NAVSEA WARFARE CENTERS



Reducing Complexity in Ship Design

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Presented by:

Dr. Norbert Doerry NSWC Carderock Dr. John V. Amy Jr. NSWC Philadelphia

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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.





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





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.



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



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

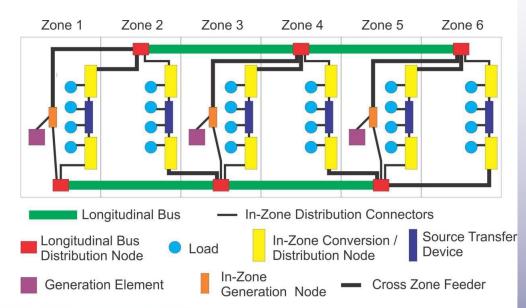


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Complexity in Service – Damage Control

- Sources of Uncertainty
 - Weapons Induced Damage
 - Cascading Failures
 - Progressive fires and flooding
 - Distributed System codependencies
 - 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.

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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 codependence.



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



Complexity in Service - Modernization

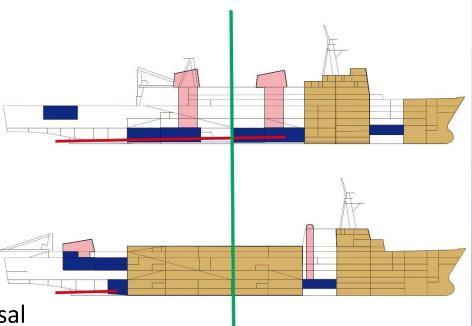
- Sources of Uncertainty
 - Equipment requires replacement over service life
 - Need to remove of interferences
 - Lack of removal routes
 - Lack of service life allowance at the right place
- How to reduce uncertainty
 - Implement modularity for systems not expected to last the ship's service life.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





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



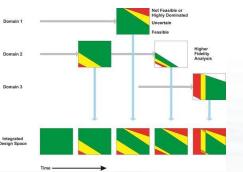


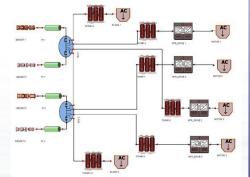
Complexity in the Design Process

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

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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

