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PHILADELPHIA

Reducing Complexity in Ship Design

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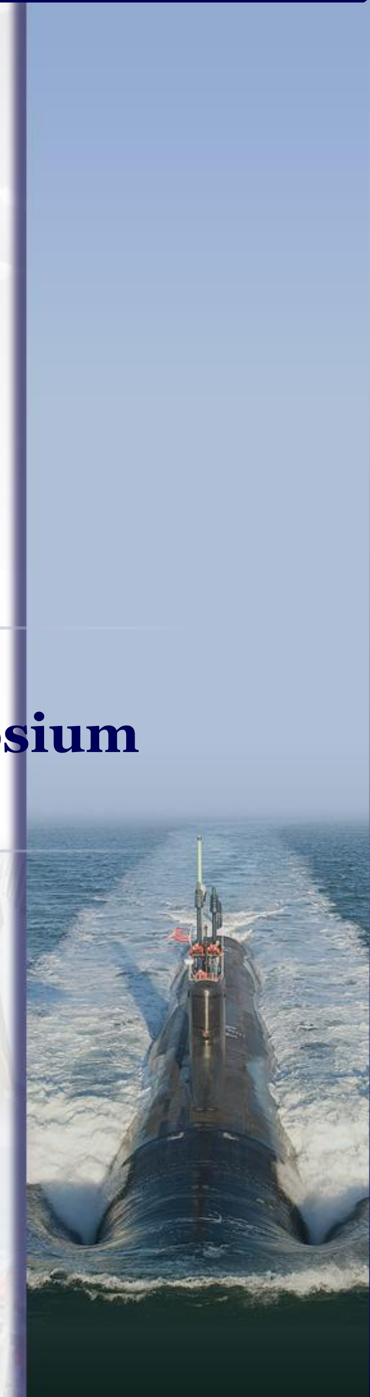

Complex vs Complicated

- Complex
  - Many elements
  - Large number of interacting elements and connections
  - Nonlinear interactions between elements
  - Not-predictable
    - Small perturbations can result in large variation in output
    - **Traditional management and engineering techniques usually not effective**
- Complicated
  - Many elements
  - Predictable
    - **Traditional management and engineering techniques usually effective.**

Simple

- A simple system achieves all Functional Requirements (FRs) with the fewest number of elements and connections.
  - Can be complex.
- Simplifying a complicated system is good if in the process the system does not become complex.

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Different Types of Complexity (Nam Suh)

- Real Complexity
  - Time-invariant uncertainty in fulfilling a Functional Requirement
- Imaginary Complexity
  - Lack of understanding about the system
- Combinatorial Complexity
  - Time-variant uncertainty in fulfilling a Functional Requirement
- Periodic Complexity
  - Time-variant uncertainty that periodically resets to a lower level

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General Process

- If outcomes are hard to predict, likely have a complex system.
- Complex systems should be converted wherever possible to complicated systems (to enable effective engineering and management).
  - Reduce number of connections
  - Reduce variability
  - Reduce sensitivity to perturbation
- Complicated systems should be simplified such that the resulting system does not become complex, yet is cheaper to own and easier to operate.

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Reducing Complexity over a ship's life

- Complexity in Service – Maintenance Planning
- Complexity in Service – Damage Control
- Complexity in Service – Normal Operation
- Complexity in Service – Modernization
- Complexity in Acquisition and Construction
- Complexity in the Design Process

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Complexity in Service – Maintenance Planning

- Sources of Uncertainty
  - Scope of work
    - Open and Inspect work items
    - Insufficient condition assessment prior to scope definition
  - Repair part availability
    - Will repair parts be available when needed?
- How to reduce Uncertainty
  - Non-intrusive condition assessment
  - Long lead parts manufactured on demand – Additive Manufacturing
  - Rotatable pools of parts and equipment
  - Implement Corrective Maintenance Free Operating Period
    - Employ Failure Reporting, Analysis, and Correction Action System (FRACAS) to understand and improve ability to assess condition

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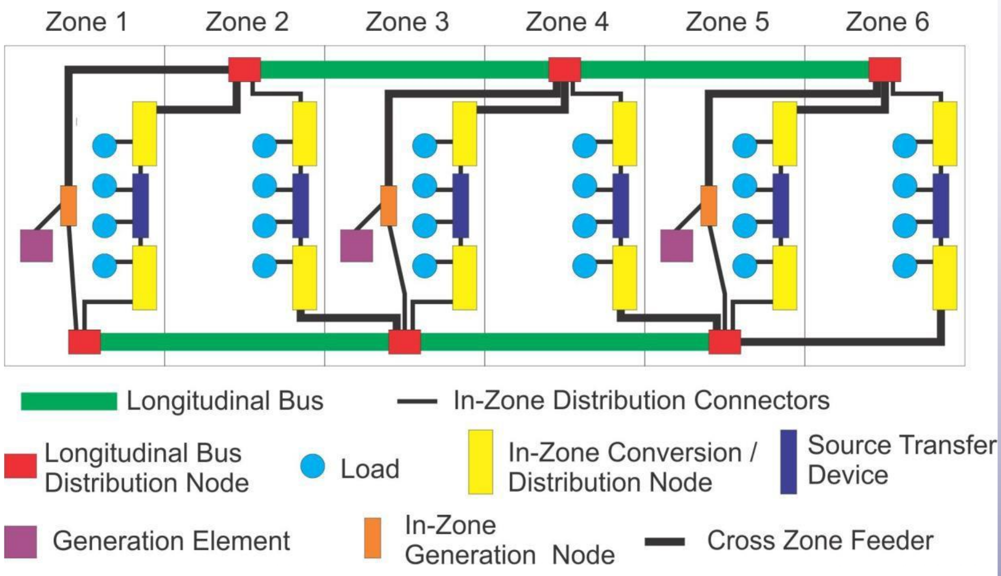
Complexity in Service – Damage Control

- Sources of Uncertainty
  - Weapons Induced Damage
  - Cascading Failures
    - Progressive fires and flooding
    - Distributed System co-dependencies
    - Spread of viruses in computer networks
- How to reduce Uncertainty
  - Zonal ship Design
    - Zone boundaries aligned for all systems.
    - Functionally redundant equipment are at least two zones apart.
    - Zonal Survivability.
    - Compartment Survivability.



- Zonal Survivability: Damage in any two adjacent zones does not impact operation in undamaged zones.
- Compartment Survivability: Undamaged loads in damaged zones can be restored to service.

Complexity in Service – Normal Operation

- Sources of Uncertainty
  - Electromagnetic Interference
  - Common Mode Currents and Voltages
  - Distributed System Co-Dependence
    - Dark Ship and Dead Ship starts
- How to reduce uncertainty
  - Topside Design – aperture stations
  - Keep CM currents local by design
  - Model distributed system co-dependence.

May 4, 1982: HMS Sheffield hit by two Exocet missiles. Transmission on SATCOM caused EMI with Electronic Warfare System

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Complexity in Service - Modernization

- Sources of Uncertainty
  - Equipment requires replacement over service life
  - Need to remove of interferences
  - Lack of removal routes
  - Lack of service life allowance at the right place
- How to reduce uncertainty
  - Implement modularity for systems not expected to last the ship's service life.
  - Allocate service life allowances to distribution system equipment.

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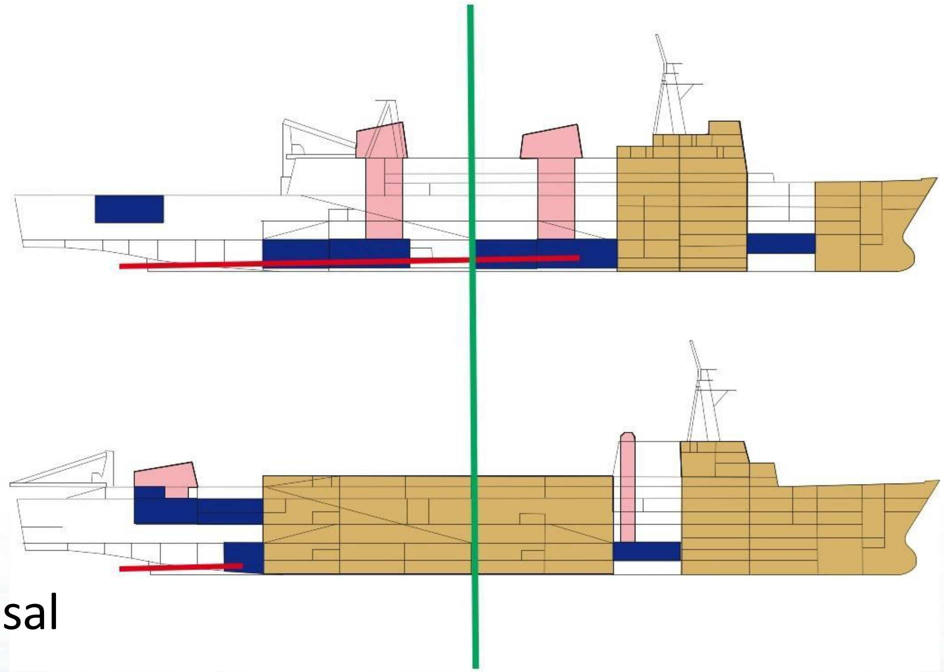
Complexity in Acquisition and Construction

- Sources of Uncertainty
  - Government Furnished Information (GFI)
  - Alignment of system boundaries with construction boundaries
  - Long Shaft Lines
    - Construction
    - Modified Repeats
- How to reduce uncertainty
  - Include GFI in the Request for Proposal
  - Consider build strategy when designing systems
  - Use Integrated Power Systems and forward propulsor to shorten shaft lines



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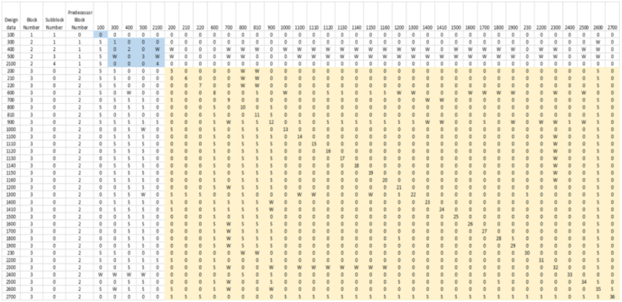
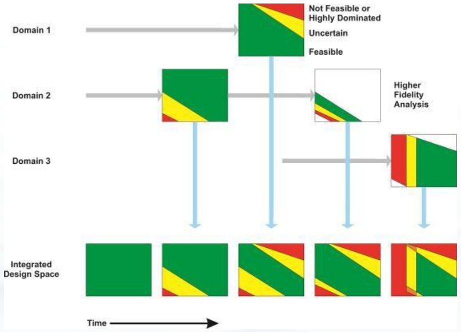
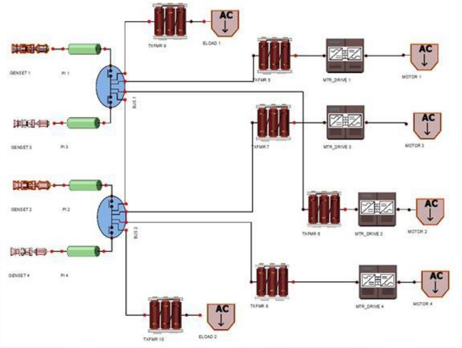
Complexity in the Design Process

- Sources of Uncertainty
  - Lack of full understanding of design process
  - Lack of understanding of system performance
  - Lack of knowledge of ship's equipment
  - Lack of design tool capability



- How to reduce uncertainty
  - Design Activity Modeling
  - Set-based Design
  - Zonal Ship Design
  - Effective use of margins
  - Improve design tools
  - Constrain design space to what can be analyzed
  - Manage and eliminate knowledge gaps





Conclusion

- Designing, constructing, maintaining, and operating ships can be complex.
  - Unpredictable results are usually not desirable.
- The naval engineering community has the power to reduce the complexity – make it complicated, not complex.
  - Real Complexity – reduce uncertainty and connections
  - Imaginary Complexity – improve understanding of systems
  - Combinatorial Complexity – improve condition assessment – convert to periodic complexity