NUCLEAR PROPULSION ROADMAP FOR AUSTRALIA®
- A FASTER WAY AHEAD?

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Nuclear Propulsion Roadmap for Australia®

- Introduction; Nuclear Submarines
- Why develop a Roadmap?
- US development of SSN(X)
- Generation IV R&D
- Earlier than Nuclear Power?
- Nuclear Propulsion requirements
- Case study: Canadian submarines
- Disposal of nuclear submarines
- Conclusions

Nuclear Propulsion Roadmap for Australia®			
	A. Impact on Legislation	B. Fuel cycle for SSN	C. Reactor sourcing
1. Rationale			
2. Consulting			
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Introduction for NPRM4A

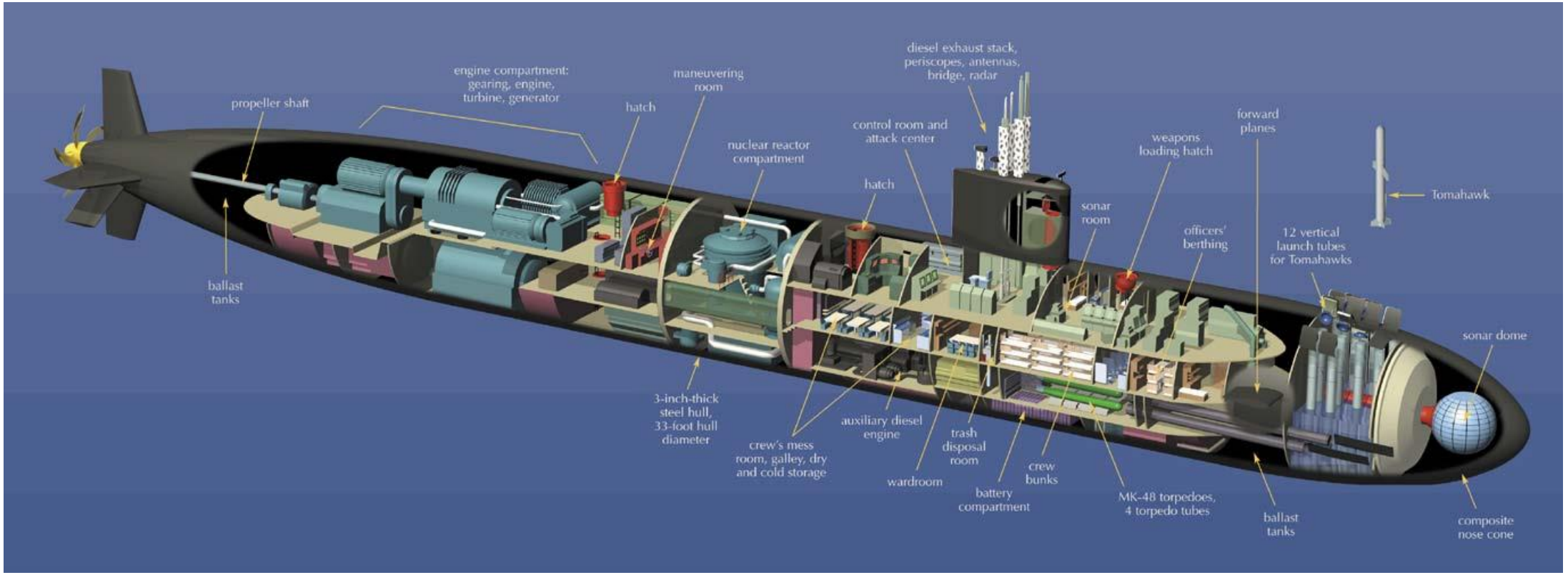
- Motivation to develop the Nuclear Propulsion Roadmap for Australia®
- There have been several published papers and reports on WHY Australia should acquire Nuclear Submarines
- But little published on HOW and BY WHOM and WHEN this should be undertaken
- The underlying assumption in most advocacy for nuclear submarines is that we must first have in Australia an established nuclear industry supporting nuclear power generation and perhaps also nuclear fuel processing
- This presentation turns this assumption around and advocates acquisition of nuclear propulsion first, which would then enable civil nuclear power.

World Nuclear Association Statement (WNA2019)

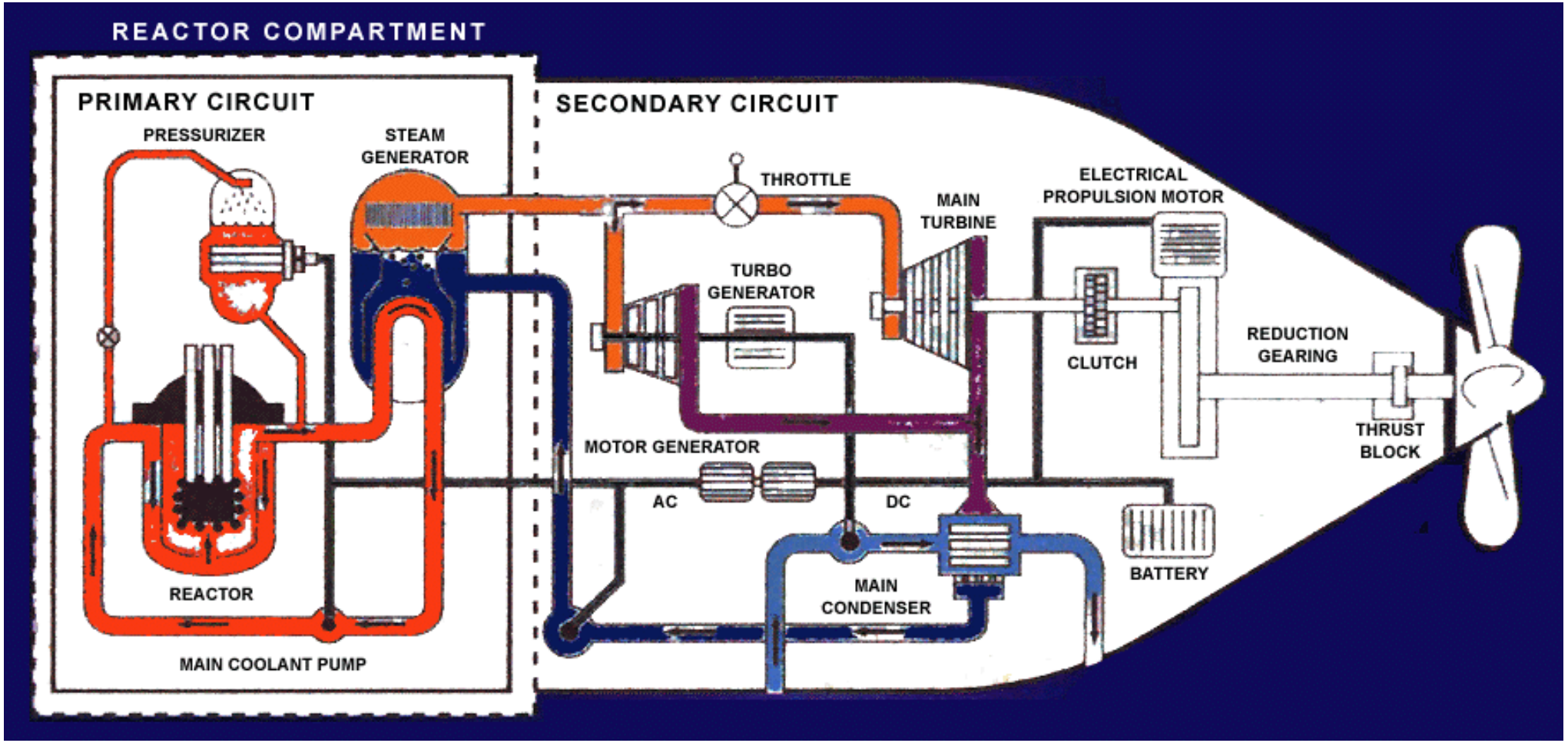
Nuclear-Powered Ships

- *(Updated May 2019)*
- Nuclear power is particularly suitable for vessels which need to be at sea for long periods without refueling, or for powerful submarine propulsion.
- Over 140 ships are powered by more than 180 small nuclear reactors and more than 12,000 reactor years of marine operation has been accumulated.
- Most are submarines, but they range from icebreakers to aircraft carriers.
- In future, constraints on fossil fuel use in transport may bring marine nuclear propulsion into more widespread use. So far, exaggerated fears about safety have caused political restriction on port access.
- WNA© 2016-2019

Nuclear Attack Submarine [SSN] - illustration



Pressurised Water Reactor [PWR] for SSN (WNA2019)

- 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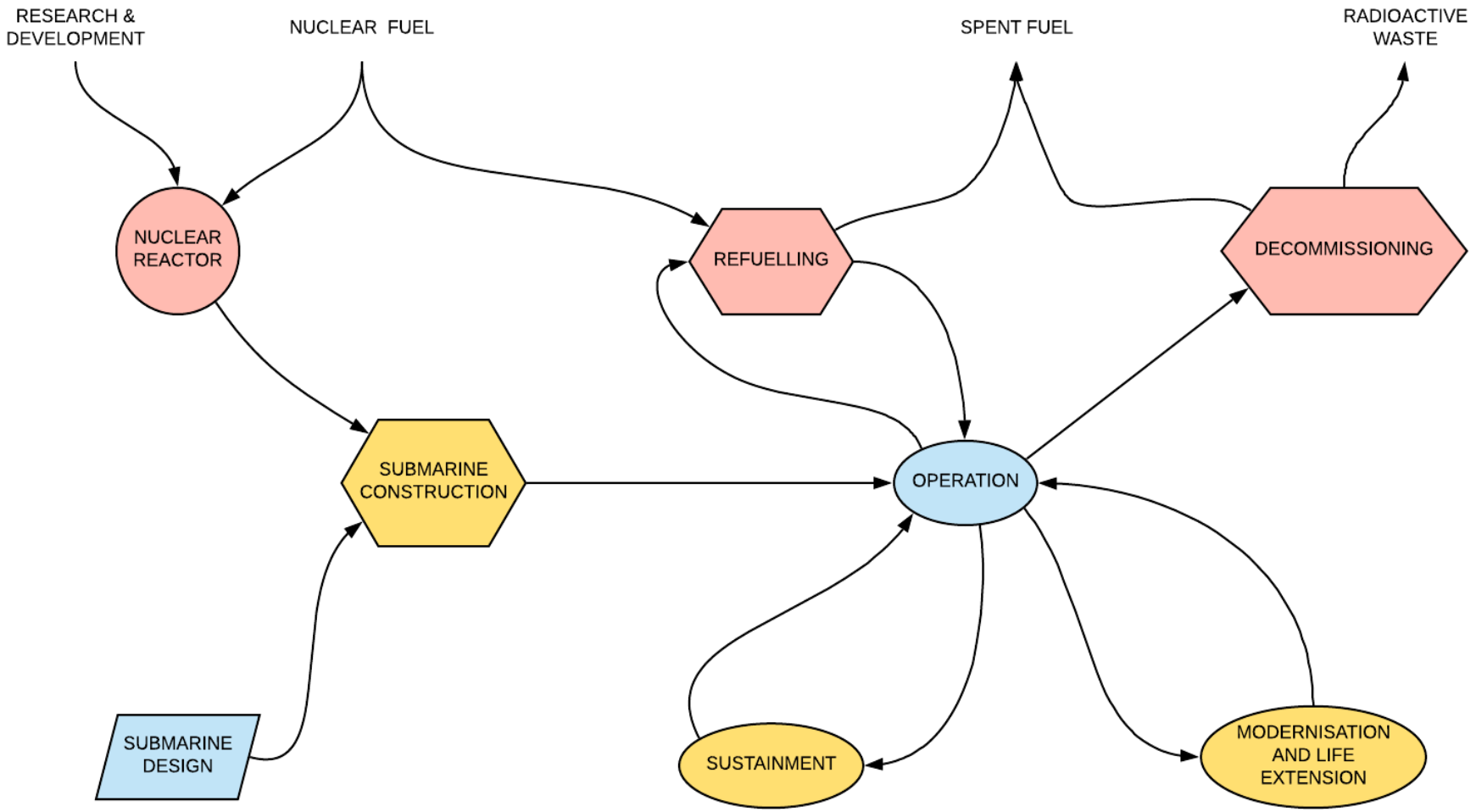
NPRM4A – Nuclear Submarine Life Cycle



NPRM4A – A Frequent Question

- A frequently raised question is why wasn't nuclear propulsion adopted for the new Future Submarine Program [FSP] to design and build the ATTACK class conventionally powered submarines in Australia
- The customary response is that Australia lacks a nuclear power industry, which is implied to be essential to provide the rigour and scope of nuclear science, technology and engineering for submarine propulsion, even for sustainment and refuelling, let alone for construction

Is there a need for nuclear industry?

Snowy Hydro's Tumut 3 power station, where Snowy 2.0 will be built if it goes ahead. PHOTO: AAP

Garnaut has energy superpower vision

29 APR 2019 AFR

Exclusive

Ben Potter

Australia needs three key reforms – including splitting Snowy Hydro into two state-owned companies – to regain its place as an energy superpower with globally competitive power in regions and cities as the world shifts to renewable energy, top energy economist Ross Garnaut says.

Professor Garnaut, economics professor at the University of Melbourne and architect of the last Labor government's never-implemented carbon trading scheme, says he has no doubt Australia can have secure reliable electricity at much lower prices that would underpin expansion of minerals processing and other heavy industry if it adopts his plan.

The first step is to split federal government-owned Snowy Hydro's existing and proposed pumped hydro assets from its baseload generation. The second is to tweak the Australian Competition and Consumer Commission's recommendation for the federal government to underwrite some firm energy generation. The third is more transmission to allow renewable energy to move more easily from generation sites to demand centres.

"After a dozen years living closely with the Australian and global energy transitions, I now have no doubt that intermittent renewables could meet 100 per cent of Australia's electricity requirements by the 2030s, with high degrees of security and reliability, and at wholesale prices much lower than any experienced in Australia over the past decade," Professor Garnaut says in the third of a series of lectures.

His optimism stands in stark contrast to the election campaign debate in which the Morrison government has slammed Labor's 50 per cent renewable energy by 2030 and 45 per cent economy-wide carbon emissions reduction targets as economically reckless.

Professor Garnaut says Australia's unique clean energy resources – in solar, wind and pumped hydro storage – mean it can contribute its fair share to global efforts to limit industrial era temperature increases to 1.5°C. It can also – with good policy – supply "firm power in globally transformative quantities ... to industrial locations in each state at globally competitive prices" of around $45 to $50 per megawatt hour. "No other developed country has a comparable opportunity," he says. But it will take many years to restore Australia's edge and the economic opportunities will be lost "if we wait until our slow-moving business institutions and policy move to correct the errors of the past".

Professor Garnaut says "fleet of foot" businesses and regional governments can get on with it without waiting for national policy, but his reforms will boost the prospects of a strong outcome. He says it is necessary to split Snowy Hydro into two because the ACCC had found in its Retail Electricity report that Snowy Hydro would have 60 per cent of the market for peaking power in NSW and Victoria if it built its proposed $5.3 billion, 2000 MW Snowy 2.0 pumped hydro expansion. He would call the pumped hydro company Snowy Energy Guarantee or "SNEG" and charge it with keeping peaking power cheap by intervening – using existing pumped hydro assets and Snowy 2.0 if it stacks up – whenever prices get out of line.

He would extend the ACCC's proposed firm generation underwriting scheme from five years to 10 and separate the process from the Clean Energy Finance Corporation to fully take advantage of the federal government's low borrowing costs.

With these tweaks to "Recommendation 4" of the Retail Electricity report, he says globally competitive power supply is feasible now in major industrial sites outside capital cities – "including Collie-Bunbury in WA, the Upper Spencer Gulf in SA, the Latrobe Valley and Portland in Victoria, Newcastle and Port Kembla in NSW, and Gladstone and adjacent inland regions and perhaps other industrial ports in Queensland".

Finally, the grid won't accommodate more than about 50 per cent renewable energy without more transmission. Professor Garnaut says this can be facilitated by reforms allowing a stronger public sector role in transmission planning, less of a role for network companies, and "reward for private unregulated investment that adds public value to the network", rigorously supervised by the Australian Energy Regulator.

- Professor Ross Garnaut says:

'... I now have no doubt that intermittent renewables could meet 100 per cent of Australia's electricity requirements by the 2030s, with high degrees of security and reliability, and at wholesale prices much lower than any experienced in Australia over the past decade.'

('Garnaut has energy superpower vision' Ben Potter, Australian Financial Review 2019-04-29)

- However he offers no evidence

Rebuttal for the Garnaut view

- Renewable energy sources require energy storage to provide reliable 24/7 energy supply
- Cost of storage must be included in comparison of energy supply
- There is also the life-cycle cost of replacement of the energy sources and storage over the effective asset lifetimes
- Location of renewable energy is sometimes remote from demand centres requiring investment in distribution networks
- The steady reduction of thermal coal for electric power generation is partially offset by increasing use of gas and oil
- The emissions reduction process is over an extended period that may be too long to mitigate global warming sufficiently
- The prices of energy supplies will reflect available supply and demand and that may exceed thresholds for some domestic industry

‘Could Australia’s Future Submarines be Nuclear-Powered?’ Green Paper.

UCL International Energy Policy Institute. August 2013

1. Developing a nuclear-powered submarine no greater challenge than unique conventional submarine design
2. Nuclear power industry unnecessary for SSN feasibility
3. Leasing would not increase dependence
4. Global shortage of nuclear regulatory personnel
5. Fuel would be provided with the reactor
6. May only need to manage short-lived radioactive waste
7. Unlikely reactor maintenance in Australia
8. Decommissioning waste could be managed here, except spent fuel

NPRM4A – why develop a Roadmap?

- The chicken and egg dilemma of the need for a nuclear industry for nuclear propulsion and on the other hand the legislative prohibition on Australian engagement in nuclear power development within the *Environmental Protection and Biodiversity Protection Act 1999* and other Commonwealth and State and Territory Acts and Regulations

- A Roadmap is proposed to examine all the options in moving forward so that the way ahead can be perceived and pursued in the light of all the known factors and options applicable
- The Roadmap will recommend preferred ways ahead as the lead time is likely to be more than two decades until an SSN is delivered

Factors influencing a Roadmap

- Nuclear propulsion differs significantly from the concept of nuclear power generation
- There is a more urgent requirement for nuclear propulsion
- The benefit/cost/risk equation for nuclear propulsion is more compelling than for nuclear power generation
- There are no alternatives to nuclear propulsion for some requirements
- The extended timeline for the current Australian submarine programs is challenging to accelerate expansion of the submarine force
- There are current opportunities for participation in the US Navy SSN(X) program
- At the same time Australia's participation in the Generation 4 International Forum could leverage Molten Salt Reactor development for naval application

Opportunity to join USN SSN(X) program

- Reference: *'US wants our help with nuke submarines'* Jacob Greber, 15 December 2018. Australian Financial Review.

- 'Republican House of Representatives member Michael Conaway… (who) sits on the Armed Services and Intelligence Committee, has launched a resolution calling on the US Department of Defense and Navy to work with… Australia, Canada, the UK and New Zealand on an "international joint-build, cost sharing program"… Despite the French deal as well as likely resistance to nuclear propulsion in in New Zealand and Canada…'
- '… to offset the estimated $US5.5 billion unit cost' (of the next generation SSN(X))

- Reference: *'Time to Re-task, Downsize, and Re-engineer the SSN'.* Duane J. Truitt. Center for International Maritime Security [CIMSEC] Part 1: 19th June 19th Part 2 26th June 2019

- 'Set an overall objective for Block 1 to build a new SSN of not more than 4,500 tons… and a crew size of not more than 70…'
- 'Total construction cost should aim for significantly less than $2 billion each in 2019 dollars.'
- 'While developing and building the Block I new SSN, the Navy can launch a new reactor design program to adapt a generation four reactor plant to provide numerous advantages over current technology (PWR) plants.'

Exploit Generation IV International Forum

- Australia 14th member of Generation IV International Forum [GIF] on 22 June 2016
- First non-nuclear power member
- GIF goals include improving:
  - Safety and reliability
  - Sustainability, including minimisation of nuclear waste
  - Resistance to nuclear proliferation
  - Economics of nuclear power
- Leap beyond light water reactors such as Pressurised Water Reactors [PWR] (as used in most SSNs today)

- GIF structural materials R&D:
  - Irradiation damage
  - Creep and fatigue at high temperature
  - Corrosion in molten salt environment
  - Combination of environments
- Collaboration with Shanghai Institute of Applied Physics [SINAP]
  - Joint Centre for Thorium Molten Salt Reactor [MSR] systems
  - Initial $400M R&D investment

(Reference: Dr Adi Paterson (2017) *'Journey from Gen III/III+ to Gen IV Reactors'* EA Nuclear Engineering Panel address 2017-11-22)

SSN Earlier than Nuclear Power?

- Even adopting Small Modular (Nuclear) Reactors [SMR] the timeline for acceptance and commitment is likely to exceed that for acceptance and commitment for nuclear propulsion
- Nuclear propulsion has an excellent safety record, with no nuclear incidents in the navies of France, UK and USA
- For nuclear power to be accepted Australia will first need to experience the shortcomings of a strategy relying on renewables only
- The creation of radioactive waste repository for decontamination of nuclear submarines will at the same time meet requirements for civil nuclear power generation
- Above all else the inherent benefits for safety and isolation from population centres accorded by nuclear submarine pressure hull and their reactor containment vessels makes them more acceptable in the community

Nuclear Propulsion Projected Timeline

Triennium	SSN Roadmap	ATTACK class	COLLINS class	SMR timeline
2019-22	Repeal nuclear bans	Detailed design		
2022-25		Start Construction	2024 start LOTE	NuScale SMR proven
2025-28	Regulatory Authority			
2028-31	Commit SSN project			2030 Renewables?
2031—34	Construction start	Deliver AC01	2033 LOTE ends	Commit to SMRs
2034-37		AC02, AC03	Exit CC01	
2037-40	HLW repository	AC04,	Exit CC02, CC03	
2040-43	2040 Deliver SSN01	AC05, AC06	Exit CC04, 05, 06	Commission SMRs?
2043-2051	SSN02 … SSN06			

Nuclear Propulsion requirements

- Submarine greater speed when submerged =>
  - reduced transit time
  - evasion following detection
- Endurance =>
  - adversary's uncertainty of submarine presence
  - Increased on-station time
- Reduced vulnerability to detection
  - Less time at periscope depth
  - Reduced radiated noise from snorting
- Enhanced deterrent effect of nuclear submarines (UK Falklands)

Requirements for Submarine Nuclear Propulsion sustainment in Australia

- Workforce
  - Recruited: UK, USA or France plus possibly India
  - Trained: in country of origin of the submarine reactor
  - Certified by Country of Origin and also by ARPANSA
- Regulatory Authority
  - Australian Radiation Protection and Nuclear Safety Agency [ARPANSA]
  - Office of Naval Reactors [ONR] equivalent
  - Safety & Security Assessments
- Maintenance facilities
  - Berthing in safety approved location
  - Shore services including redundant reactor cooling 24/7
  - Drydocking / Shiplift to be certified
  - Remote berth in case of incident
- Refueling / defueling
  - Fuel source, storage and transport
  - Reprocessing of spent fuel
  - Enclosed berth for Reactor access
- Decontamination & Disposal
  - Repository for residual waste

John Jeremy 1/2

‘May we go nuclear in the future? If so we have some work to do first, including:

- Gain political and social acceptance
- Negotiate a deal with the US, UK or France for nuclear technology transfer.
- Establish a Naval Nuclear Regulatory framework for Australia.
- Decide a procurement strategy – import complete or part-build in Australia.
- Decide on a location for submarine bases & complete environmental and security assessments.

…’

‘A Century of Submarine Development’ John JEREMY AM, The NAVY Vol.81 No.2 Apr-Jun 2019

John Jeremy 2/2 & Ian Noble

'…

- Define the nuclear specific facilities required
- Achieve local acceptance of a nuclear presence at these locations.
- Establish a training programme for civilian and naval nuclear engineers.

If we are to switch to nuclear powered submarines, we need to be starting this work now.'

'A Century of Submarine Development' John JEREMY AM, The NAVY Vol.81 No.2 Apr-Jun 2019

plus

- Plan for decommissioning, defueling, fuel disposal and hull break-up and disposal

Private communication from former submariner Ian Noble

Disposal of Old Nuclear Submarines

THE NATIONAL INTEREST

Published on The National Interest (https://nationalinterest.org)

Home > The Royal Navy Can't Seem to Figure Out How to Dispose of Old Nuclear Submarines

The Royal Navy Can't Seem to Figure Out How to Dispose of Old Nuclear Submarines

April 27, 2019 *Topic:* Security *Region:* Europe *Blog Brand:* The Buzz
Tags: United Kingdom, Royal Navy, Nuclear Submarines, U.S. Navy, Nuclear Waste

Not an easy problem to solve.

by Michael Peck

- Normal practice for decommissioned reactor materials to be placed where the residual radiation can decay sufficiently to reduce the exposure of crews that will later dismantle the submarine and dispose of the materials into a permanent site
- The US Navy buries its old reactors in a dedicated site
- The UK Royal Navy moors them in Rosyth, Scotland and in Devonport, England
- The Russian Navy has moored them in the Arctic. Some of them have sunk, and at least one is leaking radioactivity

Case Study: Canadian Submarines

- In 1987 Canada decided it needed 10 to 12 nuclear powered submarines to properly secure its national security interests, especially in the Arctic Ocean where nuclear propulsion was necessary for under-ice operations
- The Canadian Submarine Acquisition Program [CASAP] was to be based on British or French submarine design but was eventually cancelled due *"very high costs required to create and maintain the hard and soft infrastructure to operate and maintain a fleet of SSN's"* (Insight Economics 2017)
- The Canadian Small Modular Reactor (SMR) Roadmap in 2018 stated *'Canada is a tier 1 nuclear nation, with a full spectrum industry…'*
- Canada is currently considering the acquisition of 12 modern non-nuclear submarines using air-independent-propulsion [AIP] for under-ice operation. Canada does enjoy the close proximity of NATO ally the USA.

Reference: Byers, Michael & Stewart Webb. ***'That sinking feeling. Canada's Submarine Program springs a leak.'*** Rideau Institute, June 2013

Roadmap Development

- Rationale for Roadmap
- Progress on development of the Roadmap
- Next steps to be taken
- Role of the Commonwealth agencies: ANSTO, ARPANSA
- Role of the professional institutions and associations
  - Australian Nuclear Association
  - Engineers Australia Nuclear Engineering Panel
  - Submarine Institute of Australia
  - Royal Institute of Naval Arcitects

NPRM4A – Roadmap Table of Contents

The proposed Roadmap Structure is based on six proposed major work areas as follows:

1. Rationale and business case development, consultation and publication
2. Communications and consultation with community, media, government, academia
3. Design and integration; lifecycle approach, especially decommissioning
4. Source of reactor and reactor fuel cycle
5. Safety and regulatory requirements; legislative framework
6. Workforce for design, safety assurance, installation, commissioning, operation, sustainment, refuelling, decommissioning, waste recycling and disposal.

NPRM4A – Conclusions

- Nuclear Propulsion confers significant operational advantages on submarine operations
- There are significant costs involved in developing the infrastructure and operational and sustainment frameworks essential for nuclear propulsion
- The lack of a nuclear power industry in Australia is not the only, nor even perhaps the most important challenge to the introduction of nuclear propulsion for Australian submarines
- Assuming all the challenges can be overcome, the timeframe for introduction of nuclear propulsion is significant, but may be faster than approving, acquiring and commissioning Small Modular Reactors
- Objective: to introduce the first SSN in 2040 in place of ATTACK boat 07

Summary of Key Issues

- Proposed for Approval of Australian SSN Acquisition Program in 2028 – eight years hence!
- Unrealistic to contemplate SSN construction in Australia – maybe partial construction later. Therefore source overseas design, for example Barracuda class SSN from France, or possibly US New SSN
- Workforce will need to be recruited locally, trained and certified overseas then further qualified in Australia
- Facilities including spent fuel reprocessing and waste repository will need to be approved and construction started before the first SSN arrives (2040) so should form part of the initial approval decision
- Rescission of legislative constraints must proceed this Parliament

NPRM4A - References

- Briggs, Peter AO CSC Rear Admiral RAN (retired) ***'Special Report. Can Australia afford nuclear powered submarines? Can we afford not to?'*** Australian Strategic Policy Institute. October 2018
- ***'Could Australia's Future Submarines be nuclear-powered?'.*** Green Paper, University College, London [UCL] International Energy Policy Institute, Adelaide. August 2013
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- **Nuclear Fuel Cycle Royal Commission**. South Australian Government. 2016
- Truitt, Duane J. ***'Time to Re-task, Downsize, and Re-engineer the SSN'*** Parts 1 & 2, Center for International Maritime Security. June 2019
- **Uranium Mining, Processing, Nuclear Energy Review**. Australian Government. 2006

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Questions and Comments

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