SEA 1000

Design Options for the Royal Australian Navy's Future Submarine

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Glossary of Acronyms

ADIZ: Air Defence Identification Zone
AIP: Air Independent Propulsion
AO: Area of Operations
ASC: Australian Submarine Corporation
ASuW: Anti-Surface Warfare
ASW: Anti-Submarine Warfare
BMD: Ballistic Missile Defence
CBASS: Common Broadband Advanced Sonar System
DT&E: Developmental Test & Evaluation
DSTO: Defence Science & Technology Organisation
FMS: Foreign Military Sale
FOCT: First-of-Class Trials
FRP: Full Rate Production
FSM: Future Submarine
IOC: Initial Operating Capability
IP: Intellectual Property
ISR: Intelligence Surveillance Reconnaissance
MDE: Major Defence Equipment
MIW: Mine Warfare
MOTS: Military Off-The-Shelf
OT&E: Operational Test and Evaluation
PAC-3: Patriot Advanced Capability 3
PAT&E: Production Acceptance Test & Evaluation
POTUS: President of the United States
R&D: Research and Development
RAN: Royal Australian Navy
SLOC: Sea Lines of Communication
SM-3: Standard Missile 3
T&E: Test & Evaluation
TEMP: Test & Evaluation Master Plan
TKMS: ThyssenKrupp Marine Systems
TLAM: Tomahawk Land Attack Missile
UNCLOS: United Nations Convention on the Law of the Sea
US: United States
USN: US Navy
UUV: Unmanned Underwater Vehicle
VLS: Vertical Launching System

EXECUTIVE SUMMARY

In 2009 the Australian Government announced its intention to acquire 12 high-performance conventional propulsion submarines. Entitled SEA 1000, this project will substantially expand the Royal Australian Navy's (RAN) submarine force from the existing fleet of six Collins Class boats.

Acquiring Virginia Class nuclear-powered submarines from the United States is not a credible option for the RAN Future Submarine (FSM). This is because of the high acquisition cost at $31.6 billion USD (12 boats), Australia's unpreparedness for nuclear energy, the high crewing requirement and the highly protective arms export regulations of the US Government.

Similarly, acquiring a fleet of Soryu Class submarines from Japan is also not credible. This is due to their substantially shorter service life, the designs range and endurance inferiority to the current Collins Class, as well as the lack of an American combat system and full weapons complement.

As a result, only three options remain credible contenders for the RAN FSM. The first option is a collaborative design venture with Japan on the post Soryu submarine. The second option is collaboration with Germany's ThyssenKrupp Marine Systems (TKMS) on the Type 216 design concept. The third option is a collaborative effort with the France's DCNS on the SMX Ocean design concept. These three design options have been comparatively assessed in accordance with the following six criteria:

i. **Strategic Alignments:** Germany and France do not have any significant strategic or alliance commonalities with Australia. In contrast, Japan and Australia closely align with intimate US Alliances and an extraordinarily high stake in sustaining a stable, rules-based Asia-Pacific security order.

ii. **United States Classified Information Restrictions:** Australia is one of America's closest allies, as evidenced by Australia's membership in the 'Five Eyes' intelligence club and regular bilateral cooperation. The US Alliance gives Australia privileged access to highly classified US Intelligence and advanced military technology. The problem with German or French collaboration on the RAN's FSM is that the US

Government may object. This is because the RAN FSM will incorporate sensitive American submarine technologies that the US Government will zealously protect, in order to preserve its global military superiority. Although the US Government might agree to releasing the support specifications of relevant technologies to German or French shipyards, it is highly unlikely to approve of RAN FSM's being constructed in German or French shipyards. This is because it would give German or French National's 'hands-on' access to the physical technologies during final assembly, and would be viewed as an unacceptable breach of security. Conversely, Japan has a very intimate relationship with the US, thus a joint Australian-Japanese submarine venture is unlikely to attract the same degree of objection. However, these classified information restrictions could be avoided if most or all construction is executed in Australian shipyards. This would enable the Australian Government to acquire German Type 216 or French SMX Ocean class submarines whilst assuring the US Government that its sensitive technologies will be afforded every protection.

iii. **Relevant Design & Export Experience:** Both TKMS (German) and DCNS (French) have extensive experience in modifying their respective submarine designs to meet global client requirements, including the requirements of numerous Asia-Pacific powers. In contrast, Japan has a far stronger grasp of Asia-Pacific submarine operational requirements since this is where Japan's proverbial maritime 'backyard'. Additionally, Germany and France that have extensively sold their submarines around the world, indicating the potential for a similar or identical design to be sold to countries other than Australia. If this ever occurred it would severely erode the RAN's regional submarine capability edge and undermine the whole point of SEA 1000. Conversely, Japan has never exported its submarines and will be highly selective about the recipients of its advanced defence technologies, in order to help preserve its highly prized submarine capability edge. In turn this would increase the protection afforded to any joint Australian-Japanese submarine design. However, TKMS and the German Government or DCNS and the French Government could provide similar levels of design protection by selling the Commonwealth of Australia exclusive and complete ownership over their respective designs. This would prevent the transfer of a similar or identical design to any other country.

iv. **Design Concept Specifications:** No information is publicly available on the post Soryu submarine and therefore cannot be compared. However if the post Soryu Class is to be given serious consideration it should offer greater endurance, range, weapons payload and Special Forces support capabilities than the Collins Class. These performance specifications should be comparable to the Type 216 and SMX Ocean designs. On the other hand the Type 216 and SMX Ocean design concepts offer significant improvements over the Collins Class (see Table 10), but would both require modifications to accommodate an American combat system and/or weapons inventory. Overall, SMX Ocean is superior in terms of displacement, seagoing endurance and range, as well as in the area of Special Forces and Unmanned Underwater Vehicle (UUV) support infrastructure. However the Type 216 is superior in terms of its lower crewing requirement, its significantly greater weapons payload, its native support for the AN/BYG-1 combat system and its flexibility to meet changing operational requirements with multi-purpose modules.

v. **Intellectual Property Access:** It is unclear at present how willing the TKMS and the German Government or DCNS and the French Government or the Japanese Government will be to grant the Commonwealth of Australia significant access to the Intellectual Property (IP) of their respective submarine designs. Acquiring this level of access is critical to enable the independent maintenance, modification and or modernisation of the RAN FSM in Australia.

vi. **Acquisition Cost:** TKMS has stated that it can deliver 12 Type 216 boat's for around $20 billion AUD. However DCNS has not released any pricing estimates for a fleet of SMX Ocean boat's and the Japanese Government has not acknowledged the existence of a post Soryu Class submarine let alone released cost estimates.

In terms of strategic alignments, the protection of classified information and geographically relevant design experience, collaborating with Japan on the post Soryu submarine design is a very attractive option. However in order to be feasible, the post Soryu design should have superior design and performance specifications to the Collins Class (these should be comparable to the Type 216 and SMX Ocean), it must support various American submarine technologies, the acquisition cost for 12 boat's should be similar to the Type 216/SMX

Ocean options and the Japanese Government must be willing to grant the Commonwealth of Australia significant access to the designs IP. It is also important to note that unlike the Type 216/SMX Ocean designs, the post Soryu design does offer the option of complete offshore construction.

Alternatively the German Type 216 or French SMX Ocean designs could also be selected for SEA 1000. The Type 216 offers significant multi-mission flexibility, a minimum crewing requirement of 33, a substantial weapons payload plus existing support for the American AN/BYG-1 combat system. Although SMX Ocean carries less weapons than the Type 216 and has never supported an American combat system, it has superior range and capacity to accommodate future upgrades[i], plus a dedicated UUV bay and dry-deck shelter. It is also important to note that either design must support a full complement of American weapons plus the AN-BYG-1 combat system to be a credible contender for SEA 1000.

However, the Type 216 and SMX Ocean designs suffer from the risk of a similar design being sold to another country, uncertainty over the extent of IP rights that would be granted to the Commonwealth of Australia and the risk German/French nationals gaining access to highly classified American technologies. One way that these issues could be bypassed is for the respective submarine designer and government to grant the Commonwealth of Australia exclusive and complete access to their designs IP, plus support to facilitate most or all construction in Australian shipyards. This would nullify all the major objections to the Type 216 or SMX Ocean options, rendering either design a highly competitive.

In summary, the Japanese, German and French options are all credible options for SEA 1000. However, if any of these designs are to be seriously considered their respective companies and governments must openly resolve the many unanswered questions raised by this paper before the Australian Government's competitive evaluation process concludes. Ultimately, what will increase the probability of a designs selection is how swiftly and openly the respective company and government evolve to meet the Australian Government's requirements.

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[i] Due to its significantly larger hull.

I. THE COMPLEXITY OF SUBMARINES

A high-performance submarine is an undersea dominance vehicle that represents the flawless interoperation between numerous systems and components. For instance, Collins Class submarines contain 3,800,000 parts, 75 kilometres of cables, 23.5 kilometres of pipes, 400 tons of batteries and 200,000 electronic connections.[1] These components operate as 108 separate systems that must all be hydraulically, pneumatically or electronically controlled from an integrated command centre.[2] All these systems and components must then operate inside a 'pressure hull', capable of protecting the submarine's crew from the extreme pressures of the oceans depths, and all whilst remaining undetected by hostile Anti-Submarine Warfare (ASW) forces.[3]

A submarine designer must take into account many variables, including sensor and weapon loadings, the propulsion system, crew numbers and habitability, diving depth, right down to the sea state, salinity and water temperature of the submarine's principal operational environment.[4] Designers must also account for the specified range, seagoing and submerged endurance, crew life-support and mission profile requirements as set by the client navy (see Table 1).[5] Designers must then engineer a sufficiently robust hull to house all the above requirements, minimise the designs signatures across a range of detection spectrums, all whilst ensuring that the post construction submarine is neutrally buoyant and balanced (see Table 1).[6]

However, the real complexity lies in dealing with the interdependence between factors.[7] For instance, increasing a submarine's range may require larger engines and fuel tanks, in turn necessitating a larger hull and reconfigured weight distribution to meet critical neutral buoyancy and balance requirements.[8] Enlarging a boat's hull may also have other unintended consequences such as reduced acoustic stealth.[9] Indeed, altering even one design parameter can have a flow-on effect of costly and time-consuming redesign work.[10] For these reasons, and particularly the interdependence between performance parameters, designing submarines is an inherently iterative process.[11]

Due to the complexity and iterative nature of processes involved, designing a submarine class can take years.[12] For example, 16 years after defining and designing the Collins Class, the lead boat *HMAS Collins* was delivered to the RAN.[13] *HMAS Collins* took three years to construct between 1990 and 1993, plus a further three years of work before it was commissioned into the RAN in 1996 (see Table 2).[14] This leaves around ten years unaccounted for, strongly suggesting that the definition and design phase for the Collins Class took around 10 years. Similarly, the United States Navy (USN) Ohio, Seawolf and Virginia Class submarines each took an estimated 15 years from the start of design work to the delivery of the lead boat.[15] Each Virginia Class boat takes approximately five years to build, meaning that the design phase for each class took an average of 10 years.[16] These statistics provide a useful indication that the FSM design work and construction of the lead boat will take around 15-16 years, if the Australian Government seeks to develop its own indigenous bespoke design. Although, if the Australian Government collaborates with an existing and experience submarine designer this time could be significantly shortened.

Table 1. Major Design Considerations for Submarines

Design Feature	Description
Neutral Buoyancy and Balance	***Neutral Buoyancy:*** Every submarine must be balanced to enable the achievement of 'neutral buoyancy', so that each boat can maintain a given depth without requiring forward momentum.[17] This capability is vital because it enables boat's to completely stop and drift, thereby increasing the stealth of the boat and clarify of the sensor readings, whilst simultaneously reducing energy consumption.[18] ***Balance:*** A submarine is finely balanced with regard to the distribution of weight across the hull.[19] Getting the right balance has important implications for the stability of a submarine.[20]
Hull Resistance	The hull of each submarine must be streamlined to reduce water resistance incurred by forward movement, and to reduce water turbulence that reduces acoustic stealth.[21] For instance the sail of a submarine (tall fin-like section) can contribute as much as 30% to a submarine's total resistance.[22]
Hull Integrity	The stronger a submarine's pressure hull, the greater its diving depth and chances of surviving against ASW forces.[23] This is because deep-diving submarines can exploit temperature differentials in the oceans layers that distort and confuse sonar readings.[24]
Life Support	The ability of a submarine to provide a healthy and comfortable working environment is a key consideration in submarine designs, since it directly affects a crew's ability to maintain peak performance through a deployment.[25] ***Air Composition:*** The air aboard a submarine must meet certain gas composition criteria, for instance 78.08% Nitrogen and 20.95% Oxygen as is found on the earths surface.[26] If the oxygen content aboard a submarine exceeds 22% it poses a fire hazard, and if Carbon Dioxide levels exceed 5% crew performance will be affected.[27] However if insufficient oxygen is provided a crew is at risk of suffering from convulsions and hypoxia.[28] ***Atmospheric Pressure:*** If a submarine's atmospheric pressure is too high or too low, the crew can suffer a variety of symptoms ranging from discomfort to burst eardrums.[29] ***Humidity:*** Submarine's are hermetically sealed environments and accrue unhealthily and uncomfortably high humidity levels if no counter-action is taken.[30] If humidity aboard a submarine is too high a crew is at risk of heat stroke and heat stress, in addition to the elevated risk of bacterial outbreaks.[31]
Submerged Endurance	***Submerged Endurance:*** the amount of time a submarine can supply its crew and on-board systems with electrical power whilst submerged. A submarine's submerged endurance is heavily influenced by the propulsion system used. • **Conventional Propulsion:** uses combustion engines to charge batteries at periscope depth (referred to as 'snorkelling' or 'snorting') and battery power while submerged.[32] Boats of this type have a submerged endurance between several hours to several days.[33] • **Air Independent Propulsion (AIP):** allows conventional submarines to generate power whilst submerged, thereby extending an AIP boat's submerged endurance from days to weeks.[34]
Seagoing Endurance	***Seagoing Endurance:*** the number of days a submarine can remain at sea without resupply.[35] The seagoing endurance of a submarine typically includes transit times to and from the designated Area of Operations (AO), as well as any on-station patrols within the AO.[36] The deployment threshold for a submarine class typically includes transit times to and from an AO, as well as on-station patrols within the AO.[37] Two key factors affecting a submarine's seagoing endurance are 'stores' and 'hotel services'. • **Stores:** all perishable and non-perishable consumables used during a deployment (e.g. food and weapons)[38] • **Hotel Services:** all features that keep a submarine crew alive, happy and healthy (e.g. galleys, restrooms, showers, crew quarters, recreation facilities).[39]
Range	The range of a submarine design is the total distance a submarine can travel before it needs to replenish fuel stores.[40] This figure includes the return distance between a submarine's homeport and area of operations, as well as all on-station patrols.[41]
Multiple Mission Capabilities	Contemporary submarines are expected to be versatile multi-mission platforms capable of; • **Anti-Submarine Warfare (ASW):** detecting and sinking enemy submarines' [using advanced sensors and torpedoes].[42] • **Anti-Surface Warfare (ASuW):** detecting and sinking enemy ships [using advanced sensors and torpedoes or anti-ship missiles].[43] • **Mine Warfare (MIW):** detecting and neutralising mines plus mine-laying [using advanced sensors and mines].[44] • **Intelligence Surveillance Reconnaissance (ISR):** gather intelligence, monitor adversaries and survey maritime areas in support of ADF operations [using advanced sensor arrays].[45] • **Strategic Strike:** strike distant land-based targets [using Land Attack Cruise Missiles][46] • **Special Forces Support:** support the infiltration and exfiltration of Special Forces teams [using dry deck shelters and diver lockout chambers].[47]
Low Signatures	In order to remain stealthy and undetected by the Anti Submarine Warfare forces, submarines must possess low signatures across multiple spectrums. These include the minimisation of a submarine's radar, thermal, infrared, acoustic, magnetic and wake signature profiles.[48]

II. SEA 1114: THE COLLINS CLASS SUBMARINE PROJECT

SEA 1114: Project Backgrounder

In 1987 the Australian Government announced the acquisition of six submarines under the SEA 1114 Project.[49] The objective of SEA 1114 was to arm the RAN with six high-performance conventional propulsion submarines.[50] The project envisaged that the Collins Class would have a range of around 10,000 nautical miles, seagoing endurance of 70 days, and would be capable of conducting ASW, ASuW, MIW, in addition to Special Forces support, and ISR missions.[51]

Each Collins Class boat was intended to have an operational service life of 28 years, with the launch of the lead boat in 1993 (see Table 2).[52] Originally, the lead boat *HMAS Collins* was scheduled for retirement in 2024, yet the 2012 Defence Capability Guide stated that the RAN's FSMs are not expected to achieve their Initial Operating Capability (IOC) before 2025.[53] This means that the RAN risks a submarine capability gap between classes, since it took 16 years to design and build *HMAS Collins*, yet there is less than ten years between the current year 2015 and 2024.

Table 2. Collins Class Construction & Commissioning Dates

Boat Name	Laid Down	Launched	Commissioned
HMAS Collins	1990	1993	1996
HMAS Farncomb	1991	1995	1998
HMAS Waller	1992	1997	1999
HMAS Dechaineux	1993	1998	2001
HMAS Sheean	1994	1999	2001
HMAS Rankin	1995	2001	2003

Source: Commonwealth of Australia, Australia's Navy Today[54]

Lessons Learned from the SEA 1114 Project

When the Collins Class began to emerge from production in 1996 they were overcome by a range of teething problems, from an unacceptably high acoustic signature to a malfunctioning combat system (see Table 3).[55] The cumulative result was that Collins Class boats were not cleared for 'full operational release' until 2004, eight years after the lead boat *HMAS Collins* was commissioned.[56] Even after the Collins Class boats were cleared for operational release they suffered from a malfunctioning combat system, thereby rendering all Collins boats less effective than intended.[57] On current plans the replacement American AN/BYG-1 combat system will not be installed in all boats until at least 2016.[58] Assuming that the upgrades are complete by 2016, this means that all Collins Class boat's will attain full combat system functionality 20 years after the lead boat was launched in 1996.[59]

The extensive post-production issues experienced by Collins Class submarines is largely due to the inadequate use of Test & Evaluation (T&E) processes that should have identified and rectified the design flaws in *HMAS Collins* before Full Rate Production (FRP) commenced (see Table 3 & 4). Instead, the Collins Class T&E processes were never fully completed, and FRP was authorized on the false assumption that boat's would roll off the production line perfectly meeting RAN requirements (see Table 3).[60] The cumulative fallout of these failures has been the delivery of multiple Collins Class submarines with multiple crippling flaws, and not a single boat able to meet RAN requirements without modification (see Table 3).[61]

Table 3. SEA 1114 Project Challenges

Challenge	Description
Designer's Limited Understanding of Australian Requirements	The Swedish company Kockums was selected in May 1987 to design the Collins Class submarines for the RAN.[62] Although Kockums had extensive experience in designing submarines for the Swedish Navy, its design credentials were unsuitable for two reasons. Firstly, the Swedish Navy typically had week-long deployments in stark contrast to the RAN's requirement for long distance, multiple-month deployments.[63] Secondly, Kockums had extensive experience designing submarines for cold, calm and relatively freshwater Baltic operations, but no experience with designs for the rough, salty and warm Pacific or Indian Ocean operations.[64] This lack of experience resulted in excessive corrosion in the Collins Class propulsion systems since the design required seawater to be used as ballast in the fuel tanks as fuel was progressively consumed.[65] In the Baltic where salinity levels are low this design feature would not have been an issue, but for RAN submarines operating in the considerably more salty waters of the Pacific and Indian Oceans, the result was extreme corrosion and the seizure of pistons.[66] Consequently RAN crews were forced to leave around 30% of fuel in their tanks in an attempt to avoid excessive corrosion, a predicament that severely impacted on the Collins Class range and seagoing endurance.[67]
Inadequate Contingency Fund	The SEA 1114 project had a contingency fund of only 2.5%, when in reality an inherently risky project of this complexity should have been allocated a fund of between 10-15%.[68] The fact that SEA 1114 was allocated such a low contingency fund infers a poor understanding by the Australian Government and the Department of Defence of the 1980s regarding the inherently risky nature of submarine projects.
Fixed-Price Contract	The Commonwealth of Australia contracted the Australian Submarine Corporation (ASC) using a fixed price contract.[69] The problem is that it allowed for payments to the ASC well in advance of completed work. For instance, over 75% of the contract price had been paid to the ASC even before the lead boat *HMAS Collins* was delivered.[70] The fixed-price contract also provided no financial incentive for the ASC to strive for quality standards exceeding the minimum contractual requirements.[71]
Executed Immature Design	The Collins Class submarine design was not a production proven design, but rather an enlarged variant of the Swedish Navy's A17 and A19 Class submarines.[72] The design included numerous unproven and high-risk technologies that were intended to give each boat a substantial combat advantage, including an integrated combat system and a new propeller design.[73] This approach ran contrary to the long-established rule of successful submarine projects, to reduce risk by including as few unproven technologies in a design as possible.[74] Eventually these alleged improvements led to budget overruns and schedule delays.[75] It was also not helpful that the ASC began construction of the lead boat in 1989 when only 10% of the detailed design work was complete.[76] The overall design immaturity led to time-consuming and costly rework as design issues began to emerge.[77]
Poor Quality Welding	The SEA 1114 project incurred the expense of rectifying poor quality welds. Numerous pressure hull sections that were received from Kockums contained thousands of sub-standard welds forcing the ASC to engage in costly inspection and rework of faulty welds.[78] The core problem was that Kockums had sub-standard quality control practices, combined with the overconfidence of the Swedish shipyard welders.[79] In Kockums shipyards, Swedish welders ignored advice from the Defence Scientific & Technology Organisation (DSTO) and failed to understand that the Collins Class hulls were made of a new steel that would require learning about and perfecting new welding practices.[80]
Excessive Noise	The Collins Class suffered from severe noise emission problems from three key sources.[81] Firstly, the 'sonoston' alloy propeller that was intended to eliminate cavitation made too much noise.[82] The propeller material also suffered from premature metallurgical fatigue and had a tendency to crack.[83] Secondly, the Collins Class periscopes suffered from severe vibration even when moving at medium speeds.[84] This vibration generated considerable noise to unacceptable levels as the Collins Class would have been substantially visible to ASW forces.[85] Thirdly, the Collins Class hulls generated unacceptable noise from seawater flowing over the fiberglass hull casing and fins during submerged operations.[86] The source of the problem was that too much priority was given to sonar efficiency and not enough to the boat's hydrodynamic efficiency.[87] The result was the need to redesign the boat's fins to improve water flow.[88]
Intellectual Property Access	One critical mistake with the Collins Class is that Kockums the Swedish designer owns all of the designs IP, and this prevents Australia from using any of the Collins designs in the FSM.[89] This failure to acquire all or part of the baseline designs IP from Kockums prevents Australia from exercising an evolutionary approach to submarine construction, whereby progressive improvements are made with each successive class or production batch.[90] While acquiring all the intellectual property rights to the Collins Class may not have been feasible, the Australian Government should have arranged for far more extensive access to the Collins IP, so as to allow for the unrestricted maintenance, modification and modernization of the boat's.
Inadequate T&E	The Collins Class boat's were delivered without the completion of rigorous T&E processes and FOCT on the first unit of production.[91] Consequently the Commonwealth of Australia ended up with several submarines, none of which were fit for purpose.[92] What the Australian Government should have done is use the first-of-class production unit (*HMAS Collins*) as a test bed for extensive and rigorous T&E and learning from any flaws before proceeding to FRP. [93]

Guidance for the SEA 1000 Project

The SEA 1114 project was Australia's first foray in submarine construction and suffered from numerous realized risks. Hopefully the experience gained from SEA 1114 can be leveraged to guide the SEA 1000 project to success. The following seven points will improve the probability of SEA 1000 delivering all boats on budget, on schedule and in line with RAN operational requirements.

1. **Designers Understanding of Operational Requirements:** Only designers with relevant experience and/or an extensive understanding of the RAN's operational requirements should be considered for SEA 1000 (see Table 3).[94]

2. **Significant IP Access:** Contractual arrangements with the submarine designer must grant the Commonwealth of Australia significant IP access to allow for the independent sustainment, modification and/or modernization of the RAN FSM fleet in Australia (see Table 3).[95]

3. **Appropriate Contingency Fund:** SEA 1000 must be allocated an appropriately sized contingency fund that accurately reflects the projects risk (see Table 3).[96]

4. **Only Approve a Mature Design:** Construction of the lead boat should only commence once the baseline design is sufficiently mature (see Table 3). According to the RAND Corporation a submarine design is deemed to be mature enough for construction after 80 percent or more of the design work is complete.[97]

5. **Adequate T&E Processes:** The whole purpose of a comprehensive T&E process is to ensure that a finished product meets all operational effectiveness and operational suitability requirements of the client armed service (see Table 4). T&E processes are iterative by nature and seek to identify, address and rectify risks at the earliest possible point in a project (see Table 4). T&E can be performed at any time in a submarine project and includes three subordinate processes; Developmental Test & Evaluation (DT&E), Production Acceptance Test & Evaluation (PAT&E) as well as Operational Test & Evaluation (OT&E) (see Table 4). The role, execution plan and list of required resources of all three T&E processes must be documented in a projects Test & Evaluation Master Plan (TEMP).[98]

6. **Work Package Forward Planning:** FRP should only be authorized after a submarine projects lead boat successfully passes all first-of-class T&E, or alternatively after the lead boat has completed all first-of-class T&E and the baseline design has received all corrective modifications. Proceeding this way decreases the risk that multiple submarines will be delivered with crippling design or production defects. However, submarine production should not cease between the lead boat's delivery and the conclusion of OT&E for the lead boat. This is because OT&E can take 12-24 months to complete and shipyard resources[ii] cannot remain underutilized for this amount of time. The solution is to pre-emptively identify and release low risk packages[iii] to shipyards before first-of-class T&E begins, thereby keeping shipyard resources productive over the 12-24 month period. Low risk work packages may be identified and approved for release after the concurrent DT&E and OT&E that precedes construction of the lead boat.

7. **Progressive Work Package Release:** If possible, first-of-class T&E should focus on progressively vetting systems and sections of the lead boat that correspond with shipyard work packages. This will enable additional work packages to be vetted and released for shipyard construction, or delivered to engineering personnel for corrective re-work and subsequently released for shipyard construction. As a result, the work package queue of the contracted shipyards will gradually increase as first-of-class T&E progresses, as opposed to work packages only being released to shipyards after the conclusion of all first-of-class T&E.

[ii] Shipyard resources covers all personnel, materials, supplies, facilities and capital equipment such as Goliath shipyard cranes.

[iii] **Low Risk Work Packages:** activities that once completed are highly unlikely to require revisions, modifications and/or complete rework

Table 4. Test & Evaluation Processes

Type of T&E	Details
DT&E	***Definition:*** DT&E is a scientific and engineering process for maturing military technologies/designs to the point that production can commence with reasonable confidence that the product will satisfy the client armed services operational requirements, and at an acceptable level of risk.[99] ***Description:*** The DT&E process usually occurs at a land-based testing facility, devoting disproportionate attention to identifying and rectifying problems with high-risk technologies/designs.[100] Once a solution has been found and applied, the modified technology/design is then re-tested.[101] The DT&E process is iteratively repeated until the technology/design is abandoned or test results verify that a technology/design is sufficiently mature to be produced.[102] However, DT&E also performs several other functions that assist decision-makers approve a technology/design for initial production.[103] These functions include: • **Compatibility Evaluations:** assessments that determine how compatible the technology/design will be with the existing or planned inventory of the client armed service[104] • **Capability Evaluations:** assessments that determine the strengths, limitations, safety of the technology/design[105] • **Specification Evaluations:** assessments on the likelihood that a technology/design will meet the client armed services specification requirements[106] • **Records Management:** documented history of all tests, their results and any incremental modifications[107]
PAT&E	***Definition:*** PAT&E serves to demonstrate the feasibility of production processes at an acceptable cost and that units of production will meet all specifications and obligations as contractually written.[108] ***Description:*** PAT&E is facilitated by a submarine projects first-of-class boat because it gives the Quality Assurance team[iv] an opportunity to ensure that the unit of output complies with all contractual requirements, as well as providing an opportunity to identify and rectify problems with production processes[v] before FRP is authorised.[109]
OT&E	***Definition:*** OT&E involves rigorously testing a military product to ensure that it is both 'operationally effective' and 'operationally suitable' for use by combat personnel under wartime conditions.[110] • **Operational Effectiveness:** how well a given military product functions under realistic combat conditions, with consideration given to survivability and functionality particularly when faced with enemy countermeasures[111] • **Operational Suitability:** how practical a military product is for use by combat personnel in field conditions, covering its operational availability, its transportability and maintainability as well as how compatible the system is in operating with existing force assets[112] ***Description:*** A submarine projects first-of-class boat facilitates OT&E because it provides a complete unit of output to undergo comprehensive operational effectiveness and suitability testing[vi], as well as an opportunity to identify and rectify problems with the baseline design before FRP commences.[113] However, the immense cost and risk of major surface ship and submarine projects means that OT&E should not wait until the lead boat's delivery.[114] In fact OT&E should ideally be conducted in parallel with DT&E at land-based testing facilities, utilising armed service personnel to test a technology/design under simulated operational conditions (e.g. propulsion systems or system functionality).[115] The advantage of engaging armed service personnel in early OT&E is that they are the end-users and experts that are best placed to determine if a technology/design is likely to satisfactorily meet their operational requirements.[116] Consequently, technologies/designs validated through concurrent OT&E and DT&E may be approved for initial production with significant confidence that the end product will meet the clients requirements.

[iv] Usually includes a joint team composed of government and contractor personnel.

[v] Covering fabrication, assembly and integration.

[vi] As part of first-of-class T&E

III. SEA 1000: THE FUTURE SUBMARINE PROJECT

SEA 1000: Future Submarine Critical Requirements

In the 2009 and 2013 White Papers' the Australian Government affirmed its intention to acquire 12 state-of-the-art conventional propulsion submarines.[117] According to the 2009 White Paper the RAN FSM must be capable of ASuW, ASW, ISR and strategic strike operations.[118] The FSM must also be capable of supporting MIW operations, as well as the infiltration or exfiltration of Special Forces.[119] Other FSM requirements include the ability to stealthily transit long distances at high speeds, conduct extended covert patrols and then return to Australia undetected.[120]

Both White Papers' explicitly stated that nuclear propulsion was not going to be considered, instead opting for conventional propulsion.[121] The dilemma is that nuclear-powered boats possess significant advantages over conventional boats and very closely meet RAN FSM requirements. Nuclear-powered submarines can transit unlimited distances at high speeds and remain submerged for several months at a time.[122] In contrast, conventional submarines generally use diesel-electric propulsion systems that require a boat to recharge its on-board batteries every few days.[123] Conventional submarines can recharge their batteries while running on the oceans surface or at a shallow depth with a 'pipe' raised just above the waves, a procedure that is also known as 'snorkeling'.[124] Snorkeling is a very dangerous procedure for conventional submarines because it renders a conventional submarine substantially more vulnerable to detection.[125] However, new AIP technologies have extended the time that a conventional submarine can remain submerged from days to several weeks.[126] The significance of submerged endurance is that it substantially increases the survivability of a submarine by reducing its vulnerability to detection and prosecution by hostile ASW forces. Given the 2009 White Paper's requirement for extended covert patrols, high submerged endurance will be a critical requirement for the RAN FSM design.

Crewing is another factor of paramount importance to the RAN FSM. On one hand the RAN has experienced trouble finding sufficient personnel for its 58 crew Collins Class submarines.[127] Between 2007 and 2010 the crew shortages were so dire that Collins boats were sent in early for heavy maintenance.[128] This means that a submarine design that can be operated by a crew of less than 58 will be an advantage for the RAN.

On the other hand the RAN FSM must have the capacity for a large crew. This is because a submarine crew is divided into watch rotations and then cycled through the active management of a submarine 24/7 while at sea or when docked.[129] Simply put, a larger crew size means that all watch rotations are cycled through less frequently every 24 hours, thereby minimising crew fatigue.[130] The problem with crew fatigue is that mistakes are more likely to occur, to the point that driving drunk would be an appropriate analogy.[131] The fatigue of RAN Collins Class crews has at times been so bad that personnel have suffered from blurred vision and or collapsed while on watch.[132] Given the risk of crew fatigue and particularly given the protracted nature of RAN submarine patrols, the FSM design must be able to support a crew of equal or greater size than the Collins Class.

It is also important to remember that crew comfort will be another critical aspect. This is because the more comfortable a crew, the greater its willingness to endure extended deployments. One way to increase crew comfort is to avoid 'hot-bunking'. This is when one or more sailors are assigned to sleep in the same bunk (bed), resulting in reduced comfort and willingness to endure lengthy deployments.[133] Given the protracted nature of RAN submarine deployments, the provision of high crew comfort and by extension one bunk per crew member will be particularly important.

With regard to weapons the FSM must be able to accommodate the American AN/BYG-1 combat system as well as fire American Mk-48 heavyweight torpedoes, Harpoon anti-ship missiles and TLAMs (see Table 5). The necessity of American military technology is driven by a need for interoperability with the US Armed Forces that underwrites Australia's security through the Australia-US Alliance.[134] For instance, interoperability means that the RAN FSM can fire TLAMs based on targeting data provided by forward-deployed USN assets and vice versa. Interoperability is also enhanced by using common weapons since RAN or USN supply ships can mutually resupply each others submarine forces during periods of hostilities, thus reducing the burden on logistics supply-chains. In addition, it is also critical that the RAN FSM carries significant numbers of weapons to allow for the delivery of disproportionate firepower into distance theatres, without requiring at sea replenishments.

It is also important that the RAN FSM include a diver lockout chamber to deploy and recover Special Forces (see Table 5). However, it would be beneficial if the FSM also included a dry deck shelter in the baseline design (see Table 5). The significance of a dry deck shelter is that, unlike lockout chambers, they allow for the covert delivery and recovery Special Forces personnel plus bulky support equipment such as miniature submarines or inflatable boats.

Table 5. Collins Class & RAN FSM Requirements

Attribute	Collins Class	RAN FSM Requirements
Service Life	28 years	28 years
Propulsion	Conventional	Conventional
Displacement	3100 tons	3100+ tons
Max. Speed	20+ knots	20+ knots
Armament	6 torpedo tubes	6+ torpedo tubes
Seagoing Endurance	70 days	70+ days
Submerged Endurance	1+ days	Greater than 2 weeks
Range	9000 nm	9000+ nm
Min. Crew Size	?	Less than 58
Max. Crew Size	58	58+
# of Crew Bunks	58	58+
Combat System	AN/BYG-1[vii]	AN/BYG-1[viii]
Mk-48 Torpedoes	YES	YES
Harpoon Anti-Ship Missiles	YES	YES
Tomahawk Land Attack Missiles	NO	YES
High Weapons Payload	• 22 torpedo/anti-ship missiles/mines	22+ torpedoes/anti-ship missiles/land-attack missiles/mines
Diver Lockout Chamber	YES	YES
Dry Deck Shelter	NO	DESIRABLE
UUV Bay	NO	DESIRABLE

Source: Briggs,P & Roach,T; Babbage,R; Commonwealth of Australia; Woolner,D; ASPI; ASC; Pacey,B[135]

[vii] American submarine combat system.

[viii] American submarine combat system.

Option 1: Virginia Class Nuclear Powered Submarines

If Australia decides to pursue nuclear-powered submarines the USN's Virginia Class are the obvious choice, as would be acquired through the US Government's Foreign Military Sale (FMS) program. Choosing an American design over a French or British designed nuclear-powered boat would be Australia's preference due to two key factors. Firstly, Australia's closest and most important ally is the US, thus interoperability between the RAN FSM and the USN is a critical requirement. While the French and British designs can operate alongside the US Military, they face more barriers to interoperability than would an RAN submarine of the same design as operated by the USN.[136] Secondly, the RAN and more broadly the ADF rely on the US for supplies of munitions and equipment, including missiles, combat systems, torpedoes and spare parts. If the RAN were to acquire a British or French design, it would face a dilemma. The RAN could modify the British or French design at great expense and risk to accommodate an American combat system and array of weapons.[137] Alternatively, the RAN could incur the significant expense of maintaining a new inventory of weapons and spare parts, as would be needed to support British or French weapons and combat systems.[138] Indeed, interoperability between the RAN and the USN, in addition to the increased cost of making a British or French design viable means that Virginia Class is the only credible nuclear-powered submarine option for Australia.

The Virginia Class is the USN's latest class of attack submarine and is designed to control Sea Lines of Communication (SLOC), conduct ASuW, ASW, MIW and ISR missions, as well as support the infiltration and exfiltration of Special Forces (see Table 6).[139] Each Virginia Class boat is capable of staying submerged at depths exceeding 800 feet for up to three months, and can sustain speeds greater than 25 knots (see Table 6).[140] Each Virginia Class boat can carry mines, UUVs and launch or recover Special Forces while remaining submerged.[141] These capacities are in addition to the designs baseline armament of 12 TLAMs in 12 Vertical Launching System (VLS) tubes, as well as four torpedo tubes armed with a payload of 27 Mk-48 heavyweight torpedoes (see Table 6).[142] In 2026, the Virginia Class will be equipped with the Virginia Payload Module that will give each boat the ability to carry an additional 28 TLAMs in four wide-diameter payload tubes, increasing each boat's TLAM capacity from 12 to 40 missiles.[143]

The RAN's Collins Class submarines are also capable of ASuW, ASW, MIW, strategic strike, intelligence gathering and Special Forces support missions, making these boats the only conventional submarines in the world that come close to meeting the RAN's capability requirements.[144] However in stark contrast the Collins Class do have serious limitations. Firstly, each boat carries just 22 Mk-48 heavyweight torpedoes for ASuW and ASW.[145] Furthermore, the Collins Class have a limited range of around 9000 nautical miles, a maximum speed of around 20 knots and a submerged endurance of around a few days.[146]

Due to the substantial operational benefits of nuclear-propulsion it has been suggested that Australia should acquire a fleet of Virginia Class submarines. Indeed there are several advantages of this path.

Firstly, the Virginia Class meet or exceed the criteria laid down for the RAN FSM in the 2009 White Paper. The RAN FSM must be capable of covertly transiting long distances at high speeds, conducting extended patrols on-station and returning to base.[147] Whilst on-station the FSM must be capable of ASuW, ASW, MIW, strategic strike, ISR and Special Forces support operations.[148] All of these capability requirements are met by the Virginia Class, and far exceed the capability of the current Collins Class.

Secondly, acquiring a new design of conventional submarine could cost more than acquiring nuclear-powered Virginia Class submarines.[149] In 2009 the Australian Strategic Policy Institute calculated that a bespoke Australian design would cost around $3 billion AUD per boat to design and build, or $36 billion AUD for a fleet of 12.[150] Whereas, a Virginia Class submarine in 2015 dollars cost around $2.63 billion USD per boat and $31.6 billion USD for a fleet of 12.[151] Additionally, buying Virginia Class boats from an active production line in the US, Australia will substantially reduce the risk of budget overruns and schedule slippages, all while taking advantage of the USN's established crew training, sustainment and maintenance programs.[152]

Aside from the anti-nuclear rhetoric there are four practical objections to equipping the RAN with nuclear-powered Virginia Class submarines. One is that Australia does not have a nuclear energy industry and as such cannot support or maintain nuclear-powered submarines. While this is a valid point, the Virginia Class are equipped with reactors that last the entire 33 year service life of each boat.[153] As a result, expensive mid-life refuelling of these submarines is unnecessary, as is the costly disposal of the nuclear waste that mid-life refuelling generates.[154] Consequently it is unclear precisely how much onshore nuclear energy industry infrastructure would be required to sustain Virginia Class submarine reactors in Australia. The issue of mid-life refuelling aside, it is important to note that Australia does not have established nuclear energy protocols, regulations or equipment, let alone the sizeable specialised workforce that would be required to conduct the day-to-day maintenance on a nuclear powered submarine.[155]

A second objection to acquiring Virginia Class submarines is the issue of crew shortages. Virginia Class submarines have crew complements of around 135 personnel, which is more than double the 58 crew complement of a Collins Class submarine (see Table 6).[156] Given that the RAN has had difficulty in finding sufficient personnel for the Collins Class it seems highly untenable that the RAN is capable of crewing Virginia Class submarines.

A third objection is that acquiring nuclear-powered submarines would demolish the Australian submarine industry, making Australia entirely reliant on the US for capability sustainment. Although it is a valid point, it is worth pointing out that Australia already accepts a high degree of reliance on the US for almost all its military hardware. For instance the F/A-18F Super Hornets were manufactured in the US and exported to Australia, as will the future F-35A Joint Strike Fighter.[157] Similarly the Aegis combat system, the AN/SPY-1D phased array radar and Mk-41 VLS for the future Hobart Class Air Warfare Destroyers were all manufactured in the US and exported to Australia.[158] It is also worth noting that even with regard to the Collins Class, Australia already relies heavily on the US for the supply of Mk-48 heavyweight torpedoes and the AN/BYG-1 combat system.[159]

A fourth objection to Australia acquiring Virginia Class submarines may come from within US Government[ix] or from the President of the United States (POTUS). Under the US Arms Export Control Act, POTUS may authorise the sale of 'Major Defense Equipment'[x] (MDE) to Australia, but must inform both the Speaker of the House and the Chairman of the Senate Foreign Relations Committee if any sale exceeds $25 million US dollars.[160] Notification of these two individuals must take place no less than 15 calendar days before the FMS

[ix] Members of the US House of Representatives or US Senate

[x] Major Defense Equipment according to the Act includes submarines.

becomes active.[161] During this 15 day period Congress may enact a joint resolution prohibiting the FMS.[162] This means that not only could the US House and Senate block the sale of Virginia Class submarines, but also the sale could be prohibited by POTUS. A lack of approval from any one of these stakeholders within the US Government is not unfeasible, since Australia alongside Japan has been denied FMS access to the F-22 Raptor.[163] This ban is due to the US Congressional 'Obey Amendment' that prevents the aircraft's export to all foreign countries, even including close US Allies like Australia.[164] The fact that the Congressional export ban has been upheld despite the US Air Force's willingness to design an export variant suggests that the US is unwilling to export certain high-value capabilities even to its closest allies.

Despite the operational benefits of acquiring nuclear-powered Virginia Class submarines, the high cost, the absence of a domestic nuclear energy industry and the significantly greater crewing requirement erase any credibility from this option.

Table 6. Virginia Class Specifications

Attribute	Performance
Propulsion	Nuclear
Displacement	7800 tons (submerged)
Max. Speed	25+ knots (submerged)
Armament	• 4 torpedo tubes • 12 cell VLS
Seagoing Endurance	90+ days
Submerged Endurance	3 months
Range	Unlimited
Min. Crew Size	?
Max. Crew Size	135
# of Crew Bunks	?
Combat System	AN/BYG-1
Mk-48 Torpedoes	YES
Harpoon Anti-Ship Missiles	YES
Tomahawk Land Attack Missiles	YES
High Weapons Payload	• 28 torpedoes/anti-ship missiles • 12 land attack missiles in VLS
Diver Lockout Chamber	YES[xi]
Dry Deck Shelter	YES[xii]
UUV Bay	YES

Source: Newport News Shipbuilding; Work,R[165]

[xi] Space for nine Special Forces divers.

[xii] Added as required.

Option 2: Soryu Class

Another option is to acquire Soryu Class submarines from Japan (see Table 7). It has been reported that 10 Soryu Class boats could be acquired for around $20 billion AUD or 12 boats for $24 billion AUD as a Military Off-The-Shelf (MOTS) acquisition.[166] These figures rate favourably in contrast with the estimated $36 billion AUD for 12 bespoke Australian boats.[167]

Although the cost of acquiring the Soryu Class may be relatively low in contrast to an Australian design, this option suffers from five major issues. Firstly, Soryu boats have a relatively short service life of 16 years, whereas the RAN requires a lifespan of 28-30 years (see Table 7).[168] As pointed out by the Australian Strategic Policy Institute the problem with a short service life is that more frequent replacement substantially increases capital costs to the tune of 50 percent.[169] They conclude that administrative overheads, the inefficient use of industrial resources and the high capital cost of more frequent replacement is likely to outweigh any potential savings from construction related efficiencies and the avoidance of mid-life upgrades.[170]

Secondly, there are serious questions regarding the range of the Soryu Class and whether its classified range will meet the requirements for the FSM (see Table 7).[171] With an open-source range of 6000 nautical miles the Soryu is unlikely to match the Collins Class range let alone exceed it. For the RAN FSM greater range than the Collins Class is highly desirable if not a key requirement, particularly since the immense cost of the SEA 1000 Project must be seen to deliver value to Australian tax payers.

Thirdly, the Soryu design would require modifications to accommodate American combat systems, weapons and other sensitive technologies. The biggest challenge in accommodating the American combat system is that sufficient electrical power and cooling must be provided. This may too difficult for the Soryu design since the American AN/BYG-1 combat system was originally designed for a high-power output nuclear submarine. The problem with modifying the Soryu design is that it risks upsetting the delicately balanced mix of performance features, to the point that substantial re-engineering may be required.[172]

Fourthly, there is the risk that a future Japanese Government may suspend or revoke a submarine supply contract with the Australian Government.[173] On 1 April 2014, the Japanese Government under Prime Minister Shinzo Abe removed all self-imposed restrictions on defence exports, and instead replaced it with a ban on exports to countries engaged in armed conflict or countries subject to United Nations resolutions.[174] It is important to remember that Japan's support for defence exports is only a very recent development and should be approached with caution. This is because a future Japanese Government that does not share Shinzo Abe's views may revert back to a total ban on all defence exports and/or revoke an existing submarine supply contract with Australia. Unless a substantial and broad base of support within the Japanese National Diet (Federal Parliament equivalent), Civil Service and Public can be developed, picking the Soryu appears to be a risky venture.[175]

Fifthly, Japan has never before exported one of its submarines, let alone as a design for construction in a foreign shipyard. Exporting naval designs to foreign shipyards for partial or full construction risks a host of problems, as was the case with the SEA 4000 Air Warfare Destroyer Project. Essentially, the ships designer had never previously exported one of its designs for construction in a foreign shipyard and this lack of export experience led to incorrect assumptions about Australian shipyard capabilities.[176] The result was significant schedule delays and budget overruns.[177]

Taking into account all five issues and particularly the issue of range, the Soryu Class does not credibly meet the RAN's FSM requirements (see Table 7).

Table 7. Soryu Class Specifications & RAN FSM Requirements

Attribute	Soryu Class	RAN FSM Requirements
Service Life	16 years	28 years
Propulsion	Conventional	Conventional
Displacement	2950 (surfaced)	3100+ tons
Max. Speed	20+ knots (submerged)	20+ knots
Armament	?	6+ torpedo tubes
Seagoing Endurance	?	70+ days
Submerged Endurance	?	2+ weeks
Range	6000 nm	9000+ nm
Min. Crew Size	?	Less than 58
Max. Crew Size	65	58
# of Crew Bunks	?	58
Combat System	C2[xiii]	AN/BYG-1[xiv]
Mk-48 Torpedoes	NO[xv]	YES
Harpoon Anti-Ship Missiles	YES	YES
Tomahawk Land Attack Missiles	NO	YES
High Weapons Payload	?	• 22+ torpedoes/anti-ship missiles/land-attack missiles/mines
Diver Lockout Chamber	?	YES
Dry Deck Shelter	?	DESIRABLE
UUV Bay	?	DESIRABLE

Source: Briggs,P & Roach,T; Babbage,R; Commonwealth of Australia; Woolner,D; ASPI; ASC; Pacey,B[178]

[xiii] Japanese submarine combat system.

[xiv] American submarine combat system.

[xv] Soryu Class boats fire the Type 89 Japanese torpedoes.

Option 3: Collaborate with Japan on the post Soryu Design

Another option is for the Australian and Japanese Governments to jointly develop a future submarine design as successor to the current Soryu Class. Pursuing a post Soryu submarine design would enable the RAN to have significant input and get a submarine that better meets its requirements.

Collaborating with the Japanese on a future class of submarine has three major advantages. Firstly, Japan is a maritime power with extensive experience in designing high-performance submarines for Pacific Ocean operations, dating back to World War II.[179] In recent decades Japan has amassed considerable expertise in designing conventional propulsion submarines for Pacific Ocean operations. Between 1989 and 1995 Japan built seven Harushio Class submarines, followed by eleven Oyashio Class boats between 1994 and 2008.[180] The latest development is the Soryu Class and is the first Japanese submarine type to be fitted with AIP technology.[181]

Secondly, Japan has a strong vested interest in maintaining a stable Asia-Pacific security order governed by the principles of international law, and therefore has continually invested in a sizeable high-performance submarine fleet to help maintain regional stability. Three sub-factors drive Japan's continued development of its advanced submarine capability. The first factor is that around 90 percent of all global trade and 60 percent of Japanese energy supplies pass through critical SLOCs in maritime Southeast Asia, in particular the Straits of Malacca, Makassar, Sunda and Lombok.[182] The second factor is that the Chinese Government unilaterally claims almost all of the South and East China Seas as its own sovereign territory.[183] These ambit claims far exceed China's legal entitlements under the United Nations Convention of the Law of the Sea (UNCLOS).[184] The third factor is that the Chinese Government has been very active in asserting its unrecognised claims through belligerent acts, over what are highly contested maritime zones.[185] Their latest act was the unilateral declaration of its Air Defence Identification Zone (ADIZ) over the East China Sea in 2013.[186]

All three factors necessitate that the Japanese maintain a stealthy, long-range, high-performance submarine fleet, capable of defending Japanese shipping and helping to insulate the broader Asia-Pacific community against the threat of future Chinese assertiveness. In fact, Australia has the same enduring strategic interest of unimpeded seaborne trade throughout the global maritime commons, and also requires an advanced submarine capability to help deter the Chinese Government from forcefully annexing vast maritime territories, to which it is not entitled under international law.[187]

Thirdly, another point of convergence is that both Japan and Australia have very close alliance relationships with the United States. The security of Japan is ultimately underwritten by the United States from nuclear, ballistic missile and large-scale conventional attacks.[188] Similarly, Australia's security is underwritten by the United States from nuclear, ballistic missile and large-scale conventional attacks.[189] The intimacy of both bilateral US Alliances has two flow-on benefits for the RAN FSM project. One benefit is that it will be relatively easy to convince Japan on the merits of factoring in support for American combat systems, sensors and weapons into their post Soryu Class submarine. This is because Japan and Australia place an extraordinarily high premium on ensuring interoperability with the US Armed Forces and particularly with the US Pacific Fleet. Convincing a European power to make the same level of effort is likely to be far more troublesome given their lower priority on interoperability with the US Armed Forces and particularly the USN.

Another benefit is that the US is considerably less likely to block their sensitive submarine technology specifications and hardware from being handled by Japanese shipyards, whereas the same cannot be said about Germany and France. This is because Japan and Australia regularly share classified information and/or technology with the United States, both countries operate numerous sensitive American military technologies, and both countries are two of America's most trusted allies. If Japan was selected as the designer and/or builder of the RAN FSM, disclosure of the space, weight, power and cooling requirements of classified American systems and weapons would be required. This is because without such information Japanese designers would be unable to support the AN/BYG-1 combat system and American weapons inventory in the submarine design.

The combination of Japan's extensive submarine design experience, its enduring strategic interests in the Asia-Pacific and the US Alliance commonality means that a collaborative venture with Japan would be based on sound strategic logic. However, collaborating with

Japan on a follow-on submarine class suffers from similar shortcomings as the Soryu Class option. One shortcoming is the risk of a change in Japanese Government policy. This could be caused by a range of factors and is a particularly high risk given that the Japanese Government has only recently warmed to the idea of exporting its defence technology.

Another shortcoming is that Japan lacks any experience in exporting its submarine technology, either as complete boats with sustainment support or as designs for construction in foreign shipyards. The reasons for Japan's lack of defence export experience include its widespread pacifist culture, its only recently annulled export restrictions and the perceived need to zealously protect its submarine capability edge from erosion. This last factor is particularly important because the Japanese Government will want to preserve the superiority of its submarine technologies, thereby helping to insulate Japan from the risk of potential armed conflicts with the Peoples' Republic of China.[xvi] Consequently, the Japanese Government will be highly selective about the countries that receive any of its defence technology, and even more selective with regard to the export of its submarine technologies. Japan's highly protective posture is particularly valuable for Australia that also seeks to indefinitely sustain a regional submarine capability edge.

A third shortcoming is that the design and construction of the first boat may not be complete in time to coincide with the intended retirement of *HMAS Collins* in 2024. Typically it takes around 16 years to design, refine and build a first-of-class boat of a new submarine class. Even if we assume that the Soryu's successor is six years into this process, the first boat would at best be launched in 2025. Although 2025 may be sufficient to avoid a capability gap, it only works on the assumption that the lead post Soryu Class boat will not suffer from teething problems that almost always inhibit new submarine classes.

Despite the risk of a change in Japanese Government policy, a lack of Japanese export experience and the risk of a capability gap, collaborating with Japan on the post Soryu is a credible option.

[xvi] See my Masters Sub-Thesis, available from the Australian National University Digital Collections at: http://hdl.handle.net/1885/9721

Option 4: Collaborate with Germany on the Type 216 Design

Another contender is the 4000 ton Type 216 design concept that is currently being developed by the German company TKMS.[190] The Type 216 will accommodate six torpedo tubes capable of launching torpedoes, anti-ship missiles and sea mines with space for 18 reloads, presumably in addition to six weapons already stored in the torpedo tubes (see Table 8).[191] The design can also accommodate up to three multi-purpose mission modules allowing the operating navy to tailor their submarines to mission requirements (see Table 8).[192] One of the load-out options for a single multi-purpose module is seven land-attack cruise missiles.[193] By extrapolation this means that a single Type 216 would be capable of carrying up to 21 land attack cruise missiles, in addition to 18 torpedoes, anti-ship missiles or mines (see Table 8). In addition, the Type 216 boats are planned to have long-range capabilities in the order of 10,000+ nautical miles, as well as possessing submerged endurance of greater than three weeks with the use of AIP technologies (see Table 8).[194] The advanced capabilities of the Type 216 mean that it will be capable of conducting ASW, ASuW, MIW, ISR, strategic strike and Special Forces infiltration or exfiltration missions.[195]

Although the Type 216 is presently a ‘paper design’, there are four major benefits of pursuing this option. Firstly, the Type 216 Class has a surfaced displacement of 4000 tonnes, which is considerably greater than the Collins Class at 3100 tons.[196] A submarine with a larger hull confers a distinct advantage since it allows designers to include a greater complement of weapons, sensors, propulsion technologies, stores and crew accommodation.

Secondly, TKMS has a strong track record of building high-performance conventional submarines, including the Type 209, 210, 212 and 214 classes. Furthermore, TKMS has extensive experience in successfully exporting around 160 submarines to 22 countries, either as complete boats or as designs for construction by local shipyards.[197] It is also important to note that TKMS has successfully tailored its baseline designs to meet the unique requirements of its client navies.[198] However by exporting many of its submarine classes around the world TKMS and the German Government have proven that they may choose to export all or significant parts of the Type 216 design to other Asia-Pacific countries. If Australia selected the Type 216 design for the RAN FSM this would erode the

RAN's regional submarine capability edge, and is a risk that is unlikely to be looked upon favourably by the Australian Government.

Thirdly, TKMS has publicly stated that it can deliver a fleet of 12 Type 216 boats for around $20 billion AUD, and is $16 billion AUD less than the estimated cost of acquiring a bespoke Australian submarine class.[199] It is also important to note that TKMS has publicly said that it is willing to accept "full responsibility" for the price and scheduled delivery of the Type 216 boats, with the lead boat delivered in 10-11 years and subsequent deliveries every nine months.[200] This implies that TKMS is willing to wear some if not a substantial portion of the risk associated with the SEA 1000 Project.

Fourthly, the Type 216 submarine is currently in the design and development phase. This will allow the RAN to exercise greater influence over the designs final specifications than if the RAN were to acquire a MOTS submarine design.

However, there are three major hurdles that must be resolved before the Type 216 becomes a credible option. Firstly, the Type 216 design must be capable of supporting the space, weight, electrical power and cooling requirements of various American military systems and weapons. While the Type 216 is capable of supporting the American AN/BYG-1 combat system, it remains to be seen whether the Type 216 can support the full complement of American weapons that the RAN will require. This full complement of weapons includes Mk-48 heavyweight torpedoes, Harpoon anti-ship missiles and TLAMs.

Secondly, it is unclear to what extent the US Government is willing to allow German National's access to its highly sensitive submarine technologies. In order to incorporate the AN/BYG-1, Mk-48s, Harpoons and TLAMs into the Type 216, German engineers will have to be made aware of the space, weight, power and cooling requirements of these systems and weapons. It is important to remember that the US Government has placed stringent restrictions on foreign access to its sensitive submarine technology in the past. For instance, on the RAN's Collins Class submarines a one-way intermediary data-flow device had to be installed between French sensors and the AN/BYG-1 combat system, so as to adequately protect the Americans' highly classified technology and data.[201]

Even if the US Government agreed to give TKMS 'limited access' to their sensitive military hardware and system requirements, it is a dubious proposition that they would ever agree to the construction of Australianised Type 216 submarines in German shipyards. This is because it would give European foreign nationals 'hands-on' access to some of Americas' most sensitive military technology. Although Australians' are also classed as 'foreign nationals' by the US Government, Australia is a trusted top-tier US ally. This means that from the US Government's perspective, Australians' handling their most sensitive submarine technology is far less risky than having such sensitive technology handled by citizens of a non Five Eyes European power.

It is also important to remember that Australia is a member of the highly intimate 'Fives Eyes' intelligence gathering and sharing alliance, that also includes Great Britain, New Zealand, Canada and the United States. Australia has fought alongside the US in every major conflict since the early 20th Century.[202] Both Australia and the United States receive highly sensitive intelligence gathered by the jointly operated Pine Gap and Exmouth installations.[203] Furthermore, Australia and the United States have a long history of exchanging, sharing and jointly developing highly sensitive military technologies. One example is the joint Research & Development (R&D) of the Mk-48 Mod 7 Common Broadband Advanced Sonar System (CBASS) heavyweight torpedo by the USN and RAN.[204] Another example is the RAN Collins Class submarines that operate the highly classified AN/BYG-1 combat system, making Australia the only nation outside of the United States to operate this advanced integrated combat system.[205] This free-flow of sensitive military technology has been further aided by the 2007 US-Australia Defence Trade Cooperation Treaty and the 2002 US-Australian agreement on classified information handling procedures, both of which further underline the intimacy and mutual trust of the US-Australia Alliance.[206]

Thirdly, it is unclear at the present to what extent TKMS and the German Government will be willing to give the Commonwealth of Australia significant access to the IP of the Type 216. The granting of these rights will be critical to allow Australia to undertake the independent sustainment, modification and/or modernisation of the RAN FSMs. If the Commonwealth of Australia fails to obtain sufficient access to the Type 216 IP, it risks a repeat of the same IP disputes that it had with Kockums.[207]

Despite the risk of TKMS exporting a similar design, security concerns and IP uncertainties, the merits of the Type 216 render it a credible contender for the RAN FSM. These merits include the extensive submarine construction and export experience of TKMS, a range exceeding 10,000 nm, greater than three weeks submerged endurance, a minimum crew of 33 with bunks for 58, a very large weapons payload and compatibility with the American AN/BYG-1 combat system (see Table 8).

Table 8. Type 216 Design Specifications

Attribute	Performance
Propulsion	Conventional with AIP
Displacement	4000 tons (surfaced)
Max. Speed	20+ knots (submerged)
Armament	• 6 torpedo tubes • 3 multi-purpose modules
Seagoing Endurance	80 days
Submerged Endurance	3+ weeks
Range	10,000+ nm
Min. Crew Size	33
Max. Crew Size	58
# of Crew Bunks	58
Combat System	AN/BYG-1 compatible
Mk-48 Torpedoes	?
Harpoon Anti-Ship Missiles	?
Tomahawk Land Attack Missiles	?
High Weapons Payload	• 18 torpedoes/anti-ship missiles • 21 land attack missiles[xvii]
Diver Lockout Chamber	YES[xviii]
Dry Deck Shelter	NO
UUV Bay	YES[xix]

Source: Thyssen Krupp Marine Systems[208]

[xvii] Each Type 216 Class boat can accommodate up to three vertical multi-purpose modules. Each multi-purpose module can accommodate up to seven land-attack missiles.

[xviii] A diver lockout chamber can be added in lieu of one multi-purpose module.

[xix] A UUV bay can be added in lieu of one multi-purpose module.

Option 5: Collaborate with France on the SMX Ocean Design

The French company DCNS has also announced its design concept for a high-performance conventional propulsion submarine, entitled SMX Ocean. The design is a conventional variant of the Barracuda Class nuclear-powered submarines that are currently in production for the French Navy.[209] It has a surfaced displacement of 4700 tonnes, a range of 18,000+ nautical miles, around 90 days seagoing endurance, around one month submerged endurance, a maximum submerged speed of 20+ knots and an average transit speed of 14 knots (see Table 9).[210] The design can be run by a crew of as little as 40 with space for 60 crew bunks (see Table 9).[211] In terms of armaments the design incorporates eight torpedo tubes with space for 20 torpedo, missile or mine reloads, in addition to a VLS module containing six land attack missiles (see Table 9).[212] It is also important to remember that eight weapons can be stored in the torpedo tubes meaning that the SMX Ocean design concept can carry up to 28 tube-launched weapons plus an additional six land attack missiles (see Table 9).[213] The design also includes Special Forces support infrastructure including an eight-diver lockout chamber, a dry deck shelter and an internal bay for deploying and recovering UUVs (see Table 9).[214]

One benefit of the SMX Ocean concept is its relative maturity that stems from its close relation to the Barracuda submarines that are currently in production. If selected, SMX Ocean would reduce the risk of implementing an immature design by learning from the issues of the Barracuda Class project.

Another benefit of SMX Ocean is its high performance and payload capabilities. The impressive design features include its range, seagoing endurance, submerged endurance and its large hull that gives it significant scope for future upgrades (see Table 9). The carriage of 34 weapons in addition to a dry deck shelter, internal UUV bay and diver lockout chamber means that SMX Ocean would give the RAN submarine force significant multi-mission flexibility without requiring trade-offs (see Table 9).

A third benefit of SMX Ocean is that DCNS has extensive experience in designing high performance conventional submarines and exporting submarines to foreign navies, either as complete boats or as designs for construction in foreign shipyards. DCNS has exported submarines to the navies of Pakistan, Chile, Malaysia, India and Brazil, with all Indian and

Brazilian boats plus the third Pakistani boat built in local shipyards.[215] It is also worth noting that DCNS has successfully enhanced the submarine construction capabilities of Indian, Brazilian and Pakistani shipyards, as well as adapting its baseline conventional submarine designs to meet each client navies unique requirements.[216] However this experience also demonstrates willingness by DCNS and the French Government to part with its sensitive submarine technology, and by extension potential willingness to export the SMX Ocean design in whole or in part to other Asia-Pacific countries. If Australia selected SMX Ocean, the risk of France exporting an identical or similar design to other Asia-Pacific powers would threaten to undermine the RAN's regional submarine capability edge. Just as in the case of the German Type 216, this is a risk that is unlikely to be favourably looked upon by the Australian Government.

The SMX Ocean concept also has three significant limitations. Firstly, SMX Ocean is not designed to natively support an American combat system and weapons complement. Due to RAN-USN interoperability concerns, the inclusion of the AN/BYG-1 combat system and American weapons is a non-negotiable requirement. If SMX Ocean was selected as the preferred design for the RAN FSM, the baseline design will require modifications that may prove time-consuming and costly.

Secondly, including highly sensitive American technologies into a French submarine design is likely to attract a veto from the US Government. The problem is that pursuing SMX Ocean will require French National's to have some level of access to highly sensitive American submarine technology. At the very least the DCNS design team must understand the space, weight, electrical power and cooling requirements of all included American submarine technologies and weapons. Given the immense sensitivity of the American technologies involved it is understandable why the US Government would block any Australian-French submarine project.

It is also important to note that pursuing the SMX Ocean design would almost certainly rule out construction of the RAN FSMs in French shipyards, since it would give French Nationals 'hands-on' access to highly classified American submarine technology, and would be viewed by the US Government as an unacceptable breach of security. The credibility of the US Government denying France even partial access to their highly sensitive submarine technologies has precedent in their refusal to allow any data being shared between their AN/BYG-1 combat system and European sensors in the current Collins Class submarines.

Thirdly, it is unknown how willing France and/or DCNS will be to grant the Commonwealth of Australia significant access to the SMX Ocean IP. Acquiring this level of access is necessary to enable the independent sustainment, maintenance, modification and modernisation of the RAN FSM fleet in Australia, without the hindrance of IP disputes.

Aside from the risk of DCNS exporting a similar design, uncertainty surrounding substantial IP access as well as the integration and protection of American technology, the merits of the SMX Ocean design render it a credible contender for the RAN FSM. These merits include its 18,000+ nm range, 4700 ton displacement, one month submerged endurance and high weapons payload, as well as its integration of Special Forces and UUV support infrastructure into the baseline design (see Table 9).

Table 9. SMX Ocean Design Specifications

Attribute	Performance
Propulsion	Conventional with AIP
Displacement	4700 tons (surfaced)
Max. Speed	20+ knots (submerged)
Armament	• 8 torpedo tubes • 1 Vertical Launching System
Seagoing Endurance	90 days
Submerged Endurance	1 month
Range	18,000+ nm
Min. Crew Size	40
Max. Crew Size	60
# of Crew Bunks	60
Combat System	French (not AN/BYG-1)
Mk-48 Torpedoes	?
Harpoon Anti-Ship Missiles	?
Tomahawk Land Attack Missiles	?
High Weapons Payload	• 28 torpedos/missiles[xx] • 6 land attack missiles[xxi]
Diver Lockout Chamber	YES
Dry Deck Shelter	YES
UUV Bay	YES

Source: DCNS[217]

[xx] Eight weapons are stored in torpedo tubes plus 20 reloads.

[xxi] Six land-attack missiles stored in the Vertical Launching System

DISCUSSION AND CONCLUSIONS

For reasons including the high acquisition cost of $31.6 billion USD (for 12 boats), the Australian public's aversion to nuclear energy, a high crewing requirement and the Americans' highly protective export laws, acquiring Virginia Class submarines is not a credible option. The problem with the Japanese Soryu Class is that it has a short service life, does not include American systems or weapons, it has inadequate range and has the risk of a future Japanese Government revoking its export mid-contract. All these disbenefits would come with an estimated price tag of $24 billion AUD for 12 boats. Consequently, neither the Virginia Class nor the Soryu Class are credible contenders for the RAN FSM project. The remaining credible contenders are collaborative design efforts with Japan, Germany or France, and have been comparatively assessed in accordance with the following six criteria:

1. **Strategic Alignments**
2. **United States Classified Information Restrictions**
3. **Relevant Design & Export Experience**
4. **Design Concept Specifications**
5. **Intellectual Property Access**
6. **Acquisition Cost**

1. Strategic Alignments

Germany and France that have no substantial strategic or alliance points of commonality with Australia. In stark contrast, Japan and Australia strategically align across two dimensions. The first dimension is the commonalty of US Alliances. Under two separate bilateral alliance arrangements, the United States underwrites Japanese and Australian security from armed attacks through the promise of substantial conventional forces and the provision of an extended nuclear deterrent. The critical importance of the United States to both Japanese and Australian security means that interoperability with the US Armed Forces, and in particular the USN's Pacific Fleet, is a critical consideration in all naval capability acquisitions. Consequently, convincing Japan on the merits of factoring in American systems and weapons requirements into their post Soryu submarine will be far more achievable than with Germany or France. This is particularly because neither European power places anywhere near the same level of priority on interoperability with the US Armed Forces as does Australia or Japan.

Another dimension is that both Japan and Australia have extreme vested interests in ensuring that the Asia-Pacific remains stable and governed by international law. For instance, Japan and Australia have an interest in ensuring that critical SLOCs in maritime Southeast and Northeast Asia remain clear of interference by any single power. Secondly, both Japan and Australia are increasingly concerned about the potential threat posed by China, given its ambit maritime claims and assertive behaviour that only escalates regional tensions.

2. United States Classified Information Restrictions

The intimacy of the Australia-US Alliance is evidenced by two factors. Firstly, Australia is a member of the exclusive and highly secretive 'Five Eyes' intelligence sharing alliance, with membership also including the United States, Great Britain, Canada and New Zealand. Secondly, Australia and the United States regularly engage in joint ventures including joint intelligence facilities, joint R&D projects and joint military exercises. The US Government also entrusts Australia with some of its most advanced and sensitive military technology for use by the ADF. Notable examples include the export of Mk-48 CBASS torpedoes and the AN/BYG-1 combat system for use by the RAN submarine force.

The problem with engaging Germany or France is that the US Government is likely to block any such venture, on the grounds of protecting its global submarine capability edge from erosion. Any European design would require modifications to meet RAN requirements, and in practice would require giving German or French Nationals access to the space, weight, electrical power and cooling requirements of highly classified American technologies. Even this limited level of disclosure is unlikely to be satisfactory to the US Government given the extraordinary measures that were demanded to protect their AN/BYG-1 combat system data from any direct exposure to French sensors. These security concerns would also prevent the construction of RAN FSMs in German or French shipyards, since it would allow foreign nationals of a non Five Eyes power 'hands on' access to highly classified American submarine technologies.

By contrast, a joint Japanese and Australian submarine project is far less likely to be blocked by the US Government for four reasons. Firstly, Japan is one of America's most trusted top tier allies and is already trusted with highly sensitive American military technologies including the Aegis combat system, the F-35 Joint Strike Fighter (currently on order), as well as the Standard Missile 3 (SM-3) and Patriot Advanced Capability 3 (PAC-3) Ballistic Missile Defence (BMD) interceptor technologies.[218] Secondly Japan and the US already share intelligence under various agreements.[219] Thirdly, Japan and the US regularly conduct joint military exercises to enhance joint forces interoperability.[220] Fourthly, Japan and the US conduct joint R&D projects to yield highly prized and classified military technologies for use by Japanese and US forces.[221] The most notable example to date is the joint R&D of the SM-

3 Block IIA BMD interceptor.[222] Given the intimacy of the Japan-US Alliance it is highly unlikely that a joint Japanese-Australian submarine venture would raise objections regarding Japanese access to sensitive American technologies.

With a post Soryu design, the construction of the RAN FSMs could feasibly be outsourced to Japanese shipyards, with all sustainment to occur at the ASC shipyards in Adelaide. Alternatively, the Australian Government could pursue the Type 216 or SMX Ocean designs but this would only be feasible if all or significant portions of construction takes place in Adelaide by the ASC. This is because the US Government is highly unlikely to ever sanction giving European foreign nationals 'hands-on' access to its sensitive military technologies.

3. Relevant Design & Export Experience

The German company TKMS has extensive experience in tailoring its submarine classes to meet the requirements of 22 countries worldwide, including South Korea and Singapore.[223] Similarly the French company DCNS has experience in tailoring its designs to the needs of Pakistan, Malaysia and India. Consequently both TKMS and DCNS are competent at tailoring their exported submarine designs to satisfy the requirements of some Asia-Pacific navies. From their respective experiences, both TKMS and DCNS will have some appreciation of the RAN's operational requirements.

Japan has extensive experience in designing high-performance submarines designed exclusively for Asia-Pacific naval operations since World War II. This is in contrast to the German and French experience of modifying their submarines to meet a broader Asia-Pacific client base, designs that were originally developed to meet European naval requirements. Japan's specialty in Asia-Pacific submarines is evidenced by the numerous generations of high-performance conventional designs, including the recent Harushio, Oyashio and Soryu Classes.

However, Japan does not have any experience in exporting its submarine designs. This can be viewed as a drawback in contrast to the extensive export experience of the Germans and French. But, the German and French export experience also demonstrates their willingness to sell their sensitive submarine technology abroad. Therefore selecting the Type 216 or SMX Ocean for the RAN FSM raises the risk that all or significant parts of the design may be sold to other Asia-Pacific powers. If even one such sale occurred it would substantially degrade the RAN's regional submarine capability edge. The necessity of secrecy surrounding the RAN FSM design is of paramount importance because this design must provide the basis for the RAN's regional submarine capability edge well past 2060.

In contrast, a joint submarine venture with Japan is less risky in this particular instance. This is because Japan has never sold its advanced submarine technology abroad and will zealously protect its submarine capability edge from erosion, particularly given the perceived risk of a future armed conflict with the Peoples' Republic of China. Therefore in general, Japan will be highly selective about the recipients of its defence technology exports and even more rigorously selective with regard to its submarine technology exports.

For instance, Japan would never export any defence technology to Pakistan for fear of the technology being leaked, on-sold or provided to the Peoples' Republic of China, a country with whom Pakistan has close defence and export relations.[224] Whereas, Japan would consider exporting its submarine technologies to countries like Australia and the United States due to the close alignment of security interests. These interests include the need to secure critical SLOCs in maritime Southeast and Northeast Asia from annexation or control by the Peoples' Republic of China. In short, Japan will never export its advanced defence technologies to countries that may threaten its security interests (directly or indirectly), additionally these security interests align closely with those of Australia. Consequently, Australia can rest assured that, if selected, Japan is highly unlikely to export a similar or identical design to any other country, aside from perhaps the United States.

One way that TKMS and the German Government or DCNS and the French Government could overcome the perceived risk of a similar design being exported to other countries is to sell the Commonwealth of Australia exclusive and complete ownership over their respective design. However, it is unclear whether the Germans or French would be willing to agree to the sale of such extensive IP rights.

4. Design Concept Specifications

With regard to the Japanese option no information is publicly available on the post Soryu Class submarine. It is therefore impossible to add any comparative discussion about the Japanese option to this criterion. However, if the post Soryu submarine design is to be given serious consideration, it must offer greater range, endurance, weapons payload and Special Forces support capabilities than the Collins Class. These design and performance specifications should also be comparable to the Type 216 and SMX Ocean designs.

The TKMS Type 216 and DCNS SMX Ocean are very impressive design concepts (see Table 10). Both designs offer far superior performance, payload and features than the Collins Class and thus are credible contenders for the RAN FSM (see Table 10). It is also important to note that both designs will require modification to accept American weapons, and in the case of SMX Ocean to support the space, weight, power and cooling requirements of the American AN/BYG-1 combat system. The most significant differences between the Type 216 and SMX Ocean exist in eight key areas:

i. **Displacement:** SMX Ocean has a significantly greater displacement at 4700 tons, whereas the Type 216 is 4000 tons (see Table 10). The significance is that the Type 216 is likely to have a reduced space, weight, buoyancy, power and cooling capacity to accommodate new technology upgrades as they become available.

ii. **Armament:** Unlike SMX Ocean, the Type 216 is equipped with three multi-purpose modules (see Table 10). These allow the Type 216 unparalleled flexibility to meet rapidly evolving requirements, without the need for an expensive and time-consuming refit.

iii. **Seagoing Endurance:** SMX Ocean has 90 days seagoing endurance, whereas the Type 216 can stay at sea for 80 days without resupply (see Table 10). Although ten days may not seem significant, it could mean the difference between having the capability to execute long-range patrols in Northeast Asia and not.

iv. **Range:** SMX Ocean has an open source range of greater than 18,000+ nautical miles and is greater than the open source range of the Type 216 at 10,000+ nautical miles (see Table 10). This disparity is significant for the sole reason of long-range patrols that are very important to the RAN.

v. **Crew Size:** The Type 216 has a minimum crewing requirement of 33, whereas the minimum SMX Ocean crew is 40 (see Table 10). This minimum crewing requirement is important for the RAN since it offers the potential to alleviate the submarine crew shortage problems faced by Australia.

vi. **Combat System:** The Type 216 is already compatible with the American AN/BYG-1 submarine combat system and is a critical requirement for the RAN FSM, whereas SMX Ocean is yet to prove that it is compatible (see Table 10).

vii. **Payload:** The Type 216 has an extraordinarily large payload of 39 weapons including 18 torpedoes or anti-ship missiles and 21 land attack missiles, if all three vertical multi-purpose modules each house seven missiles (see Table 10). This total weapons payload increases to 45 if the Type 216 can deploy with all six torpedo tubes occupied. Under these circumstances this would bring the total to 24 torpedoes or anti-ship missiles, and 21 land attack missiles. In contrast SMX Ocean carries a maximum payload of 34 weapons with eight in the boat's torpedo tubes, 20 torpedo or anti-ship or land attack missile reloads, plus six land-attack missiles in a VLS module (see Table 10).

viii. **Special Forces & UUV Support:** SMX Ocean is equipped with an eight-diver lockout chamber, plus a dry deck shelter for Special Forces and a dedicated UUV bay (see Table 10). In contrast the Type 216 has none of these and does not natively have a dry deck shelter, although this could probably be developed at additional cost. Instead the Type 216 relies on the designs three multi-purpose modules that can accept different packages including diver lockout chambers, UUV bays and land attack missiles. (see Table 10). The advantage of the Type 216 design is that it enables the ability to be reconfigured rapidly, in order to meet changing operational requirements. The disadvantage of the Type 216 design is that increasing the weighting on a particular capability such as land-attack comes at the opportunity cost of other capabilities such as a diver lockout chamber or UUV bay.

Table 10. Comparison of Feasible RAN FSM Options

Attribute	Collins Class (Australia)	RAN FSM Requirements	Type 216 Design Concept (Germany)	SMX Ocean Design Concept (France)
Propulsion	Conventional	Conventional	Conventional	Conventional
Displacement (surfaced)	3100 tons	3100+ tons	4000 tons	4700 tons
Max. Speed (submerged)	20+ knots	20+ knots	20+ knots	20+ knots
Armament	• 6 torpedo tubes	6+ torpedo tubes	• 6 torpedo tubes • 3 multi-purpose modules	• 8 torpedo tubes • 6 cell VLS
Seagoing Endurance	70 days	70+ days	80 days	90 days
Submerged Endurance	1+ days	2+ weeks	3+ weeks	1 month
Range	9000 nm	9000+ nm	10,000+ nm	18,000+ nm
Min. Crew Size	?	Less than 58	33	40
Max. Crew Size	58	58+	58	60
# of Bunks	58	58+	58	60
Combat System	AN/BYG-1	AN/BYG-1[xxii]	AN/BYG-1 compatible	French
Mk-48 Torpedoes	YES	YES	?	?
Harpoon Anti-Ship Missiles	YES	YES	?	?
Tomahawk Land Attack Missiles	NO	YES	?	?
High Weapons Payload	• 22 torpedo/anti-ship missiles ***TOTAL: 22 weapons***	• 22+ torpedoes/anti-ship missiles/land-attack missiles/mines	• 18 torpedoes/anti-ship missiles • 21 land attack missiles (7 per multi-purpose module) ***TOTAL: 39 weapons***	• 8 torpedoes/anti-ship missiles in tubes • 20 torpedo/missile reloads • 6 land attack missiles in VLS ***TOTAL: 34 weapons***
Diver Lockout Chamber	YES	YES	YES (in lieu of one module)	YES (8 divers)
Dry Deck Shelter	NO	DESIRABLE	NO	YES
UUV Bay	NO	DESIRABLE	YES (in lieu of one module)	YES

Source: DCNS; TKMS; Briggs,P & Roach,T; Babbage,R; Woolner,D; Commonwealth of Australia; Australian Strategic Policy Institute; Australian Submarine Corporation; The Kokoda Foundation[225]

[xxii] American submarine combat system.

5. Intellectual Property Access

In order to independently sustain the FSM, it is vital that the Commonwealth of Australia obtain significant access to the IP of the FSM design. This IP access is necessary to allow the Commonwealth of Australia to independently maintain, modify and/or modernise the FSMs in Australia without any risk of IP disputes. Currently it is unclear to what extent the Japanese Government, TKMS and the German Government or DCNS and the French Government will be willing to grant the Commonwealth of Australia the necessary level of IP access to their respective submarine designs.

6. Acquisition Cost

TKMS has publicly stated that it can deliver a fleet of 12 Type 216 submarines to the RAN for approximately $20 billion AUD, and is considerably less than the previously estimated $36 billion AUD to acquire a bespoke Australian submarine class. In contrast, DCNS has not released estimated pricing for a fleet of SMX Ocean submarines and Japan has not acknowledged the existence of a post Soryu submarine, let alone discussed its potential pricing in the open-source domain.

Concluding Remarks

In terms of strategic alignments, the protection of classified information and geographically relevant design experience, a collaborative venture with Japan on the post Soryu submarine is a very competitive option. However with no information on the future designs performance specifications, acquisition cost, or IP access rights, many questions are left unanswered. If a collaborative Japanese-Australian venture is to be feasible then several issues need to be satisfactorily addressed. The post Soryu submarine must have superior design and performance specifications to the Collins Class and should be comparable to the Type 216 and SMX Ocean designs, it must accommodate various American technologies, the acquisition cost for 12 boats must be similar to the Type 216/SMX Ocean and the Japanese Government must grant the Commonwealth of Australia significant access to the designs IP. In the event that these substantial hurdles can be overcome, the Japanese post Soryu submarine may become the preferred design option for the RAN FSM. This is especially the case if the Australian Government decides to offshore all submarine construction.

Alternatively, the German Type 216 and French SMX Ocean design options offer their respective benefits. The Type 216 offers significant multi-mission flexibility, a minimum crewing requirement of 33, a substantial weapons payload and native support for the American AN/BYG-1 combat system. Although SMX Ocean carries less weapons than the Type 216 and is unproven in its capacity to support the AN/BYG-1, it has superior range, superior capacity to accommodate future upgrades[xxiii], a dedicated UUV bay and dry-deck shelter. It is also important to note that for either the Type 216 or SMX Ocean to be credible contenders for SEA 1000, they must both support a full complement of American weapons plus the AN/BYG-1.

However, the Type 216 and SMX Ocean designs suffer from the risk of a similar design being exported to another country, uncertainty over the extent of IP rights that would be granted to the Commonwealth of Australia, and the risk German/French nationals gaining access to sensitive American submarine technologies. One way that these issues could be bypassed is for the submarine designer and respective government to grant the Commonwealth of Australia exclusive and complete access to their designs IP plus significant support to

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[xxiii] Due to its significantly larger hull.

facilitate all or most construction work in Australian shipyards. This solution would nullify all the major objections to the Type 216 or SMX Ocean options, and render either or both designs highly competitive options.

In summary, the Japanese, German and French options are all credible options for SEA 1000. However, if any of the three designs are to be seriously considered their respective companies and governments will have to openly resolve the many unanswered questions raised by this paper before the Australian Government's competitive evaluation process concludes. Ultimately, what will increase the probability of a designs selection is how swiftly and openly the respective company and government evolve to meet the Australian Government's requirements.

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