Affordable Small Modular Reactors – Effective Integration of Modular Design, Manufacturing and Construction Techniques

Jim Moody
Platt’s Small Modular Reactors
June 28, 2010
Discussion Points

- Provide Electric Boat Performance Background
- Discuss Traditional Approach and Electric Boat Goals
- Identify Important Elements of Modular Design Processes at Electric Boat
- Small Modular Reactor Application of Module Configuration Expertise
Record of Delivering Multi-$B Systems on Schedule and Under Budget

**Virginia Class**
- U.S. Navy’s newest class of attack submarine
- First totally electronic ship design
- Latest ship delivered 8 months ahead of schedule and $90M under budget

**USS Jimmy Carter**
- Largest, most complex submarine hull module ever built, weighing 2500 tons
- Program went from concept design to completion of detailed design in 29 months, half the time historically needed
- Delivered 5 months later – concept to completion in 34 months

**SSGN Program**
- Conversion of nuclear-missile submarines to conventional-payload-carrying submarines
- All four ships delivered on schedule
- EB work scope completed $110M under target cost

Safety and Quality Culture Based on 100+ Years and Over 100 Nuclear Plants Delivered

GENERAL DYNAMICS
Proven History of Successfully Driving Down Cost and Build Times

VIRGINIA Class

Goal

• **Reduce cost** by $400M per ship, from $2.4B to $2B ($FY05)
• **Preserve or improve** ships’ capabilities

Execution

• **Redesigned** portions of ship and modular approach for **more efficient production**
• **Improved fab processes** to shorten schedule
• **Doubled annual delivery** to 2 ships per year to capture economies of scale

Results

• **$400M cost-reduction target achieved**
• **Reducing build time** from 84 to 60 months

“This contract is a result of the Navy submarine team’s careful and highly professional execution. They successfully met a challenging cost-reduction plan, added capability, and did it all ahead of schedule.”

Assistant Secretary of the Navy (Dec. 22, 2008)
Discussion Points

- Provide Electric Boat Performance Background
- **Discuss Traditional Approach and Electric Boat Goals**
- Identify Important Elements of Modular Design Processes at Electric Boat
- Small Modular Reactor Application of Module Configuration Expertise
Up-Front Decisions Drive Program Cost

Cumulative percentage life cycle cost

Committed costs

Cost to extract defects

100x

1000x

Full program expenditures

Time

Concept phase
Design phase
Development phase
Production/test phase
Operations through disposal
Traditionally Design and Construction Processes are Series Based

MANUAL CONCEPT DEVELOPMENT

HAND-DRAWN MOCK-UP SKETCHES

ITERATIONS

PHYSICAL MOCK-UP CONSTRUCTION

ITERATIONS

DESIGN DELIVERABLES

ENTER INTO COMPUTER

CONSTRUCTION PLANNING/SCHEDULE

MATERIAL ORDERING

WORK PACKAGES

FIXTURES

MANUFACTURING

INSTALLATION

TEST

DELIVERY

PAPER DELIVERABLES
Discussion Points

- Provide Electric Boat Background and Discuss Program Results
- Discuss Traditional Approach and Electric Boat Goals
- **Identify Important Elements of Modular Design Processes at Electric Boat**
- Small Modular Reactor Application of Module Configuration Expertise
30 years of learning and application to “class” design

Conventional top loading

Early Ohio cylinder

Early Seawolf cylinder

Seawolf fully outfitted cylinder

Virginia Class: 95% modular

Significantly increased use of modularity

1 hour to accomplish task in shop environment

3 hours to accomplish task in outfitting environment

8 hours to accomplish task at final stages of fabrication effort

Evolution of Module Configuration and Manufacture a Key to Success
Integrate Engineering and Manufacturing and Increase Modularization for Affordability

- Establish a cost effective process that ensures the design is complete, material is available and work packages are available to support construction start
- Develop a cost effective construction plan for low rate production
  - Increase modularization – (maximize 1 - 3 - 8 Rule)
  - Reduce the number of design changes identified during construction
  - 3rd ship learning on first hull
- Achieving these objectives requires:
  - Active participation of manufacturer and constructor on design team
  - Tool set to perform integrated design and manufacturing
  - Earlier funding of certain activities made part of the design process
  - Rigorous program management

Submarine Class - Standard Design, Multi-ship procurement, 30+
An Area-Based Team Framework with strong technical input is essential for success.

**Modules are based on manufacturing assembly plans**

**Major Area Teams**
- Habitability
- Stern/Propulsion
- Auxiliary Machinery Room

**System Integration Teams**
- Command & Control Systems
- Sail
- Non-Pressure Hull
- Weapons Stowage & Handling

*Customers & Suppliers are key members of each team*
A Manufacturing Assembly Plan is Developed Early and Establishes the Team Structure and Data Configuration

- Defines Major Construction Modules
- Establishes Construction Schedule
- Defines Material in Yard Need Dates
- Allows Long Lead Material Procurement
- Establishes Drawing Development Schedule

The Process Supports Rapid Assessment of Design Concepts to Support Cost Effective Construction
Electronic Tools Facilitate Module Configuration and Construction using Design Data

Ability to use multiple tools:
- CATIA/IGRIP for Navy program
- Have adopted customer-specific tools for commercial programs as needed
Efficient Modular Construction

Inherent Costs

- Design-Build
- Automated Frame and Cylinder Fabrication
- Electronic Data Downloads
  - Pipe Bends and Mechanized Welding
  - Laser Cutting and Marking
  - Accuracy Control

Structural Costs

- Weight Handling
- Vertical Outfitting
- Multi Trade Approach
- Multi Year Procurement

* Source: Make or Break, 2008 Grichnik, et. al., 2008 & BAH – adapted by EB/BAH
Laser Part Marking to reduce Fit-up and welding

Example of a Part Identification and Location from NC Design Data

Attaching Plate Footprint
EB Quonset Point Module Manufacturing Facility

- Multi-Skilled Workforce in Factory Environment
- Automated Manufacturing Processes
- Module Outfit and Pre-testing
- Modular Construction Techniques
- Air, Rail, Barge Transport

Modular Packaging and Pre-Assembly

Module Assembly
Modular Packaging and Pre-Assembly using Fixtures

- Structural Assemblies
- Component Package
- Piping Packages
- Pipe/Valve Assembly
- Sheetmetal
Reducing Acquisition Cost – FOAK Design Changes and 3rd Ship Learning Metrics

QP TOUCH LABOR (% Man Hours)

Based on production results for a major section of the ship

Errors per 10,000 Hours Worked (Lead Ship Designs)

USS Seawolf (SSN21)
USS Virginia (SSN774)
SSN 784 (Sect 1/2A)
Discussion Points

• Provide Electric Boat Background and Discuss Program Results
• Discuss Traditional Approach and Electric Boat Goals
• Identify Important Elements of Modular Design Processes at Electric Boat
• Small Modular Reactor Application of Module Configuration Expertise
Objectives of Modularization in Nuclear Plant Construction – not just “reactor”

- Reduce critical path schedule by implementing a parallel construction approach. **More predictable** manufacturing schedule.
- Take the fabrication work to the **centers of skilled labor**.
- Reduce fabrication cost and on-site duration through improved productivity.
- Improved quality through **standard shop procedures** and consistent material traceability.
- Reduces on-site safety risks.
- Standardization and repetition aids learning curve and fleet cost reduction.
- **Incorporate piping, instrumentation and electrical systems into modules (increased outfitting).**
Module Configuration and Construction is a Different Process

• Requires increased coordination and use of electronic models by designers, planners and constructors

• **Multi-system and multi-discipline** integration of design, fabrication and test — by area, not system

• Requires **schedule and planning rigor**—manufacturing assembly and erection plans incorporated from the beginning of the design

• **Standardization is fundamental**

• **Fixtures**, Accuracy Control and 3D measuring is a backbone

• Tolerance budgeting is mandatory

• Neat cuts are expected—extra stock planned on case-by-case basis

• Large assemblies are cut prior to installation based on as-built data
EB Module Configuration Methodology
Applicable to Standardized Designs

- Reduce construction identified design errors
- Optimize modularization
- First-of-a-kind execution at the 3rd ship learning curve