Radical Warship Concepts – Testing and Acceptance

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Synopsis

This paper examines the shape of future naval fleets and how they could contain radical new warship platform concepts including multi-hulls with hydrofoils able to sprint at high speed to respond to an emerging crisis. The lean, mean and green radical concept discussed is a Small Waterplane Area Nonohull (SWAN) with nine connected hulls. Propulsion arrangements are enabled by the electric ship concept, arranged for survivability in the modular multi-hull arrangement. The paper addresses the drivers for moving from evolution to revolution in warship design and how, when faced with radical new concepts, we can test, and accept them using modelling and simulation.

Keywords: disaster relief; electric propulsion; hydrofoils; hyper-modular; ISO container; small waterplane area nonohull (SWAN).

1. Introduction

At the Royal Institution of Naval Architects (RINA) Warship conference in 2015 the author, presented a historical review of naval fleets and the step changes and evolutions through history in a paper called "The Shape of Fleets to Come". That paper was developed into a forward-looking view presented at the RINA Warship conference in June 2024, which explored radical ship concepts and how they might be tested. This paper resulted from discussions with marine engineers on whether both disciplines needed to follow a radical approach.

2. The Challenge

Warships have not generally been required to carry heavy loads, but with the advent of asymmetric threats and the need for multi-role platforms to counter the rapidly changing nature of threats, a different approach is needed. The theme of the RINA Warship conference in 2019 was multi-role vessels and several papers, including that of David Andrews, further inspired this concept. Since then, there has been much development of containerised solutions and we are now in an era of offboard systems, in particular drones. Previous research by the author reviewed the success of modularity, looking back to the Danish STANFLEX concept and others. Modularity is very much with us today, and the common module of choice is an International Standards Organisation (ISO) shipping container, normally in the 20-foot robust variant. Current warfare in the Black Sea, Red Sea and Eastern Mediterranean requires much larger capacity for missiles, munitions, and the delivery of logistics. There is also a pressing need to respond urgently to rapidly developing crises. This drives a need for new types of platforms optimised for offboard systems, modular weapons, adaptability for multiple missions and the ability to sprint into action, whilst also being able to loiter for long periods in areas of strategic interest as a deterrent. Today there is a need to deliver all the following:

- Large numbers of defensive missiles
- Vast quantities of ammunition for artillery and deployed land forces
- Clean water and food for displaced civilians
- Medical and humanitarian aid
- Intelligence, surveillance, reconnaissance, and information operations
- Armour, vehicles and heavy military equipment and troops to an unprepared shore
- Offboard autonomous systems in the air, surface, and underwater domains

There is also a pressing need to deal with non-combatant evacuations and to render assistance to climate emergencies that are occurring more frequently around the globe. A lean, lithe frigate or destroyer just can't carry the payload required to really help. This paper explores a family of extremely modular ships, how they

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Matthew Hood holds the current position of Head of Practice at Nova Systems in the UK, responsible for expanding capability in support of defence systems. The Author's experience includes the Royal Corps of Naval Constructors for design, acceptance, and support of warships, auxiliaries, and submarines. He has also spent many years supporting aircraft, rail systems and C4ISTAR systems.

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might be powered and what we would need to do to test and accept such radical new platforms into service with global navies.

3. Modern Conflict

What innovative technologies are needed to respond to the challenges of modern conflict? How will we overcome swarms of small, cheap drones in the air, on the surface and under the surface? There has been a step change in the threat environment, particularly in the volume of attacks against ships. We have not been fighting a warship-on-warship war since arguably 1941. Today we need to respond and strike quickly, with the most appropriate effect, which may be missiles, drones, troops, or humanitarian aid.

Nick Childs writing on "*Britain's Future Navy*" (2012) looks at the balance of the fleet (Ch 10). Discussing the Royal Fleet Auxiliary (RFA) Bay Class Landing Ships Dock Auxiliary he identifies "*They have huge amounts of space to carry equipment and stores. They lack a helicopter hangar, but that could be added. Some critics say they are critically short on power. They are not pretty, but they are certainly imposing, due largely to an astonishing tower block of superstructure*". The dock ship is extremely versatile and suits modern warfare with offboard systems very well. However, they need to move much faster in response to rapidly changing situations. Protected space at sea is a highly valued commodity in modern warships.

A surface combatant needs to take the fight to the enemy, a combat radius of 100nm from the ship is needed, with range from base of more than 1000nm to deliver effect. That 'effect' will probably be offboard drones that loiter and react when instructed. A single warship is no longer the fighting unit, it is an operating base for offboard systems, (see the UK Defence Drone Strategy, 2023). A more unified approach across services and allied forces is demanded. War now has many more shades of sub-threshold conflict. Lawrence Freedman in his book ('*The Future of War – A History*' 2017), concludes with his view that "*War therefore has a future. It can make an appearance wherever there is a combination of an intensive dispute and available forms of violence*".

The concept presented is one of operating bases or mother ships rather than a complex fully integrated warship. Existing and operating safely within the ocean environment will remain the primary challenge for any ship, explained beautifully by Helen Czerski in her book ("*Blue Machine – How the Ocean Shapes our World*" 2023).

4. SWAN Concept

In 2015, inspired by work in Navy Command Headquarters, the author developed a concept referred to obliquely in his 2015 paper. So, what is a SWAN? A *Small Waterplane Area Nonohull*. That is nine hulls connected together. Each is a separate unit that can be designed, built, maintained, and potentially operated separately. This is a combination of a Small Waterplane Area Twin Hull (SWATH), a trimaran, a hydrofoil, and a Surface Effect Ship (SES), a schematic layout is shown in figure 1 with functions described in Table 1.

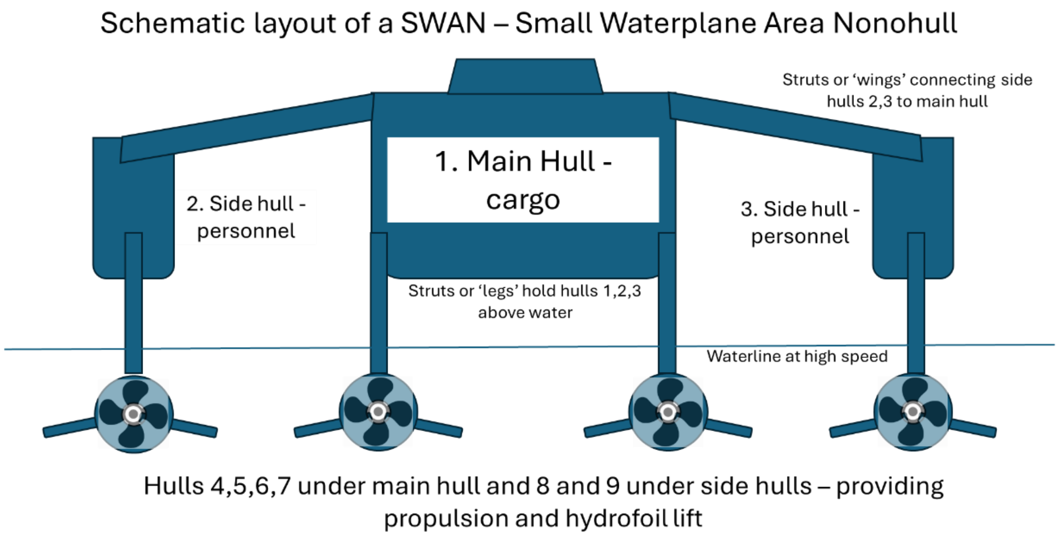

Figure 1. Schematic layout (section view) of the nine hulls of a Small Waterplane Area Nonohull

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SWAN hulls

Hull No	Purpose	Characteristics	Notes
1	**Main hull** for carrying cargo and connecting together the parts of the ship	Large hull providing strength to connect the other parts together and with large open spaces for storage and flow of cargo including a through dock	Through dock is based on a canal, rather than a pumped ballast system like a Landing Platform Dock (LPD)
2,3	**Side hulls** provide spaces for personnel and sustainment of people	The side hulls of a trimaran that distance personnel from hazardous cargo in the main hull. Separated by 'wings' that can also provide lift at high speed.	Optimised for flow of personnel
4,5,6,7	**Sub hulls** provide propulsion and lift through buoyancy and hydrofoil lift. May be azimuthing or have rudders	Relative size and buoyancy depends on mission speed profiles. May be able to retract for restricted water operations.	Can be changed during the life of the ship. May only have two under main hull.
8,9	**Side sub hulls** provide propulsion and lift through buoyancy and hydrofoil lift	Alternative layout options available. Could be designed as independent craft	May separate and operate independently as surface or underwater vehicles

Table 1. Hull purpose and modes of operation

At low or zero speed hulls 1,2 and 3 are floating. These are partially supported by buoyancy from the sub surface hulls 4-9. Once forward speed commences with propulsion from the sub surface hulls the hydrofoils provide lift, raising the floating hulls above the water. At high-speed aerodynamic lift also contributes.

Sprint capability is the key requirement for this design concept. The need to respond to an incident quickly over long distances, potentially trans-oceanic, is the primary driver. This drives the need for foiling clear of the top of the waves. The need for speed in a warship is an ancient characteristic that has been reduced today due to cost and the introduction of missiles and aircraft. However, lean, mean ships with sprint capabilities allow a nation to respond rapidly to incidents to gain military advantage or save lives. Responding within 12 or 24 hours saves lives of those injured, if the ship doesn't arrive for three to five days there will be many more casualties and disease will have set in. Speed can also help avoid trouble and evade threats or prevent an adversary from establishing a secure base. To pursue this concept, you must want to respond quickly to emerging incidents. Whether for your own benefit or others.

This concept requires high power density, well proven in gas turbines, as fitted to warships and high-speed craft. Massive power will be required making use of large gas turbines providing collectively more than a hundred megawatts to achieve the sprint speeds. Hybrid configurations of propulsion and storage enable concepts that include electric and diesel propulsion and use of other fuels. In hydrofoil mode these craft will move at 40 – 60 knots extending their radius of response to 960-1440nm in a day.

Loiter and offload are other key features of this concept. The ability to load and offload at sea and operate as an amphibious ship enables a huge range of mission types. With the rise of autonomous offboard systems this has become much more important. These SWAN ships are designed to load and offload surface and underwater vehicles. The key to this operation is a through dock, or canal in the centre of the main hull. The general principle is to onload small craft, at the bow and offload at the stern. This allows craft to be gathered with a low forward speed of the ship. Offload at the stern provides protection from waves and shields the daughter craft from hostile enemy action. The canal will vary in size across the family of SWAN ships. Around 3m wide in the smallest increasing to around 8m wide to take a Landing Craft Utility sized craft.

Segregation for survivability is a key feature of this SWAN concept. Moving the propulsion motors into separate hulls (large pods) and having many of them enables survivability through replication of propulsive power. The primary benefit is to build separate hulls for people and cargo. Each hull should be able to survive independently and operate to some extent if disconnected. Modular design will also enable swapping or cannibalisation of modules between hulls and between different craft in the SWAN family.

A family of SWANs is covered in this concept with different sizes, see figure 2. Different configurations can be achieved with the same construction modules. The smallest craft, dubbed the Cygnet, should fit into the larger craft with 8m wide docks. Lengths of craft are selectable and the sub hulls providing buoyancy and power might be changed through life. For example, to explore new propulsion motors or propulsors.

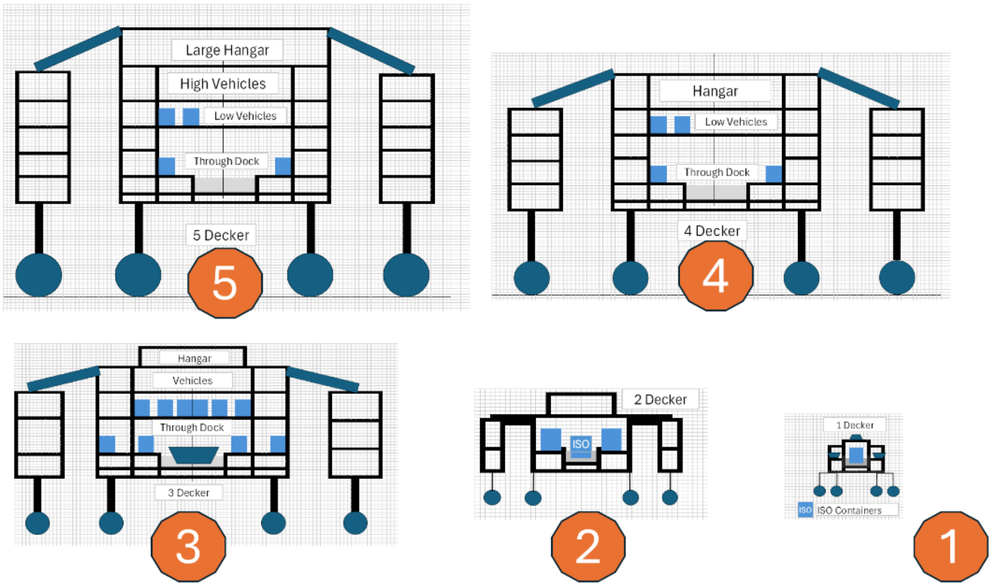

Figure 2. Family of SWAN concept craft, the small 1 Decker is the cygnet in the family

Cygnet – the one deck craft. This small craft is designed to carry up to three 20-foot ISO containers in barges (possibly inflatable), vehicles, or uncrewed craft, that fit within the through dock. It also carries 2 boats and is intended for a mission crew of 8 persons with two operators. This is conceived as a 24m long by 8m wide craft that can fit inside the dock of the larger craft in the family. Renders of the early concept are shown in figures 3 and 4. The main hull acts as an aerofoil to provide additional aerodynamic lift during high-speed transit.

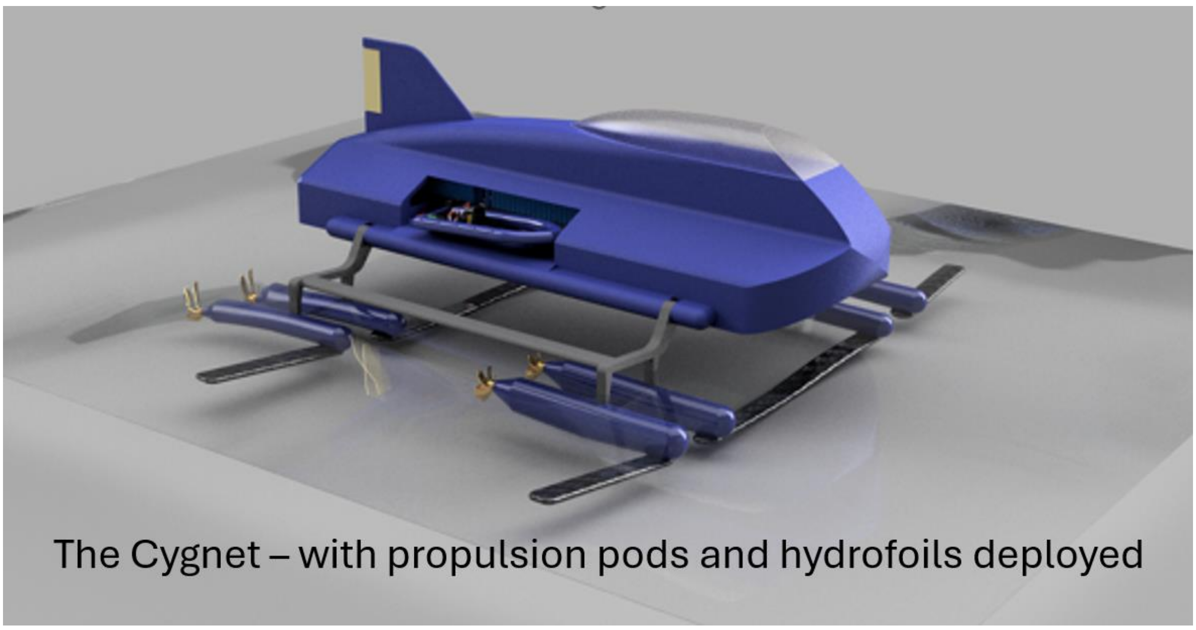

Figure 3. 1-Decker Cygnet render showing pods and foils deployed and sea boats. This craft is 24m long.

Hyper-modular construction is intended across this family of craft. Wherever possible the systems and equipment are to be included in ISO containers and 'plugged in' to the craft. This includes the following:

- Mission modules
- Propulsion prime movers
- Some electrical generation and possibly storage
- Water making and wastewater treatment
- Refrigeration and stores

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- HVAC equipment and controls
- Firefighting systems including mist or fog systems
- Computing and communications
- Secondary accommodation for passengers
- Medical facilities so that they can be donated ashore

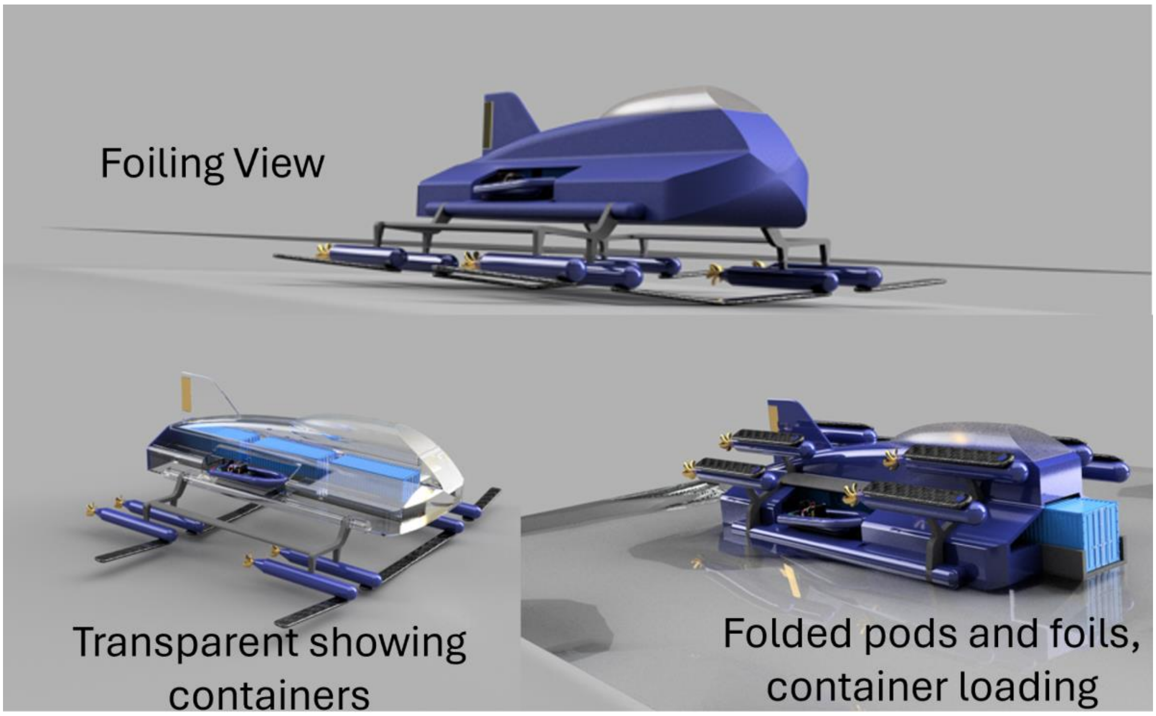

Figure 4. Renders of Cygnet craft showing different aspects including stowage of three 20’ ISO containers

Modules will be able to be swapped during life and even during operations. Consequently, there is a need to move loaded ISO containers at sea. Containers will be able to be moved around the ship, not just as cargo but as operational systems. Interfaces for containers placed around the ship will allow exchange.

Hybrid composite construction is intended to achieve the light weight. Recently developed materials including fire-resistant structural foams and carbon fibre with fire retardant resins enable new approaches. Standard external module sizes for the sandwich panels are intended with selectable sandwich cores for different parts of the ship, for example acoustic or thermal insulation, or ceramic armour.

Included within the thickness of the hybrid composite panels are ducts for electrical cabling and pipework. Deck panels will incorporate scuppers and drains and deckhead panels will have air extraction for ventilation, lighting, smoke and heat detection and firefighting spray systems built into the structure. Computer controllers will be built into the structural panels. The data gathered is used for maintenance based on actual panel use.

Evolution through life is a key objective for this concept. By separating the hulls, designing for modular construction, and incorporating many systems and equipment into containers these craft will be able to adapt. All mission systems will be modular and carried, rather than integrated. These ships will be able to carry and operate containerised UAVs and weapon systems from the upper deck.

6. Propulsion Configuration

This SWAN concept requires a flexible propulsion system, with commonality of modules across the family. Generation of electricity needs to occur in the main hull and side hulls above water. Gas turbines to achieve sprint speeds will be placed in modules high in the ship to allow large air flows. Loiter speeds and hotel loads will need smaller generators, probably diesels, also in ISO modules. Different fuels might be used for sprint and loiter to enable greener operations. The sub hulls provide propulsion thrust through electric motors in the hulls underwater.

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Electric ship principles are used. This is intended to be a Direct Current (DC) architecture with multiple prime movers as generators with at least one in each of the above water hulls. The approach of generation as alternating current (AC) current with immediate rectification to DC for storage, distribution, and powering electric motors is proposed. This approach overcomes the challenges of synchronization of AC phases between circuits in each hull.

Rotating machines such as motor generators or flywheels are proposed for energy storage and to maintain spinning reserve. These machines offer the opportunity to absorb spikes in power demand and generation from multiple prime movers of different sizes. This approach resulted in discussions with colleagues, and a reminder that this problem was solved before using synchronous-self-shifting (SSS) clutches. Hendry in his paper "*Application & Experience of the SSS (Synchro-Self-Shifting) Clutch for High Speed Gas Turbine Marine Propulsion Systems*" (2018) reviews propulsion arrangements in high-speed craft since the 1960s and how some were successful whilst others remained experimental. SSS clutches have now become a fit and forget item for the Royal Navy following careful selection.

The electricity produced and used by the different machines enables segregation for redundancy with different systems, potentially at different voltages in each hull. Digital DC propulsion motors in the pods can be fed with high voltage whilst other circuits and systems operate at lower voltages.

Flywheels enable smoothing and storage of energy, peak lopping of demand and potential use as gyroscopic stabilisers for these high-speed craft, or as drivers for a stabilisation system. This architecture avoids the need for additional running engines to maintain 'spinning reserve' as it is provided by the rotating machines.

Sustained sprint requires continuous high power for long periods and immediate consumption of generated electricity. However, in other modes of operation the electricity can be stored in batteries and/or capacitors for use at loiter speeds and alongside. The expectation is that these ships will spend most of their lives loitering, so efficient loiter operation will help to reduce greenhouse gas emissions.

7. Modelling And Simulation

This concept will go nowhere unless we can digitally model and simulate the solutions. The mathematics of the design must balance across:

- Mass and Lift
- Thrust and Drag
- Energy for endurance and speed
- Strength and deflections

Digital Engineering and Model Based Systems Engineering is used widely and forms the basis for examining radical concepts and testing them before the designs firm up. Systems can be modelled at different stages of the lifecycle, in particular developing requirements, conducting verification and validation and operational test and evaluation. A digital approach to design, acceptance and testing supported by digital modelling and simulation is needed through life. Three-dimensional computer aided design (CAD) enables a substantial amount of modelling and finite element analysis for stress, vibration, thermal loads, flows and other factors as part of the native tools as each component is designed. More integrated Product Lifecycle Management systems enable connection of product models with mathematical and physics models to test a design in purely digital format as the design develops.

8. Testing and Acceptance

The hull structures and systems modules can be tested separately, and systems integration facilities constructed ashore, distributed at different locations. By using a digital integration architecture via exchange of data messages the systems can be tested before they are brought together as a ship. The physical and communications interface being the ISO container interface that includes data interfaces. The propulsion system proposed is constructed from proven components in an unproven configuration so can be tested in a modular manner before combining to system level within each hull. Replication across multiple hulls also saves testing time.

Propulsion and electrical systems and digital controllers will need thorough testing and acceptance in offsite facilities, again replicating systems in multiple hulls saves effort. Facilities proving the generation configuration of connected machines will need to be collocated, but the motors, connected by DC do not have to be proven together with the power generation system. With a data interfacing approach, rather than tight integration between systems, it will be possible to test systems across wide area networks.

Aircraft and air systems use an extremely thorough, but more risk-based, approach to certification and acceptance. This radical platform type will certainly require a prototype of at least the smallest craft. That in turn can provide acceptance evidence to support the larger members of the family. It is normal for air platforms to enter service with limited operating envelopes that expand through life. The same approach is proposed here with constrained speed, power, payload, and weather limitations applied early in the lifecycle. The Bow Tie approach to safety is recommended for a more risk-based approach (as opposed to a design code approach), as used by the Military Airworthiness Authority, which enables duty holders to understand the residual safety risks that they are accountable for.

Sensors and weapons testing can be divorced from the life of the ship. Cooperative use of sensors and weapons across allied nations must be a key goal. These ships could carry novel weapons. The ability to separate crew from hazardous cargo and weapons, and the use of the huge electrical capacity for sprint creates opportunities for these craft to operate extremely powerful weapons systems.

9. Safety And Regulation

High-speed foiling is beyond the capability of human controllers. These platforms require multiple automated systems for stability, ‘flight control’, power distribution, and many other aspects. Operations will be automated wherever practicable, and oversight, diagnosis and analytics of operational data will be carried out ashore. First line maintenance aboard will be reduced by a deliberate approach to ‘repair by exchange’ of modules.

Each module will require its own lifecycle, type approval, maintenance checks and inspections for this concept to work. A data-driven approach to product lifecycle management is essential. Different parties are likely to maintain responsibility for different modules, some may be operated on a service basis with ownership remaining with an OEM or leasing agent, using ‘power by the hour’.

Ship safety will be based around the IMO High-Speed Craft Code (2008) with warship extensions for carrying munitions and higher survivability with the intent of complying with Naval Ship Rules. However, it is evident that this concept cannot comply directly with the current Lloyds Register Naval Ships Rules. Materials selection within the hybrid composites and fire protection will be critical. Blast radii from hazards, in particular munitions, is mitigated by the arrangement of the multiple hulls. High speed reduces vulnerability to attack by some threats but creates other hazards. The ISO containers for weapons systems will need be constructed as magazines.

The safety case for operation of armed and unarmed offboard systems in all environments will require particular care. The use of Ship Vehicle Operating Limits based on Ship Helicopter Operating Limits (SHOL) is something that is developing for drones and is being explored by my colleagues with very advanced modelling and simulation. Complications are added by remote operation of weapons from ashore under some circumstances.

To take this radical approach requires a cautious approach to regulators. A pressing need for new warship types exists and an approach that avoids acquisitions of twenty years and a billion pounds is needed. By designing an ecosystem for multi-national, multi-role, multi-type, multi-supplier solutions this concept addresses those challenges.

10. Conclusions and Further Research

This paper provides a deliberate challenge to current warship design. The thesis that a radical design concept requires a radical approach to test, evaluation, and acceptance may be flawed. Including well proven components and sub-systems could mitigate risks. INEC exists to promote advances in naval engineering and sharing of experiences between navies. This concept offers an approach that pushes boundaries and is aimed at multi-national collaborations at module, hull and ship level.

This concept is the author’s research rather than a company sponsored project, the opinions expressed are not those of my employer. Over 10,000 people a year are killed by natural disasters and whilst these ships can’t save those who are killed by the initial event, navies can and do help to save the lives of those who are injured, trapped, displaced, or left without clean water, shelter, or functioning infrastructure. There is a pressing need for internationally managed ‘peaceships’ as well as next generation warships. Further research into this need for high-speed sprint capability over long distances to respond to incidents is needed.

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These ships speak to the deterrent effect of being able to rapidly respond and to surprise a hostile entity. The most significant warlike feature of these ships is "*surprise*". Others will never know what these ships are capable of because they can be filled with non-descript boxes that can be deployed to other units, to locations ashore and could contain a myriad of different capabilities. As these ships evolve through their lives the modularity will enable them to keep up with the pace of technology and respond to different issues that threaten our sea lines of communication and our interests around the globe. They could also adapt to oceanographic changes that will driver wider climate change and political tension, resource competition, displacement of people, and war. These SWAN ships with hyper-modularity are arguably *lean, mean and green,* with the exception of the vital need to sprint into action to respond to an unfolding crisis and to save lives.

The author invites further discussion on this concept and a collaborative approach with warship designers, builders, and maintainers to stimulate further research and co-development of this concept. Equipment suitable for modular application is also sought together with implementation of the developing NATO standards for ISO container interfaces. Any sources of research funding to assist with high-speed responses for humanitarian aid and disaster relief are also welcomed.

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