer design, to maximise the availability of the aircraft. The following features should be considered to improve performance and availability:

- Shaped full width hangar or a hangar with open deck passages on each side to improve air wake effects;

- Medium and larger sized frigates and destroyers could be considered for an under-deck hangar;

- An exhaust arrangement that takes the plume clear of the pilots approach and as far away from the flight deck as possible;

- A catwalk that removes the need for safety nets and provides a useful space for stowage of flight deck material and equipment and leaves the flight deck itself clear should be considered.

Mono hulls are believed to be more attractive than trimaran hull forms for aircraft operations owing to lower ship motions over a larger range of conditions.

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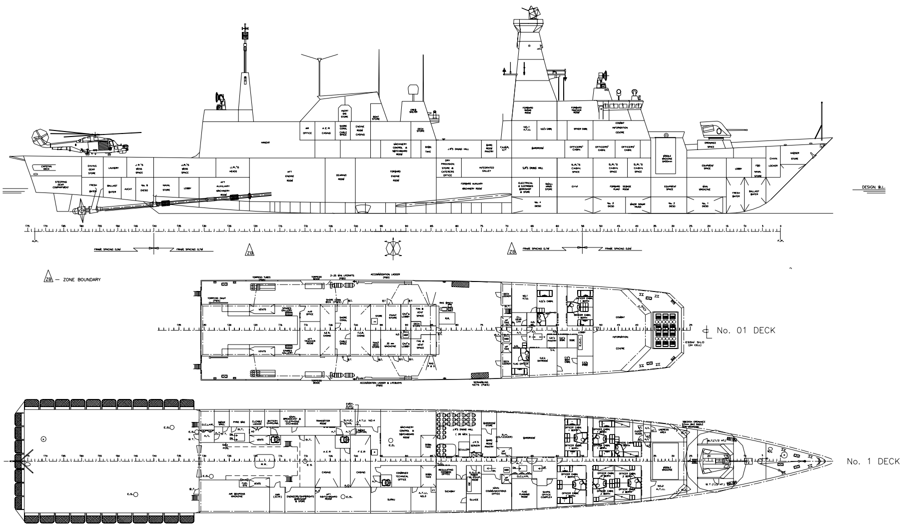
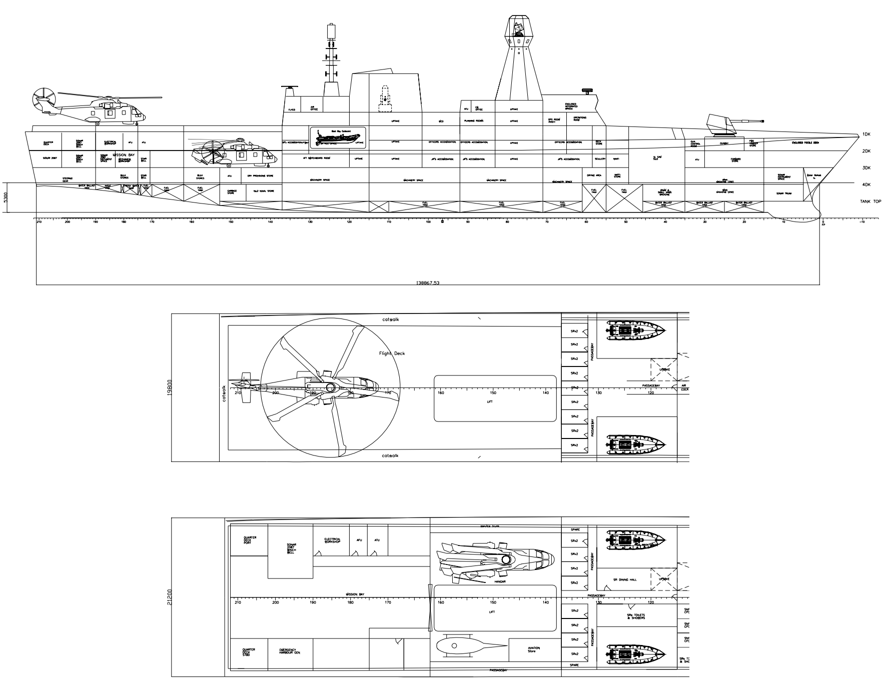
ANNEX A -PLANS



DRAWING 1 – F2000 GENERAL ARRANGEMENT



DRAWING 2 – UDH 8000 TONNE GENERAL ARRANGEMENT

ANNEX B

Design Rule for Hangar Configuration to Achieve Acceptable Air-flow for Helicopter Operations

$\alpha \;=\; a.(W.g/V2)+ b.(w/W)2.(1+ c/\beta)$

Where W (m) is the width of the hangar at 5m above deck
V (m/s) is the wind speed
w (m) is the width of the taper/step above 2.5m above deck
β (deg) is the angle shown for a taper or step

An estimate of the values for the constants is as follows:
a = 7.6, for 4 < V < 15
b = 2000, for 0<(w/W)<0.1
c = 15 for 15 < β < 45 deg

As an example,
Therefore for V = 10m/s, W= 20m, w = 0m, β = 0 deg
α = 15 deg
For V = 10m/s, W= 20m, w = 1m, β = 15 deg
α = 15 + 10 = 25 deg
For V = 10m/s, W= 20m, w = 0.5m, β = 30 deg
α = 15 + 1.8 = 16.8 deg

The aim in design would be to ensure that the angle α is maximised, and it is suggested that the angled line should not intersect the ship centreline aft of the landing spot.