WARSHIP DESIGN IN A RAPIDLY CHANGING WORLD

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With the selection of BAE Systems' Global Combat Ship — Australia (the Type 26 frigate) as the future frigate for the Royal Australian Navy, the shape of the future RAN is substantially defined, at least in so far as major surface combat ships are concerned. With an intended life of around thirty years, these ships are likely to be in service, if present plans are not dramatically disrupted, well into the latter part of this century — 2070 and possibly beyond. History tells us that, during that period, there will be radical changes in the strategic, technological and sociological environment in which they will be required to operate.

Modern surface warships are complex and expensive systems. Inevitably the number of ships we can afford is limited. Moreover, the ships themselves are only part of the equation. Basing, logistic support, and recruiting and training the highly-skilled crews they need, will also demand considerable resources. Whilst 21st century conflicts are unlikely to be a re-run of the great wars of the 20th century, present trends suggest that demands on Australia's armed forces might be frequent, varied and, at times, intense. This presents challenges for the designers of modern warships for any navy — the ships they design must be very capable and adaptable to changing demands.

Some suggest that today's warships are overly complex and that the adaptation of commercial vessels to military roles could present a more economical way to provide the number of hulls which may be needed at relatively short notice — perhaps constructed by shipbuilders without the infrastructure and cost associated with modern warship construction. For some types of ship that may indeed be practical. However, in recent decades, there has been a convergence of design standards between the commercial and naval worlds, most readily evident in the now-usual adoption of commercial standards for small combatants like offshore patrol vessels, support ships and other non-combatant vessels.

Before we look at some of the challenges facing the designers of future combat ships it is worth outlining some of the essential differences between commercial ships and warships.

The modern container ship is a remarkable vessel for its size and capability. Consider, for example, the Maersk Triple E-class container ships, of which twenty have been built or are on order. The latest of these ships can carry 18,270 TEU, are almost 400 m long with a beam of 59 m, have a deadweight tonnage of over 210,000, are powered by two 8-cylinder diesel engines each rated at 29.7 MW and have a service speed of 19 knots with a top speed of 25 knots. These very large ships greatly benefit from modern automation of machinery and systems and have a crew of only thirteen. Soon we will see autonomous container ships at sea, with the first autonomous, electrically-powered container ship to be launched in 2020 and operating autonomously in 2022.

Whilst these ships are not typical of the majority of cargo carriers plying the oceans of the world, they do illustrate the fundamental principles governing their design — cargo carriers are designed around their cargo and do most of their work in port, loading and unloading, whilst at sea they steam steadily at the most economical speed routed, if necessary, to avoid the worst of the weather. Power demands for propulsion, hotel services and cargo support are not greatly variable during the voyage. Environmental requirements are important — low fuel consumption and minimum emissions are now a high priority but, until recently, underwater radiated noise was not.

These principles are true for most merchant ships. There are exceptions, of course. Research vessels of various kinds, for example, do all their work at sea and can be very complex in their outfit and cruise ships are immensely complex hotels at sea where safety of the thousands of people on board is an overriding priority.

Naval vessels vary in function, from high-level conflict to logistic support. Warships are built to fight. They do most of their work at sea. Their payload is not containers or oil but, weapons including guns and guided missiles, surveillance systems, target acquisition and tracking and fire control systems (the combat system), communications systems, aircraft (usually helicopters), electronic warfare systems and self defence systems. The latter also includes nuclear, bacteriological and chemical defence (NBCD), requiring gas citadels and wash-down systems. NBCD became less of a priority after the end of the Cold War, perhaps, but is re-emerging today as weapons of this nature may become the tools of the modern terrorist. Warships must be able to take hits, absorb and control damage, and keep fighting.

Warships have to be able to do their work in any conditions — this is HMAS Anzac *in the Indian Ocean (RAN)*

The design of warships is driven by the general arrangement. The warship's payload must be integrated into a hull which can provide an environmentally-protected shelter capable of operating in a wide range of sea conditions, and surviving in virtually any conditions the ship may encounter. Today, her crew comprises highly-trained engineers and technicians who maintain and operate her payload, and professionals who keep the ship at sea and ready for action. They need to have accommodation in the ship which enables them to be fed and rested so that they can perform to the high level required when the ship goes into harm's way — a substantial driver of internal volume. The crew are also a very valuable and expensive asset so keeping their numbers to a minimum is desirable subject, of course, to the need to muster sufficient numbers for damage control, boarding parties etc.

It is often said that there are three priorities for a successful warship — the ability to float, move and fight. Each priority demands characteristics in the ship which are particular to a warship.

The ability to float depends on hull strength and subdivision, stability (both intact and damaged), hull services and seakeeping.

The ability to move depends on the main and auxiliary machinery and the systems which support it, and the resistance of this machinery to shock and other damage. Maximum speed, range and endurance influence fuel capacity and machinery space volume. The seakeeping ability of the ship is also relevant, particularly in extreme conditions.

Fighting not only depends on the weapons and the combat system, but hull and machinery characteristics like the ship's size and seakeeping ability (which relate to crew fatigue and weather-imposed limits on weapon deployment), radar cross section, noise and infra-red radiation and weapon-system support services like stabilised power supplies, air conditioning and chilled water.

In designing any warship all these factors must be taken into account. Somehow, those responsible must also estimate how much the payload may change over the life of the ship, how the expectations of her crew may change (accommodation standards, access to communications, email etc.) and how emerging weapons and combat systems may affect the layout of the ship and the services she must provide (hypersonic missiles, directed energy weapons and autonomous underwater and surface vessels, for example). These are all major challenges for warship designers who are also under pressure to control the growing cost of the ships they design.

One aspect of warship design which has a significant influence on cost is the design standard. Historically, nations have maintained naval design standards of their own, or adopted those of allies or the nations which have supplied their ships. In Australia, for many decades, we applied British naval standards, as defined by the Admiralty (later the Ministry of Defence). Developed over many years, these standards represented a vast accumulation of knowledge and experience, but the maintenance of the standards was a considerable burden as budgets became tighter and skilled naval architects and engineers became fewer.

In Australia, during the late 1960s, the RAN Technical Services developed a set of Australian standards, the *Naval Construction Manual*. This voluminous production coincided with the last construction in Australia of naval combat ships for many years — the destroyer escorts *Swan* and *Torrens*. It was to be 22 years after the completion of *Torrens* before another combat ship was completed in Australia. The purchase of the FFGs from the United States, and the earlier DDGs, introduced US Navy standards to Australia — in many ways quite different to our own standards as set out in the NCM which fell into disuse. Later acquisitions from different countries of origin resulted in a diversified range of naval standards, all within the one navy.

Meanwhile, Classification Societies were steadily developing their rules and procedures for commercial vessels, presenting an opportunity for navies to make use of their expertise and experience in the development of the design of these ships. In Britain, for example, collaboration between Lloyd's Register and the Admiralty had taken place for many years, but it grew in the 1950s with assistance for the submarine nuclear propulsion program and, later, with the design and construction of the helicopter carrier HMS *Ocean*. This was the first time (apart from the World Wars) that Lloyds had been involved with the classification of a warship, as distinct from an auxiliary.

In 1997 Lloyds was asked to develop *Rules for Naval Ships* — in a collaborative effort with the Ministry of Defence. The development of these *Rules* has enabled the navy to take advantage of the best in hull and machinery technology from the commercial world whilst the navy concentrates on the military aspects of ship design. The *Rules* were published in 2000, and have been used for the design of Royal Navy ships since then. The largest ships built for the Royal Navy under survey by Lloyds have been the Queen Elizabeth-class aircraft carriers.

Lloyds *Rules for Naval Ships* have also been adopted by other navies. The RAN has been working with Lloyds since 1989, when HMAS *Westralia* was acquired from the Royal Fleet Auxiliary. Gradually, other existing RAN ships have been brought into class and the involvement of Lloyds continues, with considerable advantages during construction and maintenance.

Other classification societies, including Bureau Veritas, DNV GL and the American Bureau of Shipping, have also developed rules for the construction and classification of naval ships.

Whilst the involvement of classification societies can help to reduce the direct and indirect cost associated with warship construction, the ship's military features will dominate when it comes to determining ship size. Australia's new destroyers and frigates are the largest of their type ever to be built for the RAN. The displacement of the Hunter-class frigates will be similar to that of the Leander-class cruisers *Sydney*, *Hobart* and *Perth* of the 1930s. The intended role for a warship and the selected capabilities determine the size and layout. Provision of the necessary power for propulsion and the combat system, the spacial relationship of sensors, the size of the aircraft to be carried and the size of the crew all have a significant impact on internal volume and the overall size of the ship.

There is a natural tendency to suggest that modern warships are too big, and should be reduced in size to reduce cost. Quite apart from the reduction in capability which may result, there are other important factors. By comparison with the RAN's new offshore patrol vessels, their ancestors, the Attack-class patrol boats, designed and built in Australia in the 1960s were tiny. The implications of the small size were well known to many who served in them. Increased size has benefits for crew comfort, weapon system performance and aircraft operations. The cost of the hull is a relatively small component of the total ship cost and increasing the size of the hull is comparatively inexpensive — steel is cheap and air is free.

Generous internal space and good reserves of structural strength represent insurance for the future — a margin for growth. The intended life of modern warships will encompass several generations of combat system. It is hard to predict with certainty the future power and space requirements of payloads which are not yet a twinkle in the eye of the combat systems engineer.

One thing of which we can be sure is that ships designed today will need to change during the course of their life. There are many lessons from the past which can remind us of the challenge of providing for the future. To meet the submarine threat during World War II simple corvettes, frigates and destroyer escorts were built in large numbers by shipbuilders unused to warship construction and proved to be vital assets during the Battle of the Atlantic. The development of the German Type XXI submarine, with its high underwater speed, rendered most of this large fleet of ships obsolete, not least because they were too slow. New antisubmarine weapons, sonars and radar demanded additional space, power and crew. The need for more capable ships in the post-war years saw the conversion of large numbers of the many destroyers built during the war into antisubmarine ships, but their slightly older sisters, built just before or in the early years of the war, were scrapped because their machinery was vulnerable to shock and electrical capacity inadequate.

That period of rapid change also resulted in ships being fitted with additional armament and complements grew accordingly, reducing habitability standards which were barely acceptable anyway.

At the end of World War II the US Navy had large numbers of new destroyers of the Fletcher, Sumner and Gearing classes, which were rapidly becoming obsolescent. The latter two classes were the larger ships with a full load displacement of 2,890 tons — small by today's standards. The complement of these ships was 336 men. Accommodation is a great consumer of space, and these ships were very cramped. The only effective way to improve living conditions on board was to remove capability, create addition space by enlarging the superstructure or reduce the complement, changes possible only during major modernisation.

USS Nicholas *was typical of the many destroyers built in the United States during World War II. A very successful design but these ships required very extensive modernisation for the challenges of the Cold War period (USN)*

With the expected rapid growth of the Soviet fleet of fast submarines, the US Navy was concerned that it would not have enough ships to counter the threat. Some of the WWII destroyers were given limited modernisation to function as antisubmarine destroyers but in 1958 it was decided to commence a large scale modernisation program to extend the life of many of these destroyers by five to ten years. Known as the Fleet Rehabilitation and Modernisation Program (FRAM), the program concentrated on the Sumner and Gearing classes of which 127 ships were modernised between 1960 and 1965.

The modernisation was very extensive, with enlarged superstructures providing additional space for modern electronics and anti-submarine weapons like ASROC, a rocket-delivered homing torpedo. An early drone antisubmarine helicopter (DASH) was also carried by some ships.

Accommodation for the crew was also improved, although not much.

The FRAM program US for destroyers was somewhat akin to the British conversion of 43 World War II Emergency Program destroyers into Type 15 and Type 16 antisubmarine frigates.

HMS Zest *was one of the successful conversions from a World War II destroyer into a Type 15 anti-submarine frigate (J Jeremy)*

For both navies these modernised ships were stop-gaps until new ships could be designed and built. One of the immediate post-war British designs was the Type 12 antisubmarine frigate, which began to enter service in the mid-1950s. Whilst the design was intended as a North Atlantic convoy escort, it proved to be very adaptable, growing into the extremely successful Leander class general purpose frigate. Seventy Type 12 frigates of various variants were built for seven navies between 1956 and 1981. Some are still in service today, 70 years after the completion of the original design. These ships, steam powered, had a complement (in Australian service) of up to 257. Accommodation was still cramped but somewhat improved when compared to immediate post war conditions. Six Dutch-built ships still serve in the Indonesian Navy — all converted to diesel propulsion which has reduced the complement of the 53-year old ships to about 180.

HMAS Derwent *was an Australian-built Type 12 frigate, one of a numerous class built for several navies (RAN)*

Two developments were to greatly influence the design of new ships during the 1960s — the guided missile and the gas turbine. The former required major changes to the ships' general arrangement and the gas turbine, in particular, enabled crew size to be reduced.

Two ship designs from the late 1960s and early 1970s are notable — the US Navy's patrol frigate and the DD963-class destroyer.

Despite a program to build some 62 destroyer escorts during the 1960s, the aging US fleet of modernised World War II destroyers, and the continuing need for a fleet of antisubmarine ships to keep the sea lanes open in peace and war, meant that a large number of new escorts were needed to fill the gap. In 1970 studies were begun of an escort ship with relatively simple weapons and electronics which would be capable of escorting mid-ocean convoys and defending ships against submarine, missile and aircraft attacks. A program to build 50 of these ships was approved in January 1971, designated the patrol frigate (PF 109 class). They were later reclassified as guided missile frigates (FFG 7 class).

An important consideration in the design of these ships was to control the cost, with a limit set of $50 million 1973 dollars. An upper limit was also set on standard displacement of 3,500 tons. The complement was to be reduced to 176, including helicopter crews. All gas-turbine propulsion was adopted, with 40,000 HP delivered to a single screw. An extensive program of land-based test and evaluation of the machinery installation was begun and the weapons were chosen from advanced but proven systems — the Mk 13 GMLS missile launcher, well proven in service in 30 destroyers and frigates in six navies, a evolved version of a Dutch fire control system, known in US service as the Mk 92, and a 76 mm rapid-fire OTO Melara gun.

Accommodation standards were much improved, with two berth cabins for all officers, four berth cabins for Chief Petty Officers and, in accordance with US practice, petty officers and crew in six berth bunk modules in spaces with separate but adjoining heads, bathrooms, dressing and recreation areas.

Two shipbuilders were selected to build the frigates — Bath Iron Works and Todd Shipyards, the latter at two yards. Bath Iron Works worked with Gibbs & Cox on the detailed design of the ships with the aim of reducing production cost by the maximum use of prefabrication an simplified construction standards as defined in a *PF Producibility Manual* developed by Bath and G&C. The first ship, *Oliver Hazard Perry*, was built by Bath Iron Works, and was completed in 1977. 51 were completed for the US Navy by 1989.

Australia adopted the FFG 7 following the cancellation of the planned light destroyer (DDL) in 1973 and six were built for the RAN, four in the US and two in Australia. Six FFGs were built in Spain and eight were built in Taiwan. Of the 71 ships built, over 20 remain in service today in six navies, 50 years after the design was conceived.

HMAS Melbourne*, built in Williamstown, Victoria, was one of six FFG7-class guided missile frigates to serve in the RAN (J Jeremy)*

The patrol frigate design was criticised by some because of its single screw, small gun and austere construction standards. It is fair to say that some of the early ships were a bit rough — they certainly would not have met the standards set out in the RAN's Naval Construction Manual, but the design proved to be very successful — the ships worked. It has also been adaptable as the Australian modernisation of four ships has shown, despite the limitations originally set on the design. It is notable, however, that the ships were never called upon to fulfil at least one of their intended roles, to protect North Atlantic convoys from submarine attack.

The other design from the late 1960s worthy of mention is the DD963 Spruance-class destroyer. Thirty one of these ships were procured using the Total Package Procurement model, where competition between shipbuilders resulted in Litton Industries being selected to design and build the new class of destroyers. Litton did not have prior experience in warship design and, with a limited supply of naval architects in the US, recruited abroad with staff coming from Britain, Turkey and Israel, amongst others. Litton's director of engineering, Reuven Leopold, was a 30-year old immigrant.

The design of the DD963 developed into a large ship of 8,040 tons full-load displacement with an overall length of 563 feet 4 inches (170.7 m) and a beam of 55 feet (16.7 m). Propulsion was by four LM2500 gas turbines on two shafts delivering 80,000 SHP (64 MW) for a maximum speed of 32.5 knots. The complement was large, 393 including flight crew. The design of this big and commodious ship was largely governed by requirements for seakeeping and flight deck motions in high sea states. Interestingly, in the early stage of project development, the selection of all gas-turbine propulsion was influenced by the design of the Canadian DDH280 frigate, which itself had a heritage of earlier Canadian designs which were related to the British Type 12 frigate design of 1950. The overall layout and appearance of DD963 was also influenced by the British County-class guided missile destroyers which were regarded as good looking ships with great presence.

The Spruance class ships were built in a new yard in Pascagoula, Mississippi, and were completed between 1975 and 1983. The shipyard is now a major component of the US shipbuilding base and is operated by Huntington Ingalls Industries.

USS Spruance *was the lead ship in a class of 31 large, commodious destroyers built for the US Navy (USN)*

The large size of these ships was subject to some criticism. However, the large volume facilitated the maintenance of the ship and her weapons but above all provided a considerable growth margin in volume, stability and power supply. This enabled the hull and machinery to be adapted to create the much more heavily armed CG47 class cruisers, which were fitted with the Aegis combat system and SPY-1 phased-array radar. The displacement grew to 10,117 tons and stability was maintained with the addition of some lead ballast. The upgrading of the gas turbines to total 100,000 SHP maintained a speed of 30 knots and the complement was slightly reduced.

This adaptation of the DD963 hull was not ideal — the ships pitch hard in heavy weather and often roll 25–30°. Rudder angle is prudently limited at high speeds to avoid excessive angles of heel. However, budget constraints and the lack of development of new designs left little alternative. A new design was required to replace the DDG2 and DDG37 classes of destroyer, and over a period of six years from 1980 the US Navy developed the design of a new destroyer, the DDG51 Arleigh Burke class, which had a shorter and wider hull but could accommodate Aegis with considerably more firepower than the FFG7-class frigates and at less cost than the cruisers.

The DDG51-class destroyers were designed as multi-mission ships with an emphasis on air-defence. They are intended to operate with the carrier battle groups of the US Navy and at sea world wide and would replace the older destroyers as they went out of service during the 1990s.

The first ship, *Arleigh Burke*, entered service in 1991. Since then a further 86 have been ordered, and two shipyards in the United States continue to build them today — Huntington Ingalls Industries at Pascagoula and Bath Iron Works in Bath, Maine. The US plans to continue building these destroyers for many years.

With the US Administration's policy to build the size of the US Navy to 355 ships, it is now planned to extend the life of all DDG51s to 45 years. If this is achieved, the US Navy could still be operating these ships a century after they were originally designed. Such longevity of an individual warship design is probably unprecedented, if we ignore the fact that USS *Constitution* and HMS *Victory* are still in commission!

The design of the DDG51 class has been modified over the years. The first 28 ships, or Flights I and II, initially had a full load displacement of 8,184 tons and are 154 m long overall with a beam of 20 m. Propulsion is similar to the Spruance-class with four gas turbines driving two shafts for a speed of about 30 knots. In Flight IIA ships a helicopter hanger was added and Flight III, introduced in 2017, incorporates a new radar, the Air and Missile Defence Radar or SPY-6, together with improved electrical power and cooling systems. Full load displacement has grown to 9,600 tons. The complement is 323 people.

One of the final contenders for Australia's air-warfare destroyer program was a smaller, new-design ship based on the DDG51. As built the Hobart-class DDGs, based on a Spanish design closely related to the US ships in equipment and standards, are somewhat smaller at 7,000 tons with an overall length of 146.7 m and a beam of 18.6 m. Propulsion is diesel and gas turbine. The complement, at about 180, is significantly lower than the US ships. The armament is similar, although ammunition capacity is smaller.

Over the last twenty years or so, the designs of modern destroyers or frigates — the distinction is moot — have developed towards ships of similar size and capability and cost. European examples are the British Type 45 destroyer, the French and Italian ships of the Horizon class, the French and Italian FREMM frigates and the Spanish F100 frigates. They are all very similar, and all these designs have a family resemblance to designs which were developed in the 1970s. Taking into account their expected life, there could be a period of changeless surface warship design in the navies of the world not seen since the late 18th and early 19th centuries.

There was rapid change in the mid-19th century as new technologies emerged, rendering earlier fleets obsolete in a very short space of time. Steam power, iron construction, and breech loading guns radically changed warship design.

Today there are technology developments which could have a similar effect. For example, electric propulsion is returning, directed energy weapons (lasers) will demand large amounts of electric power, unmanned aircraft will enable smaller ships to patrol large areas of ocean, missiles and torpedoes will become smarter and faster and there will be a continuing drive to provide modern accommodation for a highly-qualified but smaller crew, demanding an increased allocation of space.

The ships being built today with planned lives approaching half a century may provide excellent service for decades if the threats they are intended to confront do not develop into action. Then everything could change. To quote Carl von Clausewitz “No campaign plan survives first contact with the enemy”. The survivability and utility of our ships may depend on their adaptability and flexibility when confronted by threats not foreseen when they were originally designed.

In recent years two radical new warship designs have been produced, but both have yet to prove their effectiveness and suitability for their naval role. One is the US Navy’s DDG1000 class of very large destroyer and the other is the Littoral Combat Ship (LCS).

The DDG1000 program began in the early 1990s to produce a multi-mission destroyer capable of providing naval gunfire support to shore forces and to introduce new technologies which might be used on future naval ships. Thirty two ships were originally planned, but only three will now be built. They are fitted with two new-design 155 mm guns capable of firing long-range rocket-assisted guided projectiles, but that munition has been abandoned because each round would have cost about $US800,000. So far no replacement ammunition has been selected and the guns may even be removed. Moreover, the role of the ships has changed from naval gunfire support to offensive surface strike. The 80-missile capacity vertical-launch system will now carry anti-ship and land-attack missiles and more may be carried if the guns are removed.

These very large ships, with a displacement of about 15,600 tons, also incorporate new technologies like an integrated electric-drive system and extensive automation in order to reduce the size of the crew to about 175, within an unusual hull designed for stealth. Detailed design began in 2001 and construction of the first ship, USS *Zumwalt* (DDG1000), began in 2011. She was commissioned in October 2016 but will not be completed until late 2018. The second and third ships are expected to be completed by the end of 2022. With a total project cost of around $US13 billion, these ships might best be regarded as technology demonstrators, some features of which may appear in the next generation of US Navy surface combatants now in an early stage of design development.

The Littoral Combat Ships (LCS) are also advanced technology designs. Whilst it had been planned to select only one design for production, two very different ship designs will provide half each of the 32 ships to be built. One is an aluminium trimaran designed by Austal in Australia and built by them in Alabama, and the other is a steel-hulled monohull designed by Gibbs & Cox and built by Fincantieri Marinette Marine in Wisconsin. The LCS was intended to be an inexpensive surface combatant equipped with modular mission packages, including unmanned vehicles. The roles, depending on the mission module embarked, could be antisubmarine warfare, mine countermeasures and surface warfare, with many subsidiary roles of a general purpose nature. The LCS are high-speed ships, around 40 knots maximum speed, and have a core crew of 50 (ten more than originally planned) with another 38 for the embarked aircraft and mission package.

The first ship was completed in 2008 and about 20 have been delivered so far. Development of the mission modules has been costly and protracted and, rather than have modules embarked depending on mission, the ships will now have dedicated roles. Changes to these roles are likely to be infrequent, if they occur at all.

The US Navy originally planned to acquire 52 LCS but the ships have been criticised for considerable cost growth and concerns about survivability and armament. Finding a suitable use for the chips has also been a challenge and the US Navy is reportedly considering decommissioning the first four ships early. The US Navy is now considering industry proposals for a new class of 20 frigates, to be based on an existing design. A design based on the Austal trimaran LCS is one contender. Other ship designs offered are based on the US Coast Guard's National Security Cutter, the Italian FREMM and the Navantia F100, the latter ship very similar to Australia's Hobart-class destroyers. The first ship should be ordered in 2020 with all 20 ordered by 2030. FFG(X), as the frigate is presently designated, will in many ways be a successor to the FFG7 class guided missile frigates which are still highly regarded. Unfortunately, the ship regarded as the best option, the Type 26 frigate ordered by Britain, Australia and Canada, did not qualify because no ship of the type was in service at the start of the competition.

Against this background of design uncertainty, new technologies are rapidly being developed which could change the battle space in which the new ships will have to operate. Autonomous underwater vehicles are now being developed which are likely to have a role in discreet surveillance and, if were to be decided to be morally acceptable, even hostile operations. Unmanned aerial vehicles are becoming familiar and are likely to be part of the equipment of more ships which would otherwise be unable to operate manned aircraft.

In the Australian context, present RAN new construction plans will not result in a significant increase in the number of ships and submarines for many years. The area of sea in which Australia has an interest is very large and we may well find that we simply never have enough ships. Surveillance of these vast areas could well become practical with modern developments like Ocius Technology's Bluebottle ocean drones, developed with the aid of a grant from the Defence Science and Technology Group. The prototype, *Bruce*, is a six-metre craft with a solar sail which can deploy sensors, cameras or ROVs on 140 m of cable. It can achieve 5 knots under power and survive up to sea state 7. Drones like *Bruce* could be used in conjunction with manned and unmanned aircraft, surface ships and submarines.

Developments such as these may mean that the future RAN will need new types of ship, possibly smaller and less complex than today's frigates, but larger than the offshore patrol vessels, to support and deploy unmanned and autonomous vehicles — a modern corvette perhaps?

Every warship design is a compromise. As the cost and planned life of warships increases, new designs must have the flexibility to accommodate new technology and modular payloads as they become practicable and affordable. The Type 26 frigate selected for Australia's new frigates is a 21st century design and will have that capability. However, we cannot be sure that the world in which we live will not change rapidly and with little warning. Current procurement practices are protracted and complex. Most ship design work has been outsourced to contractors — Total Package Procurement is alive and well. Shipbuilders and ship designers will offer vessels which meet the customer's stated requirements — rarely more — and a system which seeks proven design solutions does not encourage innovation. There is a powerful argument for the restoration and nurturing of naval in-house design capability. This would not only ensure that the navy can be an informed customer, but future Chiefs of Navy should have the resources immediately available to help explore design solutions, conventional and radical, and answer the question 'What if?'

The RAN's future Hunter-class frigates are a 21st Century design adopted by three navies. This model was on display at the BAE Systems stand at the Pacific 2019 International Maritime Exposition in Sydney (J Jeremy)

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