Power System Design Activities during Preliminary and Contract Design

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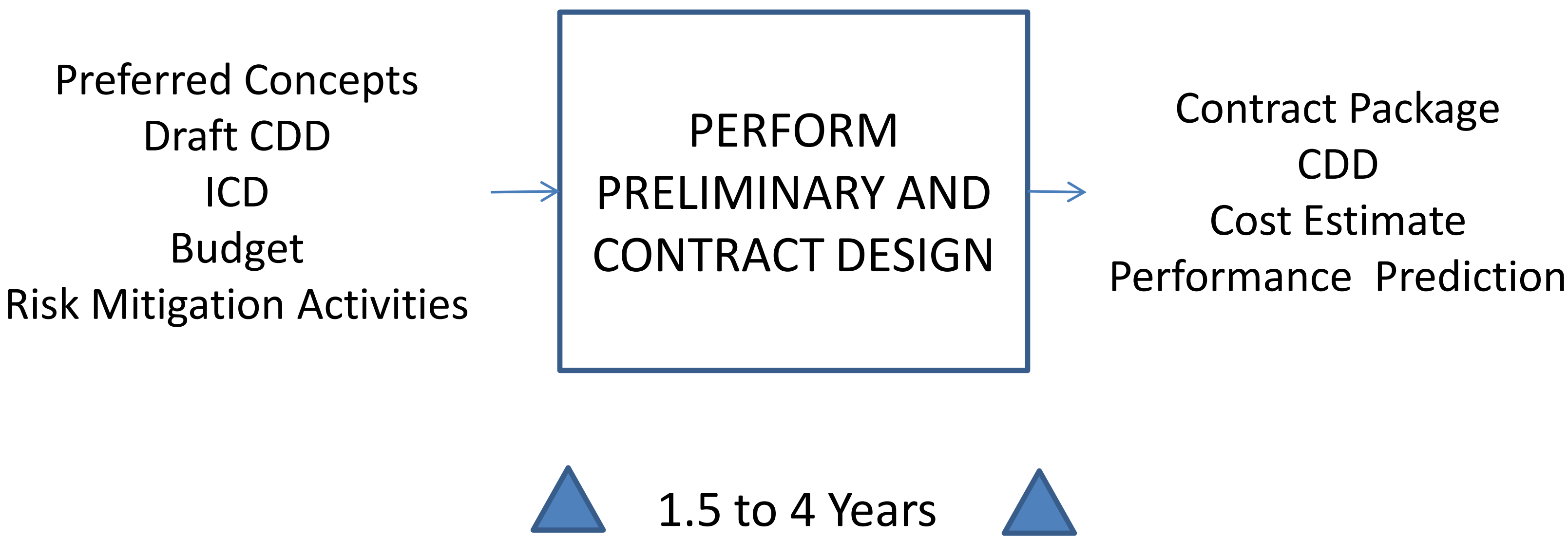
Agenda

- Introduction
- Design Disciplines
- Analyses
- Ship Specification
- Long Lead Material
- FSC Issues
- Conclusion

PD – CD: Simplified



Select Power and Propulsion Design Guidance Documents

- T9070-AE-DPC-010/001-1 General – Design Practices and Criteria Manual, Publications Index and User Guide
- 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-AW-DPC-020/200-2 Calculation of Surface Ship Annual Energy Usage, Annual Energy Cost, and Fully Burdened Cost of Energy
- 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
- T9500-AA-PRO-130 NAVSEA Design Practices and Criteria Manual for Air Conditioning, Ventilation, and Heating of 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

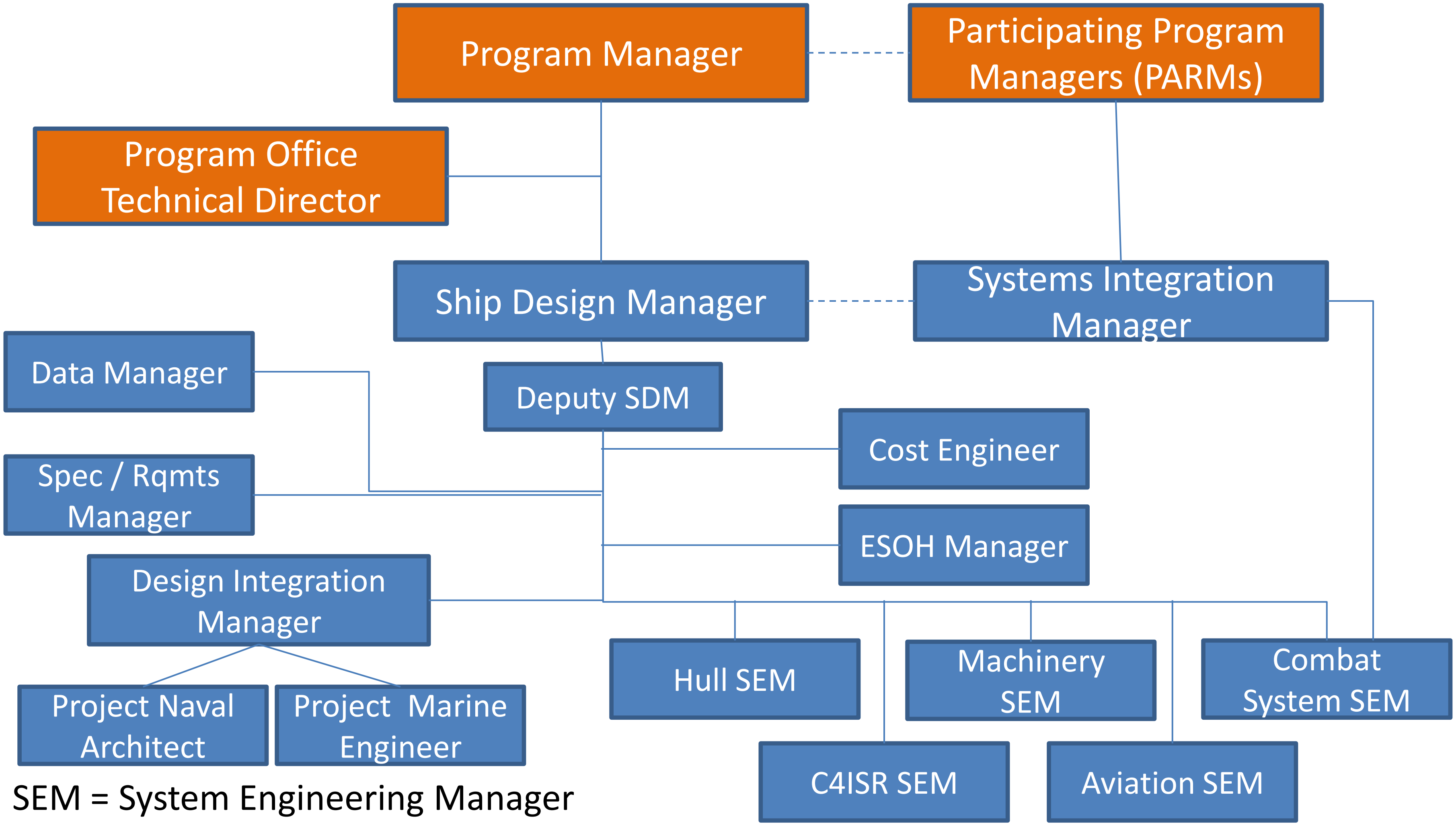
- Develop a reference design.
- Each discipline (SEM) conducts analysis to check for feasibility and gain confidence in viability of the reference design.
- Each discipline (SEM) conducts trade-studies to examine changes to the reference design in terms of being able to meet requirements and reduce cost.
- 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

Notional Design Team Organization



SEM = System Engineering Manager

Systems Engineering Managers

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

Natural Discipline Boundaries for Set-Based Design

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 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 Tet 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.