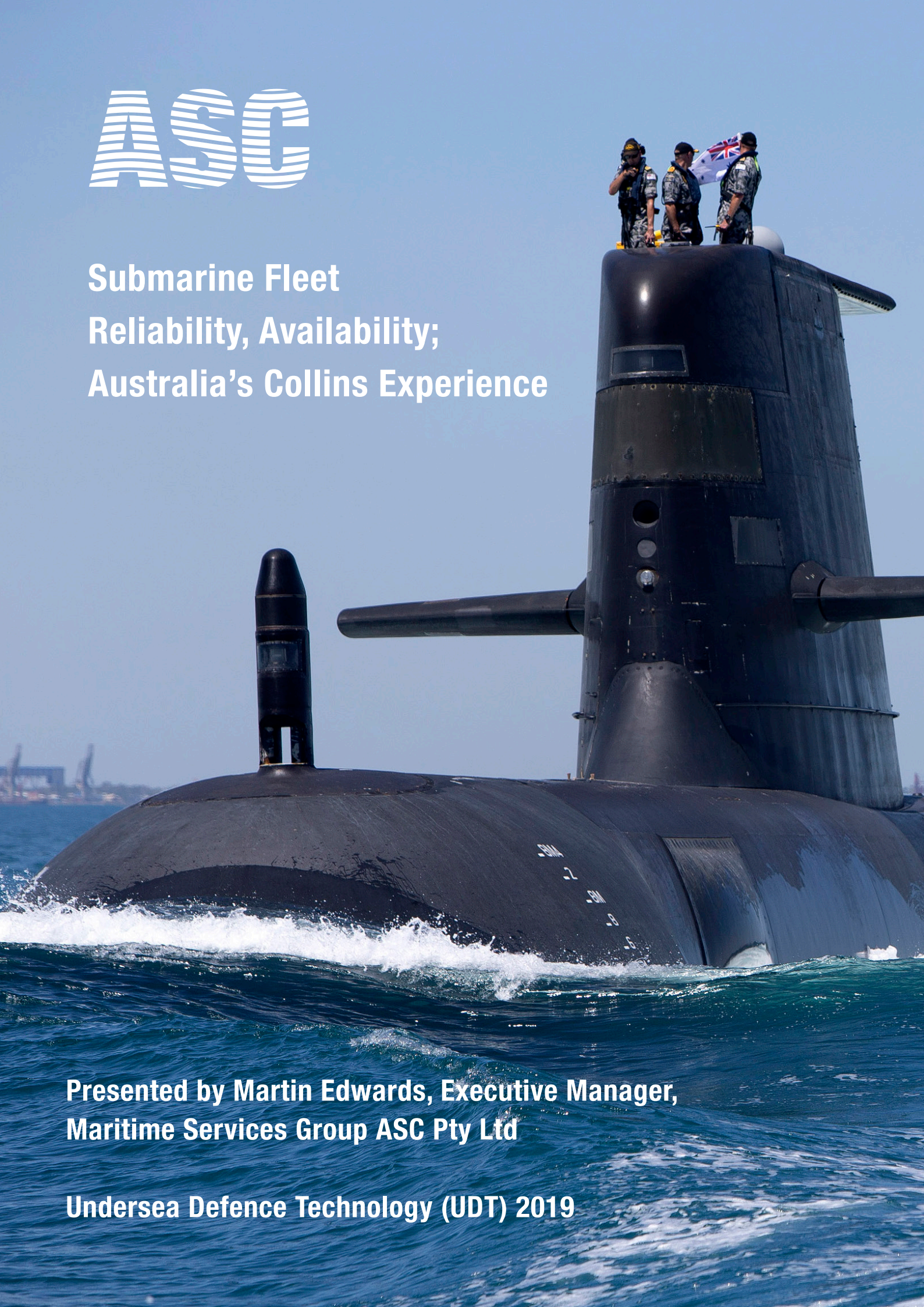

Submarine Fleet Reliability, Availability; Australia's Collins Experience

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Submarine Fleet Reliability, Availability – Australia's Collins Experience

Abstract — The business of maintaining and upgrading Australia's Collins Class Submarines underwent significant changes over a period of just a few years. Maintenance strategies were redesigned; the value chain streamlined; a Submarine Enterprise model was adopted; and investments were made in specialised infrastructure, materials and stocking of spares. This resulted in a tremendous increase in availability and overall reduction in time and cost of maintenance of the fleet.

1 ASC Pty Ltd

Australian Submarine Corporation Pty Ltd was founded 1985 as a joint venture between Kockums AB, Chicago Bridge and Iron, Wormald International and the Australian Industry Development Corporation.

The company today is ASC Ltd and is owned by the Commonwealth of Australia and run as a Government Business Enterprise (GBE).

ASC was responsible for the design, construction and commissioning of the Royal Australian Navy's (RAN) fleet of large Collins Class Submarines. ASC is currently executing sustainment and upgrades of the Collins Class from its facilities in South Australia and Western Australia, "figure 1".

ASC was also the lead shipbuilder for the Hobart Class Air Warfare Destroyer (AWD) and is currently the lead shipbuilder for Arafura Class Offshore Patrol Boat project.

ASC has 1,400 employees across operations in South Australia and Western Australia with annual revenue of A$765m.

2 THE COLLINS CLASS SUBMARINES

Australia's fleet of Collins Class Submarines "figure 2" are one of the first of the modern era conventional submarines. They are large, 3,100 tonne surface displacement, highly stealthy submarines able to transit long ranges whilst submerged in order to reach their area of patrol.

The Collins program was a fundamentally successful bespoke design and construction program based on the Kockums AB Vastergotland design. The Class of vessels was designed, built and commissioned over a period of 16 years.

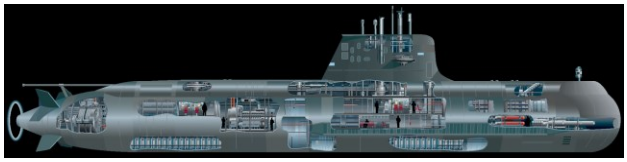
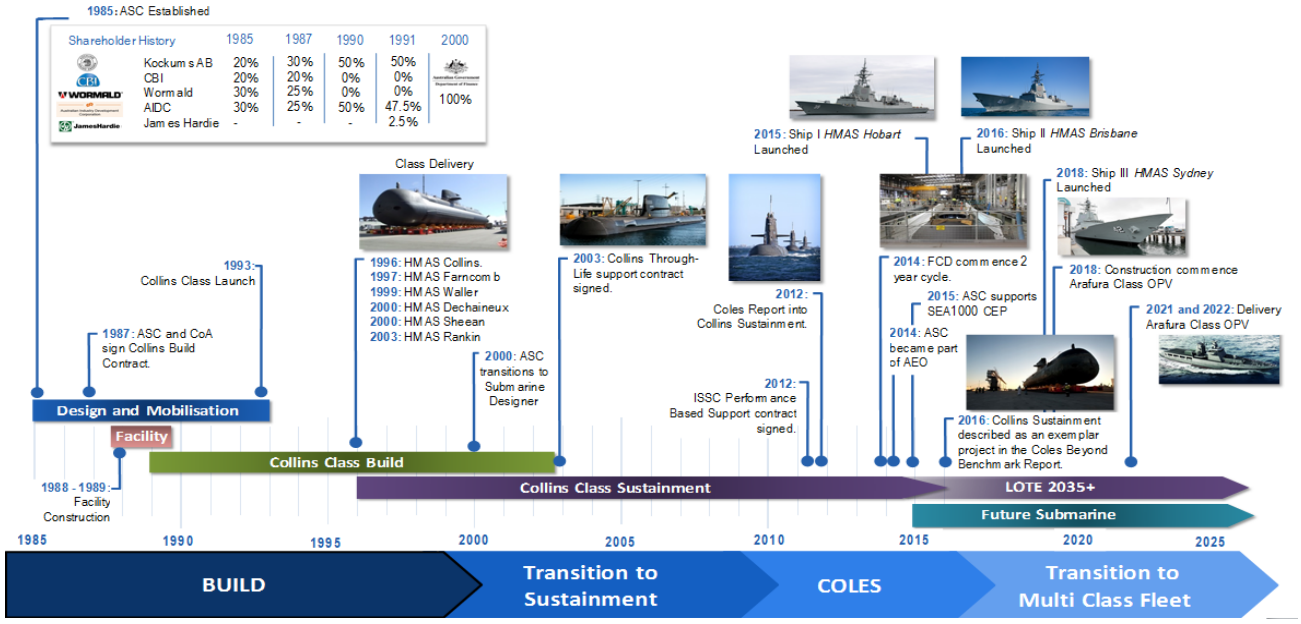


Fig. 2. Collins Class Submarine

Fig. 1. ASC's Corporate Timeline



3 TRANSITION TO SUSTAINMENT

The sustainment phase of the Collins Class got underway following commissioning of the First of Class in 1996. The industrial arrangements began through ad-hoc purchase orders for individual maintenance availabilities. A decade later saw the establishment of long term strategic industrial arrangements.

Once the Fleet had been commissioned, the Full Cycle Dockings (FCD) programme commenced, and the new and more comprehensive maintenance contracting arrangements were in place, factors progressively emerged that impacted submarine availability and cost of ownership. They included unclear roles and responsibilities in the value stream, supply chain, spare parts pool, weak alignment between submarine usage models and availability aspirations.

4 COLES REVIEW

In 2011 the Australian Government commissioned a study lead by Dr. John Coles[1] into the end-to-end business of sustainment of the submarine fleet.

The Coles Team reviewed the period from 2006/07 to 2009/10, which was characterised by declining submarine availability compared to international benchmarks developed by the Coles team "figure 3". The comparator submarine fleets used were similar in fleet size to the Collins[2].

According to Coles, the decline in availability was a result of a combination of factors related to legacy design and build issues, reliability problems and the way in which the end-to-end sustainment was organised and managed.

4.1 Submarine Availability (2006-12)

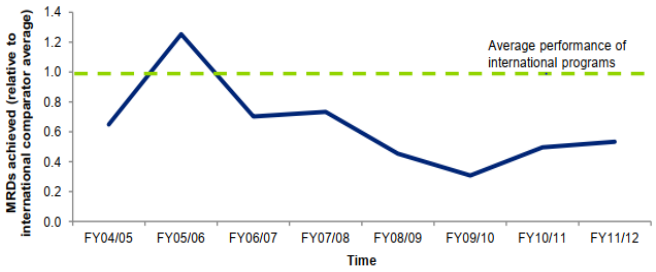


Fig. 3. Comparative Availability[2]

The review concluded that key factors driving the decline in availability included:

- Growing URDEFs (Urgent Defects);
- Unclear requirements;
- Unclear lines of responsibility;
- Lack of clearly stated strategic plan; and
- Lack of performance based ethos.

4.1 Relative Impacts on Material Ready Days

The low level of material ready days, from a planning perspective, was driven by three categories of factors with the relative contribution of each shown in figure 4:

- Long planned maintenance periods (28%);
- Overruns to planned maintenance periods (10%); and
- Defects outside of maintenance periods (6%), exacerbated by inadequate availability of spares.

The cumulative duration of planned maintenance periods had the most significant influence on the availability of the submarines.

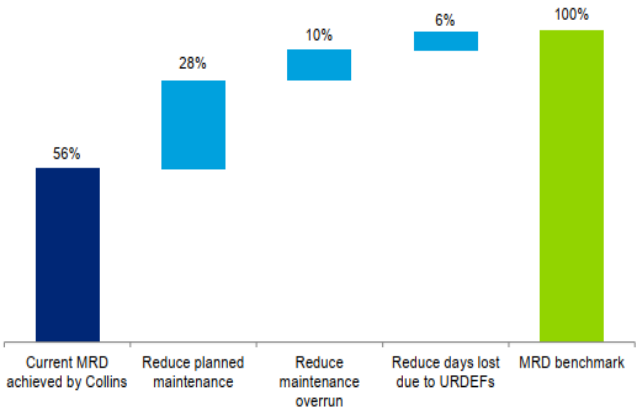


Fig. 4. Opportunities to improve to MRD benchmark[2]

Changing the Usage Upkeep Cycle, shortening maintenance periods and managing in a way that reduces overruns yields the biggest contribution to improving available Material Ready Days.

4.2 Key Findings

The study team's key findings were:

- Establish a Submarine Enterprise oversight group comprising *Navy*, Department of Defence - *Capability Acquisition & Sustainment Group (CASG)* and *ASC* with a clear and aligned set of submarine performance requirements;
- Clarify and re-align the key roles within the Value Chain; and
- Establish a 10+2 year Usage Upkeep Cycle *(from 8+3)* and a new whole-of-life Integrated Master Schedule while minimising schedule overrun for maintenance activities and reducing in-service defects.

The Coles team defined benchmarks for availability and recommended transferring responsibility for engineering and supply chain management to Australian industry[2]. Arrangements included streamlined materials management arrangements, specialised infrastructure, greater stock of spares and a rotatable pool.

5 IMPLEMENTATION

5.1 The Submarine Enterprise

An Australian Submarine Enterprise was established and charged with ensuring that Australia has an enduring and potent submarine capability. The Submarine Enterprise established a strategic partnership between the Royal Australian Navy (RAN), Defence's Capability Acquisition and Sustainment Group (CASG, previously DMO), the Department of Finance and ASC Pty Ltd, "figure 5".

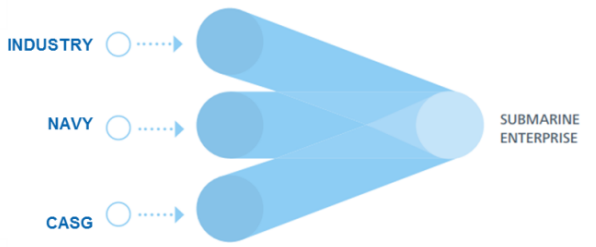


Fig. 5. Transition of the Collins Submarine Enterprise

An Enterprise Mission was established in a Ways of Working Charter. It provided for a shared long term vision, governance and alignment views on objectives and outcomes. Enterprise Governance Forums and Support Teams were the organisational means for jointly managing the implementation of the Transition Plan.

5.2 Value Chain Principles

Supply chain responsibilities and the availability of spare parts were significant drivers of submarine availability.

The Coles Team defined a Value Chain Model "figure 6" and a set of guiding principles for the purpose of optimising the Value Chain. They include:

- Clarifying of roles and responsibilities:
  - An Informed Customer, Owner and Operator
  - Supportive Industry; and
  - An Intelligent Buyer
- Transitioning to 'Good Practice', and
- Removing duplication/confusion:
  - Particularly with suppliers
  - Singular accountability.

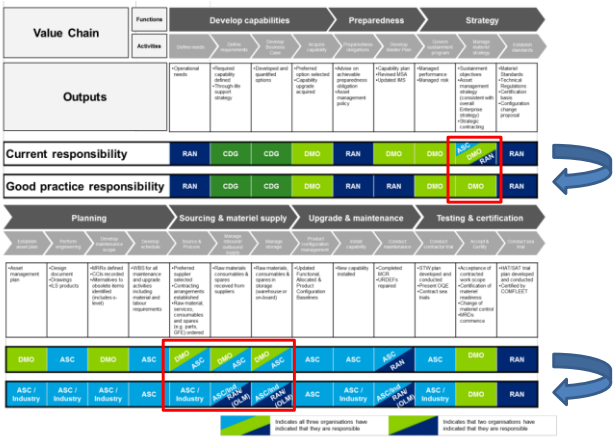


Fig. 6. Value Chain Model

5.3 Enterprise Performance Indicators

Enterprise performance indicators were derived from the Navy's overall operational requirements. Figure 7 represents a key measurable strategic requirement.

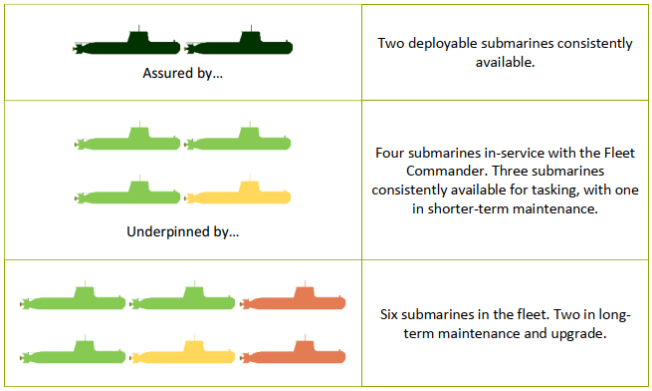


Fig. 7. The Navy Requirement[2]

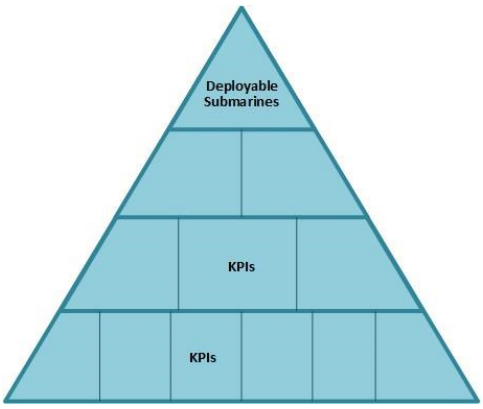


Fig. 8. Navy Requirements translated into Enterprise Measures of Success

The performance of the Enterprise is now measured according to a set of metrics that give direct insight into meeting the Navy's strategic requirements "figure 8". These measures of success are calculated periodically and used by the Enterprise to track to and beyond its goals.

The critical Key Performance Indicators include:

- Deployable Submarines
- Material Readiness Days
- Material Capability Days
- MRDs lost to P1 Urgent Defects
- MRDs lost to maintenance overruns
- Submarine days spent in planned maintenance
- Submarines available to Fleet Commander

6 TRANSITION PROJECTS

A Transition Plan was funded in order to transition the Submarine Enterprise to the new UUC and Integrated Master Schedule.

A range of tasks were planned and aggregated into 7 Transition Projects. These Tasks were largely completed within a period of 2 years in time for the start of the Project 5 first 2 year FCD.

The Transition Projects were:

1	**Usage Upkeep Cycle redesign**	From 8+3 to 10+2 years, realign maintenance baseline.
2	**HMAS Collins Pre FCD**	First circumferential hull cut, tank paint & other initiatives.
3	**Supply support**	Supply consolidation, inventory of spares, rotable pool.
4	**Core production change initiatives**	Over 14 significant change tasks, Maintenance Support Tower etc.
5	**HMAS Farncomb FCD 225**	First 10+2 Full Cycle Docking.
6	**Submarine Engineering development**	Evaluation of new maintenance baseline, Authorised Engineering Authority arrangements, Logistics.
7	**Class safety & certification**	Assurance of technical integrity, safety after revised Usage Upkeep Cycle and maintenance baseline.

6.1 Transition Project 1 - Usage Upkeep Cycle

The benchmark availabilities proposed by the Coles Team[2] required a change in the UUC from the extant 8+3 years to a 10+2 years model. Each submarine would be in-service for 10 years and then enter a 2 year Full Cycle Docking (FCD). The new UUC eliminated the traditional overlap in FCDs.

To realise the proposed UUC ASC established a program focused on the critical factors necessary to assure a 10+2 UUC. They included a re-design of critical factors of the UUC, rationalisation of the maintenance package, new infrastructure, submarine hull cuts and increase in stock of materials. Separate projects were funded to develop each factor during the transition to the new UUC.

6.2.1 Evolution or Revolution

A strategy for getting from the current state to the new state was developed by ASC. Critical options considered were to either migrate incrementally to the new UUC or chose a date to switch to the new UUC.

A migration approach would involve incrementally reworking a significant volume of inter-related maintenance baseline materiel, schedules and procurement arrangements.

It became clear that the time scale, complexity and cost of migrating incrementally would be less practical than implementing the necessary changes concurrent with a chosen final 3 year FCD of the current-state UUC and then switching immediately to the new-state UUC 2 year FCD and Integrated Master Schedule.

6.2 Transition Project 2 - HMAS COLLINS Pre Full Cycle Docking

HMAS Collins was placed into a pre-FCD activity as a key enabler to the 10+2 migration.

This provided the opportunity for the Enterprise to focus upon the development of the 2 year FCD execution philosophy.

Equipment normally refurbished as part of an FCD that impacted critical path was removed for refurbishment, through an Upkeep By Exchange/rotatable pool philosophy, particularly for the:

- Main propulsion motor;
- Diesel Generators; and
- Induction and Exhaust valves; etc.

Transition Project 2 also enabled the early testing and development of new production methods ahead of the first 2 year FCD such as single coat paint scheme.

An initial pressure hull cut process was trialled and proven.

6.3 Transition Project 3 - Supply Support

Supply chain management responsibilities had been split between Defence's Stores system and ASC. Both organisations dealt with the same suppliers for materials for different planned maintenance periods.

Material procurement and stock management was subsequently consolidated at ASC's existing facilities.

To improve the availability of spare parts the Department of Defence provided funding for the stocking of spares decoupled from the funding of individual maintenance availabilities through an Inventory Investment Program (IIP). This included the procurement of additional spares and an increase in a rotable pool.

The result of these initiatives increased the availability of material considerably during the first 2 year FCD from 60% to over 90%, providing greater certainty and ability to execute production work orders against plan.

6.4 Transition Project 4 – Core Production Change Initiatives

Transitioning to a 2 year Full Cycle Docking in one step required the development and implementation of numerous strategies to:

- shorten the critical path,
- reduce the production hours,
- de-conflict critical activities; and
- provide certainty over execution.

Particular maintenance routines had the greatest impact on the FCD critical path and its duration. Metal loss (corrosion) repairs during an FCD make the conduct of concurrent maintenance activities in many submarine compartments difficult. De-conflicting metal loss repairs with Diesel Generator and Main Electric Motor refurbishment work was critical.

6.5.1 Hull Cuts

The Diesel Generator sets and Main Motor had to be removed from the submarine for refurbishment and set-to-work off-boat, thereby allowing concurrent metal loss repairs in the vacated compartments. The solution involved cuts in the pressure hull structure to enable their removal “figure 9”.

Fig. 9. Diesel engine being removed via a hull opening[4]

Specialised repair & test facilities were established to support off boat repair & test of the Main Propulsion Motor & Diesel Generators which collectively reduced cost and removed the main critical path.

6.5.2 Single Coat Paint Scheme

A single coat paint system was introduced through the careful sequencing of paint zones for optimum execution and the implementation of a three shift production routine.

This initiative lead to a significant reduction in processing time for tanks, “figure 10”.

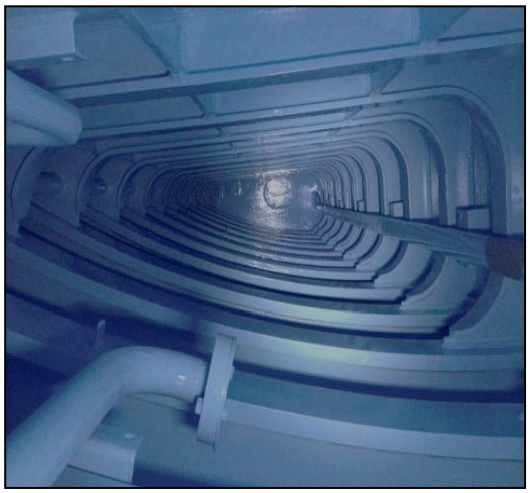


Fig. 10. Tankage implemented with a single coat paint scheme

6.5.3 Maintenance Support Towers

A critical factor in shortening the FCD timeframe was to increase the portion of the workforce’s available time in progressing maintenance tasks. Production personnel spend a proportion of their time travelling to source tools and materials, to seek engineering or supervisory advice or to rest areas for meal breaks. Keeping the work force close to the submarine would reduce time spent travelling and improve the utilisation of the effort.

Multi-storey Maintenance Support Towers (MST) “figure 11” were designed and installed in 9 months to provide the necessary facilities alongside the submarine and surrounds the submarine at all levels.

The MST contributed significantly to the overall reduction in effort required to conduct an FCD with the return on investment achieved in the first Full Cycle Docking.

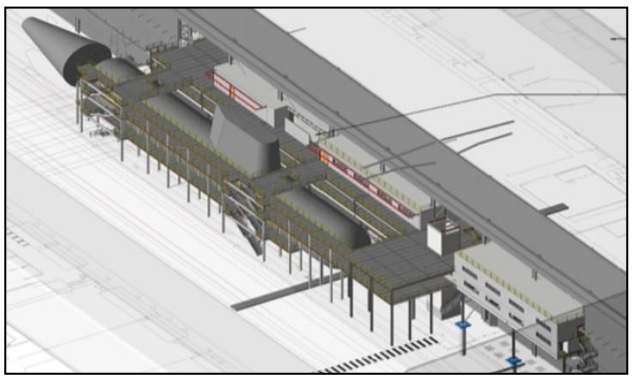


Fig. 11. Maintenance Support Tower in use during a Full Cycle Docking[4]

6.5.4 Effort

Under the existing 8+3 year UUC arrangements an FCD required in excess of a million production hours for all maintenance tasks. A key to reducing the duration of FCDs would be to reduce the number of production hours. As part of the migration to the 10+2 UUC, key innovations reduced the FCD production effort by over 25% whilst maintaining the integrity of the maintenance package.

6.5 Transition Project 5 – HMAS Farncomb FCD 225

ASC's first attempt at a 2 year FCD employing newly developed methods and maintenance baseline was HMAS Farncomb's FCD 225, "figure 12". The plan was to transition in one step. This allowed for a singular focal point for the Enterprise:

- Main motor & diesel generator exchange initiatives met accelerated schedule expectations;
- Improved material availability supported schedule adherence & reduced impact of emergent defects on critical path; and
- Work zones were established and were successful in de-conflicting concurrent work activities.

Fig. 12. The first 10+2 Full Cycle Docking

The result was that the first 2 year FCD was completed on time in 2016.

6.6 Transition Project 6 – Submarine Engineering Development

ASC became accountable for all major platform engineering and technical changes. This required the development of further engineering and asset management capabilities to support the platform through to the planned withdrawal date including the:

- Review of the entire maintenance baseline to support the new UUC;
- Critical assessment of systems to ensure platform and safety; and
- Growing ASC's W.A. engineering capability and platform knowledge base to support the operational maintenance organisation.

ASC ultimately established 13 of the 15 level 2 engineers in the Submarine Enterprise.

6.7 Transition Project 7 – Class Safety & Certification

ASC is ultimately accountable to the Submarine Enterprise Board and the Chief Naval Engineer for the assurance of technical integrity. ASC:

- Ensured that the entire change program did not undermine the submarine safety case;
- Reviewed the cumulative impact of the entire 10+2 transformation plan across the platform and delivery organisations from a safety perspective and to provide assurance of delivery; and
- Included independent validation and verification of hull cut process and solution.

ASC delivered to Chief Naval Engineer for acceptance outcome and project deliverables in parallel with all other outcomes.

7 OUTCOMES

The Coles Study provided the catalyst for a new phase of improvement across the Submarine Enterprise that comprised Defence and Industry.

This was realised through a strategy of establishing the 'Australian Submarine Enterprise' to align objectives and moving from an 8+3 year to a new 10+2 year Usage Upkeep Cycle.

Implementation achieved by a program focused on:

- Extending the operational cycle from 8 to 10 years;
- Reducing Full Cycle Docking duration from 3 to 2 years;
- New and optimised Infrastructure;
- Consolidating management of the supply chain;
- Stocking of spares and rotable pool; and
- Innovation in overcoming the Critical Path in FCDs.

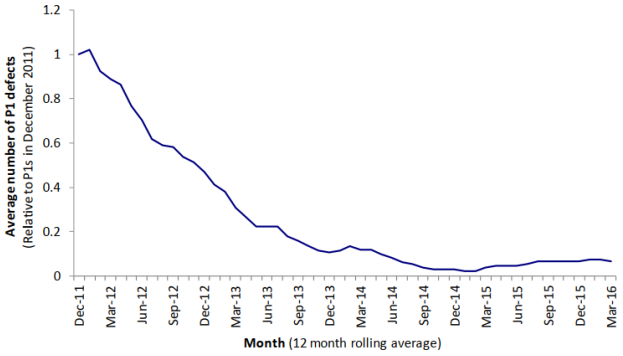


Fig. 13. Priority1 URDEFS[3]

The new arrangements have seen tremendous improvements in the outcomes of the overall business of Collins Class Submarine sustainment and upgrades.

Urgent Defects have decreased "figure 13" and Availability has increased to beyond benchmarks "figure 15".

After completing two FCDs and a number of minor maintenance periods successfully under the new UUC, with a third FCD well underway, the Australian Submarine Enterprise is now delivering submarine maintenance and upgrades to the Australian Navy's submarine force to the Navy's requirements "figure 14" and at and beyond international benchmarks, and evolving towards supporting a growing multiclass fleet.

Fig. 14. Performance against Navy Requirements[3]

The follow up Coles Team reported[4] in 2016:

"A program once that was considered a "Project of Concern" should perhaps be now treated as an "Exemplar Project" if such a category existed".

"In short, the Collins now has a sustainment program arrangement that can deliver the required output with some resilience that as a Strategic System it should have had when it entered service".

Fig. 15. Fleet on the move (courtesy RAN)

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Speaker Biography

Martin Edwards, Executive Manager Maritime Services Group, ASC Pty Ltd, Osborne SA, Australia.

As General Manager Maritime Services Group, Martin is responsible for overseeing the development of ASC's submarine capability as it relates to the future submarine project and other submarine-related opportunities.

Prior to his current role Martin was Chief Operating Officer of ASC Shipbuilding responsible for operational performance and generating an effective operating environment within the ASC Shipbuilding business unit and the Air Warfare Destroyer (AWD) Project. His primary focus was on project management, production, supply chain, quality and delivery of the Hobart Class AWDs. Martin also served as Shipbuilder Industry Participant representative for ASC on the AWD Alliance and as part of the AWD Executive Leadership Team.

Martin originally spent 19 years with ASC, having joined the company in 1988 as part of the original Collins Class design contingent seconded to Kockums, Sweden. This was followed by various design, project and business development management roles, including General Manager ASC Shipbuilding. Prior to re-joining ASC in 2011, Martin spent five years in the Middle East and Western Australia as a chief operating officer in the construction of oil rigs, onshore gas processing plant, mining site expansions and various fabrication activities.