Submarine Design and the Development of the Astute Class

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4th December 2007
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BAE Systems & The Barrow Shipyard
BAE Systems Submarine Solutions

Barrow-in-Furness (3400)

Filton (5)

Ash Vale (30)

Farnborough (107)

Weymouth (34)
What we currently do...

- Design, build and preliminary in-service support for 4 Astute class submarines for the Royal Navy. Bidding for boat 5.

- The delivery of the Swiftsure and Trafalgar class update programme for the Royal Navy

- Industry lead for successor SSBN programme

- CVF Engineering and Block build

- Export contract with Spain for build strategy and manufacture of dome pieces for Spanish submarine programme
First of Class Pedigree:

- T42 (7) Sheffield
- Swiftsure (6)
- Trafalgar (7)
- Invincible (3)
- T42 (Stretch) (4) Manchester
- Ocean (1)
- Upholder (4)
- Vanguard (4)
- Upholder/Victoria (4)
- T42 (Stretch) (4)
- Manchester
- Wave (2)
- Albion (2)
- 2000
- Astute (3+)

Dates:
- 1980
- 1985
- 1990
- 1995
- 2000
Brief History - Submarines

• First Royal Navy Submarine was Holland 1 built in Barrow in 1901

• Early Naval submarines were designed to operate predominantly on the surface, only diving to remain concealed (normally during the day). The submarines would submerge to attack a target and then remain submerged to make their escape.

• Early submarines were powered in two ways – diesel powered on the surface, electrically powered whilst submerged. Limited running time underwater

• The German Navy are said to have been the first to use diesel engines (1906) and to deploy a snorkel (1940’).

• The first nuclear submarine – USS Nautilus (1954)

• First Royal Navy Submarine was HMS Dreadnought, built in Barrow
Why Submarines?
Why Submarines?

• The ultimate stealth vessels - can fulfil roles no other vessel can:
  • Go anywhere underwater
  • Anti submarine and anti surface ship capability
  • Deny enemies the use of an area
  • Gather data (both electronically and visually)
  • Undertake precise strike / land attack
  • (Virtually) invulnerable nuclear deterrent
  • Assymetric force

• Stealth
  • you don’t know it’s there, AND you don’t know it’s not there !
Why Nuclear?

• Can stay underwater for very long periods
  • doesn’t need refuelling,
  • produce their own oxygen/water supplies,
  • Can completely circumnavigate the world underwater
  • the only limit on time underwater is food and crew endurance.

• Can deploy rapidly and covertly to any area of the globe
  • Much higher sustained speeds than diesel electric boats
  • No need to surface or snort

• Greater Stored Energy
  • Boat can be larger with more capability and greater crew comfort
  • Able to support more weapons/sensors
The Requirement
The Requirement

- The Royal Navy operates two different types of submarine SSN, SSBN
- SSBN provide the nuclear deterrent
  - The Royal Navy have 4 Vanguard class SSBNs 150m long, 16000 T
- SSNs are ‘Hunter/Killer’ Submarines
  - Anti submarine/ship warfare
  - Surveillance
  - Reconnaissance
  - Land attack using missiles.
- The RN currently has 9 SSNs, each about 85m long, weighing about 4600Te
  - Swiftsure & Trafalgar Classes
  - Astute is SSN20
The Astute Design
Design

• The Original Theory (Batch 2 Trafalgar):

  Trafalgar
  SSN 13 - 19

  Vanguard
  SSBN 05 - 08

  S&T Update

  Upholder

  Astute
  SSN 20 - 24/5

• The Reality: Greater weapons/sensors capacity, enhanced Reactor safety, enhanced boat safety and modular build means:
  • A longer, wider and heavier boat than originally planned
  • over 70% of components are new or re-qualified
The Product
Astute Class

- 97m long
- 10m draught
- 11.3 beam
- Displaces 7,400 tonnes submerged
- Depth >300m
- >25 knots
- 6 Torpedo tubes
- Stowage for 1.5 x T class weapons
  - Spearfish
  - Tomahawks
- PWR2 Pressurised Water Reactor – fuelled for life
- Astute’s sonar suite has the processing power of c1,000 Pentium IV computers
A Complex Design

• The Astute Boat 1 plan comprises:
  • 3000 requirements
  • 7,100 drawings
  • 29,000 build activities
  • 96,000 installable items
  • 10,000 devices

• A Nuclear Submarine built today by BAE Systems is comparable in engineering complexity with current space programmes (as recognised in US research programmes).
### A Complex Design

<table>
<thead>
<tr>
<th></th>
<th><strong>Space Shuttle</strong></th>
<th><strong>Astute</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Length, Diameter</strong></td>
<td>38m, 7m</td>
<td>97m, 10.7m</td>
</tr>
<tr>
<td><strong>Weight</strong></td>
<td>78 T.e.</td>
<td>7400 T.e.</td>
</tr>
<tr>
<td><strong>Components</strong></td>
<td>3 main engines</td>
<td>Nuclear reactor, 2 diesel generators, weapons</td>
</tr>
<tr>
<td></td>
<td>368 km of cable</td>
<td>148 km of cable</td>
</tr>
<tr>
<td></td>
<td>1,060 valves</td>
<td>23,000 pipes, 5,000 valves</td>
</tr>
<tr>
<td></td>
<td>27,000 tiles</td>
<td>50,000 tiles</td>
</tr>
<tr>
<td><strong>Crew</strong></td>
<td>5 - 7</td>
<td>97</td>
</tr>
<tr>
<td><strong>Mission Duration, Design Life</strong></td>
<td>5 – 16 days, 100 missions</td>
<td>&gt; 90 days, 25 years</td>
</tr>
<tr>
<td><strong>Environment</strong></td>
<td>190 – 350 miles above sea level, vacuum</td>
<td>Below sea level, very high pressure, corrosive</td>
</tr>
<tr>
<td><strong>Speed</strong></td>
<td>17500 m.p.h.</td>
<td>&gt; 25 knots</td>
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General Layout

- Engine Room
- Reactor Compartment
- Command Deck
- Accommodation
- Diesel Generators
- Weapons Stowage Compartment
- Bow Array
Build Strategy
Build Strategy

• Construction Elephant
• Modular Construction
• Pre-outfit
• Modularisation
• Maximise Construction Facilities
HMS Astute - Boat 1122 Build Definition
Construction
Explaining Build Stages
Units that make up the Astute Submarine

DDH Build Line Prior to Combination of Boat
Vertical Outfit

• Parallel / concurrent working fronts
• 360 degree working internal / external of unit
• More efficient equipment installation (improves access to pressure hull outfitting)
• Allows a greater number of tradesmen to work at one time
• Allows the use of cranes rather than fleeting / end loading
• Staging is lifted in and out with crane in levels, hence no building taking part inside unit
Horizontal Outfit Units Ready for Combination
Structural Welding

- **Materials**
  - HY80 derivative and HSLA 80

- **Weld techniques**
  - Submerged Arc automated for pressure hull (virtually defect free on Astute)
  - Flux Core for remainder

- **NDE techniques**
  - Radiography largely replaced by Time of Flight Tip Diffraction Ultrasonics allied to phased array sensing of near surface crack tip detection.

- Increasingly fabrications (often weld clad) are replacing castings
Other Welding

- **Pipe Materials**
  - 316L Stainless Steel (thick and thin wall)
  - 254 SMO Super Duplex Stainless Steel
  - 3602 Carbon Steel
  - 70/30 Copper/Nickel
  - 90/10 Copper Nickel
  - Monel K500
- Overall there are 57,000 pipe welds
- Many are high integrity welds with strict QA controls
- NDE
  - Radiography still dominant
  - 18,000 pipe welds demand radiography
Accuracy & Dimensional Control

Accuracy Control
• Necessary survey points established in plan
• Key to modularisation
• Interfaces are defined and maintained throughout evolving design

Dimensional Control
• As-built information collected for further analysis
• Interfaces managed in CAD before join up

Advantages:
• Minimise rework
• Build under control and confidence
Major Modules
Submarine Assembly – Major Modules
Submarine Assembly – Major Modules
Main Propulsion Machinery Package (MPMP)

MPMP Pictorial
Facts about Astute MPMP

• Astute MPMP took 4 years 8 months to Build, Test & Ship

• During Trials the Main Shaft turned 1,693,832 revolutions. This would mean the submarine would have travelled from Barrow to Australia (8671 Miles)

• There are 1,263 Pipes fitted to the MPMP

• There are 11,500 meters of cable fitted to the MPMP

• 3105 Tonnes of fuel oil was used (683,920 gallons)

• 10.9 Billion litres of sea water was pumped; enough to fill 4,034 Olympic-size swimming pools
Main Machinery Propulsion Package (MPMP)

Shipped 10th June 2005 into Unit 2
Command Deck Module (CDM)
Combat System

- All electronics masts
- Visual, communications, radar etc.
- Navigation - inertial sensors
- Combat management system
- Decoys, various sensors, intelligence and SF, Tomahawk Launch
Warspite Facility
Transporting CDM from Warspite to DDH
Command Deck Module
DDFOC – Shipping of Command Deck Module
DDFOC – Shipping of Command Deck Module
Submarine Assembly – Modules

- A.E.C / UNIT 1 / UNIT 2
- UNIT 3
- UNIT 4
- UNIT 5
- UNIT 6 / UNIT 7
- UNIT 8 / F.E.C

- DG MODULE
- AMM
- MRM
- Reactor Compartment
- FERM
- MPMP
- AEC
- Bridge-Fin & Casing
- CDM
- FEC
- BLK 74
- AMM
Submarine Assembly – Major Modules

A.E.C / UNIT 1 / UNIT 2
UNIT 3
UNIT 4
UNIT 5
UNIT 6 / UNIT 7
UNIT 8 / F.E.C

MPMP
MRM
FERM
DG MODULE
BLK 74
AMM
Bridge-Fin & Casing
CDM
FEC

Date/reference/classification
Submarine Assembly – Major Modules
The Finished Article
Summary

- Complex Engineering, Manufacturing and Test programme
- Highly skilled Resource
- Teamwork Essential
- Design process is iterative
- Structured Design approach
- Design above anything must be **SAFE**
- Improved working environments and methods
- There’s always more we can do to improve……………………
Astute Boat 4 and beyond

• Boat 4 based on boat 1-3 but…
  • At least 15% lower purchase cost (real terms)
  • Same capability.
  • Overcome obsolescence issues.
  • Same or lower in service costs.
  • At least as safe (preferably safer).

• Boats 5-7 are based on boat 4 but…
  • At least 5% lower purchase cost (real terms).
  • Same capability.
  • Lower in service costs.
  • Improved safety.
Sales Pitch!

• If you think your company has a product or technology that you think would be of benefit to design or construction of a nuclear submarine then let me know. We welcome alternative thinking and products.

• Our workload going forward means that we have numerous opportunities for design engineers in all disciplines.

• We also take on around 40 graduates across a wide range of areas each year for a structured training programme.

• So let me know if you or someone you know are interested.

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