Power System Design Activities during Preliminary and Contract Design

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March 16-17, 2016
Agenda

• Introduction
• Design Disciplines
• Analyses
• Ship Specification
• Long Lead Material
• FSC Issues
• Conclusion
PD – CD: Simplified

Preferred Concepts
Draft CDD
ICD
Budget
Risk Mitigation Activities

PERFORM PRELIMINARY AND CONTRACT DESIGN

Contract Package
CDD
Cost Estimate
Performance Prediction

1.5 to 4 Years
Select Power and Propulsion Design Guidance Documents

- S9000-AD-SPN-010/NCDS Naval Combatant Design Specification
- T9300-AF-PRO-020 Electrical Systems Design Criteria and Practices (Surface Ships) for Preliminary and Contract Design
- T9070-AG-DPC-010/051-1 Prediction of Smooth-Water Powering Performance for Surface-Displacement Ships
- T9070-AW-DPC-010/200-1 Calculation of Surface Ship Endurance Fuel Requirements
- T9070-AX-DPC-010/221-1 Data for Estimating Pressure Losses in Engine and Boiler Inlet and Exhaust Systems
- MIL-HDBK-2189 Section 243-1 Design Methods for Naval Shipboard Systems, Propulsion Shafting
- T9070-A3-DPC-010/310-1 Electrical Power Load Analysis (EPLA) for Surface Ships
- T9070-BH-DPC-010/568-1 Thruster Maneuvering Systems
Transitioning from Concept Exploration

• From Concept Exploration have a set of feasible and high risk for feasibility configurations for each capability concept.
  – Can eliminate design options that are highly dominated or infeasible
• At Milestone A, one or a few capability concepts have been selected.
• Potentially have new information on components and systems that was not available during concept exploration.
• Evolving description of the design is captured in a Ship System Specification
  – Used during PD / CD
  – Basis for the Shipbuilding Specification
Point Based Design Approach

• Develop a reference design.
• Each discipline (SEM) conducts analysis to check for feasibility and gain confidence in viability of the reference design.
• Each discipline (SEM) conducts trade-studies to examine changes to the reference design in terms of being able to meet requirements and reduce cost.
• Proposed changes are examined by all disciplines to ensure feasibility is preserved before the change is incorporated.
Set-Based Design

• Identify interfaces between disciplines and defined a range (or set of discrete points) for these interface values
• Have disciplines (SEMs) develop families of solutions to cover the ranges of the interface values
  – Reach Family: Potential for reduced cost, but risky
  – Target Family: Acceptable cost, modest risk
  – Safe Family: higher cost, low risk
• DIMs (+ PNA and PME) intersect families of solutions to identify opportunities for set reduction.
• SDM and PM decide on where to invest in reducing risk based on impact on integrated solution, and where to “play it safe”.
  – Keep lower risk solutions active until risk reduction efforts complete.
Design Disciplines
Systems Engineering Managers

- Hull (NSWC Carderock)
- Machinery (NSWC Philadelphia)
- Combat Systems (NSWC Dahlgren)
- C4ISR (SPAWAR)
- Aviation (NAVAIR)
Hull – CPES Interactions

• Displacement and volume
• Stability, allowable KG, V-lines
• Arrangements
• Hull resistance
• Survivability
Machinery – CPES Interactions

• Electric Plant (including Electric Plant Controls)
• Propulsion system
• HVAC systems
• Auxiliary systems
• Machinery Control Systems
Combat System – CPES Interactions

- Combat System definition
- Combat System arrangements (location)
- Combat System mass properties
- Distributed system needs
- Control interfaces
- Deactivation diagrams
- Combat System effectiveness
- Combat System tests and trials
C4ISR and Aviation – CPES Interactions

- System definitions
- Arrangements
- Mass properties
- Distributed system needs
- Control Interfaces
- Deactivation Diagrams
- System effectiveness
Analyses
Electric Plant Analyses

• Electric Power Load Analysis
• Load Flow Analysis
• Transient Analysis
• Fault Current Analysis and Protective Device Coordination Study
• Harmonic and Non-Fundamental Frequency Analysis
• Stability Analysis
• Electromagnetic interference (EMI) analysis
• Reliability Analysis
• QOS Analysis
• Vulnerability and Recoverability Analysis
• Arc Flash Analysis

What tools and data are needed for these analyses?
Propulsion and Maneuvering Analysis

• Powering Analysis
  – Hull Resistance Analysis
  – Propulsor open water efficiency analysis
  – Propulsor – Hull interaction analysis
  – Shafting and thrust bearing design and analysis

• Seakeeping Analysis
  – Anti-roll device design and effectiveness analysis

• Maneuvering Analysis
  – Steering gear design and effectiveness analysis
  – Crashback analysis – Dynamic Brake design

What tools and data are needed for these analyses?
Survivability Analyses

• Susceptibility
  – Degaussing system design and analysis
  – Acoustic analysis
  – Radar cross section analysis
  – Infrared signature analysis

• Vulnerability
  – Zonal Survivability design and analysis
  – Structural survivability design and analysis
  – Damage Control Systems design and analysis
  – Shock hardness

• Recoverability
  – Compartment Survivability design and analysis
  – Casualty Power design and analysis

What tools and data are needed for these analyses?
Maintenance and Logistics Analyses

• Consumable identification and consumption rate analysis
• Reliability Analysis
• Repair part and special tool identification
• Storeroom sizing
• Maintenance Access analysis
• Equipment Removal Route analysis
• Maintenance workload estimation
  – Preventative
  – Corrective

What tools and data are needed for these analyses?
Safety Analyses

• Interior noise analysis
• Interior temperature / humidity analysis
• Hazardous material identification
• Emergency Egress analysis
• Hazard analysis

What tools and data are needed for these analyses?
Ship Specification
Ship Specification

• Organized by ESWBS
  – Each element should be assigned to a SEM or DIM
  – Responsible TWHs should be identified

• DDG 1000 Contract Design Package:
  – 179 Specification sections
  – 1 classified addendum
  – ~44 Project Peculiar Documents (PPDs)
  – ~7 Contract Drawings

DOORS is typically used for requirements management ... anything better?
DDG 1000 Section 200

• 200: General Requirements for Machinery Plant
• 202: Machinery Centralized Control System (includes DDA console)
• 235: Electrical Propulsion System (EPS)
• 243: Propulsion Shafting
• 244: Propulsion Shaft Bearings and Seals
• 245: Propellers
• 256: Machinery Circulating Water and Cooling Water Systems
DDG 1000 Section 300

- 300: General Requirements for Electric Plant
- 302: Electric Motors and Associated Electric Equipment
- 303: Protective Devices for Electric Circuits
- 304: Electric Cable
- 305: Electrical and Electronic Designating and Marking
- 310: IPS Generators
- 313: Storage Batteries and Servicing Facilities
- 314: Electric Power Supply Conversion Equipment
- 315: Common Array Power System (CAPS)
- 320: General Requirements for Electric Power Distribution Systems
- 322: General Requirements for High Voltage Switchboards
- 324: Load Centers and Panels for Electric Low Voltage Power and Lighting
- 331: General Requirements for Lighting Systems – Distribution and Control
- 332: Illumination Requirements
- 343: Combustion Exhaust and Air Intake Systems and Support Systems
DDG 1000 other sections of note

- 072: Ship Protection from Weapons Effects
- 073: Noise, Vibration, and Resilient Mountings
- 076: Reliability and Maintainability (R&M)
- 077: Integrated Environmental, Safety, and Occupational Health (ESOH)
- 422: Navigation Lights, Signal Lights, and Searchlights
- 475: Degaussing System
- 512: Heating, Ventilation and Air Conditioning (HVAC)
- 541: Fuel Systems
- 542: JP-5 Systems
- 561: Steering Gear
- 562: Rudders
- 605: Ratproofing
- 633: Cathodic Protection
Ship Specification thoughts

• Align the structure and content of the ship specification with the acquisition strategy.

• Develop a strategy for what should be defined in detail and what should be left to the shipbuilder to define.
  – The degrees of freedom left to the shipbuilder define a design space.

• Start early
  – Complete the low-risk of change elements of the contract design package as early as possible; much of the ship specification is known on day 1 of PD
  – Track progress of design by the degree of completeness of the Ship Specification
  – Use the Contract Design Package as the endpoint for Decision Oriented Systems Engineering

• Analyze the design space defined by the Specification
  – Ensure any conforming material solution will be satisfactory to the Navy

• Think through how the detail design will be validated against the requirements (in time for CDR and PRR).

• Think through how the delivered ship will be tested to ensure it meets the requirements.

• Ship specification should implement a well thought out strategy for minimizing total ownership cost.
Test and Trials

• Need to understand CPES impact on Test & Trials.
  – Combat System testing will required power system to be fully operational
  – Some tests can only be done at sea -- what should be done to mitigate risk of failure of these tests.

• Need to understand CPES impact on Live Fire Test and Evaluation (LFT&E)
Long Lead Material
PD – CD considerations for long lead material

• Some equipment and material must be ordered from vendors before detail design is complete ....
  – Sometimes before PD-CD is complete.

• PD-CD must achieve the level of detail necessary to develop a procurement package for the long lead material to enable its delivery to the shipyard by the in-yard need date.
  – Must be aware of and mitigate the risk that long lead material requirements may change
FSC Specific Issues
Design Practices and Criteria

- Design Practices and Criteria do not exist to support pulse loads
- Design Practices and criteria do not exist to support design and integration of MVDC systems
  - MVDC Interface standards
  - Stable voltage regulation (with pulse loads)
  - Integration of Energy Storage
  - Fault detection, localization and isolation
  - Recoverability (casualty power)
  - System Grounding
  - Implementation of Quality of Service
  - Maintenance Support
- Component libraries / sizing algorithms should be validated
  - How should the validation be conducted?
- How should the Design Practices and Criteria be developed?
Electric Plant Control Design

• Historically, most of the control system design has been deferred until detail design and construction.
  – Schedule Driver
  – Integration challenges

• To what degree should the electric plant control design be completed during PD/CD?

• How should the electric plant control design be described in the contract design package?

• How should the electric plant control design be analyzed and tested during PD/CD?
Margin and Service Life Allowance for Modularity and Flexibility

• How should capacity for Mission Systems that are not defined during PD/CD be accounted for in the EPLA and electrical power system design?
  – Direct Impact: Electric Load
  – Indirect Impact: HVAC

• Mission System Definition could occur …
  – During Design and Construction (impacts margin)
  – In-service (impacts service life allowance)
Margin Policy with Set-Based Design

• Set-Based Design (SBD) can accomplish some of the goals of margin.
  – Retain ability to substitute solutions should one solution prove not viable.
  – SBD can account for known unknowns, but does not account for unknown unknowns.

• To what degree should margins be reduced (if at all) if SBD is used?

• Note: Service Life Allowances are not impacted by SBD.
Post Delivery installation of mission systems

• How can design of the electric plant facilitate the post-delivery installation of mission systems?
  – Avoid installing obsolete mission systems

• How should ship design and mission system design be conducted to ensure a smooth integration at the correct time?
Conclusions

• While the general needs for PD/CD are known, details for designing and specifying affordable MVDC (or MVAC) systems to support pulse mission systems still require development and formal documentation.

• Tools, design data, and expertise are needed to conduct preliminary / contract design.