Management of Key Technologies in the UK Naval Nuclear Propulsion Programme.

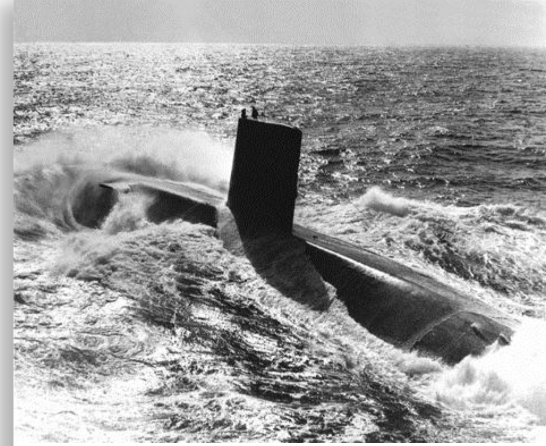
Christopher Palmer

Asst Chief Engineer – Astute

Rolls-Royce Submarines

History of the UK NNPP

- Key Dates
  - 1954 – UK NNPP formed
  - 1957 – DS/MP construction commences
  - 1958 – US/UK Bilateral Agreement signed
  - 1960 – HMS *DREADNOUGHT* launched
- HMS *VALIANT* (1966) used first all-UK plant & core design.
- PWR1 reactor plant design implemented in *VALIANT, CHURCHILL, RESOLUTION, SWIFTSURE* and *TRAFALGAR* Classes (1966-present, 23 vessels).
- PWR2 reactor plant design implemented in *VANGUARD* and *ASTUTE* Classes (1993-present, 11 vessels final).



HMS *Valiant*

HMS *Astute*

History of the UK NNPP

- Philosophy of Continuous Improvement applied within each plant design.
- 5 generations of reactor core design implemented.
- The latest Core H design represents a ten-fold improvement in core life over the first US and UK core designs and avoids the need to refuel the submarine during life.
- The installed core population to date represents an energy capacity of approx 70,000 GW hr.
- Over 30 million nautical miles steamed under nuclear power since HMS DREADNOUGHT launched in 1960.

Future developments in the UK NNPP

- SSBN Successor platform recently announced to be powered by PWR3 reactor plant.
  - PWR3 presents a significant design evolution for the UK NNPP.
  - PWR3 selected over PWR2 derivative design based upon demonstration of safety and performance improvement and total-life cost reduction.
  - Additional benefits in terms of exercising of UK NNPP design, validation and build capability.

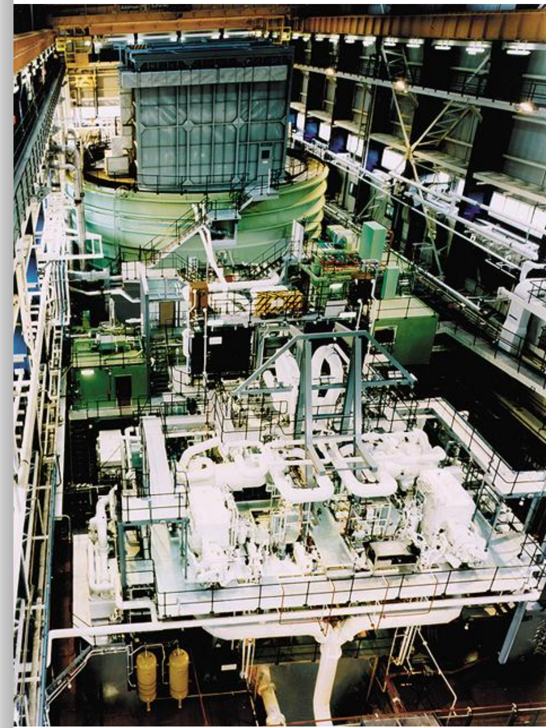
Management of Key Technologies

- Naval PWR is distinct from civil PWR in many regards.
- Long period of depressed activity in UK nuclear sector have necessitate programme ownership of key technologies.
- ‘Key Technologies’ are considered as those being unique or specific to the UK NNPP and not accessible in the wider supply chain, e.g.

  1. Reactor core and plant performance analysis, validation and verification.
  2. Major reactor plant component design
  3. High integrity electrical design

Management In-Programme

- A number of key technologies have been managed by proactive maintenance within the NNPP.
  - Typically ‘crown jewels’ technologies
    - E.g. core/plant design & performance analysis
    - Requires technology to be realistically exercised in order to retain capability
  - Dedicated infrastructure
    - HMS *VULCAN* (Naval Reactor Test Establishment)
    - NEPTUNE (Zero Energy Reactor)



HMS *Vulcan*

Management In-Programme

- UK collaboration with US NNPP has brought significant benefit.
  - Benchmarking of methods and capabilities
  - Re-evaluation of UK technology/design basis
  - Independent peer review of UK capability and design philosophy
- Helped to optimise PWR3 concept design.
- Key is to own the technology base underpinning PWR3 to ensure in-service supportability.

Management in the Industrial Base

- Strategic Technology Partners
  - A key technology requirement supplied by an organisation external to the UK NNPP
  - NNPP involvement/commitment in sustaining capability to ensure its availability
- Strategic Technology Suppliers
  - A key capability required by the NNPP but procured on a commercial basis.

Academic Engagement

- Academic institutions have been engaged to support both research and training needs:
  - Nuclear University Technology Centres (UTCs) established.
  - Masters courses and Engineering Doctorates directly supported by the NNPP
  - Bespoke technology training courses.

Challenges to UK Nuclear Sector

- Safety & Environmental Regulation
  - Office for Nuclear Regulation (ONR), Environment Agency (EA)
  - Trend towards risk-based ‘proportionate’ regulation with increasing collaboration amongst industry players and alignment between regulators
  - Basic tenet of demonstration of Risk Tolerability/ALARP however principle of Continuous Improvement can lead to ‘regulatory ratchet’ affect
  - Little direct impact to date arising from Fukushima; increased focus on assessment and resilience to extreme/dependent events

Challenges to UK Nuclear Sector

- Fuel Cycle Management
  - UK fuel manufacturing for AGR & civil PWR
  - URENCO Capenhurst (enrichment) and Westinghouse Springfields (fabrication), approx 250Te UO_2 annual capacity @ c. 7% enrichment.
  - Limited downstream routes for utilisation of enrichment tailings.
  - Reprocessing undertaken at THORP (Sellafield)
    - PuO_2 + Rep-UO_2 + 1% HLW to vitrification
  - Limited downstream routes for utilisation of PuO_2 and Reprocessed-UO_2 fuels.

Challenges to UK Nuclear Sector

- Waste Management & Disposal
  - At present, the UK has no repository for high-level or intermediate-level waste; government policy is for deep geological disposal c. 2030 or earlier
  - LLW waste routes have expanded through permissioning of disposal of LLW and V-LLW via conventional landfill
  - Current NNPP practice is afloat storage of defuelled and decommissioned vessels (currently 17) – this capacity will be exhausted by 2020.
  - UK MoD therefore consulting on best approach for interim storage of ILW prior to disposal to UK geological repository.

Summary

- For over 50yrs, the UK NNPP has developed, maintained and delivered nuclear propulsion to the Royal Navy submarine flotilla.
- A range of approaches to managing key technologies has evolved, engaging both industry and academia.
- Challenges in areas such as regulation, fuel cycle management and waste management are faced; these are common across the UK nuclear sector, both defence and civil.