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# SPECIAL REPORT

## Can Australia afford nuclear propelled submarines?

### Can we afford not to?

Peter Briggs

October 2018

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AUSTRALIAN STRATEGIC POLICY INSTITUTE

## About the author

**Peter Briggs AO CSC, Rear Admiral RAN (Rtd)** is a retired Royal Australian Navy submarine specialist and a past President of the Submarine Institute of Australia.

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# EXECUTIVE SUMMARY

This paper advocates early consideration of all aspects of a transition to nuclear propulsion for Australia's submarines, based on compelling strategic and submarine capability arguments.

While a nuclear-powered submarine force would provide strategic advantages, some quite formidable challenges would need to be to overcome to add such a force to the Royal Australian Navy (RAN).

Quite apart from the political sensitivity of such a decision, Australia acquiring nuclear-powered fast attack submarines (SSNs) would be a protracted process requiring a lead time of 15–20 years, largely because of the technical, training and educational preparations and a very significant increase in submarine-qualified personnel required to operate and maintain the force.

The current program to acquire 12 conventional future submarines (FSMs) is an essential starting point for a successful transition, which will take significant time and a national focus to achieve. The RAN must first achieve the critical mass of submarine personnel and be able to sustain the manpower required for this challenging transition. Those personnel can only be generated by an increased number of conventional submarines under the FSM program.

Attempting a transition before the RAN's submarine arm has achieved sufficient scale in platforms and personnel risks a capability gap, even if there are no delays during the transition.

Given national priority for personnel and other resources, it's estimated that the first SSN could commission in 2044. A more detailed study is needed to confirm this and identify the key milestones.

In the face of deteriorating strategic circumstances, the consequent need to transition to SSNs expeditiously and the reality that growth of the submarine arm via the FSMs is essential to starting that transition, the FSM program must be accelerated, and a national priority must be given to funds, personnel and facilities.

The core rationale for these key judgements is as follows:

- A force of modern SSNs would offer significant sea denial and force projection capabilities, providing at least twice the number of more capable submarines deployed at long range compared with an equivalent conventional submarine force (even the very capable FSMs). This provides much increased capacity to sustain a high level of deterrence and operational capability to meet the challenging strategic and operational scenarios facing Australia.
- Such a force would clearly establish Australia at the forefront of the region's growing submarine capabilities and indisputably establish a regionally superior submarine capability.
- The options for Australia to develop an SSN capability would be limited to building the nuclear submarines offshore or consolidating the submarines in Australia, incorporating reactors purchased offshore. Leasing SSNs is not a practical option, given the need for sovereign control over all aspects of their safe operation.

- Twelve double-crewed SSNs would provide three or four submarines on task at long ranges and able to operate at such ranges for extended periods, thus providing a formidable deterrent force. A target of 12 SSNs would facilitate a rolling construction program
- A force of at least 10 SSNs with 10 crews is the minimum required to maintain a critical mass of trained personnel and to generate the experience needed to maintain the senior supervisory and policy staff needed for a globally credible nuclear safety organisation.
- Greater manpower resilience, improved conditions of service and increased submarine availability could be achieved by double-crewing the operating SSNs, resulting in 16 crews.
- A force of 10 single-crewed SSNs, each with a nominal crew of 75, could be sustainably operated by an RAN submarine arm of around 2,250 personnel (some 14% of total RAN strength, after it's increased to cover the growth in submarine personnel numbers). These figures are illustrative; the final numbers require knowledge of the chosen SSN variant and its operating and sustainment concepts.
- Double-crewing this force would increase the submarine arm to 3,600, or 16% of total RAN strength.
- A force of at least 12 conventional FSMs, each with a crew of at least 60, and a total submarine arm of at least 2,160 is judged to be a conservative, safe and viable starting point for a transition to a force of SSNs.
- The current FSM program remains critical to provide strategic capability, protect against delay and build up manpower numbers to facilitate the long and challenging transition to nuclear propulsion.
- Growing the size of the submarine arm via the FSM program is a critical enabler for any SSN acquisition.
- Accelerating the FSM program is justified by the deteriorating strategic circumstances and the program's role in create the personnel for the transition.
- Selection of French Naval Group as the designer of the FSM may present an opportunity to integrate FSM systems and supply chains into an RAN SSN build program.
- Assuming that the early acquisition of an SSN capability becomes a national priority and the appropriate resources are dedicated to achieving it, the first Australian SSN could be commissioned by 2044.
- This would require an in-principle decision by the mid-2020s to allow the initiation of a training program to prepare the policymakers and senior technical management personnel necessary to order the first SSN by 2032. Because of the size and lead time of the training program, more than 250 experienced RAN submariners would enter nuclear education and training pipelines by 2036. Refining these timings should be a key output from the recommended studies.
- A supporting Australian nuclear power industry is desirable, as it would provide a broader national regulatory, technical and educational base. However, provided the costs of not having that support are clearly identified and allowed for, the absence of a domestic nuclear power industry shouldn't preclude a transition to nuclear propulsion for Australia's submarines.
- To enable an informed decision on whether or not to acquire nuclear-powered submarines, an immediate decision is needed to commit the resources to conduct feasibility studies into a transition to nuclear propulsion, with a delivery date for the studies in 2020.
- The manning, training, technical, financial, logistical and political aspects of the nuclear-propulsion option should be included in the feasibility studies in order to inform public debate and political decision-making.
- The information derived by studying the option could not only be used to inform the Australian Government's strategic decision-making but could also lead to a better informed public debate.

# THE ARGUMENT FOR NUCLEAR PROPULSION

## The strategic justification

The analysis used by the Submarine Institute of Australia a decade ago to mount the argument for an increase to at least 12 conventional submarines in order to provide Australia with a 'strategic sting' has stood the test of time.[1] Since then, Australia's strategic circumstances have deteriorated significantly. It's high time we took out some increased insurance.[2]

Australia's defence strategy set out in the *2016 Defence White Paper* provides the starting point for this analysis. Some relevant extracts describe the strategy and the capabilities required of the ADF:

> Our most basic Strategic Defence Interest is a secure, resilient Australia. The first Strategic Defence Objective is to deter, deny and defeat any attempt by a hostile country or non-state actor to attack, threaten or coerce Australia.[3]
>
> 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]

Australia's maritime environment is rapidly becoming ever more complex and operationally difficult. There is much increased diplomatic sensitivity and enhanced surveillance, as evidenced by China's program to militarise islands in the South China Sea[5] and establish ocean-floor acoustic arrays.[6]

The rate of strategic change has accelerated for the worse. This paper argues that the review of submarine technology envisaged in the *2016 Defence White Paper* for the late 2020s must now be brought forward.[7]

New surveillance systems, such as bottom-mounted acoustic arrays now being deployed more widely in our region, not just the South China Sea, will pose challenges and risks for submarine operations and will require Australia's submarines to be suitably equipped and appropriately operated.

The growth in regional submarine numbers, including nuclear-powered submarines, and their capability adds to the complexity and challenges of the emerging maritime environment for Australian submarine operations.

China's attempted unilateral extension of its maritime boundaries in the South China Sea, against the findings of the Permanent Court of Arbitration in The Hague,[8] and the subsequent militarisation of contested outcrops in the sea are wake-up calls for Australia and the region. It's time to seriously boost our strategic sting and provide a viable capability to deter the use of coercion against Australia's interests.

Submarines offer unique, asymmetric maritime strike and sea denial capability[9]—something we're going to need a lot more of, as Paul Dibb, Richard Brabin-Smith and Hugh White have recently elaborated.[10]

Let me now consider the case for increasing Australia's submarine capability to meet the new strategic reality.

## Why nuclear propulsion?

The Australian Government has recognised the need for a regionally superior submarine capability.[11] This is a key planning consideration. The current program to double Australia's conventionally powered submarine capability was an appropriate recognition of this requirement: not only was a superior submarine design needed, but the boats needed to be acquired in sufficient numbers to be an effective deterrent.

The deteriorating strategic outlook justifies serious reconsideration of whether acquiring even the most advanced conventionally powered submarine will be adequate. Conventional propulsion systems don't have the same levels of flexibility, endurance and covertness that nuclear-powered submarines enjoy when operating in an environment characterised by advanced submarines, surveillance and acoustic systems. That's the environment that Australia's future submarines will operate in.

While a modern conventionally powered submarine is a formidable and flexible platform, it will be increasingly constrained in meeting the operational demands of the developing operating environment, owing in particular to greatly increased surveillance and networked antisubmarine warfare measures combining inputs from multiple sensors and platforms.

This increasingly challenging operating environment has significant implications for the deterrent impact of Australia's submarine capability, which must be designed and operated to overcome those antisubmarine measures. The deterrent value offered by our submarine capability will hinge on:

- an ongoing ability to access areas critical to an adversary
- an adversary's assessment of the capability's potential to inflict unacceptable harm to its interests.

Nuclear propulsion provides more options for government to create desired strategic effects and to manage tensions in contested circumstances.

This is not to denigrate the current effort to increase Australia's submarine capability via the Future Submarine (FSM) program; indeed, as outlined below, the technical complexities, manpower demands and long lead times to achieve a nuclear propulsion capability mandate growth in Australia's conventional submarine force as envisaged under the FSM program. It's an essential starting point for the transition to nuclear propulsion and will provide our frontline submarine capability for several decades until a future nuclear propulsion program can yield results.

This won't be a quick, cheap or easy technical process. The first question should be: Why bother to take on such an expensive and risky program?

Nuclear propulsion offers a quantum leap in submarine capability and its deterrent effect in two principal areas.

First, it offers unrivalled mobility:

- A nuclear-powered attack submarine (SSN) can deploy at two to three times the speed of a conventional submarine and thus spend more time on task.
- It can react to unfolding situations much more quickly.
- Once in a patrol area, the SSN can position itself for best effect, whether the requirement be search, surveillance, attack or evasion.
- It can reveal its presence to achieve an effect with a greater level of confidence that it can quickly and covertly redeploy after detection to retain the initiative.
- The strategic uncertainty that a conventionally powered submarine can create is greatly amplified by the SSN's mobility.
- A potential adversary must surveil a very much larger area when dealing with an SSN.
- The SSN can create, retain and exploit the initiative gained from its mobility.

Second, the SSN:

- operates independently of the surface, freed from the need to expose the submarine acoustically and to above-water surveillance by snorting to recharge batteries
- is able to operate undetected under intense space and air surveillance for much longer than a conventional submarine, which is limited by its dived endurance[12]
- is able to operate in circumstances in which a conventional submarine faces growing surveillance risks owing to low sea states and high densities of local craft.

A submarine's effectiveness depends on its stealth; the ability to deploy and operate covertly (unless and until exposure is justified to achieve a strategic effect) is critical. Given the reality of our geography, with typically long transits to operating areas, a nuclear-powered submarine's mobility and ability to choose to avoid exposing itself are significant advantages.

In addition, the SSN's much larger electrical power generation capacity offers significant advantages in powering sensors and command, control, intelligence and combat systems and allow it to operate as a mother ship or hub for remotely operated unmanned vehicles. Such drones are one of the new frontiers for submarine operations that will be the key to submarines' future effectiveness and survivability.

A quote from Admiral Sir John Eccles, Commander in Chief, Home Fleet, Royal Navy (RN), following NATO exercises with the USS *Nautilus* in 1957 is still relevant today:

> Not only has the nuclear submarine complete freedom of action in three dimensions; its ability to manoeuvre at high speed … far exceeds that of conventional submarines … she need not for days on end put anything on the surface … In her ability to attack and destroy submarines (conventional or nuclear) and surface ships she is vastly superior to surface ships and conventional submarines.[13]

This isn't to say that the conventional submarine is unable to complete its mission in these circumstances; however, conventional technology doesn't provide the same level of assurance that nuclear power provides. Higher levels of risk would have to be accepted by the government of the day if the missions are to be completed:

- In the event of counter-detection, the SSN's mobility enables it to break contact with much greater certainty and offers the opportunity for a later re-engagement.
- This is particularly important where the rules of engagement don't allow the submarine to engage or destroy its pursuers.
- In this situation, a conventional submarine risks being hunted until its battery is exhausted and it's forced to surface and withdraw, with the attendant publicity.
- Similarly sized SSN and conventional submarines, such as the French Barracuda and the planned conventional Australian FSM have similar ability to operate in shallow water. However, the SSN enjoys the advantage of not having to snort in the constrained littoral waters where observers, such as fishing fleets, are often present (which is very relevant in the places where Australian submarines may need to operate).
- The advantages enjoyed by an SSN would provide increased flexibility and a greater range of options for the Australian Government in all circumstances.

A simple speed/time/distance model illustrates the advantage of the SSN's mobility and covertness during the long transits routinely undertaken by Australian submarines. After completing an opposed 3,000-nautical-mile transit (that is, a transit during which the submarine is aiming to remain undetected), an SSN could be expected to spend 46 days out of a total of 60 days (77% of the total mission time) deployed on station. A conventional submarine in similar circumstances would typically provide from 30% to 47% on task (depending on the amount of disruption to snorting cycles experienced en route).

I end this section with another quote from 1957, the period when the RN contemplated the cost and benefits of the transition to nuclear power and assessed the revolutionary impact that nuclear propulsion had on submarine warfare. It's an appropriate summary:

> The Submarine has not only regained the advantage which it had over the surface ship before the advent of asdic[14] and anti-submarine weapons; but has become a flexible weapon of decision as opposed to one of chance encounter. At the same time, the difficulties of detecting and attacking it from the air or surface have become truly formidable.[15]

While that statement was made 50 years ago, it's true today.

To summarise the strategic capability advantages of an SSN and the most credible path to achieve such a capability:

- The current FSM program remains a valid and certainly the quickest way to increase Australia's submarine capability in the face of our deteriorating strategic circumstances.
- An SSN's mobility and ability to avoid exposing itself enable it to achieve significantly greater time on task compared to a conventional submarine. The longer the transit and the stronger the opposition, the greater this advantage.
- A force of modern SSNs would clearly establish Australia at the forefront of the region's growing submarine capabilities and indisputably establish a regionally superior submarine capability.

# ESTABLISHING AN AUSTRALIAN NUCLEAR-POWERED SUBMARINE CAPABILITY

The strategic capability benefits of SSNs come with significantly increased cost and technical complexity. This is particularly reflected in the workforce required to operate, maintain, monitor and regulate the capability. An accurate estimate of the cost is beyond the scope of this paper and can only be made with the detailed studies that this paper seeks. Quoting the cost that the US Navy or another navy pays for an SSN is not meaningful, as it would not include the many contributions from elsewhere in those organisations to cover the cost of training, education and regulatory supervision or the commercial charges and on-costs that might be levied for intellectual property and other inputs.

While an SSN force would provide strategic advantages, some quite formidable challenges would need to be to overcome to add such a force to the RAN. Quite apart from the political sensitivity of such a decision, it would be a protracted process requiring a lead time of 15–20 years before the SSN enters service. The lead time is driven largely by the technical, training and educational preparations and a very significant increase in personnel required to operate and maintain the force, as discussed below.

## Acquisition strategy

A decision on the acquisition strategy to be pursued would require a detailed investigation of the options, which are:

- leasing
- building offshore
- building in Australia and incorporating reactors purchased from the country of origin for the selected design.

Suggestions have recently been made that Australia could lease a small number of off-the-shelf SSNs from the US Navy. The proposal implies that the cost would be significantly less than for a build and that the arrangement could relieve Australia of responsibility for safety and maintenance. It also suggests that Australia could begin operating SSNs faster this way than under another option. Unfortunately, this proposal understates or ignores the issues involved:

- To maintain sovereignty and strategic flexibility, the Australian Government must be able to demonstrably and safely operate and sustain its submarine capability independently of a foreign government.
- Public concern about outsourcing safety would be widespread.

This welcome but misplaced suggestion for nuclear propulsion prompted an unusual public statement from the US Navy's Commander of the Pacific Fleet. It can be interpreted as a statement of concern:

> Admiral Swift said that when it came to nuclear power, safety was a 'no-fail' mission. 'We spend an extraordinary amount of resources ensuring the safety of nuclear power.'[16]

On a practical level, the US Navy has no surplus, serviceable SSNs to lease; nor has it shown any interest in selling them. Indeed, it's currently struggling to increase its construction rate to overcome a developing shortfall of SSNs as its existing 688-class submarines reach their end of life, having exhausted reactor fuel and hull life.[17]

Recent reports cite the possibility of South Korea developing an SSN using a smaller modular reactor.[18] This may present an opportunity for future collaboration.[19]

While there might be options to lease SSNs from other partner navies, these same arguments would apply in each of those cases.

We can conclude that the options for Australia to develop an SSN capability would be limited to building offshore or building in Australia but incorporating reactors purchased offshore. Leasing is not a practical option.

How to build the SSNs, and where, are beyond the scope of this paper; however, it's noteworthy that the Naval Group design being developed for the RAN FSM program has the benefit of the designers' experience on an existing SSN design now under construction for the French Navy. This may offer options for interclass synergy in a transition to nuclear propulsion.

## Providing the workforce for an SSN force: the most difficult challenge?

Applied to Australian career path modelling, the workforce models developed by our allies demonstrate that the lead time to develop the skillsets needed for the transition would be approximately 15 years.

To generate an Australian SSN force from scratch presents some significant political, technical, logistic and personnel challenges. Personnel are the key to resolving all these issues, so the focus of this paper is on personnel.

Recruiting small numbers of experienced personnel from friendly SSN operators (the US, the UK and France) may assist in starting the transition but wouldn't be sustainable as a long-term manning strategy, as there are already shortages of those key personnel in their parent navies and they're highly prized. There are also practical limits to growing the required number of Australian submariners by having them work within other navies, although both those paths will be useful complementary measures.

Successful development of the workforce will be fundamental to safety and capability. It will be a challenge for a nation of 25 million people and to be successful will need to be given an appropriate national priority.

There are three workforces involved:

- the submarine arm of the RAN to operate the submarines and provide primary oversight of their safety and education and training
- the industrial workforce to sustain them
- the independent auditing team to verify the adequacy of all aspects of the safe operation of the capability in the two other workforces.

The projected numbers and roles of personnel needed to populate the three workforces are set out in detail in Appendix 1 of this report. The information in the appendix is largely based on the SSN manning and training model of the RN, the operating and manning practices which most closely align to the RAN's.

## Sustaining this workforce: minimum force structure

Safe operation is a national responsibility and requires highly trained and experienced supervisors, auditors and trainers ashore.

For comparison, to achieve this the RN's and the French Navy's nuclear-powered submarine arms operate a mix of attack (SSN) and ballistic missile (SSBN) submarines for which each has a total of 12–16 crews. The overall number of personnel in the submarine arms is 2.6 times the number in the boats' crews. An informal update advises that the French Navy has moved to a crewing ratio of 3.0 to improve conditions of service and retention. This can be referred to as the 'crewing ratio'.

The RN and French Navy experience demonstrates that the ‘12–16 crews plus a crewing ratio of 3.0’ model constitutes the minimum critical mass of trained personnel that’s essential for a resilient manpower base to safely operate the capability. However, even at that higher level, both navies sustain their submarine arms with difficulty, using additional financial incentives to retain key personnel.

Both face the additional complication of operating more than one class of submarine and of sustaining a ballistic missile capability. Given that Australia would be manning only one class of SSN, it’s considered that the minimum critical mass of trained personnel could be sustained by operating at least 10 SSNs and crews. Greater manpower resilience would be achieved by double-crewing the operational SSNs (that is, six out of 10), with one crew in each of the four submarines in maintenance routines, leading to a total of 16 crews.

Modelling of career paths indicates that a force size of fewer than 10 single-crewed SSNs wouldn’t be able to generate the trained personnel needed to maintain operations while compensating for attrition.

Furthermore, any force smaller than 10 SSNs and crews, even with double-crewing, won’t sustainably generate the number of experienced engineers, technicians or command-qualified officers needed for its safe operation; nor would it generate sufficient personnel with the right experience to man the senior posts needed to maintain a nuclear safety and training organisation that could satisfy today’s stringent international standards.

It’s likely that a condition of sale for the boats’ reactors would require the Australian Government to comply with the nuclear safety regime of the reactors’ country or navy of origin. Under the conditions of sale for the reactor, Australia would have to commit to similar manning and supervisory structures.

To allow for differences between the RN and French Navy models and the postulated minimalist single-crewed RAN manning model, it’s prudent to use a conservative crewing ratio of at least 3.0. It could be reasonably argued that the RAN should aim for more than 10 crews by double-crewing to provide increased manpower resilience.

These assumptions have been applied in the manning model discussed in Appendix 1. That model has applied realistic attrition rates found to apply in operating the Collins and Oberon classes, which clearly demonstrated that there’s a critical mass below which a trained submarine workforce can’t be sustained.

A simple speed/time/distance model demonstrates that a force of 12 double-crewed SSNs would typically provide four SSNs on station at long range. This is a significant deterrence and if required, strike capability.

In summary: A force of at least 10 SSNs and crews is needed to maintain a critical mass of trained personnel and to generate the experience needed to produce the senior supervisory and policy staff needed for a globally credible nuclear safety organisation. Double-crewing the operating SSNs using 16 crews would increase manpower resilience and should be considered.

## Total personnel requirement

Given the need for 10 SSNs in order to maintain the critical mass of trained crew, and setting aside political and technical considerations about which allied SSNs would be available for sale or to build, we can return to the question of ‘Which SSN?’ in the context of crew size and hence the total size of the submarine arm.

Using the crewing ratio of 3.0 and an SSN force of 10 of the larger SSNs—for example, the US Navy Virginia class (complement 121) and the RN’s Astute class (complement 98)—would lead to a submarine arm of at least ~3,600 or ~2,900, respectively. Double-crewing as discussed above would increase the force size to ~5,800 or ~4,700, respectively.

The French Barracuda class currently being built is expected to require a complement of 60, producing significant reductions in crew numbers through the use of a simpler (and quieter) turbo-electric power train. RAN experience and practice is to provide a ‘fourth watch’ of additional personnel to provide flexibility for the commanding officer to manage manpower issues onboard and to improve resilience and retention. For planning purposes, a crew size of 75 is suggested. This would result in a total submarine arm of ~2,250 or about 14% of the RAN's total strength of, say, 16,000, if it's increased by 1,100 to man the 12 FSMs or 10 SSNs. A double-crewed force of 10 SSNs (that is, with 16 crews) would result in a submarine arm of ~3,600, or ~16% if the RAN were increased to, say, 17,900 to man the expanded submarine arm.

In summary: A force of 10 SSNs would require a submarine arm of at least 2,250, or some 14% of the RAN's total strength. Greater manpower resilience would be achieved by double-crewing the operational SSNs, resulting in a submarine arm of 3,600, or 16% of an enlarged Navy.

## Transition issues

The RAN is currently envisaging a transition from operating six Collins-class boats with 4–5 crews, resulting in a submarine arm totalling ~600 to operate 12 FSMs. Anticipating that the FSM will have a complement of at least 60 and applying the same crewing factor of 3.0, the longer term steady-state strength of the submarine arm can be expected to rise to at least 2,160, which is very similar to the number for 10 RAN Barracuda SSNs with crews of 75.

For strategic reasons and to enable the training of submarine personnel, it's essential that this uplift in manpower is not achieved at the expense of the current operational capability of the Collins class. While it will be possible to draw on the skills and experience of the current submariners, if they're to be redirected into the FSMs they must first be replaced by additional appropriately trained personnel. To do otherwise would diminish the operational capability of the existing submarines and take us even further below the critical mass of trained manpower. In strategic terms, of course it would be unwise to be seen to be planning a period of reduced capability.

Lifting the overall submarine arm's trained strength in this way to at least ~2,160 to man 12 conventional submarines would be a safe and practical starting point for manning the training and education pipelines to commence a transition to nuclear-powered submarines. Ten SSNs, single-crewed with, say, 75 in each, would lead to a submarine arm of at least 2,250. Again, the arrangements would require sound management to ensure that the operational capability of the 12 FSMs doesn't suffer during the transition. This force would then be used to generate the additional crews required by double-crewing, should that be adopted.

A force of at least 12 conventional submarines, each with a crew of 60, and a total submarine arm of at least 2,160 personnel would provide a viable starting point for a transition to a force of 10 SSNs, each with a crew of 75. There's no short cut. The FSM is the essential starting point in both strategic and manpower terms for the acquisition of a nuclear-powered submarine capability for Australia.

## Design selection

Without prejudging the design selection for an Australian SSN, the selection of the French Naval Group to design the FSM presents an opportunity and could facilitate a future transition to nuclear propulsion. Note: this is a serendipitous situation; nuclear power wasn't a factor in selecting the French designer for the FSM.

Naval Group is also the designer and builder of the French Navy's Barracuda-class SSN, and that may facilitate the integration of RAN FSM systems, such as combat systems, some platform systems and weapons, using Australian supply chains and reducing transition impacts and costs.

The selection of Naval Group as the designer of the FSM presents an opportunity to investigate the option of integrating FSM systems and supply chains into a modified SSN.

## Timing of the transition

The timing of a transition requires a level of detailed planning and understanding that's beyond the scope of this paper and requires further study. The timings below are indicative but deliberately conservative.

In the face of deteriorating strategic circumstances, the consequent need to transition to SSNs expeditiously and the reality that the growth of the submarine arm via the FSMs is essential to starting that transition, it's self-evident that the FSM program must be accelerated. As Paul Dibb has written:

> Australia needs to refocus on its own region of primary strategic concern, building the military capability to ensure that we can deny our vulnerable approaches to any potential adversary—including China.[20]

This will require the FSM build to have:

- priority over other shipbuilding projects (the impact on other shipbuilding projects should be assessed in reaching a decision about this)
- an accelerated cash flow to match the new timings
- fast-track construction of the shipbuilding yard and supporting facilities.

Provided the current transition to 12 FSMs is accelerated, it would be possible to achieve a force of 12 conventional submarines (say, six FSMs and six Collins) by 2036. This assumes that:

- the six Collins-class submarines undergo a life of type extension
- the first FSM (FSM 01) is commissioned no later than 2030[21]
- after a gap of two years to FSM 02 to allow rectification of the issues arising during the sea trials of FSM 01, the subsequent FSMs are commissioned at one-year intervals.

This is discussed in further detail as 'Option 3—pulling out the stops' in the ASPI Special Report, *Thinking through submarine transition*, by Dr Marcus Hellyer.[22]

It would then (in 2036) be possible to commence the transition to an SSN force. Allowing for the construction of the first SSN and for training, it should be possible to achieve a conservative commissioning target of 2044. Sustaining the submarine operational capability will require building 12 FSMs as planned to preserve that capability and manpower numbers during the transition. The proposed studies should inform this consideration, which could become more apparent as the transition unfolds.

The FSM program also provides a valuable backstop, sustaining Australia's submarine capability should the transition to SSNs be delayed.

If the acquisition of an SSN capability is made a priority and the appropriate resources are dedicated to achieving it, the first Australian SSN could be commissioned by 2044. This is an ambitious plan that would require a national priority and focus to achieve and an in-principle decision to facilitate the option no later than the mid-2020s.

This would allow national priority to be given to a training program capable of generating the personnel needed to build and commission SSN 01 by 2044. An earlier decision would enable the nuclear-power requirements to influence the design and construction preparations for the conventional FSM and its shore construction facilities from its initial stages to maximise synergy with the follow-on SSN design.

To meet the build program target, it would be necessary to complete the design, identify the production capability and place an order for SSN 01 in, say, 2032, after which construction would be expected to start no later than 2034.

So that an informed decision can be made by 2020, it will be necessary to commit resources to conduct full and detailed feasibility studies with a view to completing those studies in advance of the 2020 deadline. The studies will have the added advantage of informing public debate on the issue.

An immediate decision is needed to commit the resources to conduct feasibility studies into a transition to nuclear propulsion. The delivery target for the studies should be 2020.

The current FSM program should be accelerated to meet the changing strategic circumstances and provide the manpower base for commencing a transition to nuclear propulsion if that course of action is selected.

To commission the first Australian SSN by 2044 would require an in-principle decision by the mid-2020s to allow the initiation of a training program and to capitalise on the FSM design process. This would enable an order for the first SSN in 2032.

## The lack of an Australian nuclear power industry

The UK, US and French navies transitioned to nuclear propulsion from large post-World War II fleets of conventionally powered submarines and surface ships. Those forces were a rich source of personnel with the right experience and qualifications. The three countries developed their military nuclear power programs in parallel with the development of their civilian nuclear power industries, which presented much scope for synergy and economy for their navies.

While the nuclear power industry provided a broader base for the necessary education, training and regulatory institutions, the two capabilities were operated largely independently of each other. However, in their early days the atomic energy authorities of those countries exercised much influence over the development of safe military nuclear power programs.

In the absence of a nuclear power industry in Australia, with its attendant framework for regulation, the cost of establishing and maintaining the education, training and regulatory institutions for a nuclear-powered submarine arm would have to be borne by the RAN. Those costs should be included in any assessment of the implications of transitioning to nuclear-powered submarines.

In maintaining the trained strength of an SSN force, there can be a disadvantage in having a civilian nuclear power program, which can attract the most critical categories of technicians away from the Navy. Thus, ironically, the absence of an Australian nuclear power industry could be an advantage.

A supporting Australian nuclear power industry is desirable, as it would provide a broader regulatory, technical and educational national base. However, provided the costs of not having that support are clearly identified, the absence of a domestic nuclear power industry should not preclude a transition to nuclear propulsion for Australia's submarines.

## Public perceptions

The implications, positive and negative, of nuclear propulsion ownership by Australia aren't well documented, with the result that public commentary can be misdirected. Furthermore, the lack of information on the option could lead to delays in committing, which would mean that a valuable strategic opportunity will be missed.

While this paper is intended to demonstrate the urgency of the need for detailed studies based primarily on the need for early initiation of a manning and training program, there are wider and significant political, technical, logistical and financial issues to consider. Those issues should all be included in the feasibility studies.

The information derived by studying the option could not only be used to inform the government's strategic decision-making, but could also lead to a better informed public debate.

## Cost

The cost of the acquisition and sustainment of a nuclear-powered submarine capability for Australia would be significant. We can reasonably conclude that 10 SSNs will be more expensive than a force of 12 FSMs. Whether the gain in capability justifies the expense is unknown at present.

Given the quantum leap in capability that SSNs provide, the dramatic shift in Australia's strategic circumstances and the proliferation of submarines in regional navies, the question should certainly be accurately answered.

The most reliable method to estimate these costs is a detailed study of both options that considers the various issues as they apply to Australia. Notably, the unit cost of SSNs provided to the US Congress is misleadingly low, as it doesn't include many of the commercial or on-costs that would be incurred by an Australian program.

The manning, training, technical, financial, logistical and political aspects of equipping Australia's future submarines with nuclear or conventional propulsion should be included in the feasibility studies in order to inform public debate and political decision-making.

# APPENDIX 1: ILLUSTRATIVE MANPOWER REQUIREMENTS FOR 10 SSNS

The manning details given in this appendix have been modelled on the RN structure used to sustain, operate and monitor a force of SSNs and SSBNs employing 12–16 crews.

Manpower numbers should be regarded as illustrative, rather than as precise figures. Numbers have been rounded up to avoid giving a misleading impression of precision.

Manning the capability will be fundamental to its safety and success. This will be a challenge for a nation of 25 million people and must be treated as a national project. That means that the necessary resources must be forthcoming to ensure success.

Three workforces would be involved:

- The uniformed submarine arm of the Navy would operate the submarines. This includes providing primary oversight of their safety and conducting their supporting workforce's education and training.
- An industrial workforce would sustaining the capability.
- An independent auditing team would verify the adequacy of all aspects of the safe operation of the capability in the two other workforces.

## Operational uniformed manpower

### The submarine arm

The overall size of a navy's submarine arm is determined by the number of personnel in the seagoing crews.

Based on studies in 2013 of the RN and French Navy nuclear-propelled submarine arms (which are similar in both size and their mixes of SSNs and SSBNs), a useful rule-of-thumb for the overall number of personnel in the submarine arm is 3.0 times the number in the 13 crews. That crewing ratio is used in this brief.

An SSN crew is significantly more technically and educationally qualified than a conventional submarine's. For example:

- each SSN carries two command-qualified officers, five marine engineers (including two qualified chief engineers, known as 'charge engineers' in the RN), compared with one command-qualified officer and a charge engineer in each conventional boat
- each SSN also carries highly experienced nuclear technicians and steam propulsion experts not found in a conventional submarine.

## Submarine Squadron staff

The Submarine Squadron staff provide the first level of training, supervision and support in operational, technical and safety matters. The Squadron Commander certifies a submarine and its crew as ready to conduct a defined level of operations.

Within the enlarged RAN submarine arm, an increased number of personnel would be required for supervising and supporting the operational crews and as trainers and educators.

- The growth from six to 12 conventional FSMs will also require an increase in squadron manning of a similar order.
- In the case of 10 SSNs, compared with the squadron managing six conventional submarines, it would grow in number by ~100 to ~210.

While this increase can be provided from within the total size of the submarine arm (that is, 3 × crew number), the growth in skills and experience over that of a conventional submarine squadron would be significant.

## Incident response teams

The requirement for incident response teams is new. Radiation protection incident response teams monitor and protect the health of the nuclear power plant operators and ensure that there's no risk to the public of exposure to harmful ionising radiation. This is a part of the safety ethos associated with the ownership of a nuclear power plant.

To fulfil this function, the RAN will need a responsible radiological protection team linked to an appropriate nuclear medical institution.

Three uniformed incident response teams would total ~40 personnel at the RAN's home port, providing a round-the-clock capability.

These teams would be supplemented by manpower drawn from the squadron, the nuclear repair facility and the submarine school co-located at the operational base.

The teams would have a mobile function to cover other port visits.

## Submarine policy areas

There would be growth and some new roles in the policy areas in Canberra:

- The Nuclear Training and Safety Panel is a new function made up of ~20 senior and experienced personnel overseeing all nuclear training and safety in the Navy.
- The Submarine Capability Branch is responsible to the Chief of Navy for the safe and effective delivery of the agreed level of submarine capability, within allocated resources.
- The current branch would grow slightly to ~125.
- This growth is in senior/experienced personnel for the new role.

## Design authority liaison team

Assuming that Australia remains dependent on the supplier navy for design authority, a design authority liaison team would provide an RAN interface with the supplier design authority and be a conduit to the RAN and its major maintenance facilities, with qualified personnel in the supplier navy design authority and Australia:

- It's assumed that the submarine design authority, which also has responsibility for nuclear safety within the design, remains with the supplier navy and its design authority for the SSN.
- This will involve approximately 25 senior/experienced uniformed and civilian personnel (say, 10 uniformed and 15 civilian).

### Naval technical training

It's estimated that an additional ~20 experienced personnel would be added to the Navy's existing technical training organisation at HMAS Cerberus to instruct on nuclear reactor and steam plant operations.

- A reactor simulator is used in the RN for this purpose.
- The US Navy uses decommissioned SSBNs.
- The French Navy uses a shore base reactor in addition to simulators.

### Total additional uniformed manpower

An additional ~180 uniformed and 15 civilian personnel would be required, compared to the current structure for operating six Collins-class boats.

- Many of these personnel would be highly experienced, senior personnel.
- By comparison, a force of 12 conventional submarines would probably require an additional ~140 people compared to the existing structure.
- The nuclear repair facility discussed below would require an additional ~110 uniformed personnel.

## Industrial workforce: uniformed and civilian

In addition to the traditional shipyard workforce, Australia would also need to develop a nuclear submarine repair facility at the refitting shipyard (presumably in Adelaide). A team should be provided at the facility that handles major overhauls and repairs.

It's worth noting that the Barracuda would be particularly dependent on uniformed and civilian industrial support, given its small crew size.

While the model developed by the French Navy for supporting its SSNs is very like that developed for Collins support, this would be a particular area for examination during the feasibility studies.

### Nuclear repair facility

The nuclear repair facility is a licensed intermediate-level[23] technical facility for routine maintenance and defect rectification of reactor systems. This is an essential facility to maintain the safe operation of the reactors and their associated systems.

- The nuclear repair facility must be readily accessible to the operational submarines and those undergoing deeper refit or repair at the major shipyard facility.
- Two sites would be required for supporting 10 SSNs: one adjacent to or co-located with the operational base at HMAS Stirling and the second at the shipyard, presumably in Adelaide.
- Both sites require the ability to dock an SSN.

The nuclear repair facility adjacent to the home port would be wholly uniform-manned and would require ~110 personnel.

It's assumed that the second nuclear repair facility at the shipyard would make use of the civilian shipyard workforce.

- This facility would require ~130 personnel.
- The RN uses a mix of civilian and uniformed personnel.
- For the benefit of this exercise, a mix of 100 civilian and 30 uniformed personnel is assumed.

## Shipyard incident response team

A nuclear incident response team of similar capability is required at the shipyard. It's probable that this would be considered a civilian function in that location, but training and certification are likely to be of the same origin and the team is like to be of similar size (~40 people).

## External verification team

The Australian Nuclear Safety and Technology Organisation (ANSTO) is responsible to the Minister for Industry, Science and Technology for nuclear safety in Australia. Its role would be expanded to provide independent auditing of nuclear safety by ~20 experienced personnel through a Nuclear Safety and Reliability Directorate.

The directorate is a new function to be established to support the government in discharging its responsibility for material nuclear safety:

- In the UK, it's civilian manned and located in the Office for Nuclear Regulation. It's a directorate of the Health and Safety Executive, which is responsible to the Minister for Employment.
- It comprises experienced, senior civilian nuclear engineers or former RN reactor operators.
- In the absence of a nuclear power industry, the equivalent of this group would have to be developed from Australia's ANSTO and Australian Radiation Protection and Nuclear Safety Agency (ARPANSA) structures with additional recruiting from overseas, or developed from within the RAN training program.

## Illustrative manpower totals

The total of ~400 additional personnel ashore compares with the 154-person ashore manpower allocated for six Collins-class submarines.

- ~220 are uniformed personnel, and ~180 are civilian.
- Adding the 600 personnel in the crews to this total, the balance of uniformed personnel in the 1,800-strong submarine arm are in the training/education system, taking leave, employed outside the arm, and so on.
- The size of the industrial workforce to support the minimum-manned Barracuda requires further examination during the recommended feasibility studies.

# APPENDIX 2: INDICATIVE TRAINING AND EDUCATION IMPLICATIONS

The course structure outlined in this appendix is modelled on that of the RN, the officer and sailor structure of which equates most closely to the RAN's. It's intended to show a typical array of training and education courses.

The training and experience combine to provide the right degree of expertise to operate SSNs under all envisaged routine and emergency scenarios. This is achieved through a hierarchy of nuclear watch-keeping categories, which also provide career paths for the personnel of both the required engineering disciplines (marine and mechanical).

A summary of the nuclear watch-keeping categories is provided in Table 1, at the end of the appendix.

The training regime for the minimum-manned Barracuda-class SSN requires more detailed examination during the recommended feasibility studies.

## The training course hierarchy

### Nuclear Reactor Course

#### Purpose

The Nuclear Reactor Course is a one-year postgraduate course covering the technology, theory, physics and operation of submarine nuclear reactors.

- Taught in two parts, it comprises six months of reactor theory followed by six months of plant operator training.
- It's mandatory for a Marine Engineering Officer—submarine (MEOSM) seeking the Engineer Officer of the Watch qualification. In the RN, the theory section must be delivered by a suitably accredited university faculty operating under contract and able to award course graduates with a postgraduate diploma.[24]
- The course requires the use of a reactor simulator that's used to model the live reactor; a live reactor is not required, which precludes safety issues that might arise from a working reactor in a shore training facility.
- The second part of the course consists largely of plant operation training, for which a manoeuvring room team trainer will be needed. This models both the primary and secondary plant and hence can be used to simulate both standard and emergency operating procedures.
- Experienced plant operators teach this element of the course.
- This one-year package equates directly to the US Navy's 'Nuclear Theory and Prototype' package.
- This course will best be conducted in a naval training environment, delivered by attached, resident university staff.
- A throughput of 24–31 trainees per year is estimated to be needed for a force of ten SSNs.

#### Overseas training

Provided excess capacity exists overseas and the reactor technology is appropriate, the initial batch of training to prepare instructors and the crew for the first SSN could be undertaken at a suitable overseas navy training facility.

- Thereafter, economics, this course's synergy with the Nuclear General Course discussed below and the need for self-sufficiency would dictate that it be repatriated.

The postgraduate Nuclear Engineering course offered at the University of NSW could provide a basis for repatriation.

### Nuclear General Course

#### Purpose

The Nuclear General Course provides training in nuclear technology at a level suitable for Warfare Branch, Weapons Engineer and Supply officers.

- This four-month course must be delivered by a suitably accredited university faculty.
- It requires the use of a reactor simulator; a live reactor is not required.
- There's significant commonality in staffing between the Nuclear Reactor Course and the Nuclear General Course, such that in the interests of efficiency the two courses should be co-located, preferably at a naval training site, and delivered by resident staff from a suitably accredited university.

#### Throughput

A throughput of 46–70 trainees per year is estimated for a force of ten SSNs.

#### Overseas training

Provided excess capacity exists overseas and the reactor technology is appropriate, the initial batch of training to prepare instructors and the crew for the first SSN could be undertaken at a suitable overseas navy training facility.

Thereafter, economics, this course's synergy with the Nuclear Reactor Course discussed above and the need for self-sufficiency would dictate that it be repatriated.

### Nuclear Advanced Course

The Nuclear Advanced Course is a one-year Master of Science degree in nuclear engineering.

- It isn't part of the mandatory nuclear training pipeline, but provides a desirable retention option for those with the intellect and an interest in further study.
- In the RN, most of these courses are done after the Assistant Marine Engineering Officer or Deputy Marine Engineering Officer posting, hence assisting in retention before the final Chief Engineer (Charge Engineer) MEOSM+ sea posting.
- It prepares officers for the more senior staff engineering postings and provides enhanced credibility to the Navy's standing in the nuclear engineering policy environment.
- The Nuclear Advanced Course can also be used to explore technical options for plant modifications, future design or other associated technology.

All postgraduate nuclear engineering education must be delivered by a suitably accredited university.

- Currently, Australia has postgraduate nuclear physics faculties located at the Australian National University in Canberra and the University of Sydney.
- However, neither delivers this type of course at this time. Given the small number of students, the RAN is likely to benefit from an overseas delivery.
- This should also add to the inducement value and external status of the qualification.

## Nuclear Technician Long Course

### Purpose

The eight-month Nuclear Technician Long Course is used to prepare qualified and experienced nuclear watch-keepers to oversee reactor technicians (sailors) and to certify them as Category B and subsequently Category A2 watch-keepers. These levels are explained in Appendix 1.

### Delivery

The course is undertaken within the naval training system, not a university environment.

- There's benefit in co-locating it with the Nuclear Reactor Course and the Nuclear General Course, since these courses all make use of the same manoeuvring room team training simulators.
- The course is predominantly focused on nuclear power plant operations, for which it will require access to a manoeuvring room team trainer.

### Throughput

A throughput of 25 trainees per year is estimated to be needed to sustain a force of 10 SSNs.

- This figure is based on the throughput needed to sustain the force of 10 SSNs and squadron functions. A person who completes the course is expected to have two postings as a Category B watch-keeper before they leave the submarine arm or apply to become a Category A watch-keeper.
- An attrition rate of 20% is assumed.

## Nuclear Technician Short Course

### Purpose

The four-month Nuclear Technician Short Course is used to train nuclear reactor technicians and qualify them as Category C reactor watch-keepers.

### Delivery

This course is undertaken within the naval training system, not a university environment.

- There's benefit in co-locating the Nuclear Technician Short Course with the Nuclear Reactor Course, Nuclear General Course and Nuclear Technician Long Course, since these courses all make use of the same manoeuvring room team trainer simulators.
- The course is predominantly focused on nuclear power plant operations, for which it will require access to a manoeuvring room team trainer.

### Throughput

A throughput of 30 trainees per year is estimated to be needed to sustain a force of 10 SSNs.

- This figure is based on the throughput needed to sustain the force of 10 SSNs and squadron functions. A person who completes this course is expected to have two postings as a Category C watch-keeper before they leave the submarine arm or apply to complete the Nuclear Technician Long Course to become a Category B watch-keeper.
- A 40% attrition rate is assumed.

## Basic submarine training model

Basic submarine training follows a similar sequence to current RAN submarine training, although the content may vary somewhat depending on the candidates' ranks and specialisations.

- All personnel undertake this training.
- There are separate courses, with different content, for officers and sailors.

### Part 1: Submarine training

This three-month course teaches submarine principles and is taken by all submarine personnel.

- The course is delivered in a dedicated submarine training school operated as part of the naval training system.
- Officers and sailors take different Part 1 training courses, but a common element of both is submarine escape tank training.
- It's currently customary to make completion of submarine escape tank training the milestone for commencement of submarine pay.
- Officer throughput: The likely annual training load for officers' Part 1 training is 58–70 officers, which is a significant increase over the current throughput of 8–12 officers per year.
- Sailor throughput: The likely annual training load for sailors' Part 1 training is 140–160, which is a significant increase over the current throughput of 40–50 sailors per year.

### Part 2: Technical category training

The Part 2 course trains officers and sailors in particular technical aspects of their duties on a submarine.

- The courses are delivered in a dedicated submarine training school operated as part of the naval training system.
- Content varies according to the officer's specialisation or the sailor's category. An allowance of three months is used in the modelling.
- The Marine Technician Part 2 includes an introduction to nuclear principles to enable these personnel to serve as Category D watch-keepers after they qualify.

### Part 3: At-sea qualification

The Part 3 at-sea training and assessment is the final step in the initial submarine training pipeline.

- The Part 3 training is a 'choke point' in the training pipeline and demands careful management.
- It requires bunk space in a seagoing submarine and a suitable program of basic training as well as experience in routine submarine operations.
- A dedicated training submarine has been tried and found lacking in imparting the necessary real-world experience.
- Efforts to shorten this process by greater use of shore simulators are worthwhile. However, simulator training has been found to reach a practical boundary: the familiarity, confidence and trust required to become an effective submarine crew member can only be achieved with sea time.
- Passing a final practical assessment board, conducted by the senior sailors and officers of the submarine in which the candidate will probably then serve, is an important 'rite of passage' for the trainee and, importantly, can be a final weeding process for candidates who don't fit in psychologically.

The submarine's accommodation and escape equipment capacity provide finite limits to the number of personnel who can be carried. The ability of the submarine's crew to deliver the training and supervise the trainees must also be considered.

The crew of a submarine on an operational mission is generally heavily loaded, which limits crew members' capacity to oversee training. Furthermore, if the mission requires the carriage of additional specialist teams, there must be a reduction in the number of Part 3 trainees on board.

The regime of sea acceptance trials on the completion of the submarine build is also unsuitable for carrying trainees, as an experienced team is needed to operate the systems under what are often degraded conditions. No trainees should be programmed to be carried until after commissioning.

The scheme of complement for a Virginia-class submarine includes 16 billets for trainees.

It's likely that a further 10 could be carried in spartan accommodation, but maintaining an effective training program for a total of 26 trainees would be demanding for a submarine crew whose priority is to perform operational tasks.

### Pre-joining training

A significant amount of equipment-specific pre-joining training to fit a submarine-qualified sailor for a particular posting will also be required.

- This must be tailored to the individual's skills and experience and the new equipment that they'll be dealing with in their next posting.
- An arbitrary allowance of one month is allocated in the manning models used to develop these numbers.

A manpower planning allowance must be made for the provision of short-term relief for those obliged to leave their submarines for professional training courses.

- Conventionally, it's assumed that an absence greater than one week will require a formal relief, although this requires close management so that the relief is suitably qualified. This may require the movement of candidates through other submarines of the squadron.

## Recertification for returning nuclear power plant operators

Nuclear power plant operators are required to be current in their watch-keeping position qualification before being left unsupervised in that position on a critical reactor.

- If they don't keep a watch in that position for six months (for example, due to being appointed to a shore job or training course), they're obliged to undertake a requalification process.
- This regulation, while essential to the safety of operations, places a heavy burden on the managers of the marine engineering department to ensure that the minimum numbers needed to operate the reactors (both shut down and critical) are sustained.
- If a submarine is out of operation for a period longer than six months (due to a defect or other constraint), programs for simulator training and assessment must be established or, alternatively, personnel can be sent to sea in sister submarines to maintain their qualifications.
- Requalification requires 3–4 months of training, followed by a practical assessment identical to the initial qualification.

## Training pipeline allowance

An allowance has been added to the length of the training pipelines used in developing these numbers to allow for time delays caused by mismatches in course programming and other delays.

## Overseas training allowance

If, as is expected particularly in the early days, the RAN uses an overseas-based university or training school, two months should be added to the pipeline time for travel and settling in and out.

## Lessons from the past

Any plans to increase the size of the RAN's submarine arm, whether with conventional or nuclear-powered submarines, must include a practical and achievable manpower plan. In the same paper on the implications of the FSM project and its growth to 12 submarines, it's argued that experience with the Oberon class and ongoing experience with the Collins class demonstrates the need to:

- sustain the highest at-sea tempo possible during the build-up and the transition phase
- initiate a long-term steady development of the number of crews by multi-crewing these platforms
- avoid a reduction in the number of operational submarines during the transition (that is, replace the old platforms with new submarines).

## Growing pains

Meeting these criteria would be particularly challenging during a transition from a Collins-class submarine force to an SSN force in which each crew is more than double the size. Nor would simply combining two Collins crews provide the right balance of skills for one SSN crew. Surpluses in one area (such as an excess of Warfare Officers) will be offset by shortages in others, such as two Lieutenants Marine Engineering against a requirement for four Lieutenants (ME) and one Lieutenant Commander (ME) for each SSN crew. The imbalance would be most notable in technical sailors manning the propulsion plant, where the numbers, mix and skills are significantly different. Rectifying the imbalance won't be easy or quick; the required training will be lengthy.

## Marine engineering: the most challenging?

The RN Marine Engineering Officer—submarine (MEOSM) training pipeline involves new-entry naval training, an engineering degree, postgraduate nuclear training and submarine training.

- As the final step, the potential MEOSM is examined at an Engineer Officer of the Watch Board presided over by the Submarine Squadron to assess the candidate's readiness to take on the responsibility of being an Assistant Marine Engineering Officer.
- Assuming the trainee proceeds smoothly through the pipeline, without back-classing, the initial training pipeline takes 6.5 to 7 years, with an allowance for pipeline inefficiencies.

The qualified MEOSM then undertakes a sequence of sea and shore postings, progressing through three years as an Assistant MEO, after which they complete their charge qualification, enabling them to become a 'Chief Engineer'.

- This leads to a posting as a Deputy MEO before they're assessed as fit to be appointed as an MEOSM+ in charge of the nuclear plant.
- Without any allowance for pipeline inefficiencies, this will take an additional nine years (that is, a total of 16 years from initial entry to MEOSM+).
- For comparison, the US Navy model appears to achieve this in a shorter period but, realistically, the US Navy Ship's Engineer equates more closely to the RN Deputy MEO. The US model relies on the depth of engineering experience in the executive and commanding officers to back up the engineering officer.
- For interest, the charge qualification is recognised by engineering institutes such as the Institute of Marine Engineering Science and Technology as the level at which the subject may apply for chartered engineer status.

Each RN SSN has five MEOs in its scheme of complement: a Lieutenant Commander serving as the Chief Engineer or MEOSM+ in charge of the department and four Lieutenants (a Deputy MEO and three Assistant MEOs).

- The Deputy MEO is fully qualified and able to deputise for the MEOSM+, providing redundancy in this important billet.
- Five MEOs provide sufficient numbers to meet the at-sea watch-keeping requirement and to oversee shut-down watch-keeping during maintenance periods.
- This growth from one to five MEOs on each submarine has significant implications for the RAN requirement for engineering graduates.

## RAN requirements for engineering graduates

An estimate of the RAN's current need for MEOs in its ships and squadron shore support staff, either as graduates or by promotion from the ranks of enlisted marine technicians branch specialisations, assuming a two-year first appointment as Lieutenant, would require the recruitment of 14 marine engineers per year. Removing the Collins requirement, the surface fleet would require 12 Lieutenant marine engineers per year.

The model developed for the SSN Chief Engineer (Charge Engineer or MEOSM+) requirement indicates that 15 new marine engineering graduates would be required annually to sustain 10 MEOSM+, each serving a two-year posting in the SSN force.

- Adding this to the 12 required for the surface force, the Navy's recruitment of graduate mechanical or marine engineers would increase from 14 to 27, effectively doubling the current fleet recruiting requirement.
- A fourfold increase would be required to achieve the numbers estimated for the current surface fleet plus a force of 10 SSNs.

Table 1: Hierarchy of nuclear power plant watch-keeping qualification categories

| | | | | | |
|---|---|---|---|---|---|
| **Category A1** | Warrant Officer, SBLT, LEUT, LCDR or CMDR | AMEO, DMEO, MEO acting as First Engineer Officer of Watch (EOOW1) | Bachelor degree in marine engineering | Submarine Pt 1, SETT, NRC, operator courses | Submarine Pt 3 and at-sea qualifying time of >3 months |
| **Category A2** | Charge Chief Petty Officer Technician or Warrant Officer | Charge Chief Technician acting as Second Engineer Officer of the Watch (EOOW2) | Four-year apprenticeship in marine or electrical engineering<br>(Cert. IV or Diploma) | Submarine Pt 1, SETT, NPLC, operator courses<br>At least 2 years experience as a Cat. B operator | Submarine Pt 3 and at-sea qualifying time of >3 months |
| **Category B** | Chief Petty Officer Technician | Reactor Panel Operator or Artificer of Watch (in charge of primary system operations) | Four-year apprenticeship in marine or electrical engineering<br>(Cert. IV) | Submarine Pt 1, SETT, NTLC, operator courses.<br>At least 1 year experience as a Cat. C operator | Submarine Pt 3 and at-sea qualifying time of >1 month |
| **Category C** | Petty Officer Technician | Electrical Panel Operator or Engine Room Artificer (in charge of secondary steam system operations) | Four-year apprenticeship in marine or electrical engineering<br>(Cert. IV) | Submarine Pt 1, SETT, NTSC, operator courses<br>At least 4 weeks experience as a Cat. D operator | Submarine Pt 3 and at-sea qualifying time of >1 month |
| **Category D** | Seaman or Leading Hand | Engine Room assistant,Electrical assistant | Technician certification Marine or Electrical<br>(Cert II or III) | Submarine Pt 1, SETT, equipment-specific pre- joining training | Submarine Pt 3 and at-sea qualifying time of >1 month |

RC = Nuclear Reactor Course; NTLC = Nuclear Technician Long Course; NTSC = Nuclear Technician Short Course; SETT = submarine escape tank training.

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24 In the US Navy, serving personnel deliver this training.

# ACRONYMS AND ABBREVIATIONS

| | |
|---|---|
| ANSTO | Australian Nuclear Science and Technology Organisation |
| FSM | future submarine |
| MEO | Marine Engineering Officer |
| MEOSM | Marine Engineering Officer—submarine |
| RAN | Royal Australian Navy |
| RN | Royal Navy |
| SSBN | ship, submersible, ballistic, nuclear (nuclear-powered ballistic missile submarine) |
| SSN | ship, submersible, nuclear (nuclear-powered fast attack submarine) |

**Can Australia afford nuclear propelled submarines?**
Can we afford not to?

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