

The future Submarine Weapons Stowage Compartment

A review of how the Future Weapons Stowage Compartment (WSC) Capability will fundamentally affect submarines of tomorrow.

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Abstract

Tomorrow's Weapons Stowage Compartment (WSC) could be fundamentally different. It will need to be:

- Adaptable to respond to the growing range of future threats.
- Supportive of the plethora of Under Water Weapons (UWW) and Underwater Unmanned Vehicles (UUV)s.
- Affordable, providing greater safety and efficiency.

Our paper examines how the layout and configuration of the Weapons Stowage Compartment has evolved over the last 100 years, explores future requirements and presents a proposal for a flexible and more affordable WSC for tomorrow.

1.0 Introduction

Tomorrow's requirements for the Submarine Weapons Stowage Compartment (WSC) Capability will be driven by four key factors:

- the evolution of the threat
- the make-up and operation of the submarine
- the Operational Requirements and effectors
- the development of technology

This Paper provides a definition of a Weapons Stowage Compartment and outlines how it has evolved reflecting on technologies, trade-offs and trends.

The Paper will conclude with an overview of the opportunities that could be incorporated into the design of a future submarine WSC to provide the flexibility to address evolving defence tasks.

2.0 Definitions & Challenge

The Weapons Stowage Compartment on a submarine historically is a multi-use area where torpedoes, counter-measures and other weapons are stored together with a vast assortment of other equipment, machinery and even crew.

The Weapons Stowage Compartment is a fundamental part of the submarine. It affects the Submarines size, buoyancy, effectiveness and efficiency.

The WSC design is fixed from the early design stage and yet has a fundamental effect on submarine capability.

Key design drivers include:

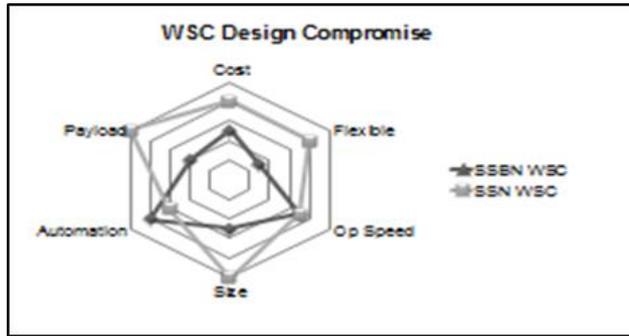
- The operational function of the submarine
- Size & diameter of the submarine
- Size & function of submarine sensor systems
- Type, size, weight, ejection of the payload

WSC Design is a balance between its cost and its size, its payload and speed of embarkation and its requirements for flexibility and automation. As the radar analysis indicates greater design compromise of SSN's rather than SSBNs.

3.0 History & future drivers

This chapter will examine the historical evolution of the WSC and how it may point towards its future layout and configuration.

1900s: The First WSC. The Holland Class Submarine was the first “modern” submarine with an internal torpedo Weapons Stowage Compartment with a single forward facing 18-inch (450mm) torpedo tube along its centreline. The whole submarine was, in fact, the WSC containing only 3 torpedoes. Torpedoes were lifted by hand with a reload timing of approx.1 hour . Loading and storing torpedoes was basic and manually intensive and fraught with risk. Firing was from near surface as there were limited ballast correction, targeting or control systems.



Feasibility Studies and pre-concept studies have shown that the WSC capital costs for SSNs are greater than that of SSBNs. The SSNs requirements for greater payload flexibility often require greater complexity with additional cost compared to that of the SSBN WSC. It is forecast that costs will continue to spiral as SSN WSC adopt numerous payloads.

Operational Speed of the WSC for both SSBNs & SSNs are broadly similar.

Counter-intuitively the size of SSBN’s WSC can be smaller than that of the SSNs as operational requirements dictate greater variety of payload for the SSNs.

Both SSNs and SSBNs use similar equipment automation so have broadly similar requirements.

In Summary, today’s Weapons Stowage Compartment is a compromise of operational, submarine and design factors.



Photo Credit: RN Submarine Museum Portsmouth

Figure 1. RN Holland WSC

1910s: Dedicated WSC’s. With the encouragement of the 1st Sea Lord John “Jacky” Fisher, RN Submarines in the early 1900s had become much bigger with their own dedicated Weapons Stowage Compartment. WWI witnessed the introduction of the Royal Navy K-Class submarine storing over 20 18-inch (450mm) torpedoes in the bow, aft and even in its superstructure. With rudimentary lifting tackle, racks and tracks firing reload was an impressive 30minutes.

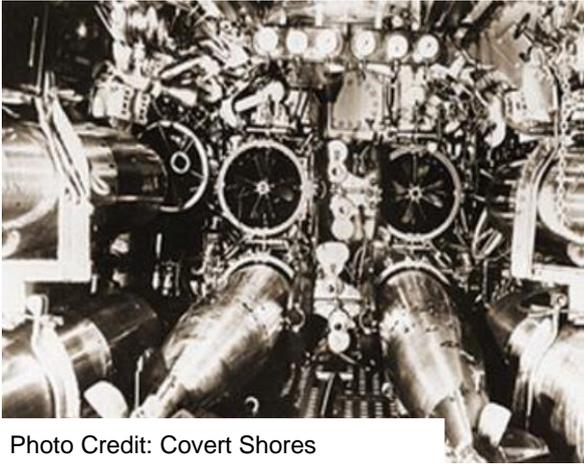


Photo Credit: Covert Shores

Figure 2. K-Class WSC

1940s. Semi-automated WSC's. WWII encouraged further rapid innovation in submarine design and development. The German Elektroboot U-boat Type-XXI is widely credited as being the "Mother of the modern submarine". With 6 21-inch forward facing fixed tubes and a Stowage capacity of 17 HWTs, the semi-mechanised WSC could reload in some 10 minutes.



Photo Credit: Defensionem

Figure 3. U-Boat WSC

1950s. Novel WSCs. Weapons Stowage Compartments continued to evolve with novel mechanical designs. The Swedish A10 Class developed a complex system for Stowage of both Heavy Weight and Light Weight Torpedoes 6 21-inch torpedoes in the bow but with no reload and 20 18-inch torpedoes stored in a revolving magazine [2]. For LWT firing reload was reduced to circa. 5 minutes.



Photo Credit: www.hjak.se

Figure 4. A-10 WSC

1960s. WSC Compromise. Forward facing Weapons Stowage Compartment design started to be compromised as more sophisticated, larger sonar arrays started to be introduced into submarines. Most submarine designs still called for 6 21-inch HWT with as many as 20 Stowage bunks but WSCs started to be positioned behind and below /above the sonar. This resulted in safer practices of torpedoes being fired outwards, around the sonar. And as the WSC / tubes were not entirely aligned firing reload was increased to approximately 10 minutes.

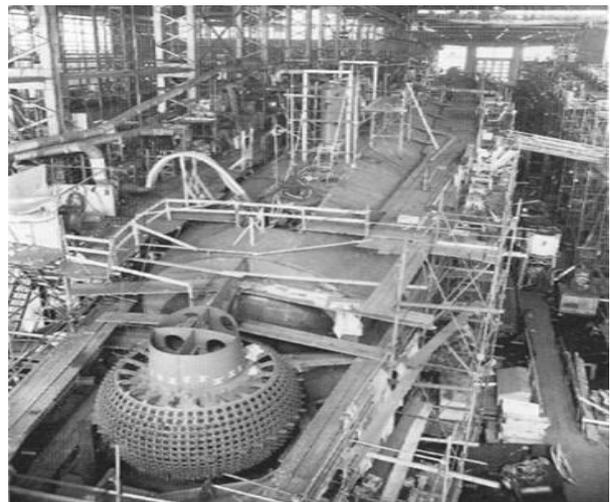


Photo Credit: NavSource Online: Submarine Photo Archive

Figure 5. Thresher Class in construction

1970s. Continued Compromise. Weapons Stowage Compartment design continued to be compromised as the submarine design evolved into sleeker, faster, quieter platforms. For example, the development of the Alpha Class in the 1960s and 1970s included a greater reliance on automation of the WSC as crew size was reduced to a minimum. The Alfa Class continued to use 6 21-inch forward facing fixed tubes. The Alpha design specified small acoustic sonar arrays thereby allowing alignment of the WSC with the torpedo tubes and as such reloading times were estimated to be below 10 minutes.

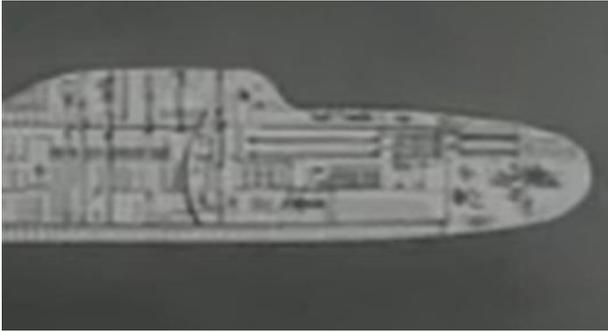
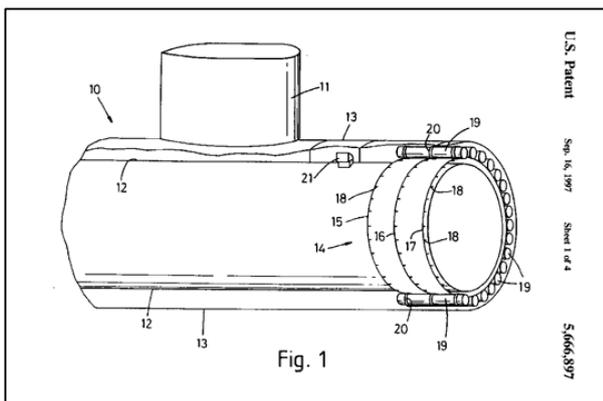


Photo Credit: www.Net-film.ru

Figure 6. Alpha Class WSC

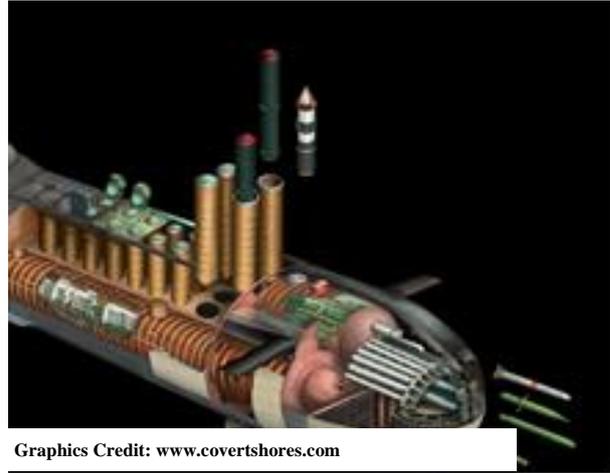
Some US patents even considered developing the drop torpedo compartments from the 1910s and Swedish A-10 magazine style from the 1950s by mounting torpedoes between the hull and the pressure hull. Thereby negating the need for the WSC. Although providing significantly more space, these designs have never been adopted in their entirety for both safety and serving issues.



Graphic Credit: "U.S. Patent No. 5,666,897." [3]

Figure 7. Hull mounted torpedoes

1970 & 1980s. Greater Flexibility. As submarines started to carry ballistic missiles, they trebled in diameter and more space could be afforded for other capabilities. Greater flexibility in payload was now possible. With the introduction of the USSR Typhoon Class submarine, for instance, the Weapons Stowage Compartment was designed above the large sonar array. For maximum efficiency, the WSC was positioned parallel to the multiple, fixed "Arch" torpedo tubes providing a firing re-load estimated to be under 10 minutes. The submarine size also allowed "Double-length" tubes with two heavy weight torpedoes loaded "Nose-to-tail". The Typhoon WSC design also provided automated flexibility of payload stowage with Squall Rocket Torpedoes and STARFISH anti-submarine missiles being carried alongside 6 21-inch Heavy Weight Torpedoes.



Graphics Credit: www.covertshores.com

Figure 8. Typhoon Class WSC

1990s Alternative Requirements. Weapons Stowage Compartments were increasingly required for alternative uses. From Special Force Stowage to Experimentation, the WSC became a spill-over for all types of additional activities. For example, the US Navy modified the USS Chicago's torpedo room to serve as a Predator UAV control room. Published in 1998, Johns Hopkins APL technical digest [1] outlined alternative uses for torpedo rooms converting it to provide an aerial capability.

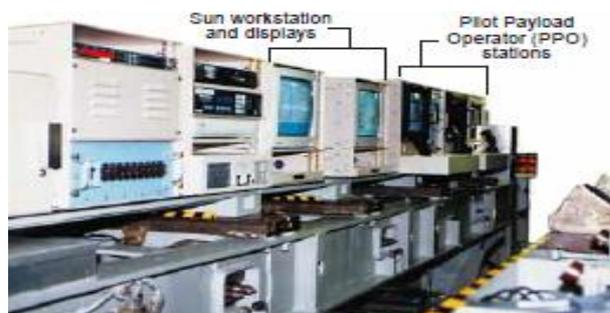
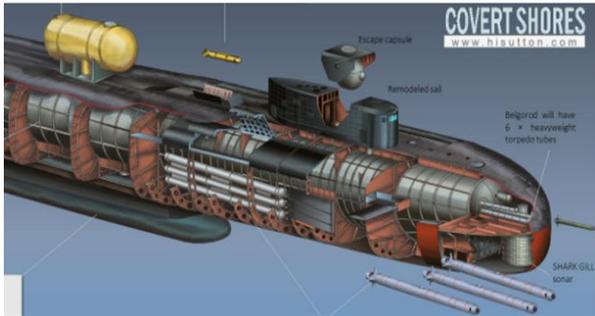


Photo Credit: John Hopkins APL Technical digest

Figure 9. USS Chicago WSC

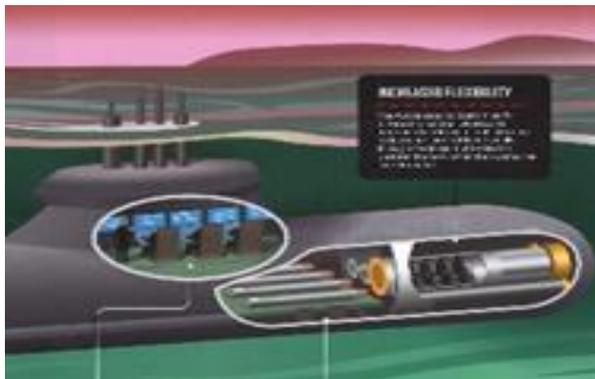
2010s: Maximizing Flexibility. Weapons Stowage Compartments continued to be designed for maximum flexibility. However, many designs were compromised, adopting separate compartments for separate payloads. The Belgorod / Oscar II Special Missions Submarine, for example, demonstrated below, is reported by Covert Shores to include a combination of 6 21-inch HWT with forward facing torpedo tubes above the bow sonar, 2-4 "Poseidon" Status 6 / KANYON Nuclear Torpedoes in a separate WSC in the middle base with the "Harpichord 2P-PM" Autonomous Underwater Vehicle (AUV) launched from a compartment at the top stern.



Graphics Credit: www.covertshores.com

Figure 10. Belgorod/Oscar II Special Missions Submarine

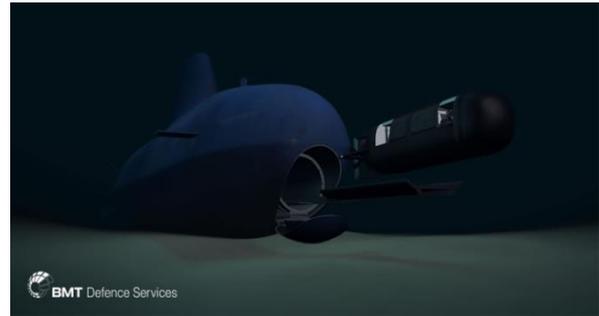
2020s: “Back to the Future”. Current submarine WSC designs are continuing to evolve and becoming more complex. Tomorrow’s submarines will be capable of multiple payloads from a single WSC. For instance, the Saab A-26 is being designed to include forward facing WSC’s aligned in parallel with the torpedo tubes ahead of the sensor systems for greater flexibility. It is envisaged that this WSC will be automated and carry a combination of HWT, LWT and UUV Payloads. It is also planned that multiple payloads could be launched from several different sized torpedo tubes using a combination of sleeves and telescopic mechanical systems to provide both launch of weapons and recovery of UUVs.



Graphics Credit: www.saab.se

Figure 11. A-26 WSC

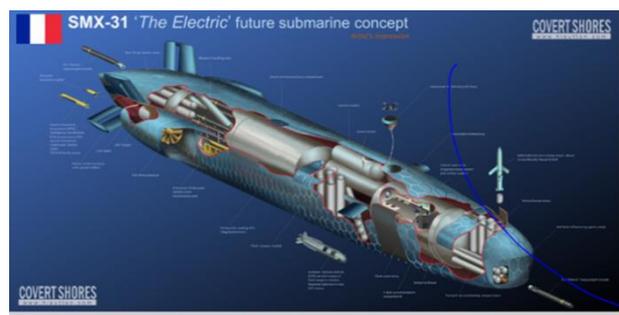
The BMT VIDAR-7[®] designed diesel-electric submarine concept goes even further than the design for the Saab A-26. BMT’s concept drawings feature a novel bow ‘dry/wet deck hangar’ from which a smaller manned or unmanned underwater vehicle can be launched alongside more tradition HWT Tube.



Graphics Credit: www.bmtdsl.co.uk/bmt-design-portfolio/submarines/bmt-vidar-submarines/

Figure 12. BMT VIDAR 7[®] UUV Launcher

Future designs from the Naval Group include reference K-Class Submarines from 1910s with both bow and stern WSC in a fully autonomous submarine. The SMX-31 Electric Future Submarine Concept from the Design House of the Naval Group provides us with both a radical vision of the future together with subtle reference to the history of WSC development. The combat load of up to 46 heavyweight weapons (torpedoes / cruise missiles) is much more than other submarines of this displacement. However, most of the weapons are carried externally to the pressure hull (referencing previous designs from the US & Sweden) which have operational and safety concerns. There is a conventional internal torpedo room in the aft-most compartment, similar to the US Sturgeon. The flank weapons module can be replaced with a Special Forces chamber with lock-out trunk. In the Special Forces configuration multiple Swimmer Delivery Vehicles (SDVs) can be carried in the outer hull, again reflecting designs from the RN K-Class Submarine.



Graphics Credit: www.covertshores.com

Figure 13. The Naval Group SMX-31 Concept

3.1 Brief History Summary:

From our brief review of historical developments below, WSCs have developed from simple Stowage Rooms to dedicated operational centres that demand flexibility and adaptability.

Table 1. WSC Historical Development Summary

Year	Platform Example	WSC Development
1900s	Holland Class	The First WSCs
1910s	K-Class	Dedicated WSCs
1940s	U-Boat	Semi-automated WSCs
1950s	A10 Class	Novel designs
1960s	USS Thresher Class	Acoustic Compromise
1970s	USSR Typhoon	More flexible WSCs
1990s	USS Chicago	Alternative Requirements
2010s	USSR Belograd	Maximizing Flexibility
2020s	A-26 Class	Multiple Uses
2030s	SMX-31	Full automation

3.2 Technology Drivers

This section outlines a selection of technology trends that may impact on the design of the future WSC.

Energy Technologies: In recent years, energy stowage and propulsion technologies have made significant advances in the automotive and aerospace sectors.

Lithium Ion (Li-ion) is the dominant technology in commercial electric vehicle propulsion. With recent developments in cathode blends and silicon doping in anodes being driven by charge/discharge rate and energy density demands, it may be possible to meet the UWW endurance, performance and safety requirements in the near future. Safety requirements may preclude the use of the most energetic of extant Li-ion variants, while safer variants such as Lithium Titanate Metallic anode cells are unlikely to meet endurance and performance requirements. Lithium Sulphur (Li-S) technology is maturing as a high energy and maybe a safer alternative to Li-ion but it is questionable whether its volumetric energy and power density would ever progress to meet UWW requirements. UWW are starting to use Silver Oxide Aluminium (AgO/Al), but speed and endurance requirements mean that cell power and energy specifications are in tension. The use of electric hybrid super-capacitor technology shows promise

Over the last decade, these new energy technologies has being adopted by UWW & UUV payloads systems. New weapons systems will include advanced battery / electric. Does this mean that tomorrow's WSC should include re-charge and power capabilities, electrification of the discharge systems, will the WSC

have to consider electric-magnetic compatibility (EMC) and electric magnetic interference (EMI) issues, different signature constraints and will new energy systems create new operational capabilities?

Advanced materials and manufacturing: Novel materials and processes (such as additive 3-D manufacture and metallic-polymer composites) may point to reductions in both stowage and operational timescales. Emerging innovations in materials and manufacturing technologies offer considerable advantages for UWW capability. Lighter, stronger payload materials may result in a greater number and variety of weapon systems with greater adaptability. However, no revolutionary trends have been identified to suggest that the WSC would become a 3D Manufacturing Centre. Not with standing this the Future WSC will need to be even more flexible to accommodate the various ad-hoc systems.

Modular “Mix & Match: The Open Architecture [4] approach combined with future automation may also aid the WSC to be better able to field a new capability more quickly, increasing the ability to modify UWW in the face of an evolving threat by developing modular weapons that can “mix & match” components.

Warhead technology development: Future UWW will need to address the threat posed by both larger, more complex vessels and smaller (and much cheaper) vehicles such as UUV. Novel warhead technologies will be required to enable a more flexible response to a broader spectrum of ASW operations.

Warhead manufacture has utilised conventional mixing processes that have largely remained unchanged for many years. For near future ASW operation, recent research and manufacturing developments have highlighted potential opportunities for improving the lethality and/or reducing the quantity of energetic materials within the UWW whilst achieving improved safety through the development of insensitive munitions (IM).

Advanced manufacturing techniques offer the opportunity to improve the uniformity of the warhead “fill” and to reduce degradation to the “fill” by coatings. Improvements in the configuration of shaped-charge cavities and delivery mechanisms could prove beneficial in improving warhead effectiveness without increasing overall mass. Reactive metals could be employed to improve blast and shaped charge effects. Processing improvements may help by allowing the use of novel materials, finer particulates and improved morphologies.

This suggests that the future WSC will have to store a greater range of safe / inert warheads for a range of applications.

Automation: Commercial Off-the Shelf (COTS) automation from both the aviation and surface ship development has progressed rapidly over recent years. For example the RN Queen Elizabeth Class Aircraft Carrier has used automotive systems similar to that used in airports to provide flexibility and speed, processing a significant variety of weapons. To cross-deck to a modern submarine for embarkation, carousels and tube launching, automation designers will need to consider additional safety, shock and signature restraints. This paper will review one automation option on Section 4.4.

EM electromagnetic rail launcher systems: EM Submarine weapons systems have been researched for over a decade with prototypes being recently demonstrated but not as yet fielded.. However, naval architects need to balance the advantages of increased speed and reduced noise signature with the disadvantages of increased EM Signature, EMC / EMI issues and the added cost & complexity of such systems.

Common Control Technologies: Naval Architects are starting to consider a more unified approach between Outboard and Inboard Systems as the platform and tactical C2 combat management systems will potentially effect both the size and dimensions of tomorrow's WSC as it becomes more automated.

Condition Based Monitoring Technologies: Maritime Platforms are starting to adopt Integrated Vehicle Health Monitoring (IVHM) Systems for both prognostic and diagnostic service support to watch keeping and damage control of the platforms. IVHM Systems are now monitoring everything from humidity to temperature to corrosion in order to reduce the cost of platform maintenance. Naval Architects will need to consider if and how IVHM systems can be integrated into the WSC to monitor the UWW and the loading systems.

Summary: Both history and technology development suggests that the design and development of the future WSC will be one of evolution and compromise rather than revolution. The next section of the paper shows how the WSC may evolve.

4.0 The Future WSC

This section outlines and discusses the opportunities for the development of the future Submarine Weapons Stowage Compartment (WSC) and some of the Platform Integration issues. The paper outlines how the future WSC will address future payloads; their attributes and outlines a number of architectural options that will enhance capability and flexibility whilst recognising the affordability challenges.

This section will also review the number of Weapons orientation and size; the weapon types Heavy Weight Torpedo (HWT), Unmanned Underwater Vehicles (UUV), Light Weight Torpedoes (LWT) and other potential payloads; their location and the number of stowage positions.

The Section will conclude with a review of how these options will fundamentally affect tomorrow's WSC and submarine design.



Graphic Credit: BAE Systems

Figure 14. Astute Class Initial Concept Design

4.1 Platform and Payload Integration

The practicalities of platform integration will fundamentally affect tomorrow's Future Submarine and WSC Capability. For example Platform spatial restrictions will have a significant influence on the WSC space envelope and therefore the WHLS design.

This paper assumes that submarine to surface / ship or land attack missiles will be located outside of the WSC in vertical launch tubes and therefore is outside of the scope of this paper.

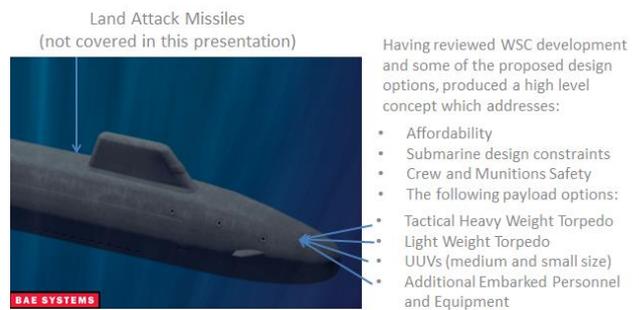
4.2 WSC Optimisation

The WSC space envelope can be optimised to achieve the following;

- Minimum payload space envelope to reduce overall submarine size and cost.

- Minimum number of discharge tubes to support optimised Platform signature and spatial integration.
- Flexible Stowage arrangements to accommodate a range of existing and emerging pay load options which could include WHT, LWT, UUVs and possibly hard kill countermeasures.

WSC Payload Configuration



Graphic Credit: BAE Systems

Figure 15. Future SSN Theoretical Payload

The minimum payload space envelope could be achieved through the design of a stowage system which has the flexibility to accommodate either a full size 7m long weapon or 2 x circa 3m long weapons in the same stowage position.

4.3 WSC Modularity

Modularity is considered to be highly beneficial to the submarine build programme; however there is a spatial trade-off that needs to be made as the Module could duplicate submarine structure which reduces available space and increases overall mass. For example the SSNs tend to have a large number of weapon stowage positions in the WSC which prevents the use of a modular stowage system whereas SSBNs tend to have a reduced WSC payload and therefore do have sufficient space to incorporate a modular weapon stowage position. For future submarine design this decision will need to be made within the early concept phase of the programme.

4.4 WSC Manning vs Increased Automation

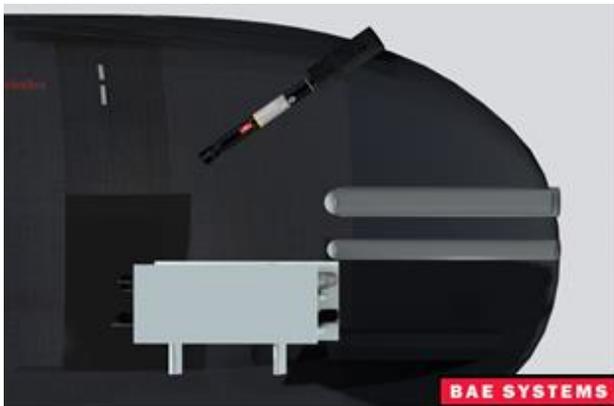
Key drivers for submarine manning are watch keeping and damage control / firefighting commitments. As weapon movements are infrequent, the cost, safety, spatial and complexity impact for automated weapon handling currently outweigh the relatively small savings in crew time. If Customer needs change, e.g. watch keeping and firefighting commitments reduce or if payload usage increases; for example through the regular deployment of UUVs then the cost / benefit trade-off for increased WSC automation can be reconsidered.

4.5 Payload Options

As identified in the previous sections the submarine and WSC designs have for many years been based on circa 7m long and 0.553m diameter torpedoes. Some of the future submarine concept designs are starting to consider much larger UUV payloads which introduces spatial and affordability challenges. This paper now considers an alternative, flexible but more affordable option using 2 standard payload sizes:

- Full length – Circa 7m long x 0.553m diameter torpedoes and UUVs
- Half length - Circa 3m to 3.5m long and 0.3m diameter LWTs and UUVs

Both of the above options could be embarked using either an inclined set of embarkation rails or via a vertical embarkation system as shown below.

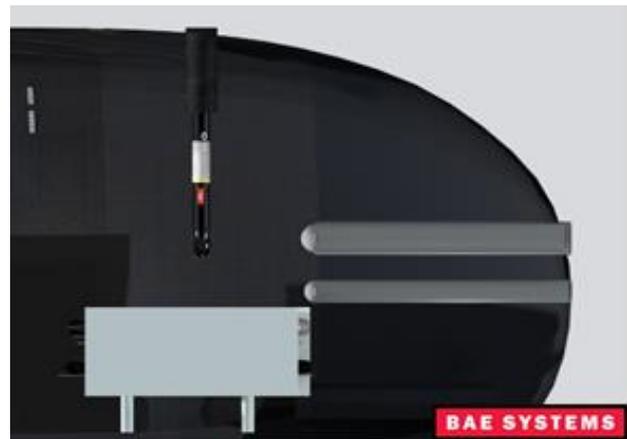


Graphic Credit: BAE Systems

Figure 16. Inclined Embarkation

ID	Payload	Length	Dia	Considerations
1	Tactical HW Torpedo	7m	0.5m	Munitions Safety, Shock protection, embarkation & stowage
2	Lightweight Torpedoes	3m	0.3m	
3a	Medium Size UUVs	7m	0.5m	Charging & Data Connections
3b	Small UUVs	3m	0.3m	Lower cost and therefore expendable
4	Bunks and lockers for Additional Personnel	3m	0.5m	Easily embarked, removed, compatible with other payloads, provides additional crew with safety and comfort

ID	Payload	Embarkation
1	Tactical HW Torpedo	Traditional embarkation trolley
2	Lightweight Torpedoes	Half length pallet
3a	Medium Size UUVs	Traditional embarkation trolley
3b	Small UUVs	Half length pallet
4	Bunks and lockers	Half length pallet



Graphic Credit: BAE Systems

Figure 17. Vertical Embarkation

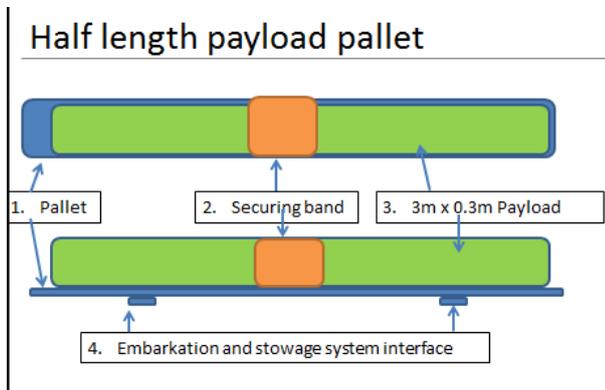
4.6 Full Length Payload Options

Full length payload options would be embarked, stowed and loaded into conventional size stowage racks and torpedo tubes which would retain all of the existing crew safety, munition safety and operability features, for example payload shock protection and magazine fire prevention systems.

4.7 Half Length Payload Options

Lightweight torpedo, UUV and hard-kill countermeasure development will continue for many years and is likely to include a wide range of options as discussed in this paper a number of submarine designs may incorporate large UUVs which introduces recovery problems. The alternative and more affordable option would be smaller expendable UUVs and the use of LWTs.

The use of pallets to embark and store these smaller payloads will be beneficial, but to enable optimum stowage and launch it is important that the variation in payload is minimised where practical. Ideally submarine payloads should be design to a standard size circa 3m long x 0.3m diameter and less than 1 tonne.



Circa 3m long light weight torpedoes, UUVs and hard kill countermeasures would be embarked using a circa 3.5m long pallet which would enable 2 x pallets to be positioned in each 7m long stowage position.

Bunk Solution



The bunk and personal locker is embarked and stowed as a pallet which includes connections that link to the weapon embarkation and handling system, enabling ease of handling. The pallet could be adapted to provide only locker space which could be used for trials equipment etc.

Smaller launch tubes will also be more energy efficient and bow cap openings will have a lower operational signature.

A circa 3.5m long pallet could also be adapted to accommodate bunks and lockers for additional embarked personnel or to accommodate additional trials equipment.

The ability to accommodate a variety of embarked full length and half-length payloads will provide the opportunity to have either a stowage system that

accommodates either 20 or 16 full length torpedo stowage positions. Any of these stowage positions could be used to accommodate 2 x half-length payloads.



Graphic Credit: BAE Systems

Figure 18. Potential Future WSC Layout

4.8 UUV Recovery

UUV recovery has been a submarine design challenge for some time. Recovery via the launch tube introduces substantive safety and submarine manoeuvrability issues and it is therefore considered that the use of either smaller or full length disposable UUVs is more practical. The recovery of larger more expensive UUVs may be achievable through the use of a payload recovery facility located on the Aft. submarine casing, but this will require the submarine to be operate at a very slow speed to reduce the risk of collision between the UUV and the submarine. Operating at a slow speed for the duration of UUV recovery will also lead to increased Platform vulnerability.

4.9 UUV Dependencies on the Submarine

UUV dependencies on the WHLS and submarine are likely to include:

- Magazine safe power supplies for battery recharge prior to launch
- Shock protection to ensure safe Stowage and use in a war scenario
- A data connection to Command and Control to allow UUV to submarine communication prior to launch and potentially for the duration of UUV deployment post launch.

4.10 Launch Tube Manufacture

The potential development of smaller diameter launch tubes (LTs) will require a change to traditional manufacturing techniques. For example painting and outfitting of LT internals has traditionally been a challenging task undertaken by humans, smaller diameter LTs may require the use of robotic tools.

4.11 Platform Signature

Platform Signature reduction is a key aspect for the design of current and future submarines. The design of the WSC can support Platform Signature reduction.

For example Platform Signature can be minimised by the number of and size of launch tubes, bow doors and the shape of the submarines bow. The use of 2 x full size Launch Tubes (LTs) and 2 x shorter, smaller diameter LTs will provide the opportunity to design the bow for improved signature performance.

5.0 Conclusion:

Development of the future UK submarine WSC provides an opportunity to introduce pay load flexibility, spatial optimisation, signature enhancement and affordability options. This paper provides the opportunity to progress this theoretical debate as an integral part of the overall submarine concept design activity.

The design of the WSC has evolved and it will be needed in the future

Tomorrow's WSC will retain:

- Munition safety
- Crew safety
- Fight capability

It could also improve:

- Affordability
- Flexibility
- Modularity
- Signature performance

5.1 Potential Future WSC Layout

Figures 19 and 20 provide an artist's impression for a potential future Weapon Stowage Compartment layout, although in the future a more accurate title could be the Future Submarine Payload Compartment (SPC).

The schematics show full length weapons in the upper stowage positions and half lengths weapons on the lower stowage positions. As discussed the WSC design provides the flexibility to stow a mixture of both full and half-length weapons, UUVs, bunks or other payload options in a variety of combinations.



Graphic Credit: BAE Systems

Figure 19. Potential Future WSC layout



Figure 20. Potential Future WSC layout

6.0 Disclaimer

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8.0 Glossary

AUV	-	Autonomous Underwater Vehicle
COTS	-	Commercial Off-the-Shelf
DSTL	-	Defence Science Technology Limited
EMC	-	Electro-magnetic compatibility
EMI	-	Electro-magnetic interference
HWT	-	Heavy Weight Torpedo
IVHM	-	Integrated Vehicle Health Monitoring
LWT	-	Light Weight Torpedo
OA	-	Operational Analysis
RN	-	Royal Navy
SDVs	-	Swimmer Delivery Vehicle
SSBN	-	Strategic Submarine Ballistic Nuclear
SSE	-	Submerged signal Ejector
SSN	-	Nuclear Submarine
UAV	-	Unmanned Air Vehicle
UK	-	United Kingdom
US	-	United States
USS	-	United States Ship
USSR	-	Union of Soviet Socialist Republics
UUV	-	Unmanned Underwater Vehicles
UWW	-	Underwater Weapons
WHLS	-	Weapon Handling & Launch System
WSC	-	Weapons Stowage Compartment

9.0 References

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10.0 Author/Speaker Biographies



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With over 25 years of international maritime defence experience with a deep understanding of the Submarine market, Alan Watson currently leads the business development of technology for underwater weapons.



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Steve Richard is an ex-submariner with more than 20 years BAE Systems engineering management experience. He has lead the development and implementation of both the Astute and Dreadnought WHLS & SSE concept designs and their integration into the submarine design.