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

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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.
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)
NPRM4A – Nuclear Submarine Life Cycle

Christopher Skinner: Nuclear Propulsion Roadmap for Australia
- a faster way ahead? EA Nuclear Engineering Panel 2019-07-17
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?

• 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.

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


- ‘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))


- ‘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

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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

Christopher Skinner: Nuclear Propulsion Roadmap for Australia - a faster way ahead? EA Nuclear Engineering Panel 2019-07-17
'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

- 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 Architects
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.

Christopher Skinner: Nuclear Propulsion Roadmap for Australia - a faster way ahead? EA Nuclear Engineering Panel 2019-07-17
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

Christopher Skinner: Nuclear Propulsion Roadmap for Australia - a faster way ahead? EA Nuclear Engineering Panel 2019-07-17
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
• 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


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


• 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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