Early Stage Systems Engineering with Uncertain Requirements

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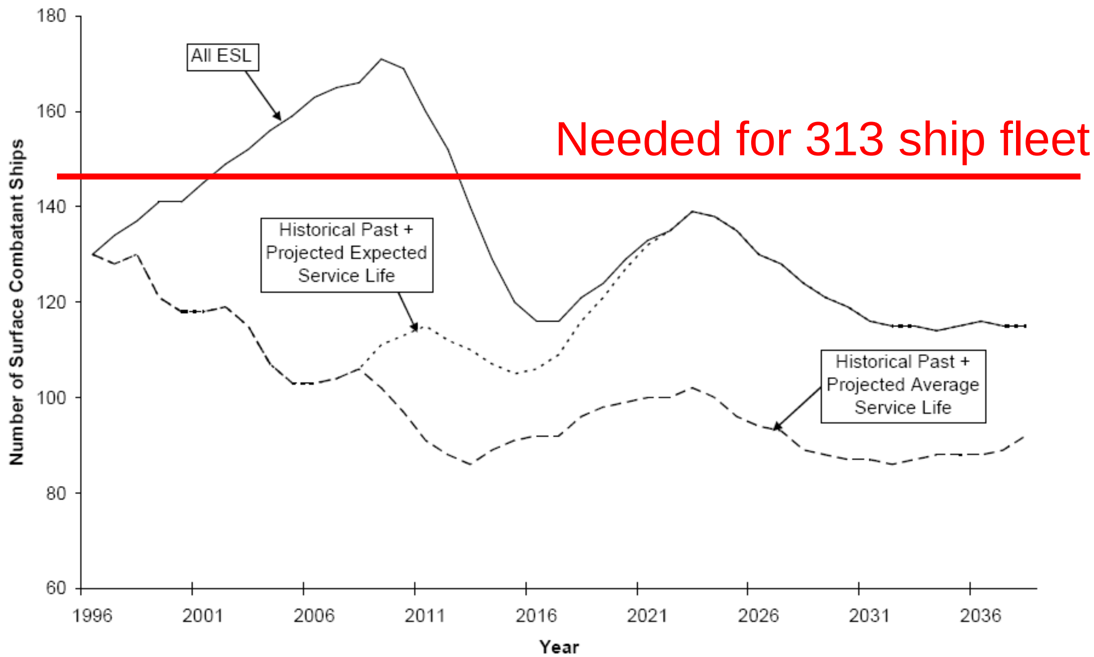
Motivation



Koenig, Dr. Philip, Don Nalchajian, and John Hootman,"Ship Service Life and Naval Force Structure," ASNE ETS 2008, 23-25 Sept 2008

Our ships must remain militarily relevant (affordably) over their Expected Service Life for the Navy to achieve Force Level Requirements

Building an Affordable Future Fleet in an Evolving World

- Face uncertain times
  - The threat is evolving
  - Our technology is evolving
  - Lean times ahead
- Ships and their systems must be robust, flexible and adaptable
- Systems Engineering must anticipate uncertain and changing requirements

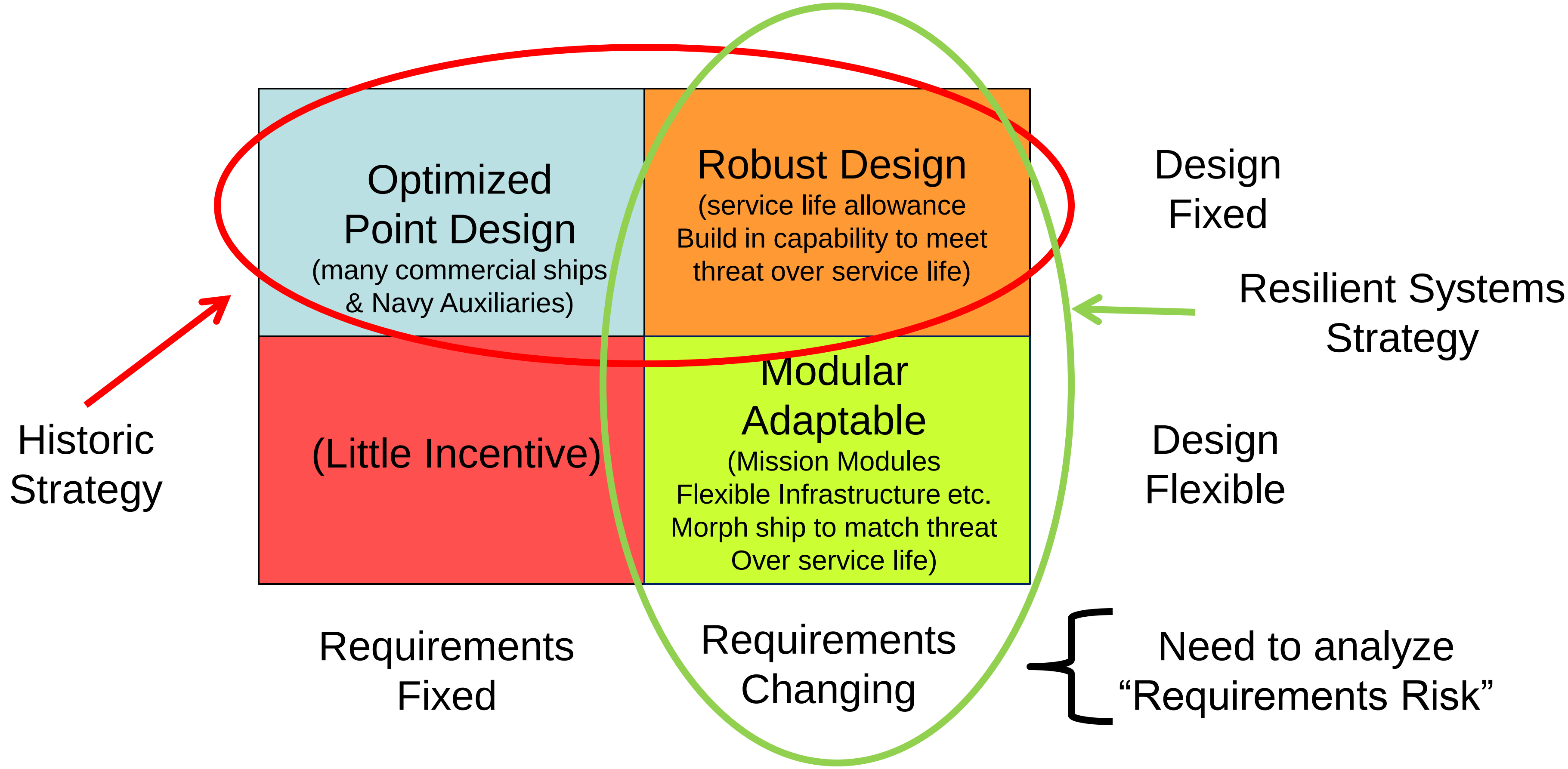
Design Strategies

	Requirements Fixed	Requirements Changing
Design Fixed	Optimized Point Design (many commercial ships & Navy Auxiliaries)	Robust Design (service life allowance Build in capability to meet threat over service life)
Design Flexible	(Little Incentive)	Modular Adaptable (Mission Modules Flexible Infrastructure etc. Morph ship to match threat Over service life)

{ Need to analyze "Requirements Risk"

A combination of strategies is likely optimal

Design Strategies

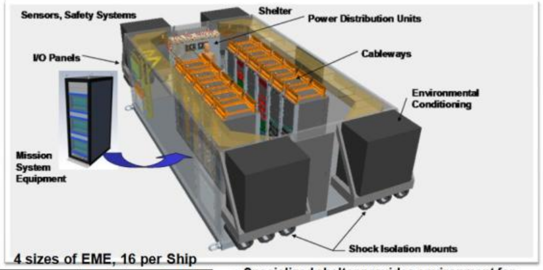


Keep Robust Design, but shift to Modular Adaptable Design

Modular Adaptable Ship Technology Examples

- "Modular Hull Ship" (bow, stern, variable Parallel Mid-Body)
- "Mission Bay" (like LCS)
- Container Stacks/Slots/Interfaces
- Weapon/Electronics Modules / zones
- Aperture Station
- Aircraft, boats, UUV, UAV, USV
- Electronic Modular Enclosures (EME)
- Flexible Infrastructure

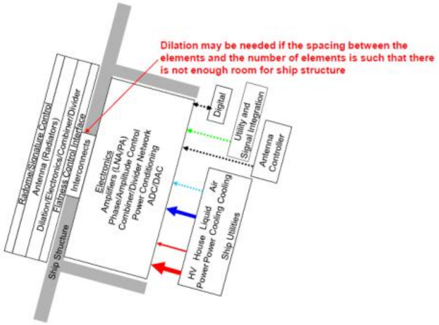
Electronic Modular Enclosures

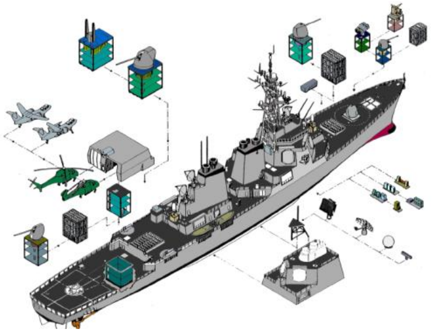


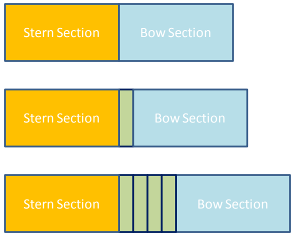
4 sizes of EME, 16 per Ship

	Length	Width	Height
Mini	18 ft	7 ft	7.45 ft
Small	25 ft	11.8 ft	7.45 ft
Medium	30 ft	11.8 ft	7.45 ft
Large	35 ft	11.8 ft	7.45 ft

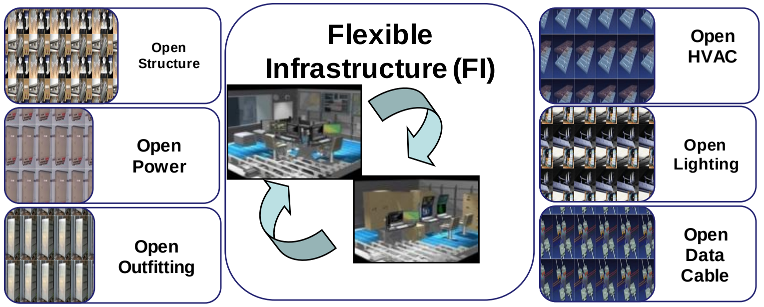
- Specialized shelter provides environment for Commercial Off The Shelf (COTS) Hardware
- 16 shelters house 236 cabinets
- Shock, Thermal, EMI, Security, & Noise Reduction
- Power Distribution and Control
- Enables Integration of electronics in factory







Schelde Naval Shipbuilding: Sigma Design Concept



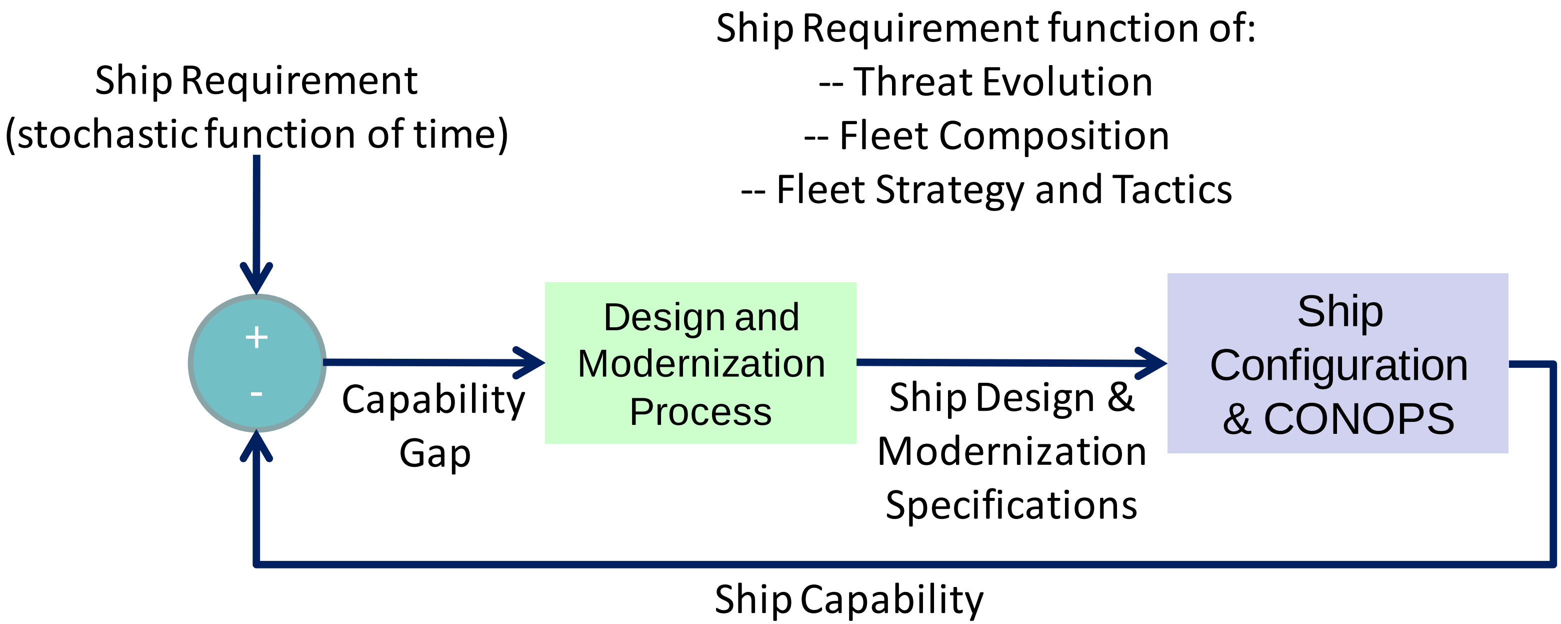
Challenges

- How should flexibility be valued?
- Incorporate how much of what type of flexibility?
  - Return on investment calculations are not easy
    - future requirements are uncertain
    - future investment is uncertain
    - future return on the investment is uncertain
  - Net Present Value analysis is not ideal
    - Alternatives generally not equal in performance.
    - Does not value delaying decisions until more information is known about requirements.

"Current valuations in naval ship design tend to focus on valuing a point designed product. Although there have been efforts to more completely explore the design space for the optimal solution, the optimal solution is based on a fixed set of requirements and preferences. In addition, optimization infers certainty. There is no way in the current system to value adding flexibility to the design, **since under certainty, flexibility has no value."**

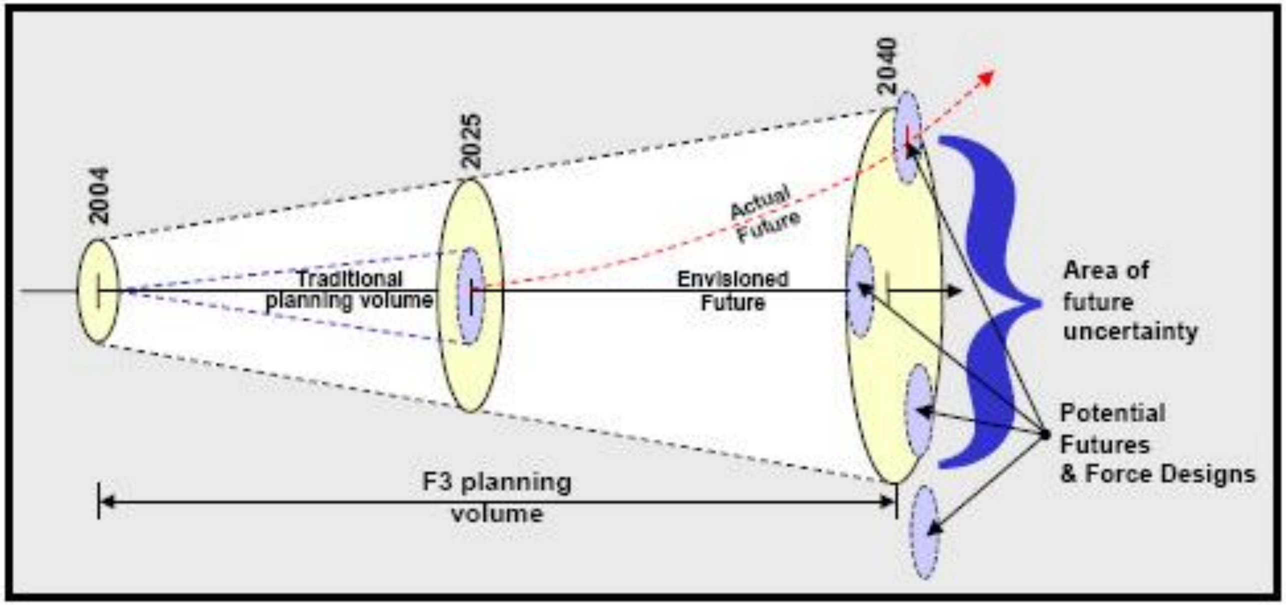
Gregor, Jeffrey Allen. 2003. *Real options for naval ship design and acquisition: A method for valuing flexibility under uncertainty*. M.S. thesis, Ocean Engineering, MIT.

Concurrently Designing the Ship, its Concept of Operations, and the Design and Modernization Process



- View the Ship Configuration, its Concept of Operations (CONOPS) and Design & Modernization Process as a dynamic system that spans the ship's total life.
- Design this dynamic system to minimize both the total ownership cost and the "Capability Gap."
- Understanding the variability of the Ship Requirements over time is crucial.

Bounding Future Requirements



Rice, Theodore L. CAPT USN (RET), “Future Force Formulation Experiment,” ASNE Day 2005, April 26-27, 2005.

- Accurately forecasting requirements over the typical 30-50 year lifespan of a warship is nearly impossible.
- Postulate “Alternate Futures” to model associated future force designs and potential needs for individual ships.
  - Enables bounding potential future requirements for individual ships
  - Helps forecast when future requirements will become apparent

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Real Options Theory

1. Naval ship design projects intrinsically create options having many (but not all) of the attributes of financial options.

There are valuation methods for financial options. Could they be modified for use in naval ship design? Or, for the general case of defense systems design and acquisition?

2. Naval ship design features have option value that is not currently documented.

Example - adaptability features: "Promoting flexibility… creates a quantifiable value, and this value exists whether or not one actually attempts to quantify it using an options pricing model."

3. If option value were explicitly recognized, design and program decisions would benefit from additional insight, and certain types of design features would be more highly valued.

Real options are like financial options in many ways
But there are key differences

Option on stock	**Real option on engineering project**
Option price Listed on financial markets	**Real option price** Ex. – funding for early stage design exploration, funding for R&D, etc.
Current value of stock Listed on financial markets	**Present value of future cash flows** Naval case: future defense **utility** (?)
Striking (exercise) price Contractually specified	**Investment cost for project** Ex. – cost to commercialize a new tech, cost to do downstream design and construction
Time to expiration Contractually specified	**Time until opportunity disappears** Ship design: economy, actions of competitors, etc. Naval ship design: economy, actions of future adversaries, etc.

Dr. Phil Koenig, "Option Value in Naval Ship Design"

Putting it all together

- Model alternate futures to bound future requirements.
  - Identify when sufficient information will be known to determine the most likely alternate future.
- Identify Modular Adaptable Ship technologies or Robust features that allow one to affordably defer investment decisions to when more is known about the future
- Concurrently design the ship, its Concept of Operations, and the ship design & modernization process to enable affordably addressing changing requirements over the ship's life cycle.
  - Consider using real options theory to guide investment decisions