A New Strategy for Submarine Payload Integration

The VIRGINIA Multi-Mission Payload Module

John Pavlos - Electric Boat
ELECTRIC BOAT

Premier Resource for Submarine Design and Construction Technology

Engineering & Design

Construction

Advanced Development

Sea Trials & Test

Life-Cycle Support

October 25, 2006
## Electric Boat Locations and Staffing (As of October 7, 2006)

<table>
<thead>
<tr>
<th>Location</th>
<th>Staffing</th>
</tr>
</thead>
<tbody>
<tr>
<td>CONNECTICUT</td>
<td></td>
</tr>
<tr>
<td>Operations and Support</td>
<td>3,901</td>
</tr>
<tr>
<td>Engineering</td>
<td>3,456</td>
</tr>
<tr>
<td>RHODE ISLAND</td>
<td></td>
</tr>
<tr>
<td>Quonset Point Facility</td>
<td>1,907</td>
</tr>
<tr>
<td>Newport Engineering</td>
<td>53</td>
</tr>
<tr>
<td>NEW YORK</td>
<td></td>
</tr>
<tr>
<td>Knolls Atomic Power Lab</td>
<td>183</td>
</tr>
<tr>
<td>GEORGIA</td>
<td></td>
</tr>
<tr>
<td>Kings Bay Trident Base</td>
<td>125</td>
</tr>
<tr>
<td>WASHINGTON</td>
<td></td>
</tr>
<tr>
<td>Bangor Trident Base</td>
<td>108</td>
</tr>
<tr>
<td>Puget Sound NSY</td>
<td>250</td>
</tr>
<tr>
<td>WASHINGTON, D.C.</td>
<td>15</td>
</tr>
<tr>
<td>VIRGINIA</td>
<td>365</td>
</tr>
<tr>
<td>UK / Australia / Other</td>
<td>68</td>
</tr>
<tr>
<td>TOTAL</td>
<td>10,431</td>
</tr>
</tbody>
</table>
Nuclear Powered Submarines

- NAUTILUS (1)
- SEAWOLF (1)
- SKATE (4)
- SKIPJACK (6)
- TRITON (1)
- HALIBUT (1)
- TULLIBEE (1)
- PERMIT (14)
- GEORGE WASHINGTON (5)
- ETHAN ALLEN (5)
- LAFAYETTE (19)
- BENJAMIN FRANKLIN (12)
- STURGEON (37)
- NARWHAL (1)
- NR-1 (1)
- GLENARD P. LIPSCOMB (1)
- LOS ANGELES (62)
- TRIDENT (18)
- SEAWOLF (3)
- VIRGINIA (10)
  (Under Contract)

Ships Built (#)
The VIRGINIA Class Submarine is One of the Most Complex Systems in Production

- Electric Boat: Prime contractor and lead design yard
- Awarded 10 ships of an anticipated 30-ship class – valued at $13B
- Lead ship SSN 774 VIRGINIA delivered October, 2004

<table>
<thead>
<tr>
<th></th>
<th>M1 Tank</th>
<th>Boeing 777</th>
<th>VIRGINIA Class Submarine</th>
</tr>
</thead>
<tbody>
<tr>
<td>Weight (T)</td>
<td>65</td>
<td>250</td>
<td>7,800</td>
</tr>
<tr>
<td>Length (Ft.)</td>
<td>25</td>
<td>200</td>
<td>377</td>
</tr>
<tr>
<td>Number Systems</td>
<td>25</td>
<td>40</td>
<td>200</td>
</tr>
<tr>
<td>Crew Size</td>
<td>4</td>
<td>10</td>
<td>113</td>
</tr>
<tr>
<td>Patrol Duration (Hr.)</td>
<td>24</td>
<td>8-14</td>
<td>2,000</td>
</tr>
<tr>
<td>Number of Parts to Assemble</td>
<td>14,000</td>
<td>100,000</td>
<td>1,000,000</td>
</tr>
<tr>
<td>Assembly Man-hours/Unit</td>
<td>5,500</td>
<td>50,000</td>
<td>&gt;10,000,000</td>
</tr>
<tr>
<td>Production Time (Mo.)</td>
<td>7.5</td>
<td>14</td>
<td>55</td>
</tr>
<tr>
<td>Production Rate (Units/Yr.)</td>
<td>600</td>
<td>72</td>
<td>0.5-3</td>
</tr>
</tbody>
</table>
Challenge: Moving From Today’s Capability to Tomorrow’s Mission Needs

Today’s Capability

Tomorrow’s Capability
The Concept Was to Minimize the Impact to the Payload and the Platform

Team 2020 VA Plus Concept

Universal Payload Adapter

VA MMM

SSBN/SSGN
Key Technologies Can Enable the Concept

**Conceptual Requirements**
- Standardized Interface
- External Payload Enabler
- High Payload Density
- Fast Logistics
- Reloadable, Recoverable, Reusable
- Adaptable to Many Sizes and Shapes
- Work in conjunction with a payload capsule

**Key Technologies**
- Composite Structure
- Compact Expendable Hatch
- Shock Mitigation
- Network-Based Control System
- Wireless Communications
- Inductive Power Transfer
Payloads and Sensors Studies Transitioned into Risk Reduction Demonstrations

Sponsored by
PEOSUB-RZ  2001 - 2006

Flexible Payload Module

18 Months FPM Demo

Universal Encapsulation

ISR Processing

DARPA 1998 - 2000

UAV ISR Capability
The Flexible Payload Module is moving from Concept Exploration through Risk Reduction

<table>
<thead>
<tr>
<th>Phase 0</th>
<th>Phase 1</th>
<th>Phase 2</th>
<th>Phase 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Concept Exploration</td>
<td>Program Definition &amp; Risk Reduction</td>
<td>Engineering &amp; Manufacturing Development</td>
<td>Production, Fielding, &amp; Operational Support</td>
</tr>
<tr>
<td>System Analysis</td>
<td>Concept Design Update</td>
<td>Detail Design Development</td>
<td>Production Rate Verification</td>
</tr>
<tr>
<td>Reqs. Definition</td>
<td>Sub-system Tradeoffs</td>
<td>Risk Management</td>
<td>Operational Test &amp; Evaluation</td>
</tr>
<tr>
<td>Conceptual Design</td>
<td>Preliminary Design</td>
<td>Development Test &amp; Evaluation</td>
<td>Deployment</td>
</tr>
<tr>
<td>Technology &amp; Risk Analysis</td>
<td>Prototype Testing</td>
<td>System Integration, Test &amp; Evaluation</td>
<td>Operational Support &amp; Upgrade</td>
</tr>
<tr>
<td>Assessment</td>
<td>Manufacturing &amp; Supportability</td>
<td>Manufacturing Process Verification</td>
<td>Retirement</td>
</tr>
<tr>
<td>Prelim. Cost, Sched. &amp; Perf. Concept</td>
<td>Supportability Considerations</td>
<td></td>
<td>Replacement Planning</td>
</tr>
</tbody>
</table>

October 25, 2006
The Composite Construction Proved to be Simple and Robust

- Analyzed for Pressure and Shock Loads
  - Robust structure in any configuration
  - Shock testing validated the analysis
- Built at Quonset Point
  - Completed in 23 days
  - Exothermic reaction easily accommodated
Compact Expendable Hatch Supports High Payload Density

- Combination of Steel Shell and Syntactic Buoyancy Element
- Eliminates Hinges and Actuators to Open and Close
- Hatch Release Actuator Designed to Maximize Packing Factor
- Floodable Air Volume Allows Hatch to Scuttle at Desired Time

Steel Dome
Floodable Volume
Syntactic Foam
Locking Hooks
Pivoting Latch
Power Screw
Motor/Reduction Gear
Watertight Housing
Shock Mitigation Pads/Launch Rails Accommodate Joint Forces Payloads

- Closed cell foam provides the mitigation for lighter payloads
  - Compresses under pressure to release capsule for launch
  - Reduces capsule accelerations to 10 - 30 g’s
- Easily reconfigured for the next payload

<table>
<thead>
<tr>
<th>Frequency (Hz)</th>
<th>Acceleration (g’s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>10</td>
<td>100</td>
</tr>
<tr>
<td>100</td>
<td>1000</td>
</tr>
<tr>
<td>1,800 lbs/in Pad Stiffness</td>
<td></td>
</tr>
</tbody>
</table>
Many of the Key Technologies Serve to Increase Payload Density

- Expendable hatch minimizes mechanical systems
- Foam filled structure allows closely packed tubes
- Shock mitigation pads reduce the accelerations and maximize packing factor
Network-Based Control System Supports Rapid Payload Insertion

- Scalable, Flexible Architecture
- Built upon COTS Technology
- Provide intelligence onboard FPM platform
  - Enables “plug and fight”
- Shipboard User Interface uploads FPM configuration

FPM Controller (ship)

FPM 1

FPM NM

Tube 1

Tube NT

I/O 1

I/O ND

LAN

WLAN

Analog

FPM GUI

GENERAL DYNAMICS
Electric Boat
Commercial Wireless Networking Employed for the Ship/FPM Interface

- Leverages Network Based Architecture
- Commercial Standard IEEE 802.11b WLAN
- Capable of maintaining 11 Mbps over small seawater gap

Attenuation of 2.4GHz RF in Seawater

- Waterproof Dipole Antennas

Maintained 11 Mbps

Slope = 37 dB/in
Inductive Power Transfer was Demonstrated Using a Split Core Transformer

- Demonstrated transfer of power from ship to FPM
  - 20 kW ultimate rating
  - 2 kW for demo FPM
- Environmentally sealed
- FPM-to-Capsule inductive coupler is under development

Output Voltage Regulation as a Function of Gap with a 200 Watt Load and a 120uF PFC Capacitor
These Technologies Were Integrated Into a Demonstration FPM

- Shipboard GUI
- Onboard Electronics
- Wireless Connectivity & Inductive Coupler
- Upper Housing
- Lower Housing
These Technologies Were Integrated Into a Demonstration FPM

Shipboard GUI

Onboard Electronics

Wireless Connectivity & Inductive Coupler

Upper Housing

Lower Housing
The Full Size FPM Was Successfully Demonstrated at Electric Boat

- Employed all key technologies
- Demonstrated full system functionality
- Executed an automatic launch sequence
- Test-fit into a D5-sized missile tube
A Second Generation Flexible Payload Module Was Built For the 2004 Navy Silent Hammer Experiment

FPM Concept Refinement
- Full Scale Production Methods
- Network Based Control
- Wireless Technology
- Buoyant Capsule Integration

Flexible Payload Module (FPM) Under Construction in Shipping Cradle

FPM integrated into a missile tube on USS Georgia
The Flexible Payload Module Provides an Open Architecture - System Level Solution To Meet Future Mission Needs

- Reduced cycle time to field new mission capability by minimizing payload specific ship modifications
- Decoupled payload development cycle from the ship development cycle
- Maintains critical warfighting performance
- Risk reduction on critical technologies has been accomplished

Electric Boat Is Moving Forward With The Payload Module Concept For The VIRGINIA Class Submarine