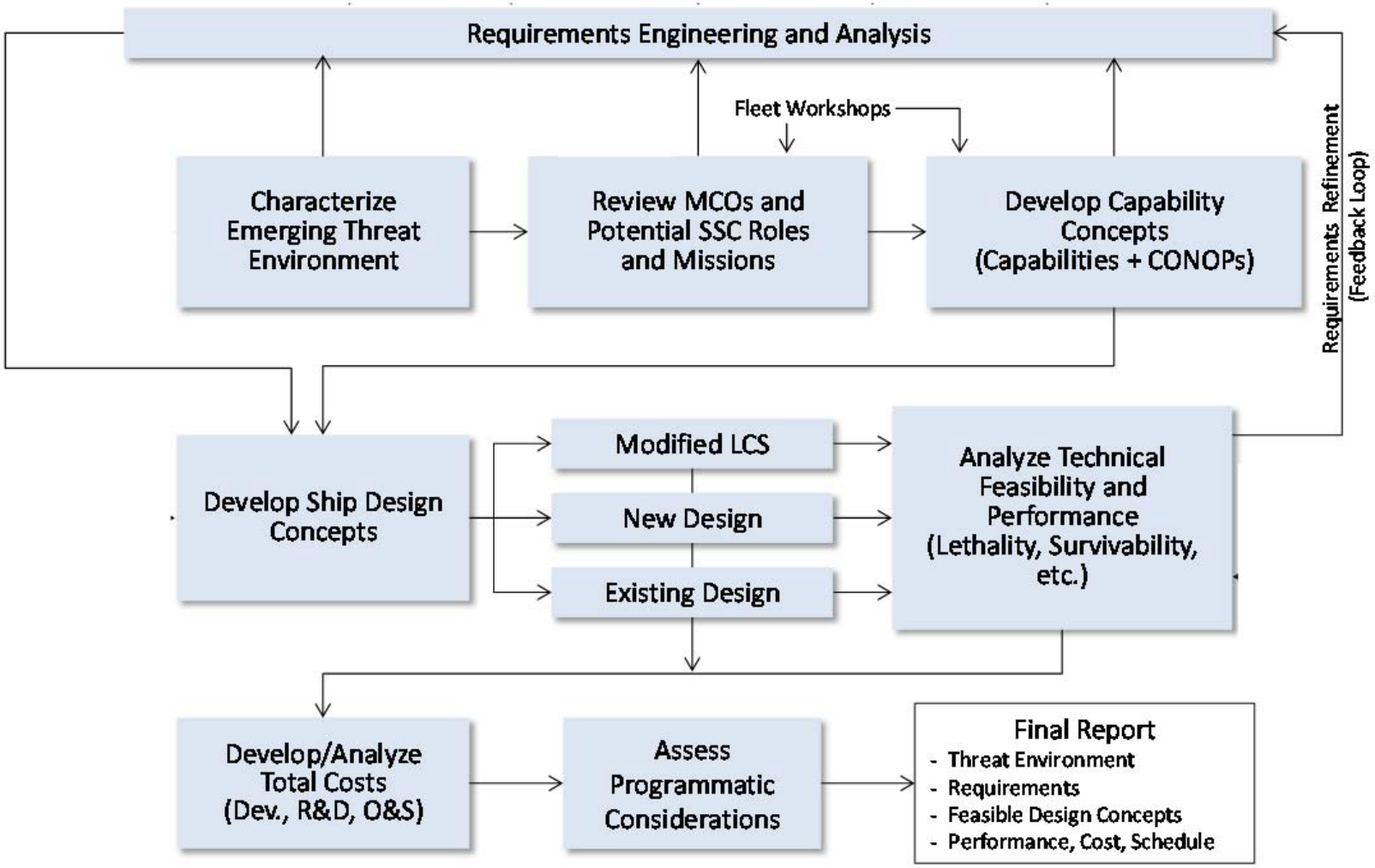
Concept Exploration Methods for the Small Surface Combatant

Matt Garner, Dr. Norbert Doerry, Adrian MacKenna, Frank Pearce, Dr. Chris Bassler, Dr. Shari Hannapel, Peter McCauley

Introduction

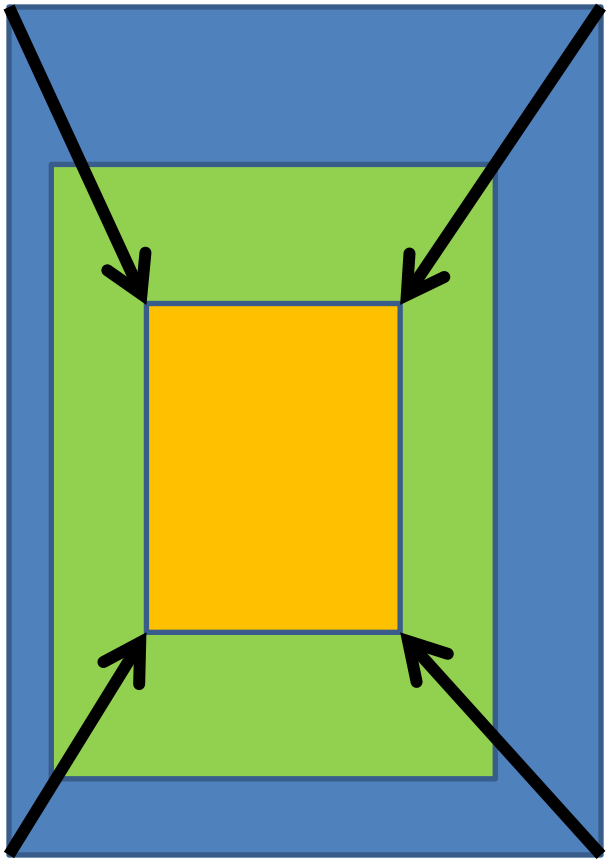
- February 2014 Secretary of Defense direction to USN:
  - Submit alternate proposals to procure a “capable and lethal small surface combatant generally consistent with the capabilities of a frigate.”
- Small Surface Combatant Task Force formed to:
  - Establish the requirements and requirements trade space of a small surface combatant
  - Assess the impact of the requirements delta to LCS
  - Translate the requirements delta into design concepts for a small surface combatant
    - Modified LCS design
    - Existing ship design
    - New ship design
  - For each design concept include:
    - Top level requirements
    - Cost
    - Major Milestone Schedule
    - Lethality of the ship to air, surface, and undersea threats
- Six month study conducted in spring and summer of 2014

Study Process



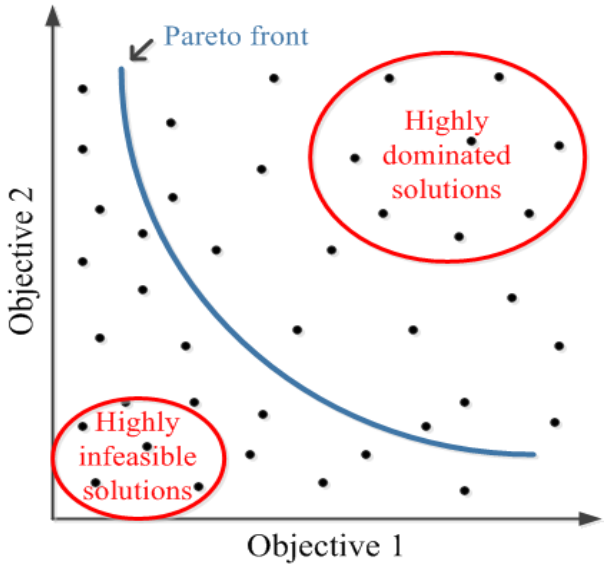
Set-Based Design

- Principle concepts
  - Consider a large number of potential solutions
  - Have specialists evaluate sets of solutions from their own perspective
  - Intersect the sets to optimize a global solution and establish feasibility before commitment
- Capability Concept
  - A set of operational capability levels, and
  - Associated CONOPS
- Configuration
  - A proposed material solution to achieve a capability concept



Set-Based Design
Feasibility and Viability

- Feasible:
  - Configuration achieves objectives based on current fidelity of modeling and analysis
- Viable:
  - Configuration achieves objectives based on future more detailed modeling, analysis, and testing
- A feasible configuration may not be viable
  - Should not choose a specific configuration as representative or optimal
  - Decisions should be made at capability concept level, not the configuration level
- Cost for a given capability concept should be based on a diverse set of feasible configurations
  - Avoid common mode failures
  - Reflect undecided requirements

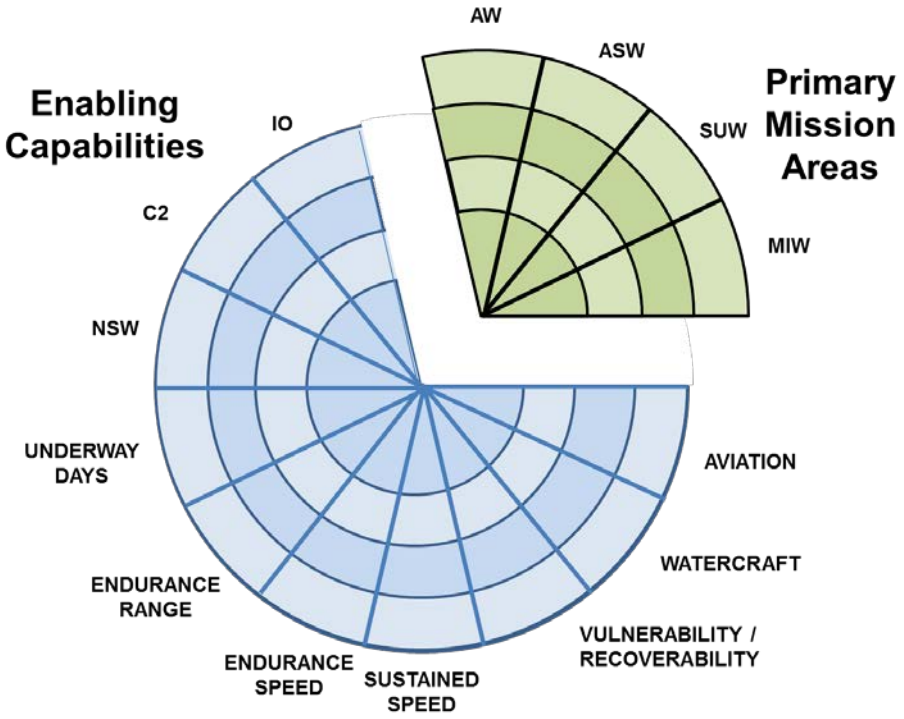


McKenney, Thomas, and David Singer, "Set-Based Design," SNAME (mt) Marine Technology, July 2014, pp. 51-55.

Systematically Eliminate
- Highly Dominated Solutions
- Not Feasible Solutions

Capability Concept

- Primary Mission Areas
  - Air Warfare (AW)
  - Anti-Submarine Warfare (ASW)
  - Surface Warfare (SUW)
  - Mine Warfare (MIW)
- Enabling Capabilities



192 Different Combinations of Primary Mission Areas

Set-Based Design used to reduce number of Capability Concepts from 192 to 8

	Capability Concept							
Mission Area Capabilities	**CC 1**	**CC 2**	**CC 3**	**CC 4**	**CC 5**	**CC 6**	**CC 7**	**CC 8**
Self Defense against Air, Surface, Undersea Threats	X	X	X	X	X	X	X	X
Capability to detect and engage small craft within- the-horizon of own ship		X	X	X	X	X	X	X
Capability to achieve mission kill of over-the-horizon surface targets					X	X	X	X
Capability to detect and engage undersea threats in support of ASW operations	X		X	X			X	X
Limited capability to defend other ships against ASCMs	X	X		X		X		X

Logical reduction process based on
- Analysis of Force Architecture
- Little difference in physical systems for several Capability Concepts

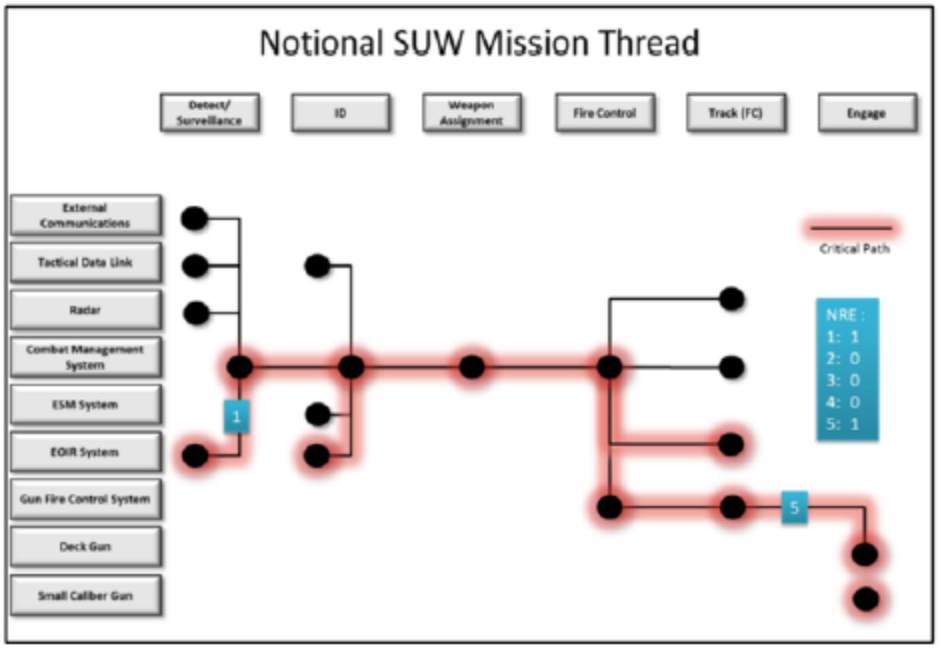
Configuration Modeling

- LCS Modification
  - Semi-manual Spreadsheet Models
- New Designs
  - Automated process
  - ~10,000 feasible configurations developed per Capability Concept
- Existing Design
  - Characterization
  - Mapped to Capability Concept and Combat System Configuration Alternative
  - Analyzed for survivability and cost

Three different design alternatives; three different configuration modeling methods

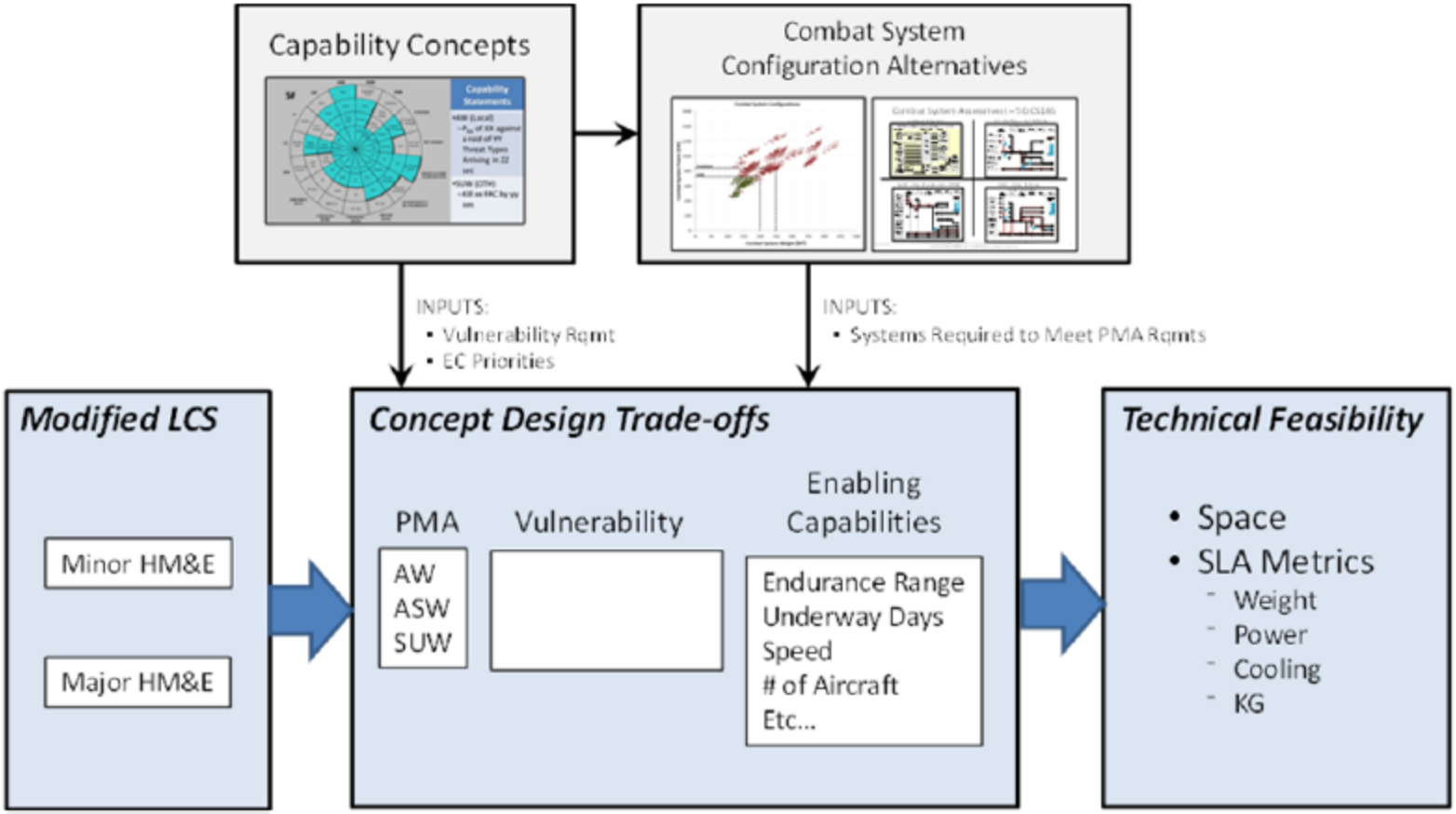
Combat System Modeling

- Combat System Configuration Alternative (CCA)
  - Mission System Alternatives for each Primary Mission Area (MA)
  - Created over 2000 unique CCAs
  - Properties
    - SWAP-C (space, weight, power and cooling)
    - Cost input
    - Manpower input

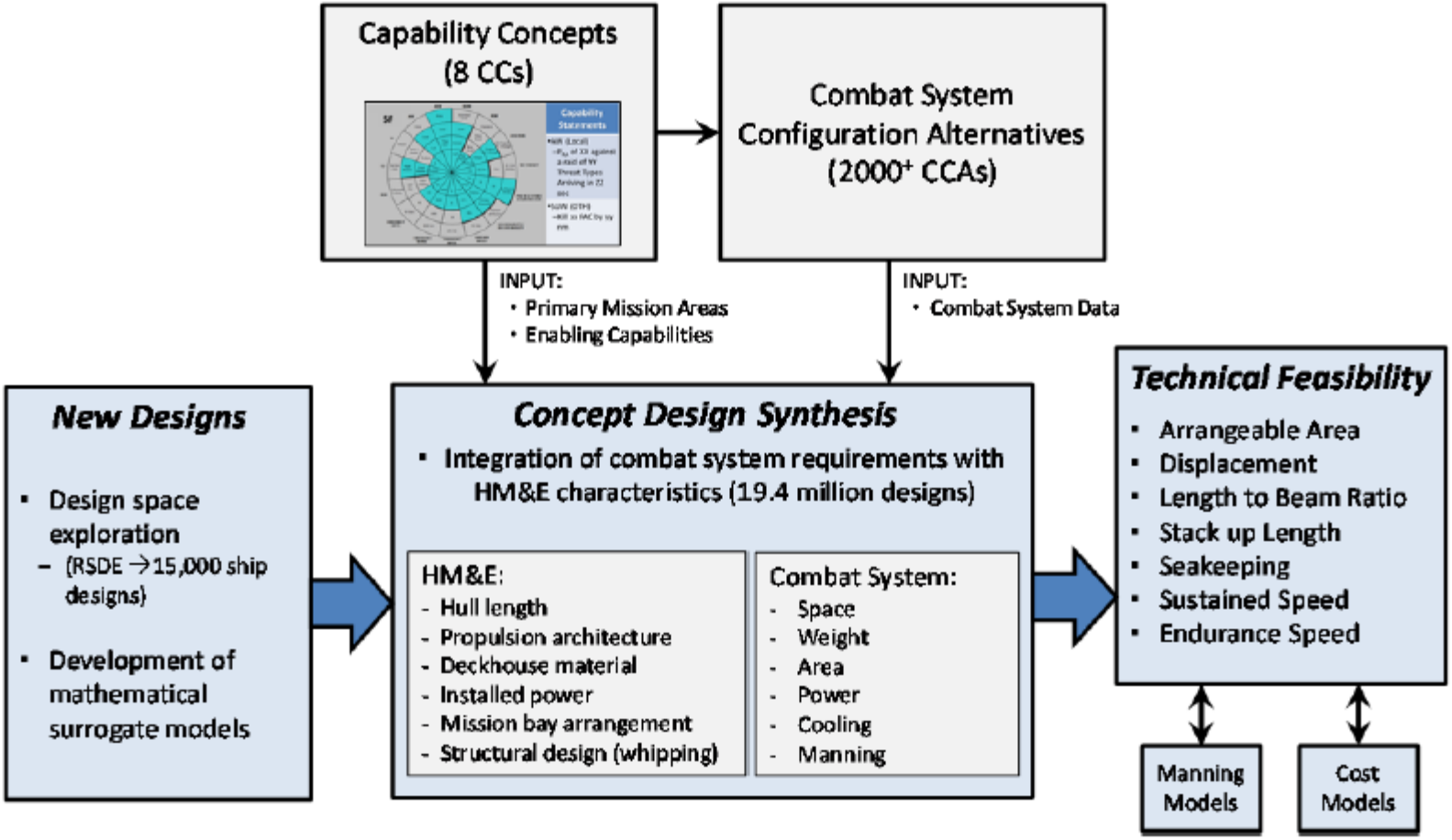


Mission Thread Analysis ensured complete detect-control-engage kill chain

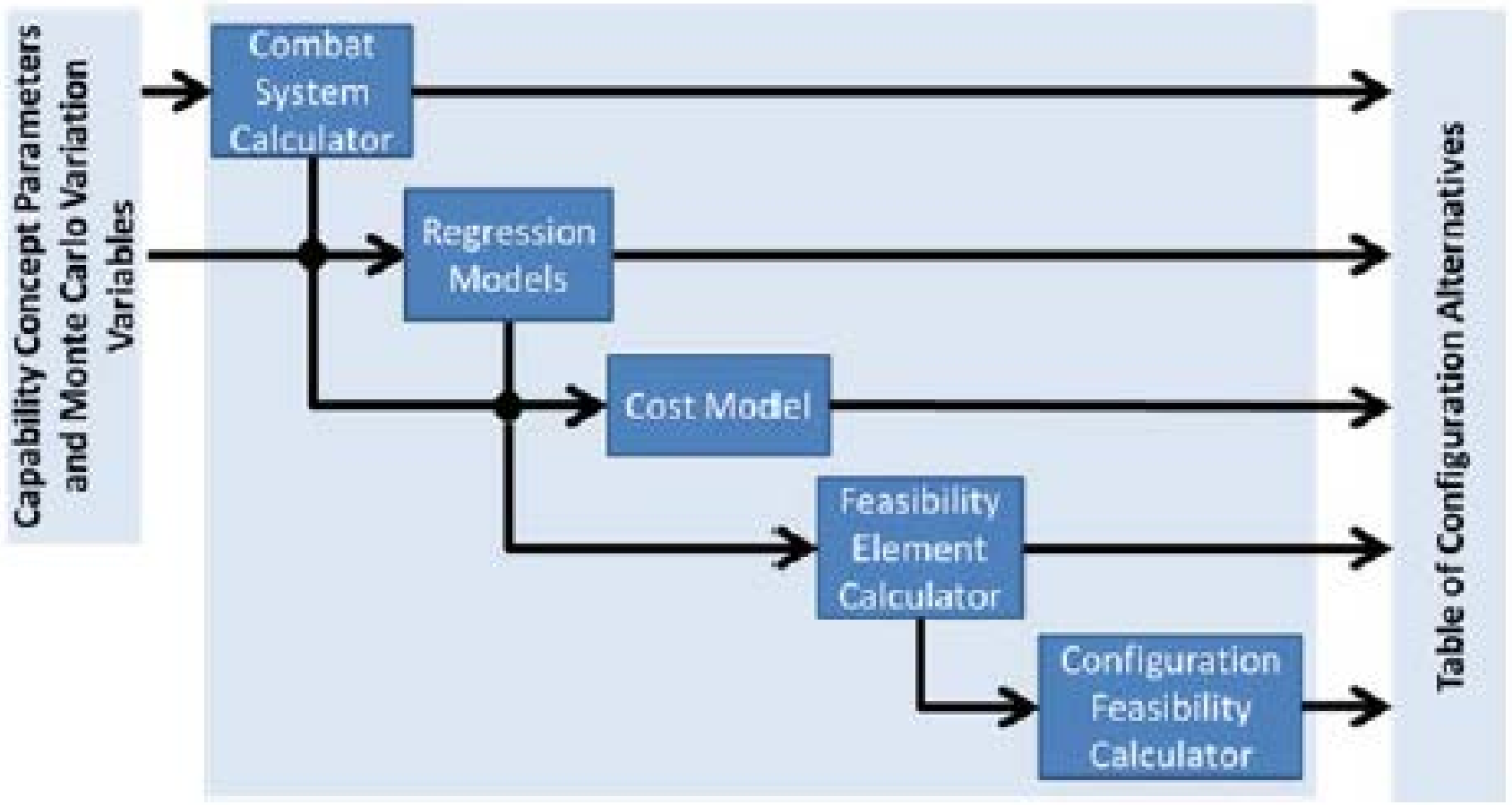
LCS Modification



New Design


Capability Concepts
(8 CCs)
Combat System
Configuration Alternatives
(2000+ CCAs)
INPUT:
• Primary Mission Areas
• Enabling Capabilities
INPUT:
• Combat System Data
New Designs
• Design space exploration
– (RSDE →15,000 ship designs)
• Development of mathematical surrogate models
Concept Design Synthesis
• Integration of combat system requirements with HM&E characteristics (19.4 million designs)
HM&E:
- Hull length
- Propulsion architecture
- Deckhouse material
- Installed power
- Mission bay arrangement
- Structural design (whipping)
Combat System:
- Space
- Weight
- Area
- Power
- Cooling
- Manning
Technical Feasibility
• Arrangeable Area
• Displacement
• Length to Beam Ratio
• Stack up Length
• Seakeeping
• Sustained Speed
• Endurance Speed
Manning Models
Cost Models

New Design Tradespace Toolkit



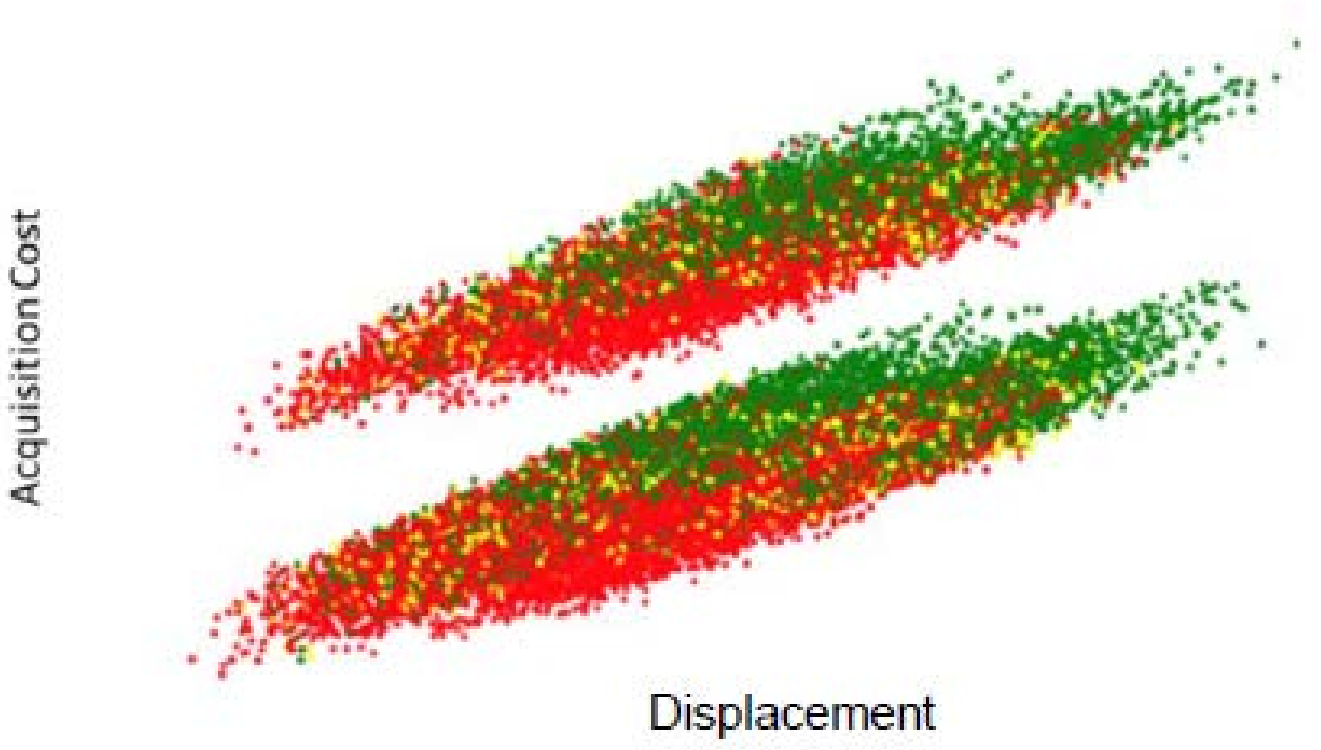
New Design Feasibility Assessment

- Feasibility elements
  - SUW Performance
  - ASW Performance
  - AW Performance
  - Sustained Speed
  - Endurance Speed
  - Arrangeable Area
  - Displacement
  - Length to Beam Ratio
  - Stack up Length
  - Seakeeping
- Feasibility element assessment categories
  - Feasible Excessive
  - Feasible
  - High Risk for Feasible
  - Not Feasible

New Design Configuration Feasibility

- Feasible
  - All feasibility elements “feasible.”
- Not Feasible
  - Any feasibility element “not feasible”, or
  - Greater than 5 feasibility elements “high risk for feasibility.”
    - Accounts for compound integration risk.
- High Risk for Feasibility
  - 1 to 5 feasibility elements “high risk for feasibility”, and
  - Remaining feasibility elements “feasible” or “feasible excessive.”
- Feasible Excessive
  - At least 1 feasibility element is “feasible excessive” and remaining feasibility elements are “feasible.”

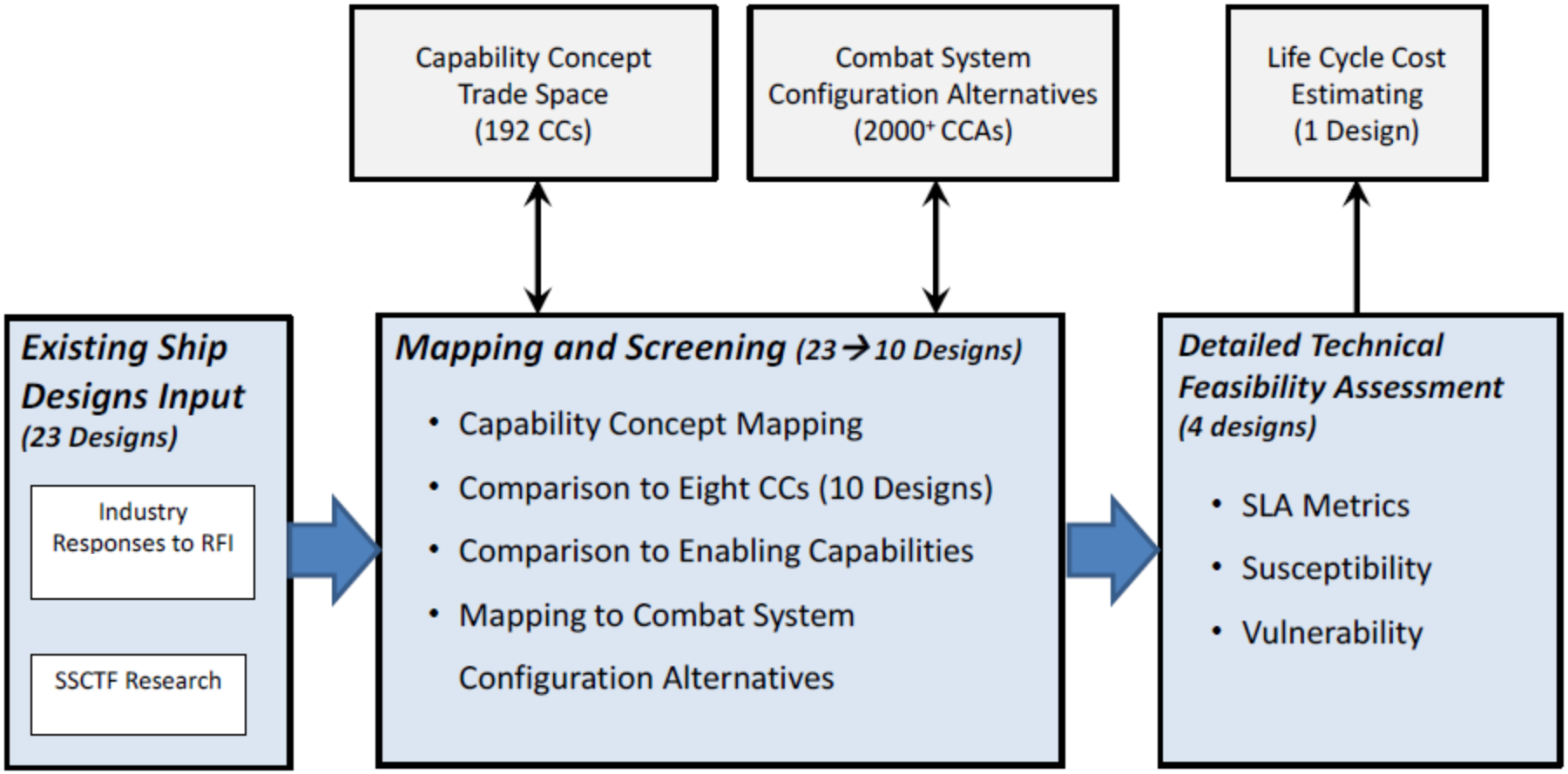
New Design Visualization



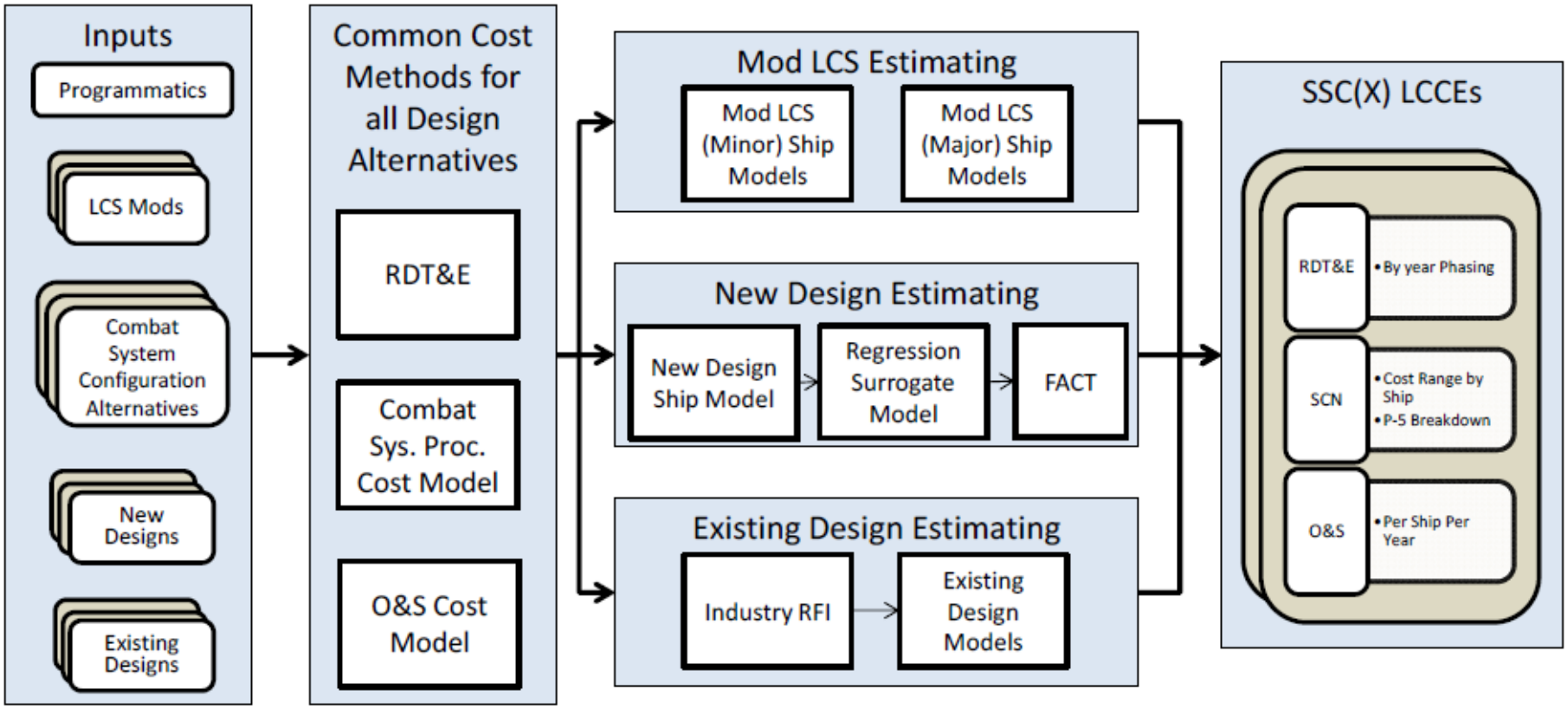
Green = Feasible
Yellow = High Risk for Feasibility
Red = Not Feasible

All configurations are for the same Capability Concept

Existing Design



Cost Analysis



Set-Based Design Review

- Consider a large number of potential solutions
  - Started with 192 capability concepts
  - ~10,000 feasible new design configurations for 8 capability concepts
- Have specialist evaluate sets of solutions from their own perspective
  - Force Architecture analysts reduced 192 to 13 Capability Concepts
  - Combat Systems Engineers reduced to 8 capability concepts
  - Developed different sets for combat systems and host ship
- Intersect the sets to optimize a global solution and establish feasibility before commitment
  - New design: Configuration Feasibility Calculator

Conclusions

"After rigorous review and analysis, today I accepted the Navy's recommendation to build a new Small Surface Combatant ship based on upgraded variants of the LCS. The new SSC will offer improvements in ship survivability and lethality, delivering enhanced naval combat performance at an affordable price,"

- Secretary of Defense

"They did a remarkable job. It was very deliberate. It was very detailed and it was very analytical and informed,"

- Chief of Naval Operations