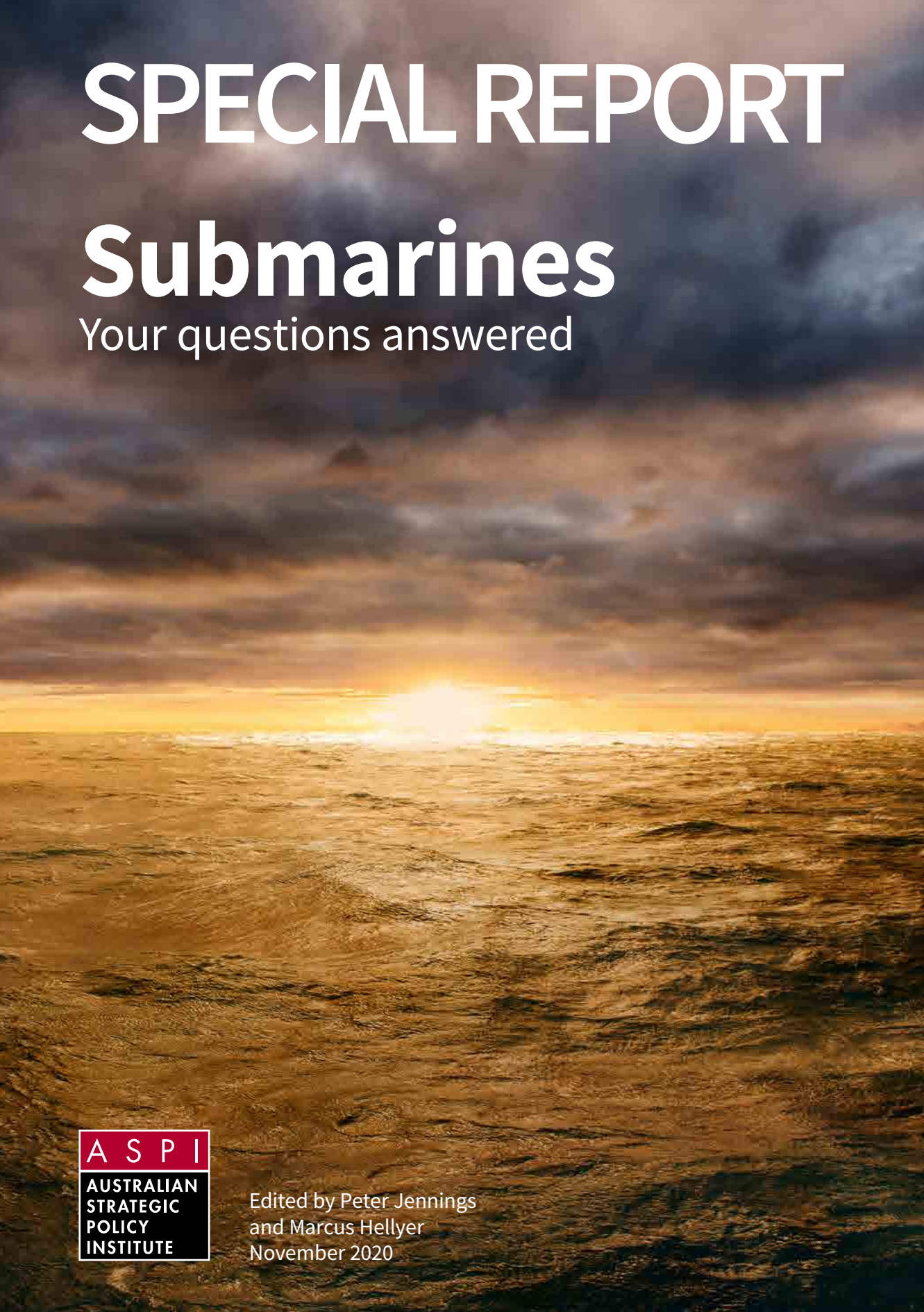
SPECIAL REPORT

Submarines

Your questions answered



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Edited by Peter Jennings
and Marcus Hellyer
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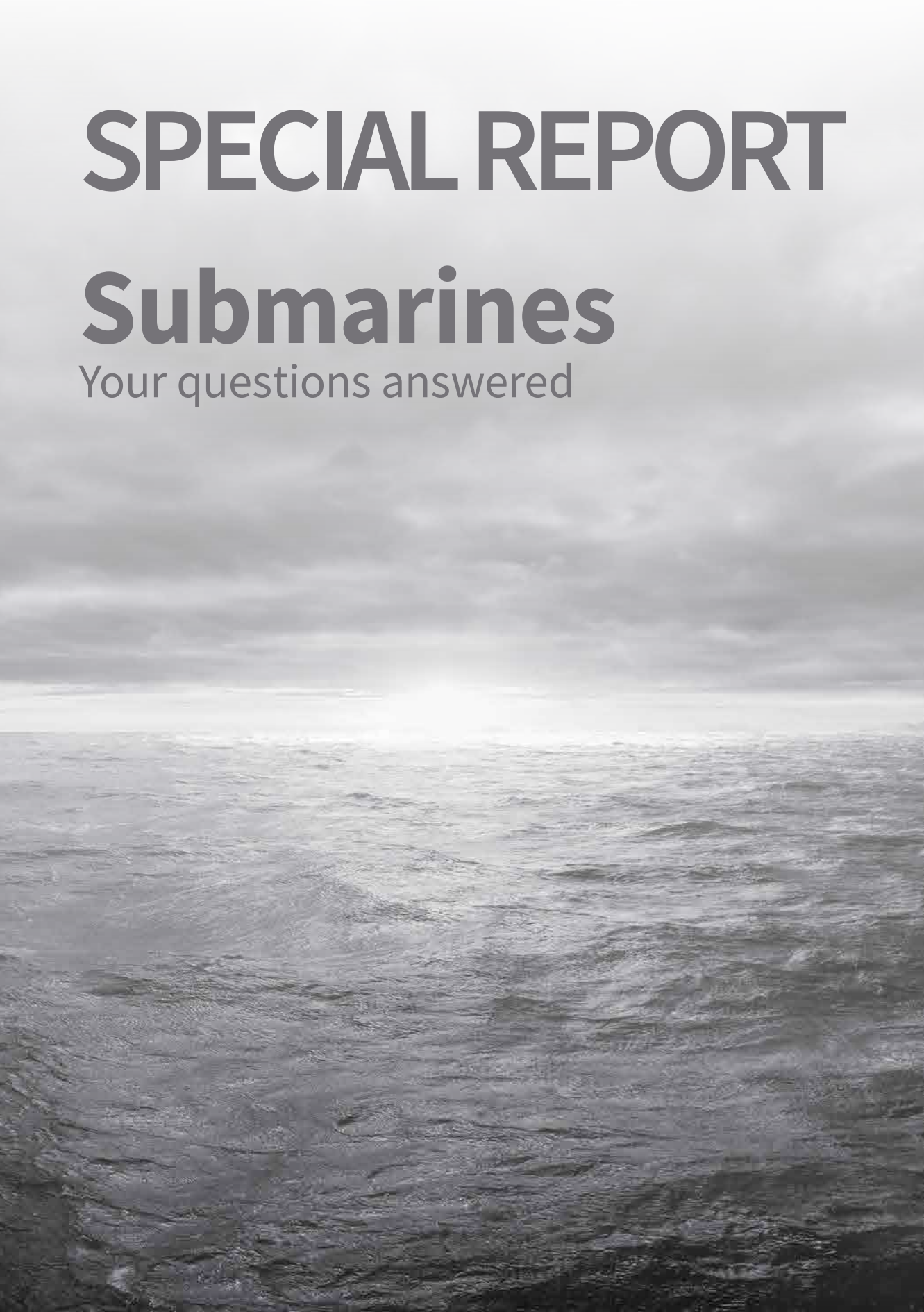

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Foreword

The Australian Government is firmly committed to keeping Australians safe while protecting our country's interests in a changing global environment. Being a credible and effective military power in the midst of the most consequential strategic realignment since World War II is a complex task in our nation's strategic circumstances. Most of Australia's trade activity occurs through Southeast Asia, so our future prosperity depends on a stable, rules-based Indo-Pacific that permits the free flow of goods and services.

Submarines are a vital element of our defence strategy and are essential in protecting those interests. Their substantial firepower, stealth, endurance and sustained presence give Australia a unique advantage: to strike without warning and inflict significant damage to adversaries.

Around 300 submarines will be operating in the Indo-Pacific by 2030, so Australia must continue to have credible defence capabilities that can contribute to regional and global security. Integrating multiple capabilities, such as submarines, frigates, helicopters and intelligence systems, into an undersea war-fighting system will give the ADF the necessary depth and resilience to prosecute antisubmarine operations.

Our current fleet of Collins-class submarines and their crews are serving our nation with distinction. The Collins class is the world's most capable conventionally powered submarine, achieving significant operational results of which Australians can be proud.

To further advance regional security and the prosperity that we have today, a larger, stronger and more formidable undersea force is needed in the future. To be able to operate far forward with a sustained presence in the Indo-Pacific and to deliver assured access and sea control, we must invest in a more substantial denial capability.

The government's decision to build 12 regionally superior Attack-class submarines in Australia is ambitious but necessary. The Attack class will bring higher levels of interoperability with the US, and its design will allow systems and capabilities to evolve and develop as threats change.

A highly capable submarine program is built on strong national foundations. We're mobilising Australian industry, academia and our emerging new workforce to deliver a sovereign submarine capability. Through strong leadership and growth in essential scientific, technological, engineering and mathematical skills, we're charting our own course to strengthen Australia's industrial capacity—to evolve and integrate new, cutting-edge technologies.

Building submarines isn't easy—the risks are high—but the reward is great. We'll carefully consider our choice of technology and industry partners over the long life of this program to ensure the best possible outcome for the ADF.

There's no substitute for the capabilities that submarines deliver. It's incumbent upon all of us to maintain our national resolve and long-term focus on this enterprise over the decades ahead. That resolve is central to upholding Australia's national security and the finest traditions of the Royal Australian Navy.

As Minister for Defence, I'm committed to ensuring the successful delivery of our submarine programs. We're on track and progressing well.

I commend Peter Jennings and Marcus Hellyer for assembling the team of authors who produced this ASPI Special Report, *Submarines: Your questions answered*. This is a plain-English guide to the complexities of Australia's submarine program. While the government doesn't endorse all of the contributions aired in this study, it's important that critical nation-building programs such as our submarine program are subjected to robust and broad analysis.

ASPI provides many different perspectives on the submarine program in this report. I trust that the report will generate further public interest in and awareness of this vital capability.

Senator the Hon Linda Reynolds CSC
Minister for Defence

Introduction

Prime Minister John Howard famously coined the term 'barbeque stopper' to refer to a political controversy so hot that it was likely to make backyard diners stop mid-shrimp-sizzle to debate the big issue of the day. If ever the specialist world of defence procurement has produced a national barbeque stopper, it would be over the question of Australia's future submarine. Why are they so expensive? Why do we need 12 of them? Why build them here? Why not nuclear propulsion? Why a French design? Why not an American, German, Japanese or Swedish design? Aren't submarines obsolete, to be replaced by drones? Won't technology make the oceans transparent?

There are many questions and few, if any, easily accessible, plain-English explanations. This ASPI study attempts to answer the many questions that Australians pose when it comes to the design, acquisition, cost, operational service and strategic implications of submarines. Our writing team includes a vice admiral and former Chief of Navy, two rear admirals—one a distinguished submariner who has served with the Royal Navy and the Royal Australian Navy; the other, one of Australia's leading naval historians. Other contributors include people steeped in strategy and capability development and with deep industry experience of defence production.

Our hope is that this volume will become the go-to guide for authoritative comment on all things to do with the present and future of Australian submarines. A draft of this work was provided to key individuals in Defence and from industry to advise on factual matters. As with all our publications, ASPI retains complete control of editorial matters.

If you think we've missed a question, please let us know and we'll do our best to provide an answer, adding it to our list online and in subsequent editions.

Our thanks go to the Minister for Defence, Senator the Hon Linda Reynolds CSC, for her generous foreword and to ASPI's Marcus Hellyer for his patience and indefatigable championing of data over dogma.

Peter Jennings
Executive Director, ASPI

Part 1: Why submarines?

Submarines are fundamentally important to our defence strategy. They are a unique and powerful deterrent to any adversary, and they are critical to protecting our national security interests. Submarines secure Australia's strategic advantage through leading-edge surveillance and the protection of our maritime approaches. Our sophisticated level of interoperability with the United States is a critical aspect of our submarine operations in our region. As are our Air Warfare Destroyers and also anti-submarine warfare frigates. Submarines are also the vanguard of strategic lethality and deterrence. With substantial firepower, with stealth, with endurance and also with sustained presence.

Our regionally superior Collins-class submarines are already very capably demonstrating all of these effects. We will see further refinements to our future Attack-class submarines. Ones that will strengthen our capability to maintain peace and security in our region.

Our submarine capability underpins Australia's credibility and influence as a modern military power. And let me make that statement again: Our submarine capability underpins Australia's credibility and influence as a modern military power.

—Linda Reynolds, Minister for Defence, speaking at ASPI after the launch of the 2020 Defence Strategic Update, 2 July 2020

Question 1: What, exactly, do submarines do?

Response 1

James Goldrick

Submarines are the apex predators of maritime conflict. They deploy a variety of highly lethal weapons—usually without warning. Submarines can lay mines around enemy ports and in shipping channels. They can sink surface ships with torpedoes or with anti-ship missiles. They can fire missiles against land targets. And they can insert and recover special forces for reconnaissance missions or small-scale raids ashore. They can also act as intelligence gatherers, sitting off an adversary's coast to listen for enemy movements and monitor the electromagnetic spectrum for enemy signal and sensor transmissions.

Submarines operate alone but play important roles in other maritime operations. They can conduct reconnaissance before a surface force enters an area, using their own sensors to confirm that it's clear of adversary units and safe for the intended operation. They can act as a barrier past which the enemy must go to attack its key targets. They can provide advance warning of enemy movements when stationed off the adversary's coast—not only of enemy ships but also of aircraft. Properly timed, their own attacks can not only weaken or even halt enemy operations outright but force the diversion of resources away from the enemy's offensive operations.

It's their ability to operate covertly that allows submarines to do those things. Because submarines remain underwater and because the oceans are a hugely complex and dynamic environment, the boats are very difficult to detect and almost as difficult to track once detected. Modern submarines almost always sail submerged, surfacing only to enter harbour. They rarely transmit on radio and almost never use active radar or sonar, which might reveal their own position. They're most effective when they can access intelligence and sensor information from other sources, allowing them to position themselves to locate and destroy their targets. This is particularly important for diesel–electric propelled boats. Nuclear-powered submarines have practically unlimited high-speed endurance and can reposition very quickly. By comparison, diesel–electric boats are slow—although they can achieve high underwater speeds for short periods—and must recharge their batteries at intervals, even when they have other 'air independent' propulsion for low-speed patrols. If they're to transit, they must use noisier diesel engines for much of the time. This means operating near the surface with a 'schnorkel' or 'snort' mast above the water, making them more open to detection. Once on station, however, they're much less vulnerable.

Although some emerging technologies may increase the probabilities of detection underwater, they have yet to threaten the ability of modern, stealthy submarines to operate covertly. Modern submarines are designed to have the smallest possible signature across the acoustic spectrum, to the point where they're effectively 'silent' at slow speed. This is the reason the great powers all operate ballistic missile carrying submarines as key elements of their nuclear deterrent forces—and why new generations of those boats are in development. Furthermore, although unmanned vehicles present a significant emerging threat, submarines' ability to deploy and recover their own autonomous vehicles will give them new options at reduced risk to themselves. Their potential as underwater killers remains high.

Response 2

Peter Clarke

Submarines are and always have been high-end military assets that come into their own during armed conflict. Possessing a fleet of submarines therefore gives a nation-state some strategic options and deters others from actions that aren't in its interests.

Whenever a submarine is submerged, everyone is focused on keeping it safe. Submariners have a saying: *It takes all of us to get the submarine to sea but only one of us to sink it*. Teamwork and trust are essential. Of course, life goes on as in any ship, with meals to be cooked, departments to be led and administered, reports to be written, training to be accomplished and all the supporting systems to be operated and maintained. All that has to continue once the submarine reaches its operating area. Patrolling hostile waters brings other dimensions: a focus on hostile forces and on remaining undetected, and maintaining the poise to take any pre-emptive or responsive action that might be required.

There are always times, sometimes days, of monotonous but intense analysis of sonar contacts—some detected by broadband noise and others that appear as a discrete frequency. And all of this is passive: the submarine never transmits on sonar or radar—it just listens to the noises in the ocean, looking for that one interesting or dangerous contact.

So all this keeps the submarine crew busy, but what can submarines actually do?

Submarines have a range of capabilities that have the potential to inflict unacceptable harm on an adversary. Here are some of the more common:

- **Disabling a ship.** Submarines carry torpedoes and missiles that can be used to strike ships and submarines; they're are used as attack weapons or in self-defence. The submarine's own sensors and onboard analyses do the targeting of the weapons, and the submarine is usually autonomous in these engagements.[1]
- **Launching a strike against a land target.** Submarines are able to launch cruise missiles to strike land-based infrastructure and strategic assets. Cruise missiles carry a conventional warhead. Larger submarines, generally nuclear powered, are also capable of launching ballistic missiles with nuclear warheads. The missiles are able to attack targets many thousands of kilometres from the submarine.
- **Laying mines.** The ability to lay a minefield covertly is valuable. Once detected (usually by a ship being sunk), the field is difficult to clear and its extent is uncertain. This causes the opposing force major disruption, delaying and complicating the deployment of its maritime assets.
- **Intelligence gathering.** Because a submarine is able to loiter off a hostile base for many weeks, it has the opportunity to observe and record activity above and below water.
- **Support to special forces.** Special forces can be deployed from and recovered to surfaced or submerged submarines close to an adversary's shore.

There are other niche activities of which a submarine is capable, but many are classified and beyond the scope of this paper.

In summary, submarines are able to conduct a wide range of activities that are useful in peacetime, hostilities and all-out war. Their inherent stealth and ability to remain on station for long periods give governments strategic and operational options that might not otherwise be available.

Figure 1: An Australian submarine on patrol

Source: Michael Wyszomierski, Flickr, online.

Question 2: How do submarines deter?

Response 1

James Goldrick

Submarines are the ace in the hole of maritime conflict. Operational submarines at sea create immediate uncertainty in the mind of the adversary. To protect surface forces against them requires a disproportionate response, which may still be ineffective against a sufficiently determined and capable submarine. This isn't a problem simply of scale but of technology and professional expertise. Antisubmarine warfare (ASW) is notoriously difficult, and many nations aren't very good at it. The most capable navies acknowledge that their protective antisubmarine operations can achieve a high probability of security against their ships being sunk, but never certainty. Any deployment by sea may be subject to submarine attack, and even great powers must be very cautious about the reality that their most valuable units—and the people on board—could be at risk.

The larger the submarine force, the more of a challenge it represents for an opponent. Numbers are particularly important where diesel–electric boats are concerned. When only one or two are available, their limitations in sustained speed mean that, if they're detected and located, the adversary may be able to avoid them completely. If the adversary can be certain that no submarine is at sea, then it will have much greater freedom of action, particularly if it seeks to take the offensive. If, however, the location of every submarine in the force can't be verified by the would-be adversary, the threat remains, for even a single unit can create devastating effects. In 1942, with a salvo of six torpedoes, a lone Japanese submarine sank an American aircraft carrier, damaged a battleship and a destroyer—and escaped successfully.

Submarines give governments several deterrence options in developing crises. Announcing that one or more submarines have sailed, particularly if the exact timing of their departure can be concealed, can be an important signal of resolve. But they can also be used with much more discretion, keeping options open and avoiding escalation. The covert deployment of submarines sends no signal and makes no open threat to a possible adversary. It doesn't escalate matters and minimises the chances of losing the moral high ground through being perceived to have acted aggressively. If the situation develops in such a way that no such threat need be made, the submarines can be brought home, leaving the adversary (and others) none the wiser. Furthermore, even if a unit is detected, it's almost impossible to confirm its nationality, allowing deniability if that's desirable.

The difficulty of establishing national identity allows ambiguity in another way—a submarine can be deployed covertly but instructed to allow itself to be detected for a fleeting moment. This creates immediate concern in the mind of any prudent commander on the other side, forcing the reassessment of any plans—and perhaps even their cancellation. In a situation in which there are other factors in play that are causing a potential adversary to hesitate before committing itself to a conflict, this may tip the balance in favour of restraint with minimal loss of face. The British used this approach to good effect in 1977 during a precursor crisis to the Falklands war—and came to regret that they didn't do it again early enough to prevent the 1982 invasion.

Figure 2: Former destroyer escort *Torrens* being hit by a Mark 48 torpedo fired by HMAS *Farncomb* off the Western Australian coast

Source: Defence image library, online.

Response 2

Peter Clarke

Deterrence is an act or process that tends to dissuade someone from doing something. It can do this by open threats (*If you do that to my interests or me, I'll do this to you or your interests*) or by more subtle means. In the defence context, the probable results of every military action are assessed for likely outcome and risk. This balance is rarely straightforward, and the risk of unintended consequences is even more difficult to assess.

An essential part of assessing risk and thereby arriving at a decision to undertake some action is to know what threat you face: the opposing force's strength, its geographical position and mobility, its endurance and its ability to inflict significant harm. Knowing what the enemy is likely to do or is capable of doing is essential and is why nation-states and their armed forces put so much effort into intelligence gathering.

All submarines and other submersibles have some inherent characteristics that make the risk profile more complex and potentially less reliable for decision-makers. In general, those characteristics stem from the underwater environment, stealth and long endurance. For example, we frequently employ methods of detection that use the electromagnetic and visual spectra (neither of which works well in water), and the accuracy of tactical or operational risk assessments decays quickly without regular updates on the position of opposing forces.

So, how might a submarine contribute to deterrence?

First, the military options available to a submarine fleet include striking ships and submarines, attacking land-based installations and infrastructure (including as a strategic strike), laying minefields to deprive an aggressor of options and complicate its planning, landing and supporting special forces and other asymmetric capabilities, and intelligence gathering. Together, those capabilities present the opportunity to inflict significant and potentially unacceptable harm on a nation-state, even to the extent that it's rendered strategically and militarily impotent.

Second, once a submarine has deployed from its base, it becomes very difficult to locate. Anyone wishing to maintain an updated position on that submarine has to employ a significant capability and, if contact with the submarine is lost, it becomes increasingly more difficult to find it again. With every passing hour, the area of probability expands and locating the submarine requires ever more assets, while the submarine's options increase. After a certain time, a deployed submarine might be anywhere. The operating authority might hint that it's in an area of significance to opposing forces or might hint that it isn't. In other words, you can say it's somewhere it isn't or that it isn't somewhere that it is. Either way, the effort to locate and maintain contact on the submarine is considerable.

Third, while on station the submarine can maintain a readiness to strike at very short notice and without warning from close to an adversary's shores. It can do that for long periods and, if sufficient submarines are deployable, indefinitely.

So, a submarine achieves deterrence by greatly increasing the risk profile for an adversary, thereby complicating its planning, constraining its options and reducing its ability to interfere with other nations' interests.

Question 3: Why is Australia's requirement for submarines different from other countries' requirements?

Tim Barrett

There are many reasons why maritime nations choose to operate submarines. For some, it may be about prestige (owning submarines completes the naval order of battle) or it may be a desire to demonstrate a great national industrial capacity, given that submarines are complex and sophisticated beasts and their building and upkeep demand a national capacity for technical expertise. For others, it's in direct response to a real or perceived threat to their sovereign interests, as is manifested in the growing number of submarine-operating nations in our region, where it's reported half of the world's submarines will be by 2030. To yet others, it may be driven by the strategic view that a submarine capability, used wisely, is arguably the most effective maritime weapon a nation can hold, and, if designed and operated properly, will deliver a substantial deterrent effect.

The reasons that have influenced other countries' decisions to acquire and operate submarines are a matter for debate. However, in the Australian case, after many years of experience of submarine operations in our region, the purpose appears to be relatively clear and is threefold.

At the *tactical* level, the submarine offers potent lethality that can be swiftly applied to abruptly halt any aggressor's military plans at sea, if diplomatic measures have failed. A harsh reality is that a submarine's firepower is substantial and exceeds that of most other conventional military capabilities by many orders of magnitude. And, while their success is contingent on strong industrial capacity ashore, an experienced and competent workforce and the political will to employ submarines, on operations it comes down to a capable combat and weapon system and unrivalled stealth. That means a customised combat system coupled with a low acoustic signature—designed for Australia's regional operating conditions. The Australian conventional submarine solution places a priority on optimising lethality and stealth, each of which requires sovereign capabilities to protect this advantage.

At the *operational* level, the need is to provide a presence at extended distances, backed by a national will to unleash it should the need arise. While our own island geography provides some protection, it also means that the maritime battlespace becomes more difficult close to our coastline—it's better to take the battle to an adversary's shoreline where its ships and submarines have little to no effect and are easier to find. That steers us towards a larger ocean-going submarine with long endurance, rather than one built for short coastal patrols.

At the *strategic* level, capable submarines are a political and diplomatic bargaining tool. They present a huge risk to any adversary's political gamesmanship that, when operated alongside our allies and partners, produces a disproportionate return on investment. A sizeable, lethal, stealthy and far-reaching submarine force of sufficient numbers allows a nation such as Australia to assume a power status well beyond its size and weight.

Not all nations have the desire, will, capacity or capability to exploit the full benefits of a capable submarine force. Australia chooses to design a submarine capability to do just those things.

Question 4: What's the rest of the Indo-Pacific doing with submarines?

James Goldrick

Despite their cost and difficulty of operation, submarines are proliferating throughout the Indo-Pacific. The great powers continue to renew and, most notably in China's case, expand their capabilities. Russia and the US are replacing their ballistic missile submarines with new designs, while China and India are making great efforts to develop underwater strategic deterrent forces. All operate nuclear attack submarines as well, although India does so with a leased unit from Russia. Its resources don't yet extend to a build parallel to the missile boats. Only the US is not investing in diesel–electric patrol submarines, although both India and China have repeatedly looked to Russia for technical assistance to supplement their indigenous building programs. China's force expansion has been accompanied by increasingly ambitious long-range deployments in both the Western Pacific and the Indian Ocean, putting pressure on the ASW capabilities of the US and its allies, as well as India. This has caused Japan to increase its number of diesel–electric submarines and is one of the reasons behind South Korea's build-up of its force.

Among smaller nations, there are three factors in play in the acquisition of submarine capabilities. The first, particularly in Southeast Asia, is a response to China's growing strength at sea and its willingness to assert that strength. The second is a perhaps inevitable element of prestige and 'keeping up' with the capabilities of neighbouring countries. Nevertheless, the realisation that submarines provide unique deterrent capabilities has long been the major justification for such investment in otherwise severely resource-constrained navies. This has led Indonesia to maintain an operational submarine force for more than 60 years, despite many challenges. In 2020, its renewal is underway, with a new order that will double the number of boats. Singapore was also an early adopter of submarines, with the same eye to their deterrent value. It operates four modernised ex-Swedish units, while four new-build submarines are on order from Germany. Vietnam's powerful group of six Russian-built boats is clearly a key element of its maritime defences against China. Malaysia maintains perhaps the minimum credible force with a pair of French-built units. It has plans for expansion, but they're unlikely to be practicable for the time being. The Philippines continues to talk of acquiring submarines but lacks the resources.

North Korea is a key example of a national effort to maintain a force that may lack sophistication but remains dangerous. Taiwan has operated submarines for many years and believes they're integral to its defence against Chinese invasion. However, with an ageing force and rejected by overseas builders, Taiwan is struggling to produce an indigenous design good enough to face the increasingly capable Chinese.

Another factor in submarine acquisition is great-power influence. Several of the smaller nations that are acquiring submarines are doing so with external assistance, which has a variety of motives. China is building a boat for Thailand (although the purchase of two more has just been delayed for at least a year) and has transferred two renovated—although unsophisticated—units to Bangladesh. At least partly in response, India has transferred an elderly Russian-built submarine to Myanmar. Pakistan is replacing its submarines with Chinese-designed units; the build is shared between Pakistan and China.

Finally, both Pakistan and North Korea have potential if not actual underwater nuclear missile capabilities. The proliferation of nuclear weapons at sea in such forms may create new problems for the strategic balance and stability of the Indo-Pacific.

Figure 3: Minister for Defence Dr Ng Eng Hen delivering the address at the launch of the Republic of Singapore Navy's first customised submarine, *Invincible*.

Source: Ministry of Defence, Singapore Government, online.

Question 5: How are China's submarine capabilities developing?

Malcolm Davis

Submarines are a key component of the PLA Navy of China. The modernisation of the navy's submarine force emphasises deploying more capable, long-range and well-armed nuclear (SSN) and conventional (SSK) boats that are equipped to undertake anti-surface warfare operations with advanced long-range anti-ship cruise missile systems. Their ability to undertake ASW against other submarines is less developed, but China's traditional shortcomings in this type of activity are being reduced as it develops more capable ASW sensors, platforms and weapons.

The PLA Navy is deploying quieter SSKs, such as the Type 039 Yuan-class SSP (with air-independent propulsion), alongside 12 Kilo-class SSKs (eight of which were purchased from the Russian Federation) for operations within the near seas that lie within the 'second island chain' running from Japan through Taiwan and the Philippines down to Papua New Guinea. Seventeen Yuan-class boats were in service in late 2019, and three additional boats are under construction. Those are in addition to older Ming- and Song-class diesel–electric submarines. All the conventional submarines, except for the Ming and the four earliest Kilo-class SSKs, are capable of launching long-range anti-ship missiles.

China's nuclear-powered attack submarines include six Type 093A Shang-class SSNs, and a newer Type 093B improved Shang-class SSN is also in development. Finally, the PLA Navy has recently deployed two additional Jin-class nuclear ballistic missile submarines (SSBNs), bringing the force to four boats out of a total of six planned.

In submarine warfare, silence is golden, and Chinese submarines are getting quieter. The early Type 093A SSN is estimated to be as quiet as the improved Los Angeles-class SSNs of the US Navy. A next-generation boat—the Type 095 Tang class—is under development. When completed, it will be newer than the US Navy's Virginia-class SSNs, giving China the opportunity to incorporate further noise-reduction technologies, including active noise cancellation and advanced electric propulsion. The recently released 2020 report on China's military power from the US Department of Defense notes that China has two Shang I class (Type 093) and four Shang II-class SSNs (Type 093A), and by the mid-2020s will build the Type 093B improved Shang-class guided-missile nuclear attack submarine.[2]

Various estimates about the growth in size of the PLA Navy submarine force have been made. In an update on the modernisation of the navy prepared by the Congressional Research Service and released in April 2020, projections from the US Defense Intelligence Agency in 2019 suggested a force of between 65 and 70 submarines by 2020; while the US Office of Naval Intelligence suggests that China's submarine force will grow from 66 boats (4 SSBNs, 7 SSNs, 55 SSs) in 2020 to 76 boats (8 SSBNs, 13 SSNs, 55 SSs) by 2030.

The PLA Navy's employment of submarines clearly emphasises anti-surface warfare as part of anti-access and area denial. The SSNs are likely to be employed in that role out to the 'second island chain', which runs through Guam, and the anti-ship missile equipped SSKs are likely to be employed inside the first island chain. In SSBN operations, until the quieter Type 096 SSBN is operational, the Jin-class SSBNs are likely to operate from defended bastions in the China Sea Basin within the South China Sea and in parts of the Yellow Sea. With the development of the quieter Type 096 SSBN and the Type 095 SSN underway, expect a future focus on open-ocean bluewater deployment for the PLA Navy's nuclear submarine fleet.

Question 6: How are the US's submarine capabilities developing?

Malcolm Davis

The US Navy's all-nuclear submarine fleet includes 69 nuclear-powered and -propelled submarines, comprising 13 Virginia-class fast-attack submarines (SSNs), 35 older Improved Los Angeles-class SSNs, 3 Seawolf-class SSNs, 14 Ohio-class ballistic missile submarines (SSBNs) carrying nuclear-armed Trident D5 submarine-launched ballistic missiles (SLBMs) and 4 converted Ohio-class cruise missile submarines (SSGNs), each carrying up to 154 Tomahawk land-attack missiles (TLAMs).

Of key importance are the US Navy's nuclear-powered fast-attack submarines—the Virginia, Seawolf and Improved Los Angeles (688I) boats. The Virginia-class SSNs were developed following the cancellation of the Seawolf class after the construction of only three boats due to the high unit cost of each Seawolf and the rapidly changing strategic environment brought about by the end of the Cold War.

The US Navy is upgrading the Virginia SSNs to replace the Improved Los Angeles SSNs, as well as the converted Ohio SSGNs. This is occurring with the Block V Virginia, which is equipped with the Virginia payload module. This is an extra section in the submarine's hull that comes with four large vertical launch tubes, which allows each submarine to launch seven TLAMs from each tube, in addition to 12 TLAMs from the submarine's torpedo tubes, for a total of 40 TLAMs per boat. That will allow each Virginia-class submarine to have a potent land-attack capability in addition to undertaking the traditional roles of ASW, intelligence gathering and support for special forces. The Virginia payload module will also support new anti-ship and land-attack missiles such as the Long Range Anti-Ship Missile, Tomahawk anti-ship missiles, hypersonic weapons and the delivery and recovery of large unmanned vehicles.

The Virginia-class SSNs are much quieter than the Improved Los Angeles class and will have superior sensor capabilities for detecting and tracking adversary submarines. Each Virginia Block V SSN will cost US$3.5 billion, and up to 10 Block V Virginias will be acquired. They, in turn, will be replaced by an entirely new type of submarine—the SSN(X)—in the 2030s.

The Ohio-class SSBN forms one leg of the US strategic nuclear triad, and, with 14 'boomers' in service, four or five are on continuous at-sea deterrence patrols at any time. Each submarine carries up to 20 Trident D5 SLBMs, and each missile normally carries four nuclear warheads as a result of limitations imposed by the New START treaty. The US is also developing a new low-yield warhead and re-entry vehicle for the Trident.

The key role of the Ohio SSBN—continuous at-sea deterrence—demands prolonged patrols in the open ocean during which the submarine uses its quietness and stealth to avoid detection. The submarines can spend up to 77 days at sea, followed by 35 days in port, with two crews—a Blue and a Gold crew—to maintain maximum strategic readiness. The 14 Ohio-class SSBNs will be replaced by 12 Columbia-class SSBNs from 2027 onwards.

In addition to the future submarine capabilities represented by the SSN(X) and the Columbia-class SSBNs, the US Navy is now investing heavily in extra-large unmanned underwater vehicles (XLUUVs), having signed a contract with Boeing for 50 Orca XLUUVs that will operate independently of crewed submarines.

Question 7: Where do submarines fit in Australia's broader defence policy?

Peter Jennings

Australian defence policy statements since 1976 have valued submarines because of their capacity to operate covertly and at distance from our shores (see box below). It's claimed that submarines would significantly complicate an adversary's capacity to attack Australia and thereby produce an element of conventional deterrence against attack.

While the core attributes of submarine capabilities haven't substantially changed, successive defence policy statements have put increasing priority on submarines. In the 1970s and 1980s, Indo-Pacific navies were only beginning to develop their own submarine capabilities and, as a result, Australian Defence White Papers (DWPs) judged that the six Collins-class submarines planned to replace the six Oberon-class boats were sufficient for Australia's needs. In the mid-1980s, a decision to home port the Collins submarines on Australia's west coast at HMAS Stirling was an important step in developing a two-ocean-navy construct for Defence, but the focus of operations remained to the north.

The 2009 DWP took the substantial step to double the potential size of the submarine fleet from six to 12 boats—a decision justified by the needs of 'our future strategic circumstances'. Beyond defending Australia's approaches, the 2009 DWP also anticipated the development of a long-range strike capacity for the Collins replacements by equipping them with cruise missiles. Subsequent DWPs shelved the cruise missile capability, presumably on the basis that this would somewhat simplify the replacement project.

By the time of the 2020 Defence Strategic Update, we see the submarines as part of a naval and maritime force that's a 'vital element of our defence strategy'. The emphasis in that policy statement is on submarines 'at long range from Australia' operating over 'vast distances'. Indeed, the strategic update envisages the entire ADF with longer range strike weapons at great distances from their home bases.

Over the past half-century, submarines have moved from the periphery of Australian thinking to being much closer to the core of our defence priorities. If the defence of Australia begins in maritime Southeast Asia (the core planning idea of the 2016 DWP), then submarines will be the centrepiece of that approach. The rapid growth of Chinese military capability underpins this shift in Australian thinking. Whereas in the 1980s attention was paid to the risk of a possible clash with Indonesia, right now Jakarta is thought to be a more likely ally than adversary.

There's also some perhaps deliberately opaque policy thinking about the balance of priority between our submarines operating as part of a larger allied force or operating alone. This isn't an either/or proposition, but we should ask which scenario is more likely and whether that should drive capability design.

Since the replacement of the Oberon boats in the 1980s, all Australian governments have found the idea of locally building and sustaining submarines to be simply irresistible. They cost a lot of money, and governments would rather spend onshore. In recent decades, this has created an uncomfortable clash of priorities—a need for speed to handle unwelcome strategic change versus a desire to create a long-term sustainable shipbuilding industry.

What's the future for submarines in Australian defence thinking? No one should be surprised if the idea of fitting a long-range weapon such as a cruise missile resurfaces. There's also a pressing need to integrate planning for a range of autonomous underwater systems to be integrated with the future submarine.

On balance, submarines are likely to continue their move to the centre of Australian defence thinking even at the possible expense of other long-valued military capabilities, such as, for example, major surface combatant ships.

Submarines in Australian defence policy statements

Australian Defence (November 1976)[3]

51. Submarines are a potent deterrent with important functions in anti-shipping and anti-submarine warfare, covert reconnaissance/surveillance and patrol, clandestine operations, and mine warfare. They provide the only means of sustained interdiction in areas where local air superiority cannot be established.

55. The effectiveness of submarines, and the complexities of the medium in which they operate pose very difficult problems for the defender and impose a disproportionately high strain on his resources.

Review of Australia's defence capabilities (March 1986)[4]

… submarines can operate covertly at low risk in areas where an opponent has sea and air control. They are versatile and can contribute in a range of contingencies in such areas as intelligence collection, surveillance, mining and special operations. A modest force of about six submarines, able to operate concurrently from both our west and east coasts, would be a major inhibition on an enemy's use of surface assets against us at all levels of contingency. (pp. 66–67)

The Oberon submarines are expected to be paid off during the 1990s, and the Government is planning to build new submarines in Australia. (p. 122)

… Australia might wish to have the option of maintaining submarines on station in more than one operational area—if only to ensure that an opponent, having detected the presence of one of our submarines in one area, could not count on the absence of a submarine threat in another area. Six new submarines of the capability proposed should be able to provide a sustained presence in three separate areas simultaneously, a major improvement over that available from the existing Oberons. (p. 123)

The Defence of Australia 1987[5]

4.43 The Government is introducing a new class of submarine which will be constructed in Australia. We will acquire six new submarines which, with their modern equipment, high performance and greater availability, will enhance the capability of our submarine force.

4.50 As well as being able to conduct strike operations against surface ships and other submarines, the submarine force can conduct reconnaissance and patrol, and operate in conjunction with the Army's special action forces.

Defending Australia: Defence White Paper 1994[6]

5.30 Our fleet of Collins Class submarines will be an important element of our capacity to deny our sea approaches to hostile shipping and to mount strike operations at long range.

These submarines are difficult to detect and therefore are less vulnerable than surface ships and aircraft, while their sensors and weapons allow them to detect and attack shipping with accuracy at long range.

5.65 Our Collins Class submarines provide a very significant capacity to strike ships using a variety of sensors to locate targets and a combination of missiles and torpedoes. Even without launching an attack, submarines by their very nature would create significant uncertainty for an adversary and force precautionary defensive measures. They are therefore an important means of discouraging attacks on Australia.

Defence 2000: Our future defence force[7]

3.46 Another key development is the expansion of submarine capability in the region. Over the coming decade it is likely that the capabilities of submarines being operated by regional navies will improve significantly, and a number of navies will acquire submarines for the first time. Anti-submarine warfare capabilities will also improve.

8.63 The Government plans to bring all six Collins class submarines to a high level of capability by major improvements to both the platform and combat systems.

Defending Australia in the Asia Pacific century: Force 2030: Defence White Paper 2009[8]

8.40 In the case of the submarine force, the Government takes the view that our future strategic circumstances necessitate a substantially expanded submarine fleet of 12 boats in order to sustain a force at sea large enough in a crisis or conflict to be able to defend our approaches (including at considerable distance from Australia, if necessary), protect and support other ADF assets, and undertake certain strategic missions where the stealth and other operating characteristics of highly-capable advanced submarines would be crucial. Moreover, a larger submarine force would significantly increase the military planning challenges faced by any adversaries, and increase the size and capabilities of the force they would have to be prepared to commit to attack us directly, or coerce, intimidate or otherwise employ military power against us.

9.3 The Future Submarine will have greater range, longer endurance on patrol, and expanded capabilities compared to the current Collins class submarine …

9.4 The Future Submarine will be capable of a range of tasks such as anti-ship and anti-submarine warfare; strategic strike; mine detection and mine-laying operations; intelligence collection; supporting special forces (including infiltration and exfiltration missions); and gathering battlespace data in support of operations.

9.5 The boats need to be able to undertake prolonged covert patrols over the full distance of our strategic approaches and in operational areas …

9.74 The Government places a priority on broadening our strategic strike options, which will occur through the acquisition of maritime-based land-attack cruise missiles. These missiles will be fitted to the AWD, Future Frigate and Future Submarine …

Defence White Paper 2013[9]

8.46 Due to the strategic value and importance of Australia's submarine capability, the Government remains committed to replacing the existing Collins Class fleet with an expanded fleet of 12 conventional submarines that will meet Australia's future strategic requirements. The future submarines will be assembled in South Australia.

8.47 The Future Submarine Program is a capability design, construction and sustainment challenge of unprecedented scale and complexity, and will span decades. Implementation will require a sustained and coordinated national effort.

2016 Defence White Paper[10]

4.25 Submarines are an essential part of Australia's naval capability, providing a strategic advantage in terms of surveillance and protection of our maritime approaches. The Government has determined that regionally superior submarines with a high degree of interoperability with the United States are required to provide Australia with an effective deterrent, including by making a meaningful contribution to anti-submarine warfare operations in our region. The key capabilities of the future submarine will include: anti-submarine warfare; anti-surface warfare; intelligence, surveillance and reconnaissance; and support to special operations.

4.26 The Government will increase the size of the submarine force from six to 12 boats. The doubling in size of the submarine fleet recognises that Australia will face a more challenging maritime environment in the decades ahead. By 2035, around half of the world's submarines will be operating in the Indo-Pacific region where Australia's interests are most engaged.

2020 Defence Strategic Update[11]

3.13 Australia's naval and maritime forces are a vital element of our defence strategy. They must be able to project force at long range from Australia, operate across vast distances and work closely with civil maritime security agencies to protect our borders … This includes the acquisition of 12 Attack Class Submarines …

Part 2: History

Question 8: What did Australian submarines do in World War I?

James Goldrick

The Commonwealth of Australia and the practical submarine were born almost simultaneously. The first American submarine was completed three months before Federation in January 1901, and the first British unit started construction a month later. From the outset, submarines seemed to have great potential for Australia, which was concerned about maritime self-defence when there was increasing doubt about Britain's ability to protect the empire. Alfred Deakin was particularly interested, his enthusiasm confirmed by a spectacular demonstration staged in Portsmouth for the 1907 Colonial Premiers Conference.

Deakin's conservative naval advisers were more cautious. Submarines were still experimental, had unreliable petrol engines for surface running, weren't very seaworthy, had limited endurance and required substantial technical support. A periscope was only an afterthought to the first British boat (the original American design had none). The first retractable periscopes weren't developed until 1908. Radios weren't carried by submarines before 1911 and initially had an effective range of only 30 nautical miles.

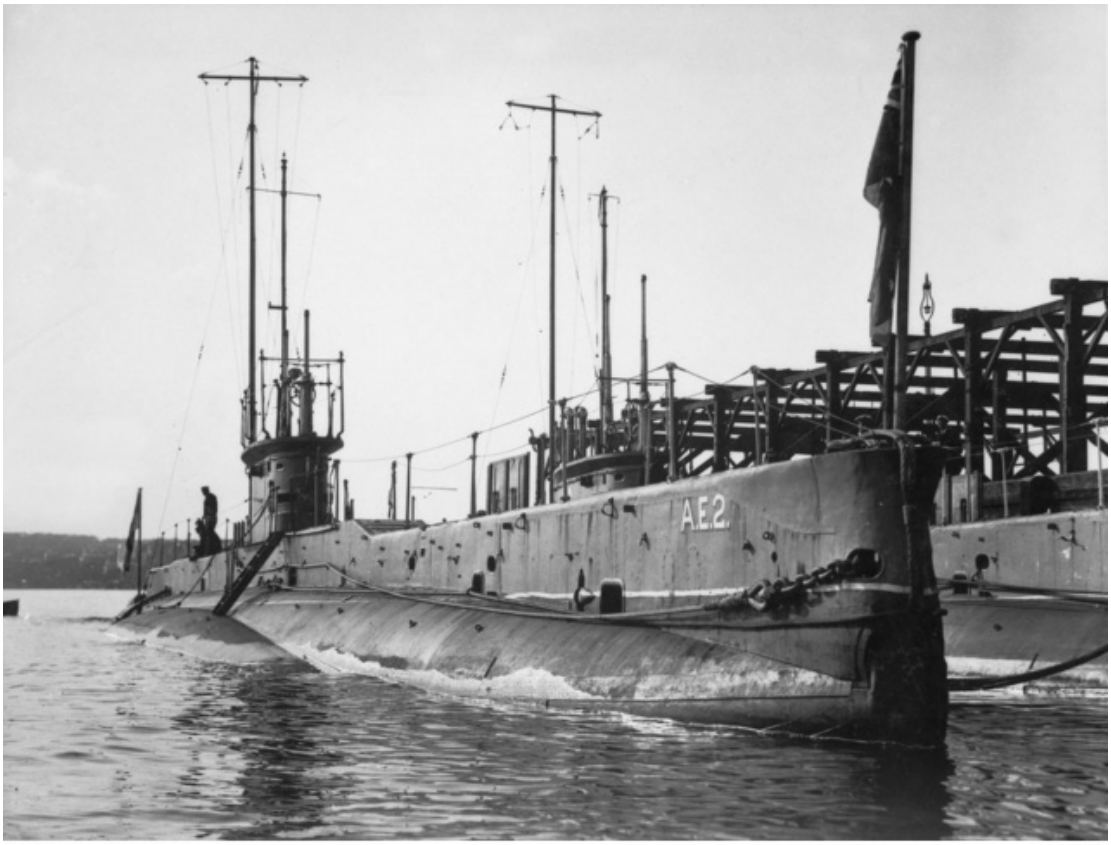
Submarines were evolving so quickly that the Australian Government's lack of funds in its first decade probably prevented too early a commitment. Deakin's plan for purchasing nine C-class submarines over three years was overtaken by the 'Dreadnought scare' of 1908–09, which saw Australia promise to pay for a capital ship for the Royal Navy. That promise mutated into the brilliant 'Fleet Unit' concept presented to the 1909 Imperial Conference by Admiral Sir John 'Jacky' Fisher, under which Australia acquired a balanced force centred around a battle cruiser and including light cruisers, destroyers and submarines. It was perhaps the most timely and effective defence investment ever made by Australia. When the government was ready to order submarines, the latest type was the much-enlarged E class. Their greater cost meant that initially only two were acquired. *AE1* and *AE2* were commissioned in February 1914 and arrived in Sydney in May 1914. Conscious of their strategic importance, the Admiralty had given the boats priority over Royal Navy units in fitting the latest wireless installations.

The outbreak of war in August 1914 saw both boats deploy with the force sent to occupy German New Guinea. On 14 September, while on patrol off Rabaul, *AE1* disappeared without trace with 35 men on board. The wreck wasn't found until 2017, and the cause of sinking was identified as a partly open valve that flooded the engine room.

With the German naval threat in the Western Pacific dealt with, *AE2* (Figure 4) would be much more useful in the European theatre, and the submarine deployed there as an escort to the second Australian Imperial Force convoy. The planned attack on the Dardanelles meant that *AE2* was retained in the Mediterranean. As the ANZAC and other Allied forces went ashore on 25 April, *AE2* became the first submarine to penetrate the Dardanelles and enter the Sea of Marmora, and the report of her success provided a vital morale boost for the embattled soldiers. *AE2* torpedoed and damaged a Turkish gunboat before falling victim to the torpedo boat *Sultanishar* on 30 April. Holed by gunfire and unable to dive, the submarine was scuttled and the crew were taken prisoner. *AE2*'s wreck in the Sea of Marmora was located in 1998.

Australia's desire to buy replacement submarines couldn't be met because of Britain's other priorities. Nevertheless, money was appropriated, and 10 technical personnel were sent to the UK by Cockatoo Island Dockyard to study submarine construction. By 1918, the RAN planned for at least two new boats, but any acquisition would have to wait until the war had ended.

Figure 4: Australia's first two submarines—AE2 in the foreground and AE1 behind it



AUSTRALIAN WAR MEMORIAL H11559

Question 9: How were submarines meant to defend Australia in World War II?

James Goldrick

After World War I, the British were concerned about the threat from Japan in the Far East. Stationing a powerful fleet permanently in the region was impractical, but submarines provided a solution to the need to buy time. Even before the maturing of plans for the Singapore naval base and for dispatching a 'main fleet' from European waters in a time of crisis, the deployment of the Royal Navy's most capable submarines had started. By 1920, 12 British boats (more than were in the Home and Mediterranean fleets combined) were based at Hong Kong.

Australia was involved from the outset. A British gift of six long-range J-class submarines—the biggest diesel–electric units in service—was intended as the core of the postwar RAN's offensive capabilities. Although the J class didn't last long (due to technical problems and inadequate funding), Australia recommitted at the 1923 Imperial Defence Conference. As well as cruisers for trade protection, the RAN would acquire six submarines. In conflict, the 21 boats that the British planned to maintain in theatre would defend Hong Kong and Singapore and menace shipping in Japanese waters. Australian units, forward-based at Darwin, would block the passages through the archipelago to prevent Japanese forces threatening sea communications in the Indian Ocean.

Boats to do the job would need to have greater endurance than any before. The British immediately started designing the first 'overseas submarines'. Australia ordered two to follow the lead unit, *Oberon*. *Oxley* and *Otway* were commissioned in 1928. It would have been wiser to wait until the British had perfected their designs. Still prototypes, the boats were troubled from the start, having their diesel engines rebuilt in Malta before they could continue to Australia. An increasingly grim financial situation meant that additional units were never ordered. By 1931, money was so short that the RAN had the choice of maintaining cruisers or submarines. The two boats were given to the Royal Navy, and the Australian submarine force was abandoned.

Despite financial restrictions, the British largely fulfilled their plan. Fifteen submarines were on station by the late 1930s. They developed wolf-pack tactics for the South China Sea, with Royal Air Force flying boats guiding them to their targets. Secret surveys were made around the Spratly Islands to find safe operating water—and to ensure that the British knew as much as the Japanese, who did their own secret charting. After the start of the war with Germany in 1939, the submarines remained in the Far East to guard against Japanese opportunism. Only in 1940 were they withdrawn for service in the Mediterranean. In December 1941, there was a single British boat in the region, refitting in a Singapore dockyard.

The Dutch had developed a parallel concept to defend the Netherlands East Indies and, despite heavy losses, had some successes in 1941 and 1942. The Americans, who had reinforced their submarine force in the Philippines shortly before the outbreak, achieved little, crippled by faulty torpedoes, poor tactics and lack of familiarity with the environment. However, the US Navy learned from its failures.

Australia's role in the Indo-Pacific War was as a base for the submarine offensive. Working from Brisbane and Fremantle, American units waged an increasingly effective campaign that devastated the Japanese Navy and merchant marine. Later, British and Dutch boats also operated from Western Australia. Many Australian personnel served in Royal Navy submarines, some achieving great distinction, particularly in midget boats, but the only unit to serve in the RAN was the old ex-Dutch *K9*, which had a brief and largely unsuccessful career as a training vessel.

Question 10: What role did submarines play in the Cold War?

Peter Clarke

The Cold War (1950–1991) was a significant time for submarine warfare, which shifted from a primarily anti-ship and special operations focus to one that underpinned the strategic philosophy of the time. Of its very nature, the Cold War was one fought by deterrence, and both antagonists invested enormous resources into maintaining their respective deterrents. The strategy of 'mutually assured destruction' was adopted by the Soviet Union and by the NATO allies. Both sides maintained such large nuclear arsenals that neither could make a first strike without precipitating a devastating strike in return. The theory was that this would keep the peace and, to a large extent, it did.

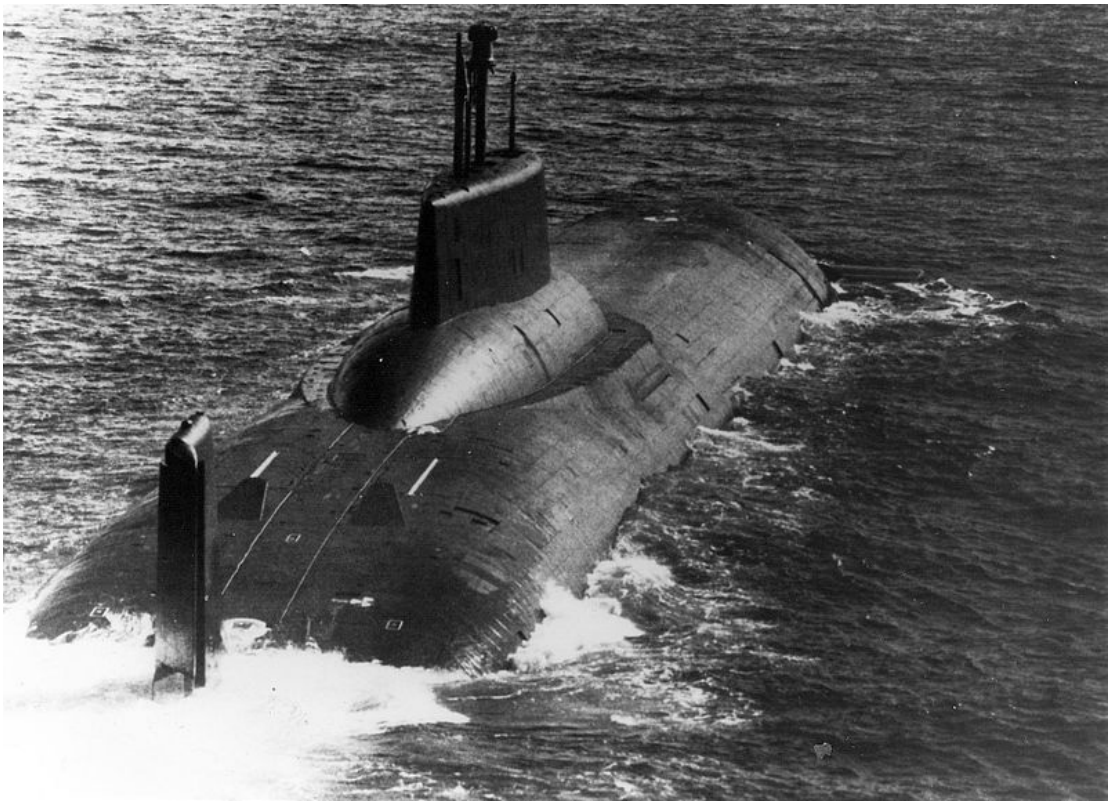
In the early 1950s, the delivery platform for the strategic nuclear arsenal was long-range aircraft (bombers). They were kept at short readiness so they could get airborne as soon as an incoming strike was detected, but they remained vulnerable because their bases were known and it took time to get the aircraft into position to launch their weapons. In the 1960s, the preferred delivery platform shifted from aircraft to submarines, which had the ability to remain undetected and closer to potential targets to reduce the warning of an attack. This policy was adopted by both sides and led to a proliferation of Soviet, US, UK and French SSBNs.

SSBNs would patrol in wide areas of ocean, in the marginal ice zone, close to home and close to the other side's coasts. When they were deployed and settled into a patrol posture, they were almost impossible to detect. Thereby, the mutually assured destruction strategy was maintained, but, as neither side trusted the other, it became increasingly necessary to protect the patrolling SSBNs to ensure that they couldn't be detected and neutralised. Both sides invested enormous funds in developing classes of fast-attack nuclear submarines to hunt the other's SSBNs while protecting their own.

Although SSBNs could operate autonomously, the instruction to launch came from a headquarters ashore. This meant that the SSBN on patrol had to maintain reception of a broadcast or satellite transmission, never needing to transmit but always ready to receive. Once orders were received and authenticated, the SSBN could launch its missiles, which could contain pre-programmed targeting information, within a few minutes.

Vast underwater low-frequency sonar arrays were placed in maritime choke-points to intercept deploying Soviet submarines and, although this was often successful in alerting NATO forces to a deployment, it did nothing to detect the long-range missile submarines that were able to operate in the Barents Sea and Arctic Ocean. Hiding under the ice or in the marginal ice zone, those submarines were undetectable by anything other than another submarine. For example, a Soviet Typhoon-class boat (Figure 5) would operate at slow speed, acoustically camouflaged by the noisy waters close to the Arctic ice edge, while a protecting SSN would operate in the vicinity, often a few thousand metres astern, to detect any unwelcome interest from a NATO SSN in what was known as a 'delousing' operation. This led to the well-publicised cat-and-mouse games that have spawned fictional epics such as Tom Clancy's 1984 novel, *The hunt for Red October*. And were there ever collisions? It would be hard to believe that there weren't.

Figure 5: A Soviet Typhoon-class submarine, the largest submarine ever built, armed with 20 ballistic missiles.



Source: Wikimedia Commons.

Question 11: Why did Australia acquire the Oberon-class submarines?

James Goldrick

In 1949, the Royal Navy established the Fourth Submarine Flotilla in Sydney to provide ASW training to the Australian and New Zealand navies. British submarines would be stationed in Australia until the late 1960s, and the costs would be shared between the governments concerned. The arrangement had three important results for Australia. First, the submarines provided continual evidence of their offensive capabilities against surface forces. Second, many RAN personnel were given first-hand experience of submarine service. Third, the maintenance requirements of the three units in the squadron created increasing local technical expertise. After 1960, Cockatoo Island Dockyard successfully conducted extended refits of the British boats.

By the late 1950s, the British were warning that they couldn't sustain the arrangement indefinitely. At the same time, increasing strategic uncertainty and the planned demise of the RAN's fixed-wing aviation arm brought a new focus on the need to develop offensive capabilities. In addition to providing ASW training, submarines would be an independent force with strategic weight.

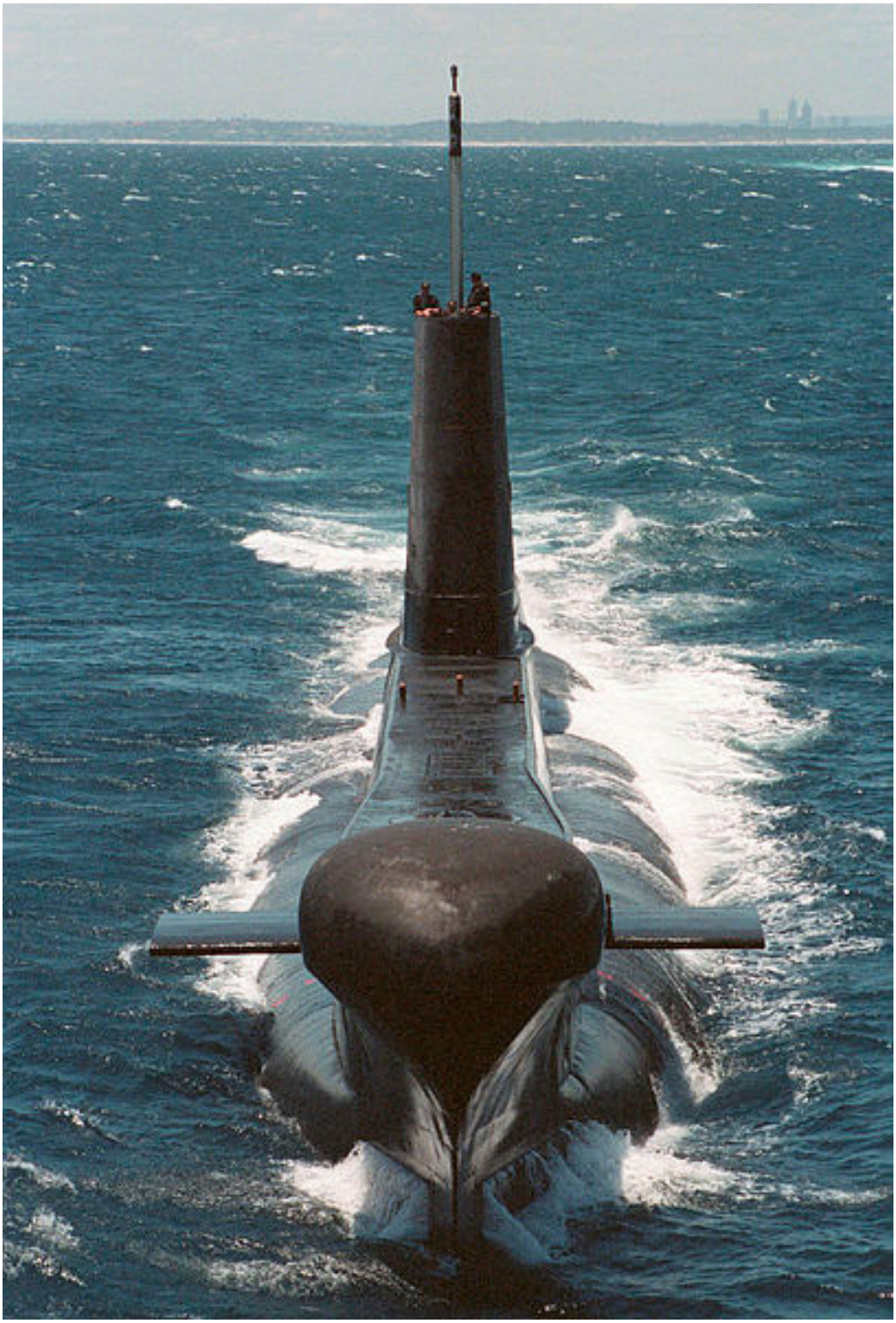
At that stage, the emerging potential of nuclear-powered submarines had great attraction. Although the RAN's initial plan was for two batches of four diesel–electric submarines, the hope was that they would be followed by nuclear boats. Local construction, because of the 70% price premium it was assessed to involve, was rejected, as was an American design. In 1963, the cabinet approved the ordering of four Oberon-class submarines from the UK. The British build had the advantage that the Royal Navy provided extensive training support, although it, too, benefited at a time when it was retraining its own submariners for new-build nuclear units. Australian and Canadian submariners were vital for several years in keeping the existing Royal Navy diesel–electric force operational and committed to NATO.

The first boat, *Oxley*, was commissioned in 1967, and all four were in service by the end of 1969. Only two of the planned four of the second batch were ordered in 1971. The revival of the Fleet Air Arm meant that the funds were diverted to provide additional A4 Skyhawk strike fighters for HMAS *Melbourne*. At the same time, the increasing cost and complexity of nuclear-propelled boats pushed the long-term ambition to acquire them into a distant future, although planning for a replacement to the Oberons began in the 1970s. Delayed by cabling problems during their UK build, *Orion* and *Otama* weren't commissioned until 1978.

The Oberon class proved extremely successful in service. In addition to their other roles, the Australian submarines acted as covert surveillance units, making important contributions to intelligence gathering at a key period in the Cold War. Initially hindered by old-type torpedoes and unsophisticated sonar, between 1977 and 1985 all six units underwent the Submarine Weapons Update Program. This allowed them to fire Mark 48 homing torpedoes and the Sub-Harpoon anti-ship missile, as well as vastly improving their detection capabilities. The program provided not only an enormous boost to the Oberons' capability but an indication that Australia could evolve its own solutions to submarine design.

Intended to be replaced by the Collins class, the first of the Oberons to leave service was decommissioned in 1992. The last, *Onslow* and *Otama* (Figure 6), which were run on for longer than originally planned because of problems in introducing the new boats, went in 1999 and 2000.

Figure 6: Oberon-class submarine HMAS *Otama* off Rottnest Island during Exercise Lungfish 99



Source: Defence image library, online.

Question 12: What did the O-boats do?

Brendan Nicholson

Because their operations are secret, we know little of what Australian submarines do except that they gather intelligence through the region, often far from home. In peacetime, they loiter unseen and listen in distant places while honing the skills they'd need in wartime.

We've some idea of their possible roles from what they've done in the past.

Journalist Geoffrey Barker uncovered extraordinary details of how Australia's Oberon-class submarines, or 'O-boats', won their spurs during the Cold War by spying on Russia and China. On 16 operations between 1978 and 1992, HMAS *Orion* and HMAS *Otama* lurked dangerously close to potentially hostile ships to record communications and propeller signatures.

Orion carried out the first mission off Libya in 1978 as it sailed from Britain to Australia on its delivery voyage. The US and Britain asked that the submarine be sent to monitor signals from Colonel Muammar Gaddafi's ships based in Tripoli, Benghazi, Darnah and Tobruk.

Only prime ministers Malcolm Fraser, Bob Hawke and Paul Keating, their defence ministers, the Chief of the ADF and some Defence personnel knew about such operations.

As few as five key crew members knew where they were and what they were doing, and the chart table was often curtained off.

In February 1986, Hawke was briefed on a patrol that took *Orion* into Vietnam's Cam Ranh Bay, then the largest Soviet naval base outside the Soviet Union. He was shown brilliantly clear footage of *Orion* behind and beneath a surfaced Soviet nuclear submarine heading into the port.

The video, shot through *Orion*'s periscope, showed the Soviet submarine motoring towards the harbour. The Australians closed in until they were just below and behind the Russian boat, its turning propeller clearly visible. They filmed sonar and other fittings along its hull and then moved ahead of the Russian boat to film the other side as it passed.

The Australians recorded radio transmissions to gather information that could be used to jam Soviet naval communications in any future conflict and studied the adversary's command and control systems.

On another occasion, HMAS *Orion* waited outside Cam Ranh Bay to record the arrival of a nuclear-powered Kirov-class cruiser.

The briefing is said to have convinced Hawke to build submarines in Australia.

On a later patrol, *Orion* was nearly exposed in Shanghai Harbour, where it was sent, at the request of the US, into the shallow, murky and crowded waters to gather intelligence on the PLA Navy. It appears that the nuclear-powered US submarines were too big to be sent into those waters. Civilian language specialists were on board to translate Chinese transmissions.

But *Orion* became caught in fishing lines and nets, dragging one fishing boat down by its bow. The fisherman cut away the net with an axe.

Fearing his crew's capture, and possible execution as spies, the submarine's commander abandoned the operation.

After that, the patrols were stopped for several years until the Howard government approved six more missions, mainly monitoring communications around Indonesia and East Timor, where Fretilin guerrillas were fighting for independence.

Figure 7: An Australian Oberon-class submarine on patrol

AUSTRALIAN WAR MEMORIAL NAVYM2442/09

Question 13: Why did Australia acquire the Collins-class submarines?

Andrew Davies

Some common themes emerge from Australia's on-again, off-again relationship with submarines between its 1910 order for two E-class submarines from Britain and the acquisition of the Oberon class in the 1960s. First, it was frequently the case that enthusiasm for submarines was more marked in the political class than in the RAN. Second, there was always discussion about the relative merits of a local build in Australia and acquisition from a foreign supplier. Third, the local maintenance and upgrading of submarines was problematic due to a shortage of the right skills and the vicissitudes of a long-distance supply chain. All of those factors were in play before and after the decision process that led to the acquisition of the Collins class.

A local build of submarines had been contemplated but rejected on the basis of cost during the purchase of the Oberon class in the 1960s, although the local industrial base was steadily improving. An Australian-designed upgrade program for the Oberon class in the 1970s fitted the boats with a digital combat system that allowed them to use sophisticated American-sourced torpedoes and guided missiles, resulting in a world-class submarine.

When it came time to plan their replacement, that success spurred the Hawke government to take the step of designing a submarine to meet Australia's demanding operational requirements (all previous boats had been built to British requirements) and—in a major vote of confidence in local shipbuilding—to construct them locally. Then Minister for Defence Kim Beazley was a strong advocate for the submarine project and for the local construction model, despite occasional active resistance from the Defence bureaucracy.

As we saw in Question 3, Australia's operating environment is challenging in a number of ways, but the geography of the Asia–Pacific region is a primary driver. The long transits into North Asian waters required to meet alliance commitments dictated a submarine large enough to accommodate sufficient fuel and to house a large enough crew to make deployments of more than 60 days workable. As well, Australia wanted to consolidate the fine upgrade work on the Oberons by fitting the new submarines with a combat system compatible with American weapons. In the 1980s, as now, no existing design met all of those criteria.

The tender process for the new class that began in 1983 attracted bids from seven companies from six European nations (including, not for the last time, a French bid of a conventionally powered version of a nuclear submarine). Given that the company's previous designs were significantly smaller than was required to meet the tender requirements and that Sweden wasn't a NATO partner of the US, it was to the surprise of many that the Swedish firm Kockums was chosen as the preferred industrial partner. But the tender evaluation had found that, as well as being able to meet the submarine performance requirements, Kockums had the most modern approach to design (being the only tenderer using computer-assisted design) and production management. Given that the aim was to produce a world-class submarine starting from a 'greenfield' site, those were deciding factors.

Further reading:

Peter Yule, Derek Woolner, *The Collins class submarine story: steel, spies and spin*, Cambridge University Press, 2008.

Question 14: Are the Collins-class boats an effective capability?

Andrew Davies

Despite a generally poor public perception of the Collins class, the short answer to this question is, 'Yes, they're a world-class platform', although it would be fair to add 'but it took a long time to get to this point'. The negative reputation is largely due to a combination of crude politics during the build and delivery phases, exacerbated by poor fleet management over the following decade.

Kim Beazley's enthusiasm for the Collins project, once a strong asset, became a liability when the perceived underperformance of the submarines was used by the Coalition (abetted by the press) to attack him when he became the federal Labor leader in the second half of the 1990s. In fact, with the exception of the combat system—something of a saga in its own right, which took several iterations to get right—the Collins class suffered from no more than the initial problems expected with any new type. Many of the problems went unresolved for too long because of inadequate contingency provisions in the program budget, causing problems between the builder and the Navy as the end user. Because of the politicisation that by then dogged the program, those problems tended to be widely reported, often with significant exaggeration.

That inauspicious start was compounded by chronic under-resourcing of the support arrangements after delivery, which led to low levels of reliability and availability—attracting more negative headlines. The program suffered from too much focus on the build phase and an inadequate appreciation of the requirements of being a 'parent navy' after delivery, as opposed to previously being a customer for parts and services from an offshore supplier. Remediation came only after a series of high-level reviews into fleet management and the provision of adequate support funding.

Today, after a significant but little-publicised effort, the Collins-class fleet is on a robust support footing and provides the RAN with availability at or above the world best practice benchmark, with four boats usually available for operational tasking or training requirements. Their combat system and sensor suite allows them to target adversaries from long range with advanced torpedoes and guided missiles, and they have the endurance and stealth to be operationally effective far from home.

But, in answering a question about military capability, it's important to look beyond the equipment itself. The Defence Department identifies nine 'fundamental inputs' into capability, which must come together in a coordinated fashion to provide effective military capability: command and management; organisation; major systems; personnel; supplies; support; facilities; training; and industrial support.

The gradual transformation of the Collins-class fleet from promising machines into a serious war-fighting capability required the development of effective approaches to all of those factors—and all of them required work at various times. For example, in order to perform maintenance and refitting activities efficiently, the support contractor, ASC, developed a purpose-built 'support tower' that allows access to the boats at multiple levels simultaneously. And the personnel management and training of submarine crews was the subject of a major review in 2009. Before that, the number of suitably trained and qualified submariners was well below that required to effectively man the fleet. Today the situation is much improved and, due to the better availability of the boats, the government can be confident of always having one or more very capable submarines at its disposal.

Part 3: The future submarine

Question 15: How was the Attack-class design chosen?

Marcus Hellyer

The 2009 DWP announced the Australian Government's intention to acquire 12 large, advanced conventional submarines. The program was to have the first submarine ready for operations by 2025, which was around the time the first Collins boat was scheduled to retire.

Over the next several years, Defence conducted studies that led it to advise the government that off-the-shelf designs wouldn't meet the capability requirements. The government decided that only evolved designs (such as an enhanced Collins) or new designs should be further considered.

In 2013, a Coalition government was elected. As the program hadn't yet commenced a competition to select a design, the new prime minister, Tony Abbott, was concerned that there would be a capability gap and began discussions with Prime Minister Shinzo Abe of Japan on the possibility of acquiring a version of Japan's Soryu-class submarine—the only existing conventional submarine with capabilities comparable to those sought by Australia. However, it also appears that elements of the government were concerned that this would lead to the future submarine being built in Japan.

Subsequently, on 19 February 2015, the government announced that Defence would conduct a competitive evaluation process (CEP) under which Defence would 'seek proposals from potential partners for:

a) Pre-concept designs based on meeting Australian capability criteria;

b) Options for design and build overseas, in Australia, and/or a hybrid approach;

c) Rough order of magnitude costs and schedule for each option; and

d) Positions on key commercial issues, for example intellectual property rights and the ability to use and disclose technical data.'[12]

Three entities were invited and funded to participate: Direction de Constructions Navales Services (DCNS) of France; ThyssenKrupp Marine Systems GmbH (TKMS) of Germany; and the Government of Japan. Both DCNS and TKMS proposed new designs, as they didn't have existing conventional designs with the required capabilities. The Japanese Government offered a modified Soryu-class submarine. The Swedish company Saab, which had acquired Kockums, the company that designed the Collins, wasn't invited to participate. Since it wasn't part of the CEP, an evolution of the Collins design pedigree ceased to be an option.

On 26 April 2016, Prime Minister Malcolm Turnbull announced that DCNS, subsequently renamed Naval Group, had been chosen as the preferred partner. The government hasn't published the precise reasons for its selection. While a broad range of factors were considered in the CEP, it appears that the submarine's acoustic performance was a key capability discriminator. Defence has subsequently stated that all three proposals were similar in cost.

While some have suggested that the CEP was intended only to find a design partner, not the builder of the future submarine, Defence has testified at Senate Estimates hearings that the intent of the CEP was always to find a partner that would be both the designer and the builder.

The Australian National Audit Office subsequently assessed that Defence had 'effectively designed and implemented' the CEP.[13]

Further reading:

ASPI's *The Strategist* has published numerous pieces on the selection of the future submarine, including Graeme Dobell's series:

- 'The strange submarine saga: how did we get there?', 10 August 2020, online.
- 'The strange submarine saga: vital yet vexed', 17 August 2020, online.
- 'The strange submarine saga: the industry policy puzzles', 24 August 2020, online.
- 'The strange submarine saga: Son of Collins to son of Collins', 31 August 2020, online.
- 'The strange submarine saga: nuclear-powered poser', 14 September 2020, online.

Figure 8: Naval Group's Attack-class submarine

Source: Naval Group Australia.

Question 16: Why aren't we buying off-the-shelf submarines?

Marcus Hellyer

The ocean is a big place. It's hard to find the adversary's ships in the open ocean and even more difficult to find submarines. Also, a conventional submarine is slower than surface warships, so the submarine might not be able to reach a ship to attack it even if it knows where the ship is. Therefore, the best place for conventional submarines to operate is off the adversary's ports and bases or in strategic choke-points that the adversary will have to transit. In the Australian context, those bases and choke-points are far from our submarine base.

Therefore, Australia requires submarines with not only long range but also endurance; there's no point being able to reach the area of operations if the submarine can't spend time there. Australian submarines also operate in busy waterways and have enhanced sensor suites to collect intelligence. Large submarines can also support larger sensor arrays, enabling them to detect targets before they are themselves detected. All of those factors drive larger size.

There are no off-the-shelf submarines that meet those requirements. The only one that comes close would be the Japanese Soryu design, and even it would likely fall short in key areas. European boats are smaller, as they don't have the same requirement for long transits and extended periods on station. They tend to be in the 1,200–1,800-tonne range, compared to around 3,300 tonnes for the Collins and 4,500+ tonnes for the Attack class.

While some assume that 'off the shelf' implies 'not built in Australia', that isn't necessarily the case. French and German submarine designs have been built in several other countries, such as South Korea, India and Indonesia.

Following the 2009 DWP, Defence examined the feasibility of acquiring off-the-shelf boats. The government accepted Defence's advice that off-the-shelf boats wouldn't meet Australia's requirements for range and endurance, regardless of how many boats were acquired.

Off-the-shelf boats would, however, be substantially cheaper than the Attack-class submarine. By using an existing boat, the design costs would be significantly lower. Also, construction cost is largely driven by size, so a boat that was less than half the size of the Attack class would cost much less.

If Australia were to acquire off-the-shelf boats, that would force the Navy to adopt a fundamentally different operating concept. It would be likely to limit our submarines to operating close to Australia, fundamentally limiting their utility. An off-the-shelf submarine could potentially be based in a friendly country in Southeast Asia, such as Singapore (which operates a modified off-the-shelf European design). The risk with this approach is that, should access to the forward base be denied, either by the host country or by enemy action, the utility of Australia's submarine capability would be severely compromised.

There may have been a 'happy medium' between off-the-shelf designs and the Attack class—one that might not have had the same capability as the latter but provided a better balance of performance and cost. Perhaps an updated version of the Collins might have been that Goldilocks design. The government didn't pursue that option.

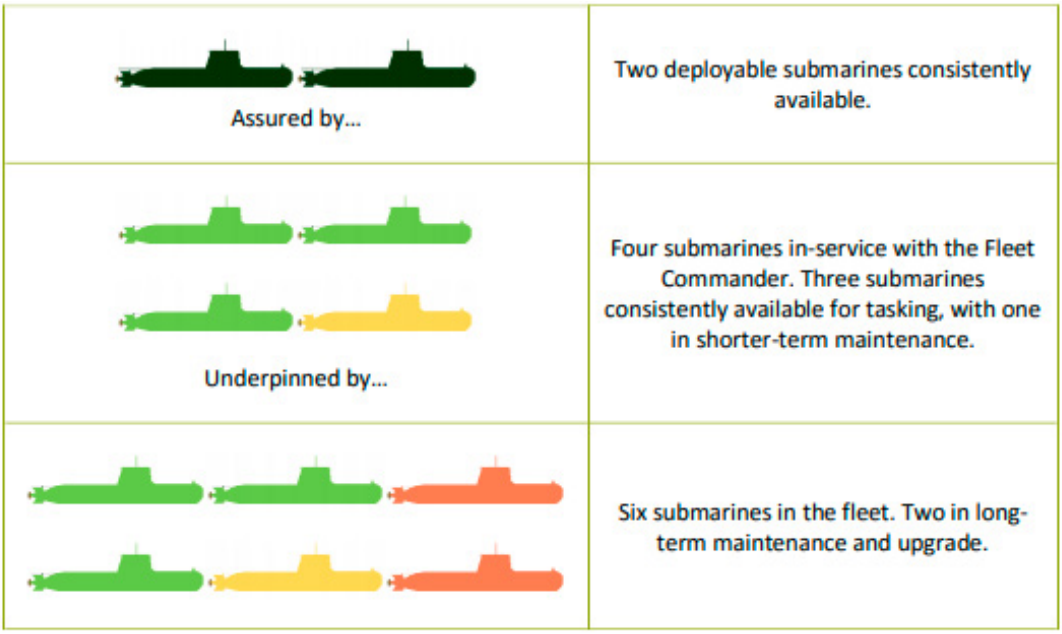
Question 17: Why 12 submarines?

Marcus Hellyer

There's a common rule of thumb in militaries known as 'the rule of threes': for every three platforms you have, you can deploy one. This is how the Australian Army is structured, and it broadly applies to ships and aircraft as well. Militaries can surge beyond this for short periods, but that's not sustainable in the longer term due to deferred maintenance, lack of training, burnout of personnel and so on.

The rule of threes is reflected in the Navy's current requirement for submarine availability (Figure 9). Of the six Collins-class submarines, two are in deep maintenance and upgrade. Four are available for service, with three available for tasking and one in shorter term maintenance. Of those four, only two are deployable.

Figure 9: The Navy's submarine requirement: two from six



Source: John Coles, *Study into the business of sustaining Australia's strategic Collins class submarine capability: beyond benchmark—May 2016*, Australian Government, Canberra, 2016, online.

That doesn't mean two will always be in the area of operations. Since the likely areas for submarine operations are far from Australia, a large percentage of any deployment is spent in transit. The exact percentage depends on the distance, the kind of operation and so on, but the net result is that it's unlikely that the Navy can sustain one submarine on station in an area such as the Malacca Strait or the South China Sea for an extended period. If, in a future conflict, the operational concept isn't to maintain a submarine on station but to conduct offensive operations at a time of our own choosing, it might be possible to surge to two submarines in the area of operations, but that couldn't be sustained.

The requirement for 12 submarines first appeared in the 2009 DWP. It wasn't driven by the Department of Defence but appears to have come from then Prime Minister Kevin Rudd. Since then, it has remained a constant in Defence's strategic planning documents.

With 12 submarines, it's reasonable to assume that four would consistently be available for operations, with greater capacity to surge. That would be likely to allow the Navy to keep one submarine on station at a long distance from Australia while simultaneously supporting some presence closer to home.

There are factors that influence presence and time on station other than just numbers of submarines. Increasing the endurance of the submarine could potentially have a large impact. The Collins is reputed to have around 50 days' endurance. If, for example, a 10-day transit is required to reach the area of operations, a Collins boat effectively has only 30 days on station. If the future submarine has 70 days' endurance (a 40% increase), that would result in 50 days on station in the same scenario (a 67% increase). Put another way, two Attack-class submarines would provide greater presence than three Collins. Also, if the pump-jet propulsor that's to be used in the Attack class can increase its transit speed without consuming more fuel, that could reduce transit times and further increase time on station.

Since nuclear-propelled submarines have much greater transit speed than conventional submarines and endurance constrained only by the crew's resilience, a smaller number of SSNs would provide greater presence than 12 conventional submarines.

Another factor is the Attack-class submarine's pump-jet propulsion system (Figure 10). While Defence has been tight-lipped about the pump-jet's performance, it could potentially result in greater time on station by reducing transit times.

Reductions in the amount of time spent in maintenance would also improve availability. However, the Collins submarines are now already meeting and exceeding international benchmarks, so it could be difficult to achieve significant improvements beyond the current availability requirement and thus escape the rule of threes.

Figure 10: The Attack-class submarine's pump-jet

Source: Naval Group Australia.

Question 18: Why does it take so long to design and build a submarine?

John Davis

Designing and building modern, capable military submarines is one of the most complex and challenging undertakings we humans take on.

In doing so, we push the limits of engineering and human ingenuity—designing and building an underwater city capable of sustaining and protecting human life, deploying high-level technology and managing lethal capabilities. Submarines also need to be able to withstand the harshest physical realities and pressures of the deep sea, work flawlessly with other military assets and, perhaps most importantly of all, be almost undetectable.

It's a big, important, complex job, and the lives of so many depend on it, including the lives of our service men and women.

So it's no wonder, given the enormousness of the undertaking and all the excitement about the benefits of the Attack-class submarines, that one of the questions I get asked most often by Australians young and old is, 'Why does it take so long?'

To create a regionally superior submarine capable of defending our country for generations requires every aspect of the submarine to be designed and built to the most demanding standards. Every step in the process is meticulously planned, executed and verified to deliver the end product. And a wonderful and critically valuable product it will be!

In the design phase (the phase our Attack-class submarines are currently in), we work very closely with the customer (the Australian Government and representatives of the RAN) to ensure that each element of the submarine design will meet capability requirements.

That requires some of the world's best engineers and scientists to find solutions to the most complex engineering challenges. Those solutions must fit within a finite size (there's a lot to pack into an almost 100-metre-long submarine), weight, power and cost envelope.

Experience has taught us that it's critical to take the time to resolve these complex challenges in the design phase to avoid potential problems during the build that might affect the build schedule and cost, and to ensure that the boats can be effectively sustained through their lives.

In the case of the Attack class, while the submarine design is taking place, the submarine construction yard itself is also being designed and built: as the submarine design matures, the shipyard design must also evolve. We're working closely with Australian Naval Infrastructure Pty Ltd to deliver the submarine construction yard that will enable us to build the Attack class and future submarine classes. The new construction yard will boast modern, purpose-built facilities and equipment, including the main production halls, the blast and paint workshop, warehousing and other critical facilities, all specifically designed to enable the most efficient build of Australia's future submarine fleets.

In the build phase, we'll integrate an estimated 1 million parts in each submarine, and each part will have met its own construction requirements and gone through the most rigorous testing and analysis. Individual parts will be painstakingly put together into 'rafts', and the submarine will be consolidated.

Once a boat is built and initial system integration and testing are complete, a significant process with the RAN will test all aspects of the functionality of the submarine. Critical testing will also take place at the Platform Land-Based Test Facility, which for the first time in Australia will test the entire propulsion system. This will be the world's most advanced land-based facility for a conventional submarine.

We're already working with Australian suppliers and manufacturers to prepare them and their vital products in preparation for the build. Equipment procurement contracts will be signed and products manufactured to the highest standard. We've held 11 industry briefings, more than 1,800 companies are registered on our industry network, and we've had focused engagement with suppliers across Australia and collaborative ventures with other defence shipbuilding primes.

We'll also be ramping up our workforce. Over the next 50 years, thousands of Australians will be involved in this complex, detailed program, and the benefits to local industry, manufacturing capability and sovereignty will be clear. The 12 Attack-class submarines are being designed and built to a deliberate schedule that will ensure they meet Australia's critical submarine capability requirements into the future.

The Attack-class submarine schedule: key milestones for the Future Submarine Program

- Systems functional review—contracted milestone—contracted to be conducted in January 2021.
- Preliminary design review—proposed to be conducted in May 2023.
- Completion of the propulsion system land-based test facility—scheduled for handover to Naval Group in 2022.
- Completion of the combat system physical integration facility—scheduled for handover to Lockheed Martin by 2022.
- Construction of the first future submarine—scheduled to commence in 2023.
- Construction of the second future submarine—scheduled to commence in 2026.
- Sea trials for the first future submarine—scheduled to commence in 2031.
- Acceptance of first future submarine—scheduled for 2032.

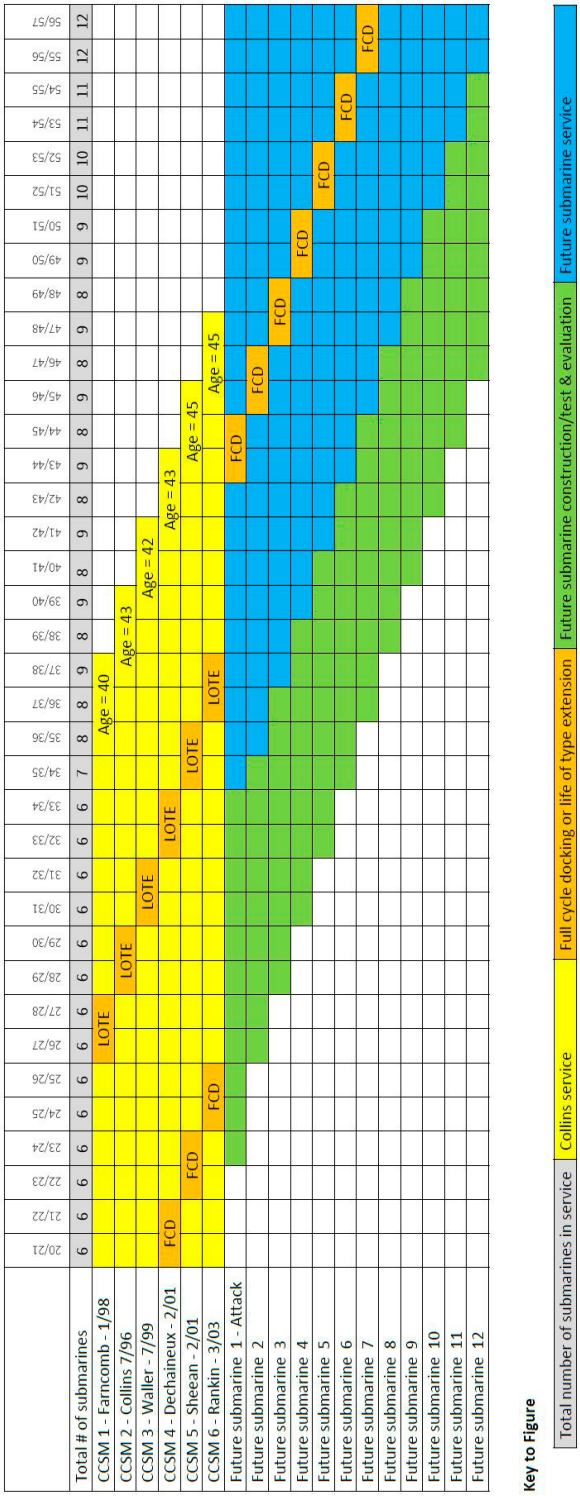
Source: Department of Defence response to Senate Foreign Affairs, Defence and Trade Committee, Supplementary Budget Estimates 2019–20, question reference no. 109, 31 January 2020.

Table 1: Projected time frames for Attack-class submarine contractor sea trials and operational test and evaluation

	Projected contractor sea trials	Projected operational test and evaluation
Submarine 1	2031–2032	2032–2034
Submarine 2	2032–2034	2034–2035
Submarine 3	2035–2036	2036–2037
Submarine 4	2037–2038	2038–2039
Submarine 5	2039–2040	2040–2041
Submarine 6	2041–2042	2042–2043
Submarine 7	2043–2044	2044–2045
Submarine 8	2045–2046	2046–2047
Submarine 9	2047–2048	2048–2049
Submarine 10	2049–2050	2050–2051
Submarine 11	2051–2052	2052–2053
Submarine 12	2053–2054	2054–2055

Source: Department of Defence response to Senate Foreign Affairs, Defence and Trade Committee, Supplementary Budget Estimates 2019–20, question reference no. 109, 31 January 2020.

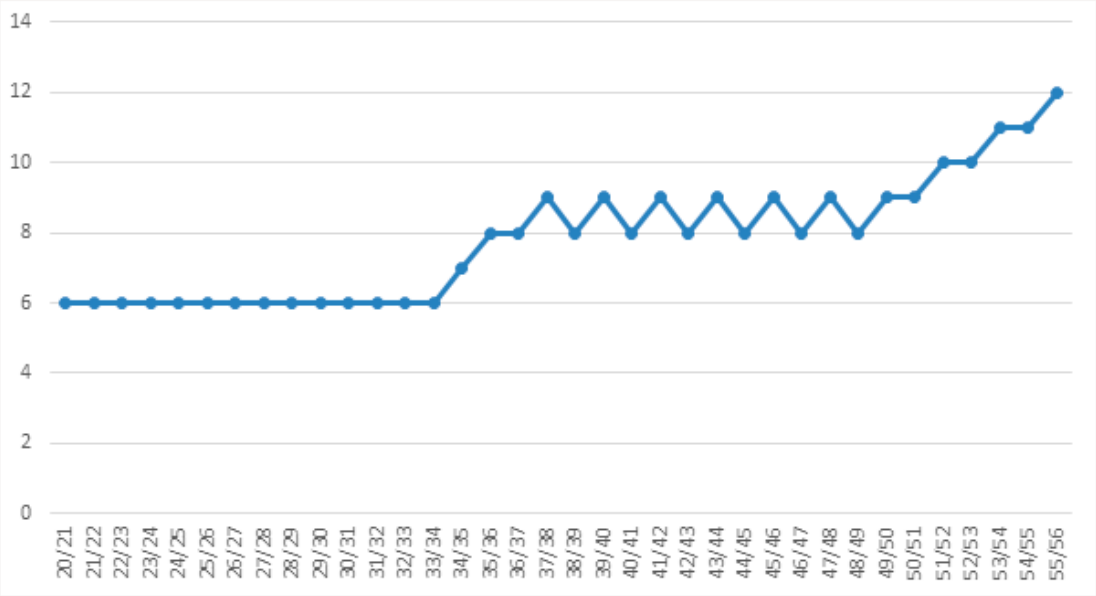
Figure 11: The submarine transition plan



Note: Collins-class numbers assume that all six boats go through a LOTE and serve a further 10 years. Attack-class FCDs assume a similar maintenance cycle to the Collins class.

Source: Compiled by Marcus Hellyer. Attack-class schedule from schedule text box and Table 1.

Figure 12: Total number of submarines during transition



Source: Figure 11.

Question 19: What are the benefits of building locally?

Brent Clark

Creating a sovereign submarine enterprise makes good strategic sense. There have been notable cases in which the Australian military has faced significant challenges in deploying forces due to the unavailability of spare parts, including when Australian submarines couldn't go to sea due to the UK hoarding spare parts for its own submarines during the Falklands War and in East Timor when Australian forces were heavily reliant on the US Government providing parts and equipment. Moreover, Australia initially experienced many difficulties in the sustainment of the Collins-class submarines.

Those events framed the Australian Government's approach to the replacement program; it's very explicit about its requirement to create a sovereign Australian industry for submarine sustainment. This involves the upskilling of industry, the transfer of intellectual property and the transfer of knowledge—that is, the know-how, the know-why and the know-what—necessary to establish greater self-reliance and ensure that Australia is able to maintain and modify the submarine, without the need to continually seek assistance from a foreign government.

Establishing a design authority in Australia for sustainment activities is central to this plan. This requires the transfer of detailed design activities to Australia to ensure that the design authority role can be undertaken in Australia for subsequent sustainment and upgrade.

The establishment of a sovereign industrial base also requires ensuring that Australian companies in the supply chain have access to the intellectual property and understanding of the equipment fitted to the submarine—in other words, the transfer of technology.

In addition to the strategic case, the creation of industry capability also has broader economic benefits. Well-designed defence equipment programs deliver know-how, know-why and know-what. They often upgrade plant and machinery and invest in new technologies. This grows Australia's industrial base, allowing for the pursuit of non-defence work, bringing overflow benefits into adjacent industries such as aerospace, energy and mining, which further enhance the return on investment to the Australian Government through taxation and R&D.

This activity also upskills the workforce, and the requirement for greater numbers of better skilled technical and professional workers provides benefits to universities, TAFEs and schools, enhancing the total education ecosystem.

Numerous studies have detailed the multiplier effect of expenditure in the local economy, ranging from a dollar spent creating an additional dollar up to a dollar spent creating an additional two dollars. Without this expenditure flowing through to Australian industry rather than being funnelled to offshore supply chains, none of this activity takes place.

There's no reason those strategic and economic goals can't be achieved. Australian companies have a proven track record of being able to adopt new practices and technologies to provide the highest levels of service on multiple platforms. BAE Systems Australia has successfully upgraded the Anzac-class frigates to deploy CEA Technologies' phased-array radar and is the design authority for the vessel. Thales Australia exports Australian sonar equipment to the UK and France. Australian companies have been supporting the Collins submarines for 30 years and have achieved 92% local content in their sustainment. While the Attack class is different from the Collins class, the systems on board both submarines are similar.

However, at the time of writing, Defence and Naval Group's plan to achieve these outcomes isn't clear. For example, they haven't published their plan to transfer detailed design activities to Australia. Moreover, Naval Group has stated that it's struggling to bring Australian companies into its supply chain and recruit appropriately qualified individuals for design activities.

Naval Group would have presented an Australian industry capability plan during the CEP that Defence conducted to identify its design and build partner. It can only be assumed that, in selecting Naval Group, the department assessed it as meeting the government's industry policy requirements.

What's required is for the department to enforce the commitments made during the bid phase of the program. In fact, the government's recent 2020 Defence Strategic Update mandates Defence to use 'contractual and non-contractual means to ensure that prime contractors meet the Government's expectation that they maximise Australian industry involvement'. Doing so would deliver both strategic and economic benefits to the Australian taxpayer.

Question 20: How do we maximise Australian industry capability?

Rob Bourke

A logical starting point for maximising the value of Australian industry capability (AIC) from building and sustaining the future submarines is to define the supporting industrial capabilities critical to hold in-country for military–strategic reasons while recognising that a push for higher AIC can potentially increase project costs. Some capabilities are likely to be more important than others for industrial 'sovereignty' to be achieved. Those capabilities form the core of any AIC plan.

Next, maximising AIC might depend in part on the future submarine build incorporating the lessons learned from managing previous Australian shipbuilding projects. To achieve a relatively high level of Australian industry content of more than 70%, the Anzac frigate build re-engineered overseas designs to suit potential domestic component and service providers. Associated workshop drawings and work orders were created in a way that facilitated construction in Australia.

For Australian-based small to medium-sized enterprises, in particular, to be given adequate opportunity to participate in the Future Submarine Program, measures must be in place to ensure that builders and sustainers of the vessels—at all levels of Australian industry—deliver against their contractual AIC obligations.

Building the Collins-class submarines demonstrated that contractually agreed AIC targets aren't always met. For that build, some imported materials and components for the vessels appear to have passed through Australian-based companies with minimal value-adding, but subsequently counted as domestic content. To avoid the pass-through problem, stringent monitoring of AIC commitments by Defence is required, accompanied by appropriate penalties for noncompliance. Those penalties potentially include liquidated damages and the AIC performance of a company being considered when evaluating its bids for further government work.

As indicated by the current minimum target of 60% AIC for the future submarine build, it might not be feasible for all inputs for the vessels to be produced in Australia in the short to medium term due to constraints relating to schedule, quality or cost.

Moving beyond that level of AIC could depend on Australia progressively increasing our own capacity for submarine design, to the degree that it's economical to do so. Indigenous design is the best way to ensure that the technical specifications of the submarines align with the capabilities of Australian-based defence manufacturers. It's also an important avenue for enhancing AIC's effects on the broader economy through 'jobs and growth'.

Because the Future Submarine Program must be paid for somehow—through higher taxes, lower levels of government spending elsewhere or increased government borrowing—and draws resources (such as skilled labour) away from other Australian industries, the economic benefits of AIC can be smaller than expected.

However, overseas experience suggests that a substantial domestic design capability can bolster the economic impact of AIC through two avenues. One is by assisting Australian-based manufacturers, at all levels of the future submarine supply chain, to improve their international competitiveness through export market development. The other is by promoting new technologies and workforce skills that spill over to improve productivity beyond the Future Submarine Program. Productivity improvement holds the key to Australia's long-term economic prosperity.

Question 21: Will we be able to crew the future submarines?

Marcus Hellyer

There's no doubt that it will be difficult, but not necessarily impossible.

Many reviews have highlighted the historical challenges that the Navy has had in crewing submarines. Those challenges go back to the Oberon class and were exacerbated by the relocation of the submarine capability to the west coast.

The total number of submariners required is at least double the number serving on the boats at any one time to enable submariners to have shore postings, training opportunities and broader career development. A larger workforce is also more robust; currently, the departure of even a small number of people can leave critical gaps in key trades.

With the improvement in the availability of Collins submarines, the Navy has been able to train more submariners and is making good progress towards its goal of developing the appropriately sized workforce to operate the Collins fleet by 2025. But the number needed to operate 12 Attack-class boats, which will have larger crews than the Collins, will still be around three times as many as the Navy has now—in the order of 2,000–2,500 people.

Developing and retaining the necessary workforce will be likely to require the following measures:

- **An east coast base.** All studies have concluded that access to the population centres of southeastern Australia would help to address the Navy's longstanding problems with crewing a fleet of six submarines and would be essential to crew a larger fleet. An east coast base would increase the pool of recruits and also reduce the strain of relocation on spouses.
- **Maximum use of simulation.** The Navy uses simulation to train its people on land so that minimal further training is required at sea to achieve certification. It will be an essential part of the future submarine training system for both individual and collective training.
- **Ensuring maximum availability of boats.** Simulation has its limits. It can't fully substitute for at-sea experience, and without actual boats there'll be a cap on the number of submariners the fleet can generate. If the availability of the Collins-class submarines collapses as they age, it will be extremely difficult to rebuild crews for the Attack class. Therefore, all six Collins boats must be put through the life-of-type extension (LOTE) program to ensure that they can operate for as long and as reliably as possible.
- **Collins as a training fleet.** One potential approach further down the line, once some Attack-class boats have entered service, is to use the Collins primarily as a training fleet. This would allow Collins sustainment to focus on availability rather than capability enhancement. Installing systems common to the Attack class in the Collins LOTE would also help.
- **Attractive employment offering.** While submariners are dedicated to their craft, the Navy will still need to provide inducements to retain personnel, including additional pay and retention bonuses. The measures described above should also help to retain personnel by reducing burnout.

Figure 13: Instructor Justin Woodward of ASC oversees trainees operating the diving safety console and manoeuvring control console in the Collins-class submarine simulator at the Submarine Training and System Centre at HMAS Stirling in Western Australia

Source: Defence image library, online.

Question 22: Is the cost of the future submarine escalating?

Marcus Hellyer

The Future Submarine Program was always going to be an extremely expensive undertaking. Many aspects of the program drive its cost up. The Attack class is a new design. The requirement to be 'regionally superior' means that it must have capabilities beyond both existing and future submarines. Also, to have the range, endurance, weapons and sensor load that the Navy requires, the Attack class will likely be the largest conventional submarines ever built. Moreover, continuous shipbuilding doesn't necessarily reduce costs; the extended build process draws out construction in an inefficient way and requires constant alterations to the design to ensure that later batches remain relevant. And, as the parent nation of a unique design, Australia will bear all the costs alone.

To date, Defence has spent around $1.5 billion on the project. The government has approved expenditure of $6,018 million. This only gets to the start of construction and doesn't include the acquisition of any submarines.

Until the release of the 2020 Force Structure Plan, Defence didn't publish its exact cost estimate for the whole program. Before 2015, it provided only very vague numbers that bore little resemblance to the actual cost (such as '>$10 billion'). In October 2015, senior Defence officials advised the Senate that the cost estimate was $50 billion in out-turned dollars; that's an estimate that reflects inflation over the life of the program. The Department of Finance has released information saying that at the time Defence's internal estimate was actually nearly $79 billion.

Nevertheless the 2016 DWP presented a cost of '>$50 billion'. Two years later, Defence officials finally advised the Senate that Defence's cost estimate was $50 billion in constant dollars; that's an estimate that doesn't take inflation into account but is expressed in present-day dollars. At the time, a $50 billion constant estimate was roughly equivalent to an $80 billion out-turned estimate.

Why Defence kept providing a figure to parliament and the public that was around $30 billion less than its actual estimate is a mystery. It resulted in considerable media speculation about cost blowouts, undermining the government's and Defence's credibility. (For Defence's perspective, see its response to this question provided in full below.)

Variations in exchange rates also affect the estimate. Recently, Defence advised that the out-turned estimate had risen to $90 billion due to the fall in the Australian dollar. If the dollar recovers, the estimate would of course decrease.

In short, it appears Defence's estimate has consistently been around $50 billion constant for at least the past five years, which translates into something between $78 billion to $90 billion out-turned depending on inflation and exchange rates.

The annual cash flow required for the program is also important. When production is up and running, the spend will be around $1.5–2 billion per year in current dollars.

Some commentators have claimed that other designs submitted in the CEP would be significantly cheaper. That's unlikely. Any design that sought to be 'regionally superior' would come at a huge cost. Defence has also stated that all three contenders had similar costs.

According to Defence, the sustainment cost of the future submarine over its life will be around $50 billion constant, or $145 billion out-turned. That's nearly $2 billion per year in current dollars. The annual cost of sustaining the Collins fleet is around $600 million. Since there will be twice as many Attack-class boats, each around 40% larger than the Collins and technologically more advanced, $2 billion is likely to be a minimum figure.

Further reading:

Marcus Hellyer, 'Has the cost of Australia's future submarines gone up? Part 1', *The Strategist*, 22 April 2020, online.

Marcus Hellyer, 'Has the cost of Australia's future submarines gone up? Part 2', *The Strategist*, 28 April 2020, online.

Andrew Davies, Marcus Hellyer, 'The very hungry future submarine', *The Strategist*, 5 November 2019, online.

Defence provided the following comments on this question on 22 October 2020

- The revision of the article is based on a misunderstanding of the response from the Department of Finance. The classified funding provision for the Future Submarine Program of $78.9 bn was not made public at in 2016 (not 2015 as could be interpreted from the response) [*sic*].
- Defence has been clear and consistent in its advice on the estimated cost of acquisition since the Government announced the Program in April 2016. The estimated cost of acquisition of the Attack class submarine is unchanged at $50 billion in 2016 dollars.
- Prior to publication of the 2016 Defence White Paper various projections of costs of the Future Submarine Program were based on varying assumptions including different numbers of submarines, and different construction strategies covering on- and off-shore builds. October 2015 pre-dates the submission of proposals from the participants in the CEP (received on 30 November), which included their cost estimates.
- In February 2016, the 2016 Defence White Paper set out the plan to acquire 12 future submarines. The 2016 Integrated Investment Program stated that the approximate investment value was >$50bn out-turned. The full IIP provision was not declared due to commercial sensitivities noting the Competitive Evaluation Process remained underway.
- In April 2016, the Government announced that the 12 submarines would be built in Australia.
- On 29 May 2018, Defence witnesses at Senate Estimates hearings clarified that the estimated acquisition cost was $50 bn on a 2016 constant price basis.
- On 29 November 2019, Defence witnesses at Senate Estimates hearings stated that $50 bn in 2016 constant dollars was around $80 bn in out-turned dollars.
- On 4 March 2020, Defence witnesses at Senate Estimates hearings stated that the estimated acquisition cost of $50 bn in 2016 constant dollars had not changed.
- Defence's estimate has consistently been $50 bn in 2016 constant dollars since Government announced the Program on 26 April 2016 (the past 4.5 years). There has not been a cost blow-out, and Defence has remained consistent in its advice.

ASPI's final word

Aside from the fact that ASPI has not asserted that there has been a cost blowout, Defence's response leaves open the following issues:

- Regardless of what Defence's precise estimate was at the time of the Senate Estimates hearing in October 2015, one can ask whether Defence officials' testimony giving a single-point estimate of $50 billion out-turned gave senators reasonable insight into the range of possible costs for the submarine across the different 'assumptions' for numbers and build strategies.
- Why, if it was concerned about commercial sensitivities, did Defence not provide a cost band for the future submarine project in its public investment plan, as it did for every other project, bar the future frigate (whose public cost estimate has also increased significantly), that again might have given a meaningful range?
- Why did Defence continue to publicly use the figure of $50 billion out-turned for over two more years even while it was advising the government the cost was around $50 billion constant (that is, $78–80 billion out-turned)?
- Why did Defence continue to publicly use the figure of $50 billion out-turned for two more years even after the 'assumptions' around numbers and built strategies had been decided and publicly announced?
- Why did Defence not correct the record, and only admit publicly that its estimate was $50 billion constant ($78–80 billion out-turned) for the first time in May 2018 when explicitly asked by a senator if the cost estimate was still $50 billion out-turned?

Question 23: What do we do until the future submarine is delivered?

Marcus Hellyer

The first future submarine is currently scheduled to be available for operations in 2034. Subsequent boats will arrive on a two-year drumbeat, meaning that the sixth boat will enter service around 2044 and the 12th in the mid-2050s.

According to the current Collins-class schedule, the first Collins is due to retire in 2026 and only one Collins submarine will still be in service by 2034. Defence's strategy to address the capability gap is centred on a LOTE program for the Collins. The LOTE will extend the life of each Collins boat that goes through it by 10 years. Putting four Collins through the LOTE would keep the combined submarine fleet at six submarines until the seventh Attack-class boat arrives in 2046, but extending five or six would mitigate any delays to the Attack-class program and even grow the combined submarine fleet to seven or eight boats. If all six Collins undergo LOTEs, the last Collins will be in service until around 2048, so any transition plan must ensure that we can sustain the Collins submarines for another 25+ years (see Figure 11).

Due to the importance of the Collins LOTE as a strategic risk mitigator, it's important to minimise the risks in that program. If it becomes too ambitious, technical risk could increase, creating schedule delays and leading to fewer available boats. Defence has indicated that it's considering a substantial program of enhancements, including replacing the diesel generators, main motor, electrical distribution system and periscopes. It has, however, informed the Senate that it considers the technical risks to be manageable. Those new systems would also provide commonality with the future submarine.

Undersea warfare capability consists of more than just submarines—it's an integrated network of capabilities—so it's important for Defence to also be developing and acquiring complementary systems. Other systems can deliver many of the effects provided by submarines, but they do it differently and, potentially, more economically.

Some measures could involve acquiring more of things that are already in the ADF's inventory, such as P-8A maritime patrol aircraft, which can detect and attack submarines. Other measures could include enhancing existing or planned platforms—for example, by adding ASW systems such as towed sonar arrays to the offshore patrol vessels currently under construction.

Unmanned systems must also be part of the mix. Examples include small unmanned surface vessels that can tow sonar arrays. By using artificial intelligence, large numbers of small vessels can form persistent but responsive ASW barriers. Another is the acquisition of very large unmanned underwater vessels such as Boeing's Orca, which is currently being developed by the US Navy. That vessel has a very long range and can deploy systems such as seabed sensors or smart mines off an adversary's ports. It's also much cheaper than manned submarines.

By distributing capabilities among a range of complementary systems, the requirements for both the Collins LOTE and the future submarine itself can potentially be reduced, limiting the technical risk to those programs.

Further reading:

Marcus Hellyer, 'What exactly is the Collins life of type extension? Part 1—A policy gap', *The Strategist*, 15 November 2018, online.

Marcus Hellyer, 'What exactly is the Collins life of type extension? Part 2—A mindset', *The Strategist*, 20 November 2018, online.

Marcus Hellyer, 'Submarine transition plan takes shape', *The Strategist,* 12 March 2019, online.

Marcus Hellyer, 'The compounding risk in Australia's transition to new submarines', *The Strategist*, 6 February 2020, online.

Figure 14: The US Navy is acquiring Boeing's XLUUV, based on the Echo Voyager pictured here

Source: Boeing, online.

Question 24: How do we design the future submarine for the future?

Michael Shoebridge

What we know about the future submarine that Naval Group is designing and building for Australia is that it will be diesel powered, use the US submarine combat system and be armed with US Mark 48 torpedoes. Within those constraints, we're assured that it will give Australia a 'regionally superior' submarine capability from the mid-2030s, when the first turns up, and presumably retain that capability through the 2070s, when the last of the initial 12 will still be in service. We also hear that maybe the second and subsequent boats will be different from the first—by necessity, owing to simple obsolescence issues, but also by design. Just how is unclear.

The pressing issue for now, in 2020, is how the design is being developed to make it most likely to succeed in the undersea operational environment of the 2030s and beyond. Just surviving in a dense undersea environment that has a proliferation of detection systems such as acoustic sensors, seabed arrays, roving sub-detecting unmanned underwater vehicles (UUVs) and other submarines, all complemented by surface, air and space-borne ASW systems, looks hard.

But just surviving isn't enough. The future submarine's total weapon system needs to be able to project lethal force at a range that keeps it safe while it survives, unless it's simply to be an intelligence, surveillance and reconnaissance platform.

So, the design challenge is immediate. The design brief needs to drive Naval Group—and the Australian designers working with the company—to create a flexible foundational design that can accommodate what seem to be at least the most likely new types of technologies and capabilities that will be essential for mission success.

We know that design decisions taken now will either constrain or enable the development of the submarine over its life. Experience with other defence systems and platforms shows that flexibility that enables modifications and development over the life of particular designs allows capabilities to stay effective. Designs without such flexibility cause costly rework and redesign, often with performance limitations as a result, so baking flexibility into the highly constrained future submarine is difficult but essential work.

That starts with different battery systems from the lead–acid ones in the Collins boats now, because of the promise in efficiency, power and range able to be provided by alternatives, not just the lithium-ion batteries already at sea in the latest Japanese submarines.

But it's a much bigger, deeper conceptual issue for the design than this. Any manned submarine, no matter how quiet, will need to operate with a wide range of unmanned and autonomous undersea systems over its life. It needs to be able to launch, recover and accommodate multiple such systems, which will come in different sizes and shapes. They won't all fit through a Mark 48 torpedo tube or under the boat's outer skin. The submarine will need to communicate with and control them, as some of those autonomous systems will be extensions of its weapon system.

The Navy's future frigate, designed by BAE, faces the same problem. That design has grappled with the problem by providing a large 'multi-mission bay' in the middle of the ship with space, weight and power available to accommodate a range of new systems and capabilities, some of which haven't yet been imagined, let alone developed.

The design brief must comprehend the need for this conventional submarine to be the major node in an undersea sensor and weapons system that it controls and orchestrates. Some highly unconventional systems and technologies will be in this orchestra in the 2030s and might make conventionally armed Mark 48 torpedoes look quaint. That's what 'regionally superior' requires.

Part 4: Nuclear power

Question 25: How does nuclear propulsion work?

Peter Clarke

In common parlance, there are two types of 'nuclear submarine': one is nuclear powered and has conventional weapons such as torpedoes and cruise missiles; the other fires nuclear-armed ballistic missiles—and will most likely also be nuclear powered. Their roles are very different, but both employ nuclear propulsion because it offers enormous advantages in power and endurance. An approximate comparison of energy densities is in Table 2.

Table 2: Approximate comparison of energy densities for fuel types

Fuel type	Energy density (MJ/kg)	Common uses
Li-ion battery	Less than 3	Smartphone or tablet battery
Liquid fossil fuels	Between 40 and 60	Sea and land vehicles
Liquid hydrogen	About 145	Rocket fuel
Uranium-235	79,390,000	Nuclear reactors

Power is extracted from uranium by a process called nuclear fission. Uranium atoms are 'split' by collisions with neutrons. This process emits heat, subatomic particles and radiation. Put simply, the potential power locked inside a uranium atom is mind-boggling: 1 kilogram of coal will give you 8 kilowatt/hours of heat, whereas 1 kilogram of uranium will create 24,000,000 kilowatt/hours, or 3 million times as much.

The availability of high power is important for a submarine because it allows all the boat's sensors and systems to be designed for optimal performance with less regard for power consumption. It also provides for prolonged periods of high speed (over 30 knots or 55 kilometres/hour). Endurance is important because it allows the submarine to remain on station for longer and, most importantly for nuclear power, remain independent of the atmosphere; that is, it can remain submerged and deep for months.

So, how is nuclear fuel used to power a nuclear submarine?

A reactor core contains a few hundred kilograms of uranium (^{235}U) in fuel cells clad with zirconium, which is a stable metal. The natural decay of the uranium is enhanced and held at a critical state of reactivity; this generates enormous heat. Water surrounding the fuel cells is then pumped around a circuit to a steam generator, where it produces steam in a secondary circuit. The steam turns a steam turbine and that drives the propeller through a gearbox. The steam is also used to generate electricity to power sensors, weapons systems, submarine control systems and domestic systems.

Most submarines use a pressurised water reactor (PWR) because it's efficient and stable. The newest designs of PWRs don't need refuelling throughout the life of the submarine (generally 27–30 years), so that reduces the cost of owning and operating a nuclear-powered submarine and increases its operational availability.

Many safety systems protect the nuclear power plant in a submarine, and control rods made from hafnium are used to increase or decrease reactivity. Control rods are dropped into the reactor core to shut down the reactor; when that happens, reactivity falls instantly. This is known as 'scramming' the reactor. To enable a submarine's reactor to be scrammed and restarted at sea, the submarine is fitted with a large battery and a diesel engine. The battery provides essential power to the submarine as the reactor is restarted by slowly withdrawing the hafnium control rods. *In extremis*, snorkelling, similarly to the procedure used in conventional submarines such as the Collins class, can charge the battery using the diesel engine.

Question 26: Why didn't Australia consider nuclear propulsion?

Peter Jennings

After the publication of the 2016 DWP in February that year, I was approached by a senior politician who had been involved in the earlier stages of the White Paper's production wanting to ask a 'couple of questions about Defence'. Started in early 2014, the White Paper had the unique history of being developed under the direction of two prime ministers and three defence ministers. We duly met at a Canberra institution, the Charcoal Restaurant.[14] Over blue steak and red wine, my friend's puzzlement became clear: 'Why didn't we talk about nuclear propulsion for submarines during the White Paper process?'

Why indeed! I would venture that there hasn't been a detailed discussion of nuclear propulsion around the Australian cabinet table since the nuclear crisis in ANZUS in 1984, in which New Zealand cast away the alliance over the vastly improbable risk that a US warship might sneak a nuclear weapon into Auckland Harbour. I was closely involved in the DWPs produced in 2000 and 2016 and had a ringside seat at the 2009 DWP. To my knowledge, nuclear propulsion wasn't part of any formal cabinet consideration. The 2009 DWP quickly dismissed any interest—'The Government has ruled out nuclear propulsion for these submarines'—at the same time as it stressed the importance of range and 'prolonged covert patrols over the full distance of our strategic approaches and in operational areas' (paragraph 9.5).

At a major maritime conference in 2019, the Chief of Navy, Vice Admiral Mike Noonan, tentatively ventured the thought that a slow build of 12 boats might allow nuclear propulsion to be considered at a later stage ('A change in the propulsion system for the Attack-class submarines; it's something that will no doubt be discussed over the next 30 years, bearing in mind that by the time we deliver no. 12 it will be 2055.'), but the government quickly said that this wasn't under consideration.[15] In fact, there doesn't appear to be a strong constituency for nuclear propulsion inside the Navy, which is still culturally an organisation built around surface ships. The wider Defence organisation has the Attack-class project to deliver, which is complex enough without adding a major new challenge to master nuclear propulsion.

Parliament is filled with many MPs on both sides of politics who will privately advocate for nuclear propulsion but publicly shy away from discussing the capability. The fear is that it isn't possible to build a bipartisan consensus for nuclear propulsion in ways that prevent one side of politics rejecting the idea, leaving the other side with a potential political liability. That was certainly the outcome of the 2019 House of Representatives Standing Committee on the Environment and Energy review of the future of nuclear technology in Australia. Government members of the committee recommended 'adopting a strategic approach to the possibility of entering the nuclear energy industry'. This was countered with a Labor Party dissenting report claiming that 'There is simply no case for wasting time and resources on a technology that is literally the slowest, most expensive, most dangerous, and least flexible form of new power generation.'[16] Nuclear propulsion for submarines wasn't considered, but it's clear at least in the short term that there's no prospect for bipartisan cooperation on this issue.

Political ambivalence is fuelled by popular concerns. In Australia, there are strongly divided views for and against nuclear power in any form. The parliamentary committee review acknowledged that 'the will of the people should be honoured by requiring broad community consent before any nuclear facility is built.'[17]

Is anything likely to change this situation? Potentially, yes. The strategic ground is changing quickly under our feet, and those developments might, in future, force a more urgent government consideration of the submarine capability Australia needs. The 2016 DWP pointed to the need to keep the submarine capability under examination, stating that a review would be needed 'in the late 2020s to consider whether the configuration of the submarines remains suitable or whether consideration of other specifications should commence' (paragraph 4.29). A significant pressure point may emerge in the next couple of years, when the detailed design work for the Attack class will reveal the capability parameters of the boats' propulsion system. How that plays out against the advertised need for a 'regionally superior submarine' could lead to some arresting discussions around the cabinet table.

Question 27: What would Australia have to do to develop a nuclear navy?

Peter Jennings

The House of Representatives Standing Committee on the Environment and Energy reported in December 2019 on the steps needed to develop a domestic nuclear energy capability in Australia. Its sensible and measured report, titled *Not without your approval: a way forward for nuclear technology in Australia*, didn't consider nuclear propulsion for submarines but still highlighted what government must do to start down that path. That included:

- 'consider the prospect of nuclear energy technology as part of its future energy mix'
- 'collaborating with, and learning from, international partners with expertise in nuclear energy'
- 'embracing a principle of transparency with the Australian public in all nuclear related matters'
- 'seeking bipartisanship where possible, especially on major public policy decisions relating to nuclear energy'.[18]

The body of the report recommended a series of studies and community engagement activities designed to facilitate this journey. Sadly, the report was dead in the water on launching. A Labor dissenting finding concluded that 'There is simply no case for wasting time and resources on a technology that is literally the slowest, most expensive, most dangerous, and least flexible form of new power generation.'[19]

It's clear that a bipartisan approach on nuclear power isn't likely in the near term, and that suggests that a broadly backed community social licence will be difficult to achieve. Even for the narrower objective of developing nuclear propulsion for submarines, political bipartisanship and some degree of community comfort with the project are critical starting points.

In a submission to the parliamentary committee's report, the Submarine Institute of Australia argued that a nuclear propulsion capability 'would not be reliant upon an Australian civil nuclear power generation industry', but that it would nevertheless take 'at least 15 years' to develop the systems and structures necessary to support nuclear-powered submarines.

Doing this would require:

- partnering closely with the US, UK and French navies to determine the best options for Australia and drawing on those 'parent navies' to help build the necessary skill base
- an extensive education and training program, starting at the level of secondary schools, to build a cadre of individuals with the necessary knowledge base
- establishing a 'small nuclear power reactor' to support engineering training and nuclear R&D
- building an appropriate group of nuclear engineering specialists in the Navy
- establishing an appropriate regulatory and safety regime to support nuclear propulsion
- determining appropriate basing infrastructure as well as support and sustainment capabilities.[20]

Those are all challenging tasks, but they're not beyond the national capacity of Australia should there be agreement that the need is great enough to justify the investment. The 'need' is, to a large degree, shaped by our strategic outlook, threat perceptions, and calculation of the likely military capabilities that

we may have to defeat and the likely responses of our friends and allies. In other words, what might look like an impossible challenge today could well become an urgent national priority tomorrow, depending on events.

Given continuing community interest in the possibility of nuclear propulsion for Australian submarines, the government could make a modest start by adapting a recommendation from the *Not without your approval* report and adding one crucial word: commission 'an expert body to manage an independent community engagement program that would educate and inform Australians on nuclear [propulsion] technology, answer their queries and hear their views'.[21]

Question 28: Would the US sell us nuclear boats?

Peter Jennings

It's often asserted in public commentary on the submarine issue that Australia should approach the US to see whether it's possible to lease or buy American nuclear-powered vessels, such as, for example, the Virginia-class cruise missile fast-attack submarine, which is in long-term production. At first glance, it looks like an attractive proposition. The Virginia class is based on an established design and has 19 boats in service, the most recent of which, the USS *Vermont*, was commissioned in April 2020.[22] The design of the boats is under continuous modernisation and adaptation, and the Virginia class is likely to remain a central element of the US Navy well beyond mid-century.

On occasion, US politicians hint at the idea that Australia might be a suitable partner to bring into submarine development—not least to share the development cost burden—but Washington is generally reserved about the idea.[23] The then US Defense Secretary, Chuck Hagel, was reported to have told his Australian counterparts at the October 2014 AUSMIN meeting 'that technical difficulties associated with Australia acquiring nuclear submarines would be difficult to overcome'. The US Government's formal position was that it 'supports Australia's decision to purchase conventional submarines'.[24]

The US sees value in Australia operating and maintaining high-quality submarines, but it would be absurd to imagine that Washington DC would easily open the door to what are some of the most technologically sophisticated and highly classified military capabilities on the planet. My own assessment, based on close engagement with the US defence establishment over decades, is that America won't easily hand over the nuclear keys. There are some areas of defence activity that even the closest allies won't be given access to. For that to change, the US would surely need to be convinced that Australia is irrevocably committed to developing and sustaining a nuclear propulsion capability. Even then it would be a big call for the US to open access.

While the prospect of leasing or owning a Virginia-class submarine any time this decade seems to me to be very low, that's not to say that Australia shouldn't pursue deeper cooperation with the US on submarine technology. We could, for example, seek to dramatically expand the numbers of RAN submariners seconded to the US Navy for training. As the US pursues a strategy of 'transitioning from large, centralized, unhardened infrastructure to smaller, dispersed, resilient, adaptive basing',[25] why not offer a berthing arrangement for a Virginia-class boat at HMAS Stirling in Western Australia? An Australian investment in US R&D on remotely operated submersibles could lead to valuable outcomes for both countries. The challenge here is to think creatively and laterally. Closer engagement of this type might, over time, allow the conversation to come around to nuclear propulsion in such a way that a 'No' in 2020 could be turned into a 'Maybe' by 2030.

Figure 15: Los Angeles-class fast-attack submarine USS *Albuquerque* (SSN 706) and Collins-class submarine HMAS *Rankin* off Rottnest Island, Western Australia, in 2015

Source: Defence image library, online.

Question 29: Aren't nuclear-propelled boats too noisy?

Peter Clarke

Submarines achieve an asymmetric effect in part because they're very difficult to detect. A well-operated modern submarine on patrol might remain undetected for months while retaining its ability to strike at sea or land targets at short notice, thereby delivering deterrence.

Early submarine nuclear reactors were relatively noisy. The philosophy was to build a fast submarine capable of using the high power and independence that the reactor offered. The powerful main coolant pumps that circulate water around the reactor core, the heavy and noisy main isolating valves and the large rotating machinery of the secondary systems generated both broadband noise and a number of discrete frequencies. Some of the noise energy was transmitted through the submarine's hull and into the sea, providing an opportunity for an adversary's ASW assets to locate and track the boat. That said, the fact that the submarine didn't rely on snorkelling to charge batteries still gave it a great advantage. Also, its considerable turn of speed meant that, if it were to be detected, it stood a good chance of evading ASW forces.

With every new class of nuclear submarine, reactor design and efficiency and radiated noise levels have improved significantly. Reactors now run silently, without the need for pumps to circulate the coolant; secondary steam systems and rotating machinery have been developed to optimise quietness rather than efficiency; and decoupling techniques have been developed to prevent noise escaping into the ocean.

A number of factors affect a submarine's noise signature. They include:

- the manner in which the submarine is operated
- the hydrodynamic shape of the submarine and its speed through the water
- the design of the submarine's propeller
- radiated noise from internal systems and machinery.

Those factors apply to all types of submarine, regardless of their type of propulsion. Clearly, any submarine will be noisier if it goes faster, as increased noise is emitted from vortices around the hull and propeller vibration or even cavitation.

A nuclear power plant is capable of generating immense power, but with that comes the risk of increased noise. Fortunately, new technology is able to harness some of that power to eliminate the potentially harmful noise. This is done by passive methods that involve isolating all noisy machinery and systems from the hull with specially designed mounts (conventional submarines use this technology, too) and by using active noise-cancelling techniques. These active measures are energy intensive, but that isn't a problem if you have a nuclear power plant.

In the end, it comes down to a compromise. When you design a conventionally powered submarine, power consumption is always front of mind. The greatest risk of counter-detection for a conventional submarine is when it has to operate at periscope depth to charge its batteries. Even boats with fuel cells and hybrid plants might have to do that from time to time, so power is always at a premium. The design philosophy for a nuclear submarine is fundamentally different. With relatively unlimited power, systems, sensors and other equipment can be designed for optimal capability and with much less regard for the energy bill. That gives designers many more options to deliver a potent and stealthy platform.

Part 5: Myths and mysteries

Question 30: What are the politics of submarines?

Peter Jennings

Absent major crises, defence isn't a day-to-day political issue in Australia, but Defence procurement, particularly of large iconic projects such as submarines and combat aircraft, is often the subject of critical media commentary. The Collins submarines could never quite escape the moniker of 'dud subs' that sounded as noisy as 'an underwater rock concert'.[26] It didn't matter whether that description was fair or accurate; the Collins was marked for life once Australia's boisterous media latched onto the term. Alas, there's no juicer story for Australian journalists than that our defence platforms are lemons.

Parliamentary committee hearings, particularly estimates committee hearings tied to the annual budget cycle, provide one of the few occasions when officials can be publicly pressed by opposition politicians on details of the procurement process. As successive governments and the Defence organisation have reduced the flow of public information about procurements, committee hearings (along with Australian National Audit Office reports) offer small glimpses of insight into complex projects. The process would work much more efficiently if governments and officials weren't so tightly gripped by the fear of being seen to declare cost, schedule or capability changes. A more mature conversation would admit that working at the leading edge of technology on projects intended to constantly evolve their designs over decades doesn't lend itself to ironclad assurances on cost and schedule.

Opposition pressure on defence procurement is an appropriate exercise of parliamentary functions, keeping Defence on its mettle and necessarily keeping ministers accountable. None of this typically defines the major political issues of the day. Indeed, what's remarkable about the politics of submarines in Australia is the depth of bipartisanship between government and opposition, rather than division. From a defence planning perspective, this is a fortunate reality because it offers some longer term assurance on fundamental policy settings, such as the alliance, levels of defence spending and a preference for a high-technology ADF.

Politically, Labor has tended to see national security as an issue that plays to Liberal and National Party strengths. Especially around election times, that can mean that Labor tries to reduce any Coalition advantage by offering bipartisanship on defence issues and focusing on Labor's social policy strengths. Labor works hard to avoid being squeezed by the Coalition into positions that might be characterised as 'weak on security'.

A second factor behind the largely bipartisan approach on submarines is that government and opposition realise that they'll inevitably be custodians of the project at different points in its history. Over the half-century life (and more) of the Attack-class vessels, we'll most likely see many more defence ministers than there will be submarines. Since the 2009 DWP, which announced the decision to double the submarine fleet from six to 12 boats, we've had seven defence ministers (three Labor, four Liberal) to mid-2020. Whatever the opposition's critique of the program today, Labor realises that it will have to steer the program at some stage as a future government. Sensibly enough, that leads to a certain muting of criticism and a shared interest in trying to ensure that the program remains on course.

The challenge of balancing an opposition's natural instinct to oppose with the realisation that one day the project will be its to manage was on full display when deputy Labor Party leader Richard Marles addressed the National Press Club in early August. Marles started with the feisty claim that 'the Morrison Government has bungled the Future Submarine Program to the enormous detriment of Australia's national security', but a few moments later declared:

> And none of this should be taken as a criticism of Naval Group. They are a first-rate builder of submarines with a proud history and a superb track record. They certainly have the capability to produce for Australia the long-range submarines that we need.[27]

As is generally the case in Australian politics, opposition parties tend to critique governments on process but seldom propose major strategic changes to defence priorities or force structure. That's a wise approach, given that oppositions are starved of the resources and advice necessary to convincingly shape major defence capability decisions.

Question 31: Will France and the US cooperate in the Future Submarine Program?

Peter Jennings

A persistent popular view is that the US might not be 'prepared to hand over its most high tech and sensitive systems … for installation and integration with European sensors in a submarine of French origin'.[28] This supposed US reservation about doing defence business with France was often put forward as a reason why France, in the form of DCNS (now Naval Group), wouldn't be chosen as the preferred design partner as, of course, it was in April 2016.

In late 2016 Lockheed Martin Australia (LMA) was selected to be the combat system integrator for the Attack-class submarines, and a 'multi decade contract for the design, build and integration of the submarine's combat system' was signed in January 2018. LMA says that the combat system will be 'designed and integrated in Australia' but that there'll be 'reach back to [the] US based Lockheed Martin Team'.[29] Moreover, in October 2019, LMA and Defence awarded a contract to Safran Electronics & Defense Australasia Pty Ltd—a company with deep French roots—to 'deliver the preliminary and detailed designs for the combat system's optronics search and attack mast, navigation radar and navigation data distribution components'.[30]

All of this might be taken to prove that claims that the US and France won't cooperate in building an Australian submarine are false. In fact, technology for the Attack class will be a remarkable mix of European, US and Australian intellectual property. None of this is to say that the cooperation will necessarily be easy. Countries and companies jealously guard their proprietorial information and work hard to ensure that information sharing is controlled and compartmented where it needs to be to protect national and company equities. Had the design selection gone to the German or Japanese competitors, similar challenges would have been faced in integrating US technology.

The lineage of Washington's views on France goes back centuries. French Navy and Army units aided George Washington's comprehensive defeat of the British at the Siege of Yorktown in 1781. The Pentagon describes France as America's 'oldest ally',[31] and current security cooperation is deep, although in the intelligence sphere it isn't as closely integrated as among the Anglosphere Five Eyes partnership.

There have been frustrations, too. In 1945, the US Army developed a question-and-answer booklet for combat troops deployed in Europe, *112 Gripes about the French*, which sought to defuse tensions between the GIs and their French hosts. A modern assessment concludes that France operates according to its own definition of the national interest:

> US military members are particularly sensitive to certain actions of the French, such as their perceived abandonment of NATO in 1966, the refusal to grant overflight of French airspace in the 1986 bombing of Mu'ammar Gadhafi's compound in Libya, and, of course, the most recent flare-up over the invasion of Iraq in 2003.[32]

On Iraq, many people might conclude that the French made the right strategic call in 2003. A lesson from all of this is that cultural dispositions and historical memories, often more imagined than real, shape perceptions of France in both Australia and the US. The need, surely, is to be clear about the national interests of all parties, to maximise shared strategic views and to work through differences when they arise. It's unlikely that the combination of French (really, European) and US technology will produce a showstopper for the Future Submarine Program. If that had been a real prospect, Washington would have surely made it known in Canberra. Sorting out differences on all matters from culture to technology to national strategic perceptions will be the essence of the project.

Question 32: Do the media report accurately on submarines?

Brendan Nicholson

Adverse media reports can damn the reputation of a submarine as surely as depth charges can wreck its hull. A classic example is the Swedish-designed and Australian-built Collins class. Those boats are among the world's best conventional submarines, but as a nation we've done our best to convince ourselves otherwise. They've had so much bad publicity that most Australians may view them as 'dud subs'.

The Collins project had major problems but they were no worse than expected in any country launching such a program. Through cheap politics and in-service rivalry, we've accepted that an extremely difficult project was a disaster. It wasn't. It's likely that the original criticism of the Collins came in leaks from officers in the Navy's surface fleet, resentful of what they saw as the focus on submarines over surface warships. The 'dud subs' tag was perpetuated by political opponents of former Defence Minister Kim Beazley after he became opposition leader to bash his reputation when he appeared to be heading for an election victory.

Media reporting on submarines isn't as detailed as it might be, but that's not just the fault of journalists. Most submarine operations are, of necessity, secret so it's hard to get information about them. The Navy has tried to rescue the Collins's reputation, taking defence writers on trips and passing on snippets such as how an Australian submarine on an exercise penetrated the defensive screen around a US fleet and was credited with 'sinking' an aircraft carrier.

Long-term efforts to find a replacement for the Collins became even more politically tangled inside Defence and within a succession of governments. In a 'captain's call', Australia's Prime Minister Abbott asked Japan's Prime Minister Abe for a fleet of Soryu-class submarines to be built in Japanese shipyards. As a newspaper defence writer, I was invited to Japan for briefings on its program and to tour a Soryu.

In the meantime, consternation in South Australia, which expected to build whatever new boat was chosen, was such that it seemed the decision to construct abroad might cost the federal government the election. The 'build in Japan' plan was hastily replaced with a CEP looking at options.

One such possibility should have been to use the knowledge accumulated in designing, building and improving the Collins to produce, with Swedish help, an evolved version, or 'Son of Collins'. One day, I told a senior Canberra Defence official that I was going to Sweden to look at its submarines. He told me that I was wasting my time and should look elsewhere for submarine builders. I did fly to Sweden and learned of the complexity of searching the shallow Baltic for Russian intruders—and how the Swedes were using their experience building the Collins to improve their own boats.

On my trip home, I saw a news report that submarines from Japan, France and Germany were being considered under the CEP, but not from Sweden. Then, the Canberra Defence official's comments made sense. It was never properly explained why a 'Son of Collins' wasn't even contemplated. Now such a submarine, offered by Sweden, is being considered by the Netherlands.

Later, as the CEP neared completion, I wrote that France was favoured to win, Germany was second and Japan was trailing. This was how Japanese officials learned they'd missed out. They were beside themselves and rang me to ask how sure I was. So, journalists can write about submarines, but they may first have to negotiate minefields of political manipulation and misinformation.

Question 33: How should governments publicly explain the submarine program?

Peter Jennings

In late April 2016, in 13 paragraphs and just over 500 words, Prime Minister Malcolm Turnbull announced 'the largest and most complex defence acquisition Australia has ever undertaken'. The selection of DCNS, now Naval Group, 'as our preferred international partner for the design of the 12 Future Submarines' was presented by Turnbull almost exclusively as a job-creating, industry-developing initiative. Turnbull's media release pointed to the 2016 DWP, released in February that year, to explain the 'unique national security requirements' that justified the investment.[33] The White Paper pre-dated the design selection so it remains the case that the government didn't seek to provide a detailed statement about the strategic requirement for the program or to outline the case for a strategic relationship with France.

The strongest case for submarines as a military capability rather than an industrial project was made by Defence Minister Linda Reynolds, speaking at ASPI after the launch of the 2020 Defence Strategic Update (quoted at the beginning of Part 1 of this report).

While the minister's statement is clear and very much in the tradition of past Australian policy papers on the value of submarines, it's remarkable that successive defence ministers and prime ministers have spent so little time publicly explaining the case for the future submarine and, for that matter, setting out the necessary case for upgrading the Collins-class submarines. Too much of the public explanation about submarines has been left to Defence officials giving evidence to Senate Estimates committees. Inevitably, that forum creates a fragmented focus on cost and schedule issues at the expense of the bigger capability and strategic picture.

What should the current and future governments do?

First, it's important to recognise that what's often described as the biggest infrastructure project in the history of the Australian federation can't be treated as though it's a classified 'black' Defence project, not to be openly discussed. The prime minister needs to lead the public charge. One way to do that would be with an annual meeting with the French president, followed by a communique and a media conference. Does anyone doubt that the value and strategic importance of the project doesn't merit regular attention from the two countries' political leaders?

Second, the minister for defence should seek to make twice-yearly statements to the Australian Parliament, setting out the status of the project and making the case for its strategic value. A parliamentary statement would enable a debate in the House of Representatives, which means that the opposition, members and senators could all stay informed and focused on developments.

Third, the defence minister needs to address many of the public questions, tropes, myths, worries and hopes that we have sought to address in this study. The absence of clear, detailed explanations about the project has led to a public policy vacuum being filled with many half-truths about the submarine capability. The weight of that discussion begins to eat away at the sustainability of the project. In short, the government needs to defend its policy decision or run the risk that the citadel will ultimately fall.

Finally, the government should develop a program to give parliamentarians, journalists and others who are active in the public debate an opportunity to spend some time looking at our current submarines, talking with submariners and Defence officials, engaging with industry and having a hands-on experience

of submarine life at sea, however brief. A tiny amount of this currently happens, but nowhere near enough to give essential opinion-formers some confidence that the project is on the right track.

None of this is complicated. It's simply a matter of more actively engaging in providing the public with a rounded explanation of why submarines are becoming more important to Australian security and how the government plans to strengthen this capability into the future. Tell the story and then tell it again. For the investment cost of this program, Australian taxpayers surely have a reasonable claim to be engaged in this way.

Part 6: The future

Question 34: Where should our submarines be based?

Marcus Hellyer

There are several options.

West coast

There's general agreement that submarines should continue to be based at HMAS Stirling on the west coast. Strategically, it offers the best access to the Indian Ocean and Southeast Asia. It's also where the existing submarine infrastructure is.

East coast

There are good reasons to also base submarines on the east coast. As discussed in Question 21, all workforce studies have concluded that access to the population centres of southeastern Australia is essential to crewing a larger submarine fleet. Without an east coast submarine base, there's a significant risk that submarines will be tied up for want of crews to operate them.

There are also good strategic reasons for an east coast base:

- It provides better access to the South and Central Pacific.
- It provides redundancy in case HMAS Stirling's ability to support submarine operations is impaired.
- It creates greater opportunities to train with other ADF assets, mutually enhancing both submarine and ASW capabilities.
- It creates greater opportunities for submariners to train in busier waterways.

Various studies conducted over time for an east coast submarine base have reached very different conclusions about where to site it. Recommendations have included Sydney Harbour, Newcastle, Port Kembla and Brisbane. There's no obvious, stand-out solution, and every option is a trade-off shaped by different priorities. Sites with the right attributes have already been either developed or protected (Jervis Bay, for example). There are no obvious greenfield sites, so establishing a new base will require relocating the current occupants.

Establishing an east coast base will be a difficult and expensive decision, and such decisions don't get easier with the passage of time. Identifying and securing a site now would prevent further civil development both on and around it. It would give Defence more time to plan as well as to resolve legal issues, and give any affected stakeholders time to relocate.

There's currently no provision in the Future Submarine Program's budget for an east coast base. The cost could be reduced by not duplicating maintenance and training facilities on the east coast, but that would increase the amount of time submarines and submariners would spend in transit between the east and west coast bases.

Darwin

The case for basing submarines at Darwin isn't compelling. While it's closer to some areas of strategic interest, it isn't closer to others, such as the Malacca Strait. Moreover, the transit there is more difficult. Also, the approaches to Darwin are shallow, exposing submarines to detection when entering or leaving.

Forward basing

Some have suggested basing submarines in countries closer to areas of strategic interest such as Singapore. By reducing the long transits required from HMAS Stirling, the demanding requirements for range and endurance could be reduced, allowing Australia to buy smaller, cheaper submarines, potentially off the shelf. The risk with this approach is that should access to the forward base be denied, either by the host country or by enemy action, the utility of Australia's submarine capability would be severely compromised.

Further reading:

On 27 June 2018, in response to a freedom of information request, the Department of Defence released three reports prepared for the Future Submarine Program on submarine basing issues and options. They are available on Defence's freedom on information disclosure log, online.

Figure 16: HMAS Stirling port services sailors help dock the submarine as HMAS *Collins* returns home to Fleet Base West from deployment

Source: Defence image library, online.

Question 35: Will submarines become easily detectable in the future?

Andrew Davies

Submarines are formidable weapons primarily because of their stealth. And they need to be hard to find—even a very small weapon that holes the pressure hull will at least mission-kill them. The relative opacity of seawater works in their favour and makes the development of long-range sensors difficult, making ASW a specialist discipline. Aircraft and surface vessels are susceptible to detection by radar at ranges of hundreds of kilometres—far further than the usual detection distances for submerged submarines, which tend to be tens of kilometres or less.

If, as was often the case historically, ASW forces are attached to a taskforce or convoy, submarines have often been able to manoeuvre within weapon range of targets before being detected. In many engagements, the first sign of a hostile submarine was an incoming torpedo track or an explosion on its arrival.

However, clever applications of modern technologies and more imaginative tactical approaches to ASW could radically change that picture. Modern signals processing and networking capabilities can allow even subtle signals to be picked out of a noisy background. The ability to collect and move around data from arrays of dispersed sensors on long-endurance platforms could change ASW from a usually short-range engagement in which the submarine has the upper hand to a long-range contest in which the submarine has its work cut out to remain undetected.

That isn't an entirely new idea, as fixed underwater sensor arrays were deployed during the Cold War to help track submarine movements. Those arrays were useful but limited—the adversary knew where they were—and relatively expensive to deploy and maintain. But, today, several more decades of exponential growth in computing speed and network bandwidth, combined with the development of low-cost, high-endurance unmanned platforms, mean that the development of cheap, flexible and redeployable arrays that provide a quantum leap in detection capability is likely.

Conversely, trying to further reduce the detection signature of submarines is likely to be expensive and relatively ineffective. For example, there were large reductions in the acoustic signatures of successive submarine classes in the first 70 years of submarine design, but the curves have flattened significantly since then as diminishing returns have set in. The return on investment is likely to be much higher for the hunter than the hunted.

If, as seems likely, future sensor performance allows submarines to be detected more readily, the last part of the ASW mission is the engagement phase. Modern ASW weapons such as the ADF's Mark 54 lightweight torpedo rely on having accurate tracking data of the submarine for precision engagement. That gives submarines a fighting chance of carrying out their missions—albeit at higher risk—even if their presence in an area is known. But we've been there before; wide-area weapons, in the form of arrays of depth charges, mines and dispersed mortar-like clusters were used effectively in the past when technologies didn't allow for precise tracking, and we could see a return to that approach in future. In Question 37 we examine what all that means for Australia's future submarine.

Question 36: Are space capabilities a threat or an opportunity for submarines?

Malcolm Davis

Imagine the following scenario. An RAN Attack-class submarine has been deployed into the South China Sea to monitor PLA Navy operations out of Hainan. Its crew are unaware that they've been detected—not by another submarine employing a towed passive-sonar array, or by a warship 'pinging' them with an active bow sonar, but from a Chinese satellite orbiting 400 kilometres above the Earth's surface. The satellite is equipped with a lidar (light detection and ranging) laser, which can detect a submarine several hundred metres below the waves.[34]

Furthermore, at the time of this hypothetical scenario, the Chinese Government will have benefited from cooperation, under the 'Thousand Talents Plan', with Australia's CSIRO through the Centre for Southern Hemisphere Oceans Research.[35] This collaborative research, which is currently underway, will allow China to develop a sophisticated sensing mesh incorporating data from a variety of sensor platforms—including space-based sensors—to better provide an accurate real-time model of the undersea environment. That information would be communicated at high speed using sophisticated satellite communications to PLA Navy vessels, allowing them to precisely track the RAN submarine and engage it when they choose to.

That scenario is fiction, for the moment, but a recent report from the National Security College at the Australian National University has suggested that the oceans will become increasingly transparent by 2050 as new sensor, computing and communications technologies merge.[36] The report argues that 'the adaptive sensing mesh itself would be built from space platforms' as well as unmanned systems and emplaced sensor arrays. That would end the key advantage of the submarine—its undetectability—and force a rethink on how to wage undersea warfare.

The answer lies in technology related to lidar—space-based laser communications—and the possibility of quantum communications via satellite. Those technologies open up the possibility that submarines, or large UUVs, will enjoy an ability to 'plug and play' with existing command and control networks more directly.[37] The ability to understand the underwater battlespace with greater fidelity, combined with the potential for XLUUVs to manoeuvre below the crush depth of most crewed submarines, expands the underwater battlespace and allows greater innovation in thinking about undersea warfare.

Space will therefore play a critical role in enabling—or denying—undersea warfare, whether it's with a crewed submarine deployed out of harm's way or with forward-deployed XLUUVs such as the Orca. Space-based submarine detection and ensuring connectivity open up dramatic new approaches to undersea warfare and to exploiting the undersea battlespace. The traditional dominance of the submarine may be drawing to a close, thanks to the prospect of space-based detection capability, but the potential of unmanned systems is just now becoming apparent.

Question 37: How do we ensure that the future submarine remains relevant?

Andrew Davies

No weapon system is guaranteed a future. Sometimes they're overtaken by evolutionary changes that gradually reduce their effectiveness and sometimes they're rendered obsolete overnight by revolutionary changes. As we saw in Question 35, there are foreseeable evolutionary changes in detection technology that will make life harder—possibly much harder—for future submarines.

Given the $50 billion cost of Australia's future submarine fleet, it's worth pondering how that investment might be future-proofed. In fact, we've already passed up a risk mitigation step by investing heavily in a capability that will be fully-fledged only in the 2050s. That makes little sense at a time of potentially disruptive changes in ASW technology. (And the error is compounded by the likely timescale of strategic changes.) A smaller investment in submarines able to be delivered sooner—even if some performance compromises have to be made—would be more prudent.

That said, even if much-improved sensors come along, submarines will still have advantages over other platforms. They'll always be harder to detect than surface vessels because the latter don't have the benefit of being submerged and are relatively easy to detect at long range. So, if Australia wants to have a long-range maritime force projection capability for high-end operations, that capability is likely to be resident in the submarine fleet. The question then becomes how to keep as much effectiveness as possible while reducing the risk posed by new ASW systems.

For reasons discussed elsewhere in this report, avoiding detection will be increasingly difficult and the reduction of electronic and acoustic signatures will be increasingly expensive and relatively small—with one significant exception. A diesel–electric submarine is substantially noisier when it's running its diesel engines than when operating on batteries. Reducing—although never eliminating—the need to run the diesels by employing advanced battery technology and air-independent propulsion systems could repay investment.

But, regardless of their signatures, future submarines will need to be more capable of delivering their mission effects at longer distances. Increased detectability will make choke-points such as narrow straits and harbour approaches essentially no-go areas and will tend to push the patrol areas of submarines further away from shore. That will be a particularly acute problem for Australia's diesel–electric boats because they lack the speed and endurance of nuclear submarines for effective wide-area operations.

Instead, they'll need to collect data and deliver weapons from further away than before. There's a limit to how much effective long-range detection capability can be fitted in the submarine, so the ability to deploy sensors and weapons remotely will become crucial. A wide range of UUVs is under development at the moment, and the ability to deploy and recover them should be a very high priority for Australia's future submarine fleet.

A review of submarine technology is scheduled for the late 2020s, and we can hope that some of the necessary technologies can be accommodated then. However, the risk is that we've committed ourselves heavily to a monolithic approach to the future submarine that won't be flexible enough to accommodate the changes likely to be required for effective operations in the future.

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Acronyms and abbreviations

ADF	Australian Defence Force
AIC	Australian industry capability
ASW	antisubmarine warfare
CEP	competitive evaluation process
CSIRO	Commonwealth Scientific and Industrial Research Organisation
DCNS	Direction de Constructions Navales Services
DWP	Defence White Paper
lidar	light detection and radar
LMA	Lockheed Martin Australia
LOTE	life-of-type extension
NATO	North Atlantic Treaty Organization
PLA	People's Liberation Army
PWR	pressurised water reactor
R&D	research and development
RAN	Royal Australian Navy
SLBM	submarine-launched ballistic missile
SSBN	ship, submersible, ballistic missile, nuclear (nuclear-powered ballistic missile submarine)
SSGN	ship, submersible, guided missile, nuclear (cruise missile submarine)
SSN	ship, submersible, nuclear (nuclear-powered fast-attack submarine)
SSK	diesel–electric fast-attack submarine
TKMS	ThyssenKrupp Marine Systems GmbH
TLAM	Tomahawk land attack missile
UUV	unmanned underwater vehicle
XLUUV	extra-large unmanned underwater vehicle

Submarines

Your questions answered

This ASPI study attempts to answer the many questions that Australians pose when it comes to the design, acquisition, cost, operational service and strategic implications of submarines. Our hope is that this volume will become the go-to guide for authoritative comment on all things to do with the present and future of Australian submarines.

> ‘Our submarine capability underpins Australia’s credibility and influence as a modern military power.’
>
> —Linda Reynolds, Minister for Defence

> ‘Submarines are the apex predators of maritime conflict.’
>
> —Rear Admiral (Ret.) James Goldrick