Widening the Net of the Future Air Dominance System

A L Pardoe MEng AMRINA AMIMarEST [1*], M F Lathrope MEng AMRINA AMIMarEST [1], O H Streit BEng AMRINA [1]

[1] *Steller Systems Ltd., UK*
* Corresponding Author. Email: alex.pardoe@stellersystems.co.uk

Synopsis

As aerial weapon systems continue to advance in capability, the ability to detect and neutralise such threats quickly and efficiently is becoming increasingly important. Advanced airborne threats, such as sea-skimming missiles and low-flying aircraft, are becoming more difficult to detect with current radar technology. Meanwhile cheap, 'swarming' attack drones threaten to overwhelm air defence systems through sheer force of numbers. The proposed Future Air Dominance System aims to utilise a *system of systems* approach, with anti-air systems remaining a critical component to dealing with these emerging threats. Capabilities are split across multiple 'nodes' within the system to provide protection over a wide area. This presents an opportunity for a radar picket ship to form one or more such nodes. A platform operating on the periphery of the task group's radar detection range can detect and neutralise airborne threats before the rest of the task group can be targeted. The use of existing platforms in a radar picket role presents an immediate means of widening radar detection range. However, the increased danger and risk associated with radar picket role's up-threat position means that a purpose-built radar picket platform may be considered as more acceptable and cost effective. This paper discusses the role of a radar picket and how such as role may be fulfilled in the future naval battlespace, considering factors such as radar technology, crewing and armament.

Keywords: Naval; Future; Radar Picket; Future Air Dominance System; Airborne Early Warning

1. Introduction

The recent Red Sea Crisis has highlighted the continued requirement for anti-air systems as well as maritime protection roles. Aerial weapons including one-way attack drones, cruise missiles and ballistic missiles have been launched against shipping lanes. HMS Diamond, operating as part of a wider taskforce, has destroyed these threats with both Sea Viper missiles and the ship's guns (Navy Lookout, 2024). The Type 45 destroyer – of which HMS Diamond is one of six – is the Royal Navy's current anti-air warfare (AAW) capability. The current out-of-service date for the Type 45s is 2038 and by this point the successive class should be in service (HC DEB, 2024).

The Type 45 planned replacement, the Type 83, is expected to operate as one part of the Future Air Dominance System (FADS) which will utilise a *system of systems* approach to detect and neutralise threats. As threats increase in capability, they will need to be detected, and neutralised, at ever greater ranges. To achieve this FADS aims to utilise multiple, disaggregated sensors and effectors.

How to increase the range of detection is not a new problem. Radar picket ships saw service in WW2, the Falklands, and the Gulf where they were used to provide early warning of incoming threats. What is new is the size of the net now required to achieve aerial dominance. This paper will explore the potential options required to expand this system using current technology and development.

Author's Biography
Alex Pardoe is a Senior Naval Architect at Steller Systems and an associate member of RINA and IMarEST. Since joining Steller Systems in 2020, Alex has worked on several concept designs ranging from small scale uncrewed vehicles to large naval ships.
Michael Lathrope is a Graduate Marine Engineer at Steller Systems. After studying Marine Technology at Newcastle University, he joined Steller Systems in 2022 and has since worked on power, propulsion and auxiliary systems for a range of concept designs. He is an Associate Member of the IMarEST and the Royal Institution of Naval Architects.
Oliver Streit is a Graduate Naval Architect at Steller Systems and an Associate Member of RINA. Oliver joined Steller Systems in 2023 after graduating from Newcastle University with a degree in Marine Technology. Since joining he has worked on various aspects of concept designs, having mainly focussed on electrical and structural tasks.

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2. Widening the Net

2.1. Increasing Radar Coverage

Radar is a technology that is limited by line of sight, so there is always a necessity to increase overall coverage beyond the radar horizon. Just as in the past, any ability to provide early warning to a major asset increases the time within which reactions can be made. Furthermore, modern-day threats still include sea skimming missiles and low flying aircraft which are both becoming more advanced. Additionally, there is likely to be an increased use of swarming one-way attack drones flying relatively low and targeting maritime assets. Any amount of early warning is a benefit to the task group and in future conflicts a radar picket role will be highly beneficial.

The radar picket role involves increasing radar detection range to detect airborne threats earlier and has historically been performed by ground-based stations, submarines, naval vessels, or aircraft.

The primary function of FADS will be force protection over a wide area, primarily centred around a carrier strike group (CSG). As a system of systems, FADS will be made up of multiple nodes. Whilst many of the nodes will have offensive capabilities, radar coverage is limited to where these assets are located. Through the use of additional nodes in FADS, this radar coverage can be expanded.

In order to increase radar coverage, a platform performing a picket role must operate on the periphery of the task group's radar detection range. With the aim being to detect incoming airborne threats, a picket ship would be best situated in the anticipated direction of such threats. Such a position, described as 'up-threat', inherently comes with increased risk to the platform from airborne, surface and submarine adversaries due to its isolated position.

2.2. Airborne Platform Host

Airborne Early Warning (AEW) is currently provided to the Royal Navy by Merlin helicopters fitted with a Crowsnest system. While this system is currently operational, there is an intention to replace the use of a crewed helicopter with an uncrewed system by about 2030 (Navy Lookout, 2022). AEW provides a highly effective air and surface surveillance and detection capability due to its ability to host a radar at height, vastly increasing the lines of sight. AEWs are capable of vastly widening the FADS net in comparison to surface ship radar capabilities.

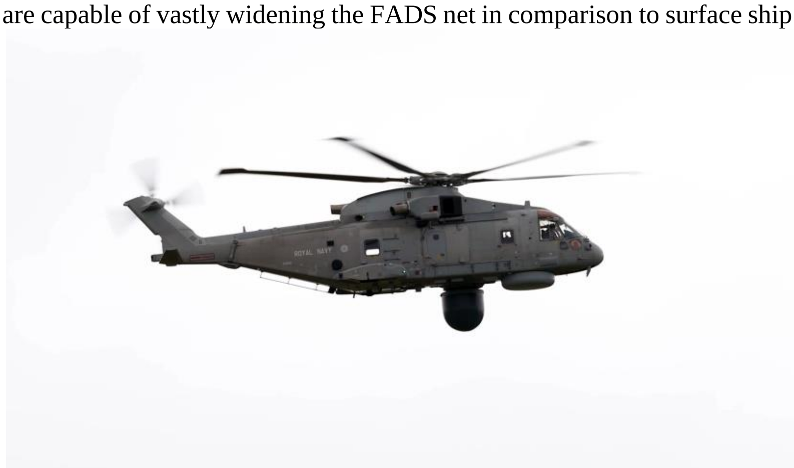

Figure 1 - Merlin Crowsnest with Radar Dome Lowered (Royal Navy, 2021)

The downside to AEW systems – crewed or uncrewed – is that their endurance is likely measured in hours, rather than days or weeks. Therefore, around-the-clock monitoring is likely to be difficult, due to the number of vehicles required. Airborne systems could also be considered to be highly vulnerable, especially as AEW systems are required to fly high to increase radar coverage but at the same time this allows them to be detected easier. Furthermore, not every task group that FADS is protecting will have an aircraft carrier with the capacity to host multiple AEW systems.

2.3. Naval Platform Host

Hosting the early warning radar function on a naval platform as opposed to an airborne platform has the potential to significantly increase the availability of the system. Requiring less energy to maintain position, and with higher capacity for weight and outfit, a naval platform has the potential for a much greater endurance than that of its airborne counterpart.

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A naval platform can provide increased radar coverage for a task group for extended periods of time depending on its size and requirements. For example, a smaller craft may be able to remain at sea for multiple days, whereas larger vessels, such as frigates or destroyers, may remain at sea for several weeks at a time without replenishment.

Moving towards a naval platform would typically limits the altitude of the radar system, losing a key advantage of airborne hosts such as AEW and UAVs. At sea level, the radar system will detect low-flying airborne threats at much shorter ranges than an AEW system due to the curvature of the earth. Whilst high altitude airborne threats such as ballistic and cruise missiles may still be easily detected, low-flying threats such as sea-skimming missiles operate in a blind spot for low altitude radar systems. As such, radar systems should be placed as high as practically possible, whilst avoiding other obstructions and minimising interference from other emitters. The main restrictions on the height of the radar is vessel stability. Higher radars will also increase the vessel's own radar cross section.

Conventional ships, such as frigates and destroyers, are able to house large, capable, radar systems. For example, the RN Type 45 destroyer is outfitted with a SAMPSON multi-function radar positioned at almost 40m above sea level, bringing the radar horizon to around 22.6 km – without considering refraction. Larger and taller radar systems, in addition to the increased size and weight of their respective masts, raise the centre gravity of the whole platform, negatively impacting stability. Radar size and height restrictions may be overcome by other vessel characteristics, such as utilising different hull forms – like a trimaran – to compensate for the impacts on stability.

3. Using an Existing Ship

3.1. Benefits to using Existing Platforms

With a fixed surveillance radar a naval platform may fulfil the high availability required by the radar picket role, which may also be supplemented with a hosted AEW system of its own. Whilst a radar picket ship may be a bespoke vessel, the use of an existing RN platform to fulfil the role of a picket ship should first be considered.

Existing naval platforms such as frigates and destroyers already host capable AAW radar technology. Operating such a vessel as a picket ship within FADS would meet the requirement for increased AAW capability without requiring a new vessel to be designed and manufactured. Furthermore, the vessel would remain sufficiently capable outside of FADS without the need for retrofit.

3.2. Specialist AAW Platform – A Destroyer

The RN already operates specialist AAW platforms, namely the Type 45 destroyer, and its successor, the Type 83 destroyer, is currently in development. Such platforms have the capability to easily fulfil the role of a picket ship. However, an argument can be made that the high capability of these platforms is in fact excessive and undesirable for a radar picket platform.

The Type 45 destroyer is equipped with an advanced multi-function radar system, which can track multiple airborne threats simultaneously and perform fire control functions for onboard weapon systems. The ability to neutralise airborne threats after detection is desirable capability for a radar picket, as it may therefore defend itself and the rest of task group for which it is providing an early warning.

However, operating such a platform as a radar picket would involve accepting the increased risk associated with the up-threat position. A significant component of this risk would involve the high crew complement of such a platform – 190 personnel, up to potentially 285. Furthermore, when operating as a radar picket, other platform capabilities would likely be underutilised or be less effective due to the ship's position away from the rest of the task group. This includes the use of the ship's helicopter, an embarked military force, and land attack weaponry. Therefore, it can be argued that the radar picket role should also have limits on crew complement and platform capability in order to keep the consequences of losing a vessel as low as possible.

The Type 83 destroyer currently in development is intended to play a key role in FADS. Whilst it can be assumed that the size of crew complement may be lower than that of its predecessor, publicly released concepts for the Type 83 indicate that it may carry a significant weapons payload with advanced sensors. Such a large payload capacity would likely well exceed the requirements needed in the radar picket role.

Operating such an advanced AAW platform as a radar picket puts at risk a highly capable vessel and an unnecessarily large number of crew. Losing such an asset would be unacceptable politically and therefore these advanced platforms would be best deployed in the manner in which they were intended to be as opposed to as a radar picket.

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3.3. General Purpose Warship

A general-purpose frigate (GPF) is more preferential to fulfil the picket role than a specialised destroyer such as the Type 83. A GPF will still have a capable radar that allows the radar coverage to be extended, without using up a much more specialist craft. Furthermore, it continues to have capability outside the picket role.

A GPF is likely to be cheaper than a purpose-built AAW destroyer and have equipment that is more acceptable to be lost, however there is still an increased risk to the platform when operating in a picket role. Whether or not it is acceptable to operate a large, crewed asset in such a way would be determined by operational needs at the time, but with limited hulls, any attrition of major surface combatants would likely be undesirable.

4. A New Design - Bespoke Picket Ship

4.1. Sensor Outfit

A bespoke design of picket ship could take several forms which balance cost and capability. Surveillance radar systems range from 2D medium range radars through to highly capable 3D multi-function radars. Airborne threat detection is a primary requirement for the picket role and therefore the choice of surveillance radar presents an important decision.

More capable radar systems typically have a greater impact on the overall design of the ship, the main factors for which include increasing system weight, space, and power requirements. Furthermore, radar mast height plays an important role in a radar system’s effectiveness and is particularly relevant in cases where an advanced 3D medium or multi-function radar system has been selected. The selection of a lower-capability radar system may be justified by the decision to deploy a larger number of vessels and fulfil the picket role of increased radar coverage through quantity.

A bespoke picket vessel does not necessarily have to rely solely on standard, mast-mounted, radar systems. Secondary means of increasing radar coverage include deployable UAVs, AEW systems and tethered airborne radar systems. Whilst the operation of such systems can be disrupted by adverse weather conditions, airborne surveillance systems can significantly increase the radar horizon as a result of the high altitudes that can be reached.

Tethered airborne radar systems potentially offer a greater radar horizon whilst maintaining higher endurances and availability than UAV and helicopter-mounted AEW systems. Such systems have seen extensive use in ISR operations by the United States Coast Guard (USCG) and United States Army. A notable example includes Raytheon’s Joint Land Attack Cruise Missile Defense Elevated Netted Sensor System (JLENS), which tracked long range surface-to-air missiles as its primary function (Horitski, 2016). The altitude, flight endurance and payload weight of an aerostat typically scales with its size, with larger aerostats carrying payloads of up to 1,600kg, having endurances of up to one month, and potentially increasing radar horizon to up to 250km.

Figure 2 - Carlson Tide with TCOM Sea Based Aerostat (TCOM, 2014)

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Hosting aerostat surveillance systems from naval platforms has been demonstrated in the past with the U.S. Army’s Tide-class Small Aerostat Surveillance Ships (SASS) and the USCG Mobile Aerostat Platform, which saw use from the early 1980s until retirement in 1994 (Lobner, 2023). These programmes demonstrated that aerostats could be deployed from slow-speed naval platforms to detect low-flying aircraft at long distances, but were ultimately terminated due to adverse weather limitations and carrier ship availability. If these limitations were to be overcome with modern technology, a tethered aerostat radar system may have use onboard a radar picket platform.

4.2. Uncrewed Platform

The use of an uncrewed platform to fulfil the requirements of a picket ship presents an attractive solution as the lack of crew allows for a smaller platform with reduced defensive capability and other secondary platform functions. With currently available technology, a complete lack of crew is only feasible on smaller platforms.

Autonomous systems contribute to the platform’s complexity and upfront cost. Therefore, a smaller platform should consider eliminating unnecessary capabilities whilst utilising autonomy where necessary to minimise vessel complexity. Furthermore, maintenance, damage control and warfare operations are limited without the versatility offered by a well-trained and experienced crew. As such, an uncrewed solution will drive the design towards low-complexity, cheaper solutions.

It may be possible to field multiple autonomous vessels to collectively fulfil the picket ship role within FADS. By using less capable radars on the design to lower the cost, the reduction in capability may be offset by fielding an increased number of vessels. Minimising platform costs and removing the crew will allow for each vessel to become more expendable, a desirable feature for a vessel required to be up-threat and subject to an increased chance of enemy attack.

As mentioned previously, with current technology, complete autonomy is currently limited to smaller, less complex, vessels. Whilst on larger platforms autonomy may be applied to more generic marine systems, such as those associated with manoeuvring, military-specific systems still require a minimum number of crew. Weapons and damage control systems are perhaps the most significant systems that will currently struggle with automation and drive the need for a minimum level of crewing. Furthermore, a radar picket’s up-threat position requires a minimum level of defensive weapon capability to increase survivability.

4.3. Crewed Picket Ship Platform

In order to become a viable option, a picket ship should mitigate against the risk of loss. This can be achieved by increasing the capability of the design so that it may defend itself, or through the use of multiple nodes to increase resilience in the whole FADS task force. Cost versus capability is the big driver.

A more survivable platform comes through the use of a crew: damage control is possible to extend a platform’s life after action, more advanced weaponry can be included as this can now be maintained and operated, and maintenance can be conducted extending potential endurance. This likely means that a crewed picket ship will be larger than its uncrewed counterpart due to the increased space needs of a crew including accommodation, dining, medical and other facilities. Having a survivable platform is a much more crucial feature when hosting a crew.

By having advanced weaponry, the survivability of the platform is vastly increased, as well as providing an option to counter threats to the CSG earlier than the CSG could. Several Tactical Mk41 VLS cells could provide great flexibility to the platforms CONOPS. For example, Sea Ceptor missiles (Common Anti-Air Modular Missile) or their future equivalents can be quad-packed for a point defence and local defence capability. A Mk 41 VLS can also accommodate Aster 15 and Aster 30 missiles, as well as American SM-2 missiles for longer range targets. This increase in survivability comes with a large increase in cost, not just from the silos and missiles, but also the accompanying equipment necessary to operate a complex weapons system. Furthermore, such weapon systems lead to a larger crew requirement. Simpler self-defence weaponry, such as CIWS, may be better placed on a picket ship. These will be cheaper, have smaller crew requirements and will be better placed to be remotely operated from an external position. Weaponry could also include counter-UAS systems such as DragonFire; major threats would then be countered by other FADS nodes, with simpler targets being attended to by the picket ship.

Overall, the capability of the picket ship needs to be carefully balanced with its cost to ensure that a high value unit, such as a GPF, is not simply replaced with another unit of equal value.

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5. Potential Options

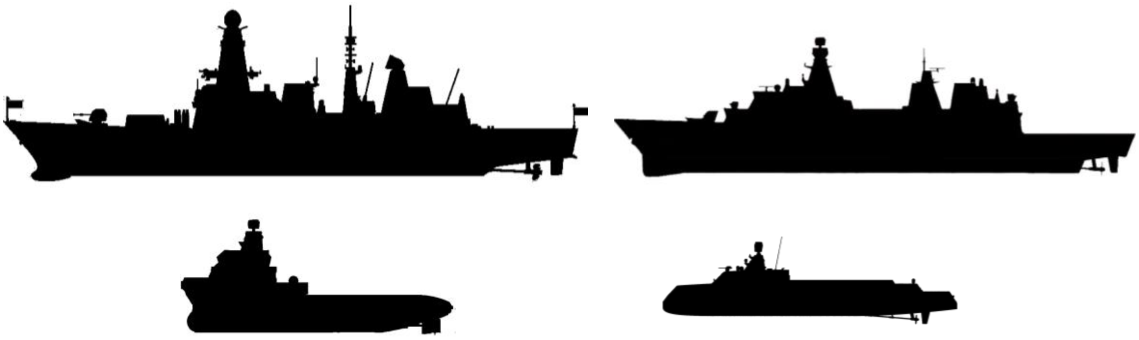

Figure 3 - Potential Options for a FADS Picket Ship

The four potential options discussed in this paper are as follows:

- A specialised, capable AAW destroyer with an advanced radar and significant weapon arsenal – the Type 83 destroyer. A destroyer, whilst being the most capable ship in the list, is likely to only be built in small numbers and could be overly complex for a picket role.
- A general purpose frigate – for example, a Type 31 – which provides a much more rounded (but significant) capability more suited for the role of a picket. However, this still results in putting a major crewed warship in an up-threat position.
- Multiple cheap, uncrewed picket ships, capable of extending radar horizon with minimal additional capability. Uncrewed vessels remove the crew from immediate danger whilst extending coverage. Multiple ships creates resilience in the system. However, the platforms would be largely limited to surveillance roles.
- A simple, low-cost, lean-crewed picket ship – with additional capability to its uncrewed counterpart but simple enough that the consequences of loss are limited. A purpose-built platform provides a more optimised design for use in the picket role whilst also providing the option to perform other tasks. Furthermore, this design could function as a test bed for transition from lean-crewed to fully autonomous operations.

Although the preferred option of a low-cost lean-crewed picket ship constitutes a new design, the wider RN may benefit from having another type of warship in its fleet to provide a diversified capability. A simpler warship will diversify what can be achieved.

6. Further Design Considerations

The choice of surveillance radar system is an important consideration due to its cost and its impact on the overall design of the radar picket platform.

At a minimum, the purpose-built radar picket platform will require a fixed mast-mounted surveillance radar. A 3D medium range surveillance radar, such as the Type 997 Artisan radar system, offers a suitable level of capability to meet this requirement. This fixed radar system may then be complemented with an airborne means of radar detection to reduce the blind spot created by the radar horizon. Either a tethered airborne radar system or a more traditional AEW system should be considered.

As with the fixed radar system, the choice of airborne surveillance system will also impact the overall design of the platform. The most obvious impact of these systems is perhaps the space required above deck. Both tethered and AEW systems would require a sizable amount of deck space for use as either a mooring station or flight deck.

In the case that the platform is to operate independently with a more traditional AEW system, a hangar space would be necessary to protect and maintain helicopters or UAVs between deployments. Alongside adequate flight deck and hangar spaces, internal space for airborne operations planning and flight crews would also be required.

A tethered radar system has different, albeit slightly similar, effects on the rest of the platform. The system's mooring station would need to be located at the aft of the vessel so that the aerostat, which may take up a considerable volume and length once inflated. The platform will require a control and data processing centre, a suitable winch system and sufficient power capacity to deploy, operate and retrieve the airborne radar system.

The purpose-built radar picket platform should be equipped with self-defence weaponry including counter-UAS systems, such as DragonFire, and CIWS. Vertical launch system silos will be sacrificed to reduce the complexity of the platform, major threats will therefore have to be dealt with by other nodes in FADS. The

 https://doi.org/10.24868/11190

possibility of designing the purpose-built platform 'for but not with' particular weapon systems should be considered, as doing so would allow for defensive capability to be tailored to a given adversary's level of weapons technology. For example, during peace time weapons outfit can be reduced to minimise crew requirement and platform cost.

7. Conclusion

Airborne threats continue to develop through multiple avenues, including both advanced missile technology and cheap, low-tech, swarming drones, which operate at low altitudes to evade radar detection until as late as possible. The RN's FADS system will control air space over a wide area surrounding a CSG using multiple systems and nodes. Historically used to extend radar coverage, radar pickets are ideal nodes within FADS. Operating up-threat of the CSG, a radar picket will detect incoming airborne threats, providing early warning and neutralising threats where possible. The radar picket will specialise in maintaining an increased radar horizon to ensure low-flying airborne threats are detected as early as possible.

The RN currently operates the Crowsnest system to perform AEW. Whilst AEW may be used as part of FADS, current AEW systems have limited endurance that makes constant operation difficult. Operating a naval platform as a radar picket has potential to provide increased radar coverage more efficiently and for longer periods of time.

The role of radar picket ship could be fulfilled by either an existing RN platform or a bespoke radar picket ship. Specialised, highly capable assets such as the Type 83 could be seen as overly complex for the picket role and would present too great of a risk when operated as a radar picket. General purpose frigates are more suited towards the radar picket role, however they still require the commitment of an asset that could be used more efficiently in other roles.

A fleet of uncrewed drones, relying on cheaper radar systems to increase coverage through quantity over quality offers another potential option. However, such a system would likely be limited to surveillance roles and be vulnerable to less advanced enemy weapons.

A purpose-built radar picket platform presents a means of optimising the role of radar picket. A lean-crewed platform that focuses on radar capability could successfully perform the radar picket role whilst reducing its associated risk. Such a platform would host a capable fixed radar system, whilst also maintaining an airborne radar system to increase detection of low flying threats. Fitted 'for but not with' airborne defence systems such as DragonFire and CIWS will allow for operating costs and risks to be reduced depending on the adversary and roles outside of FADS.

8. Future Work

A purpose-built radar picket platform may provide an efficient means of maintaining effective radar coverage over a wide area for extended periods of time, to provide early warning and protection for a CSG. However, for such platform to succeed, advancements in autonomy would need to be made. The development of the picket ship as a test bed for autonomous systems would permit confidence to be gained in the technology and permit ever leaner crewed vessels. This would have great utility far beyond the radar picket ship and allow for leaner crews to be used on all RN vessels in the future.

A radar picket platform would benefit greatly from such autonomy, and in turn FADS would benefit greatly from a radar picket capability. Investigation into the utility of the picket ship concept should be conducted as the FADS concept is progressed.

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