Concept Exploration

Dr. Norbert Doerry,

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Concept Exploration

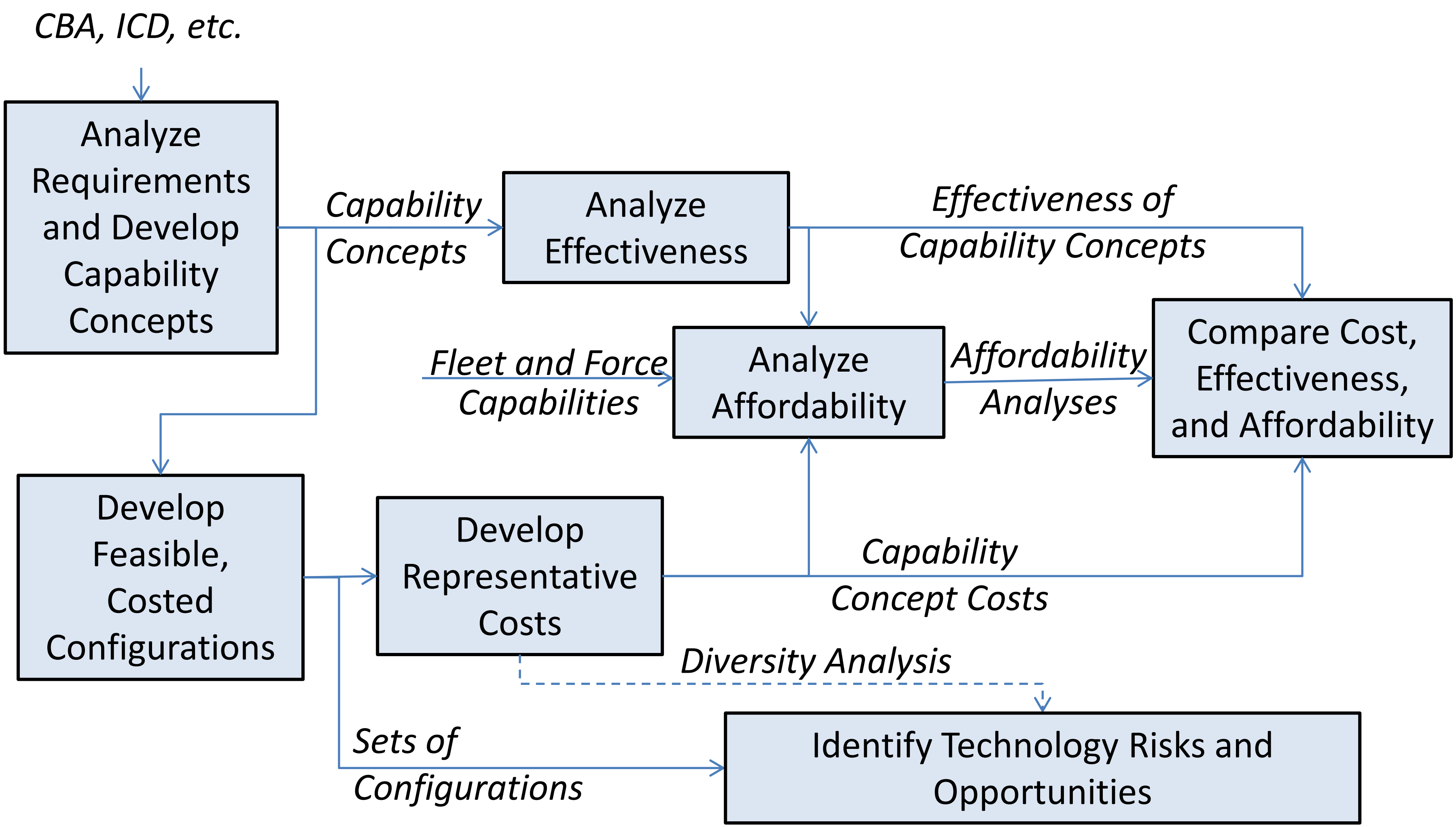
- Understand the interaction of
  - Cost
  - Affordability
  - Capability
  - Feasibility
  - Effectiveness
- Provide insight on the value of maturing specific technologies

Concept Exploration Process

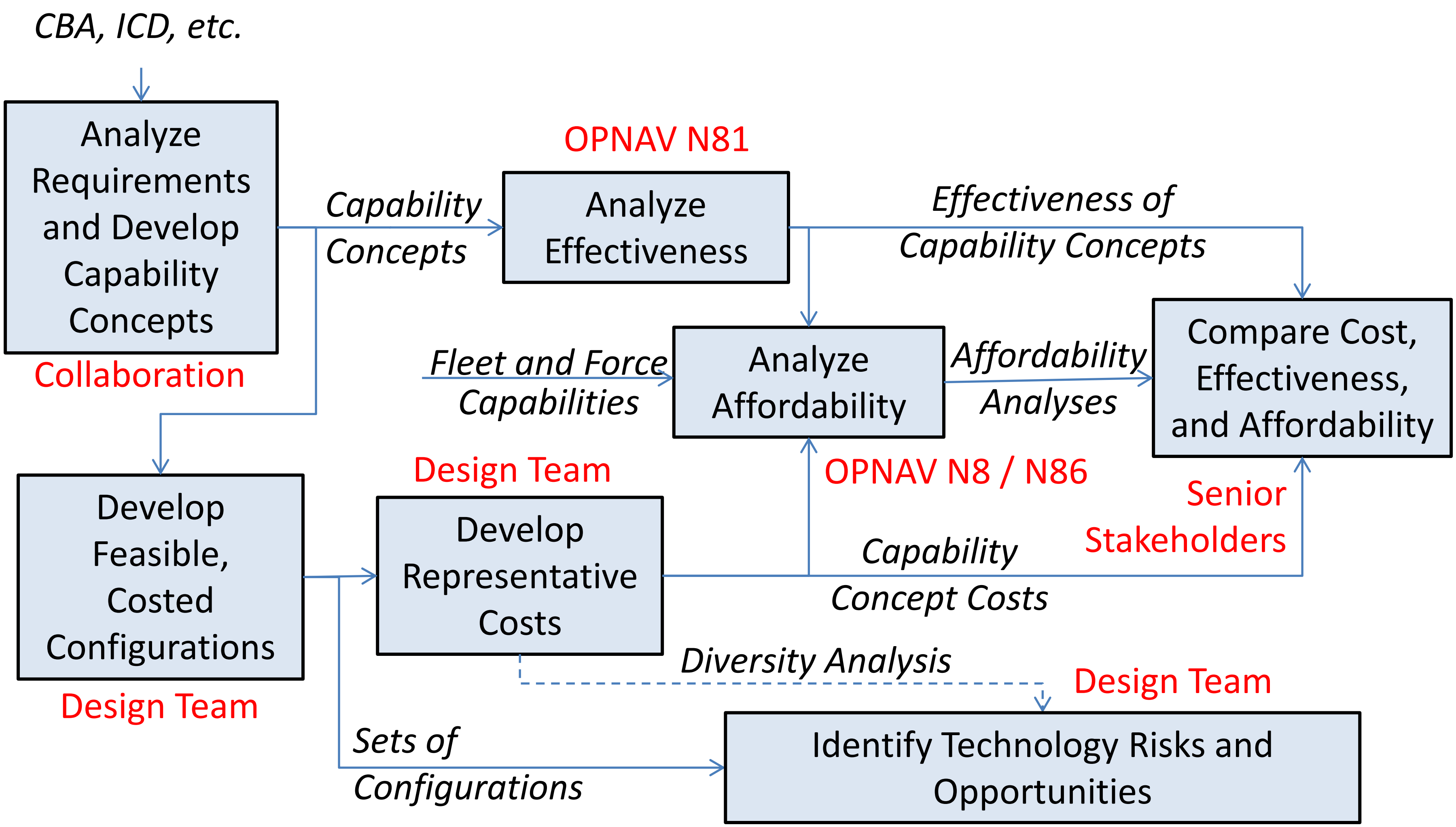
- The actual Concept Exploration process will be defined in the future by the design manager based on
  - Tasking
  - Available Tools
  - Available Data and Models
  - Expertise
  - Schedule
- Goal of DT&M WIPT is to identify a toolbox of …
  - Tools
  - Data and Models
  - Expertise
- to enable future design managers to respond with a sound engineering approach for ships requiring CPES, when tasked to conduct Concept Exploration.

Flexible Design Tool Infrastructure is of Great Value

Reference Concept Exploration Process



Distributed Execution



Definitions

Capability Concept

- Requirements set + Concept of Operations (CONOPS) / Employment + Acquisition / Support Strategy

Configuration

- A specific set of components comprising a complete system
- Many configurations can typically be developed for a given capability concept

Feasible Configuration

- A configuration that our current analysis predicts will work and meet the requirements of the associated capability concept

Viable Configuration

- A configuration that actually works when produced and meets the requirements of the associated capability concept – (anticipated feasibility confirmed)
- Configurations currently deemed Feasible may prove not to be Viable due to future analysis, testing, or real world experience

Feasible Capability Concept

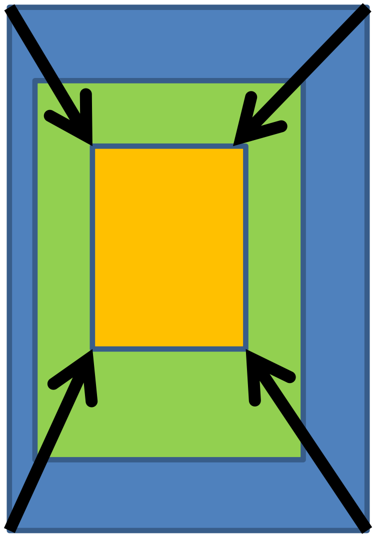
- A Capability Concept with sufficient feasible configurations of sufficient diversity such that the risk that none of the feasible configurations are viable is low

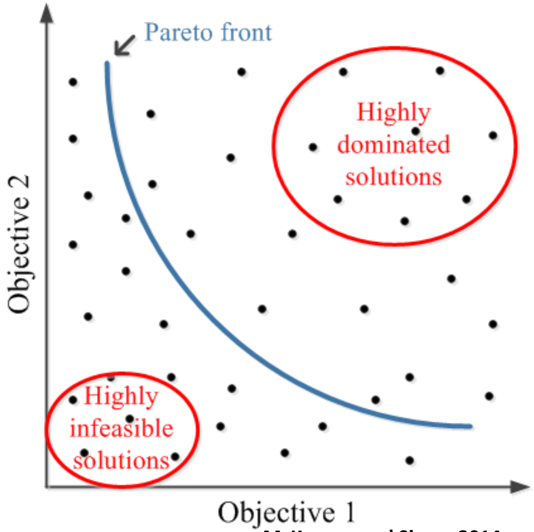
Diversity

- A metric of the degree to which the feasible configurations within a design region are different from each other
- High diversity of feasible configurations implies lower risk that no viable configurations exist for a capability concept

Set Based Design

- Consider sets of configurations (Design Space) rather than point designs for each Capability Concept
  - If there is one feasible configuration, then there are likely many feasible configurations for a given Capability Concept
  - Enough feasible configurations of sufficient diversity indicates a feasible capability concept
- Design Decisions eliminate regions of the design space; they do not pick solutions
  - Eliminate regions where a feasible solution is unlikely or …
  - Eliminate regions that are Pareto Dominated, and remaining region still has sufficient diversity
- Enable different design disciplines to work in parallel
  - Integrate by intersecting feasible regions as defined by multiple design disciplines
- Sets of Feasible Configurations: Not Point Designs
  - Base "representative cost" for a Capability Concept on the set of feasible configurations, not any one point design.
  - Make decisions at the Capability Concept level, not on specific point designs – Don't decide too soon!

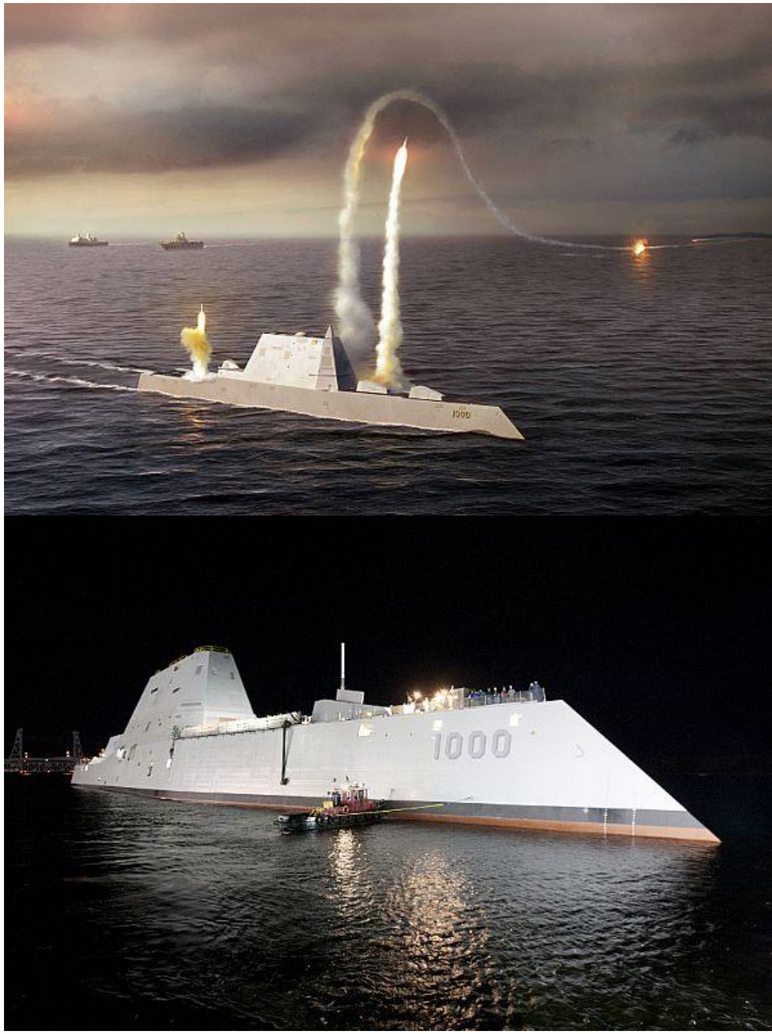




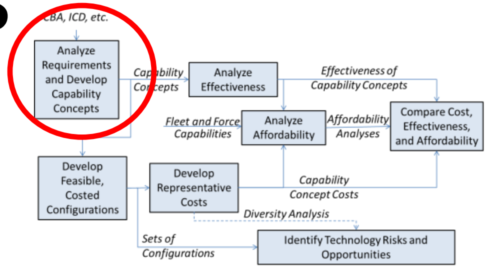
McKenney and Singer 2014

Viability vs Feasibility

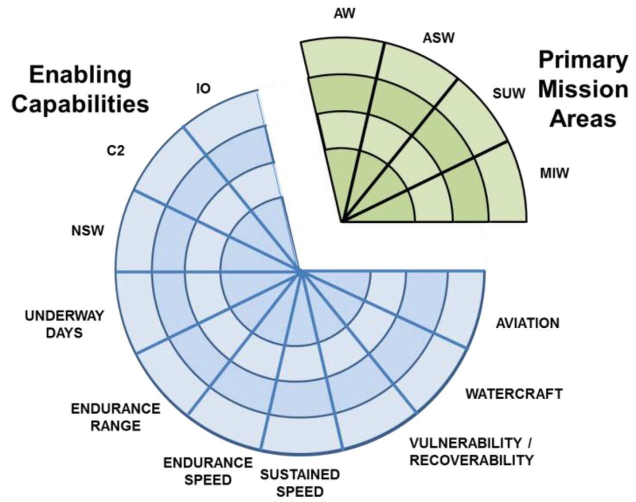
- Feasibility does not always imply Viability this early in the development process
  - Some performance areas not assessed
  - Modeling not always indicative of real world
- A configuration that is not feasible is probably not viable either
- A Feasible Concept has many feasible configurations with sufficient diversity
  - Chances of all feasible configurations not being viable probably low if …
    - a Set-Based Design approach is used, and
    - a common mode failure is not likely
- Amount of diversity for sufficiency and margin policy are related
  - More margin means less diversity needed
  - However, more margin may hide value of technology opportunities



Analyze Requirements and Develop Capability Concepts



- **<u>Understand the Tasking (What are the QUESTIONS?)</u>**
- Develop a set of Capability Concepts
  - Primary Mission Areas (PMA)
    - Major drivers
  - Enabling Capabilities (EC)
    - Less major drivers
- Identify capability levels for each area
  - Discrete levels of performance
- PMAs and ECs should be sufficient to analyze effectiveness.
  - Enable parallel assessment of representative cost and effectiveness
- Restrict total number of Capability Concepts
  - Use SBD principles to minimize the set of Capability Concepts to study.
    - For Example: SSCTF reduced set from 192 to 8
  - Good range is between 8 and 50 capability concepts
- Define other requirements
  - Fixed value, or …
  - Provide range for the requirement
    - Representative cost and effectiveness analysis should consider the full range in assessing performance.
  - Document in Ground Rules and Assumptions
- Can conduct side studies for understanding impact of ECs.
  - May be deferred until Pre-Preliminary Design



Capability Concept Definition Example

Note: Ground Rules & Assumptions not depicted.

Matt Garner, Dr. Norbert Doerry, Adrian MacKenna, Frank Pearce, Dr. Chris Bassler, Dr. Shari Hannapel, and Peter McCauley, "Concept Exploration Methods for the Small Surface Combatant," presented at the World Maritime Technology Conference 2015, Providence, RI., Nov 3-7, 2015

SSCTF: Set-Based Design reduced number of Capability Concepts from 192 to 8

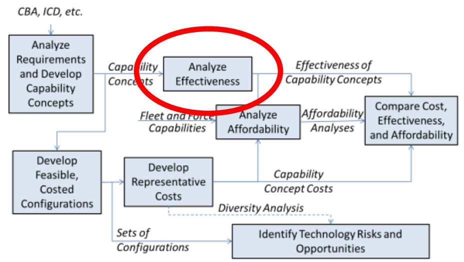
Mission Area Capabilities	Capability Concept CC 1	CC 2	CC 3	CC 4	CC 5	CC 6	CC 7	CC 8
Self Defense against Air, Surface, Undersea Threats	X	X	X	X	X	X	X	X
Capability to detect and engage small craft within- the-horizon of own ship		X	X	X	X	X	X	X
Capability to achieve mission kill of over-the-horizon surface 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

Requirements Traceability

- Requirements Traceability tools (such as DOORS) have proven useful in managing the Capability Concepts
  - Important to configuration manage the requirement sets for each capability concept
  - Includes all the requirements, not just the ones that are compared. (Ground Rules & Assumptions)
- Help ensures consistency within the concept exploration process.

Analyze Effectiveness



- Military Effectiveness evaluated based on the Capability Concepts
  - Evaluating sets of requirements, not specific configurations
  - If a ship characteristic significantly impacts the military effectiveness, it must be defined as part of the Capability Concept
  - If a configuration meets the capability concept levels of performance, then its effectiveness in the fleet would be ….
- Analysis often is classified
- Likely led by OPNAV

Comparing Capability Concepts Effectiveness (typically by OPNAV)

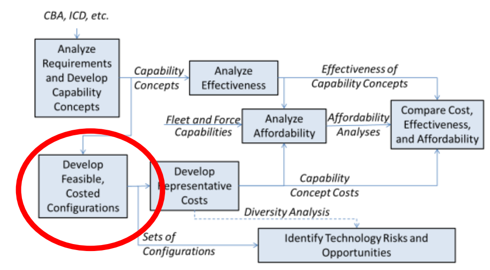
Capability Concepts

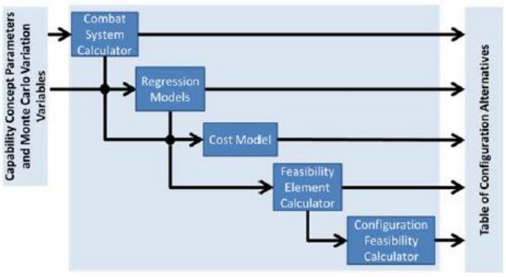
	Mission A	Mission B	Mission C
AAA	7	0	7
AAB	10	0	3
ABA	5	4	8
ABB	8	6	4
BAA	6	0	8
BAB	9	0	4
BBA	4	5	9
BBB	7	7	5

Performance / Effectiveness Metrics

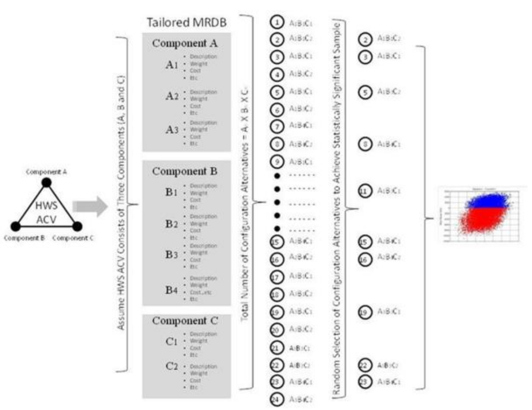
Develop Feasible Costed Configurations

- Use synthesis tools to produce many diverse configurations for each capability concept.
  - SSCTF produced ~10,000 feasible configurations per capability concept
  - Use methods such as Monte Carlo to create configurations
  - Configurations should span the impact of requirements not fixed by the capability concept and not yet decided upon.
    - For example: single and twin shaft propulsion.
- Configurations represented by fixing values for a group (vector / list / array / table) of “design variables”
- Evaluate configurations for feasibility.
  - Incorporate as many feasibility “tests” as practical.
  - As the rigor of feasibility assessment increases, and as the degree that criteria are exceeded increases, the more likely feasible configurations will be viable.
  - Insight can be gained from configurations that are not feasible. (Technology Opportunities)
- Develop cost estimates for each (feasible) configuration.
  - Acquisition costs (including Combat Systems)
  - Operations and Support costs
  - Total Ownership costs
  - Include uncertainty of the cost estimate



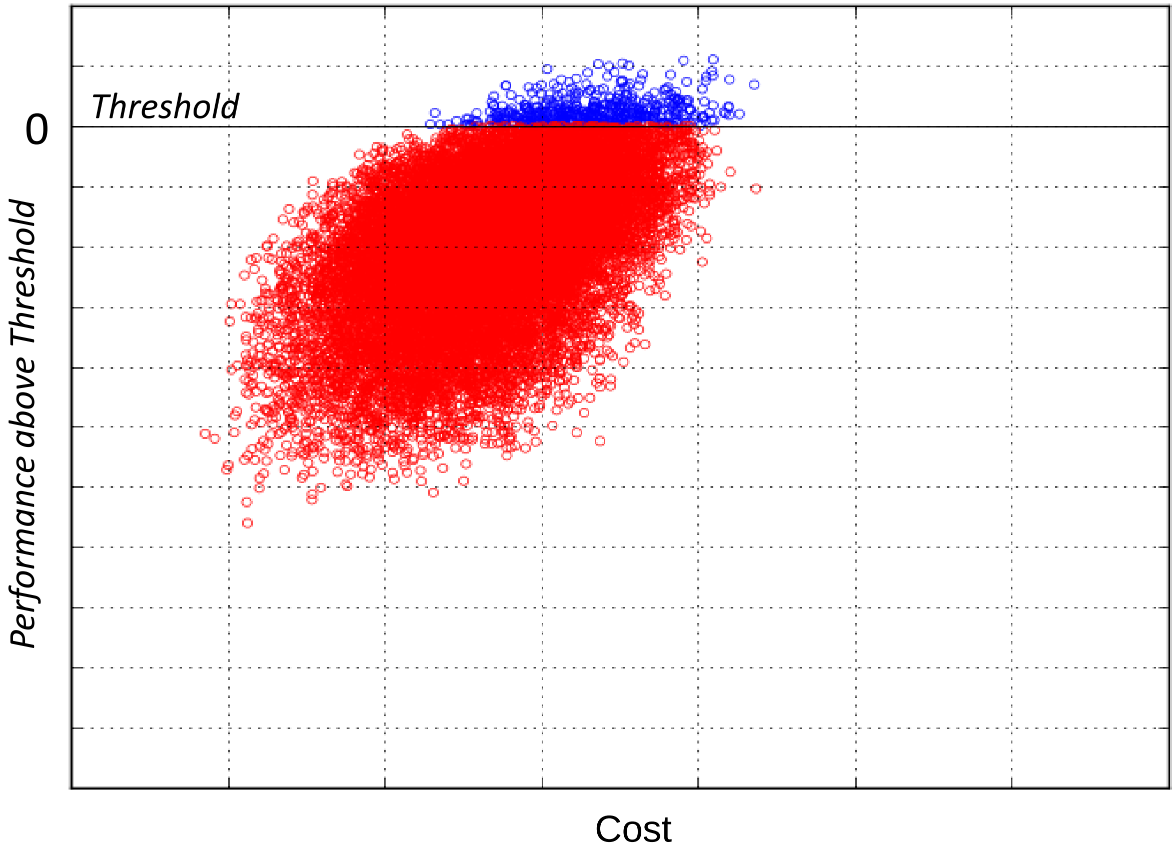


SSCTF Configuration Production

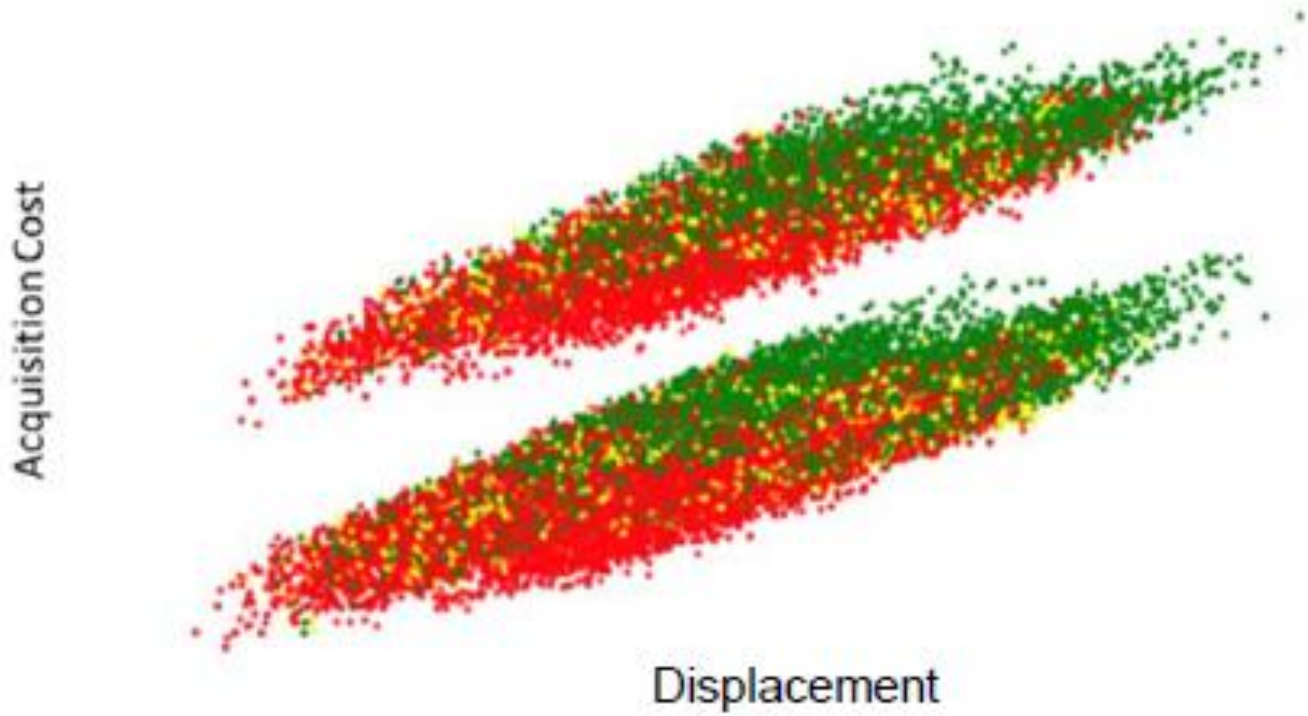


Monte Carlo Method

Capability Concept Visualization Example



Capability Concept Visualization Example (continued)



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

Capability Concept Feasibility Evaluation (ACV)

Capabilities	14 Troops; "A" Direct Fire Protection	14 Troops; "B" Direct Fire Protection	17 Troops; "A" Direct Fire Protection	17 Troops; "B" Direct Fire Protection
"C" Under-Blast Protection; Weapon "X"	**Feasible**	**Feasible**	**Feasible**	**High Risk Feasibility**
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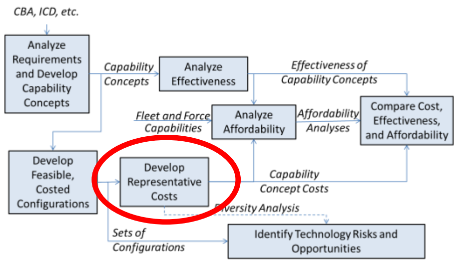
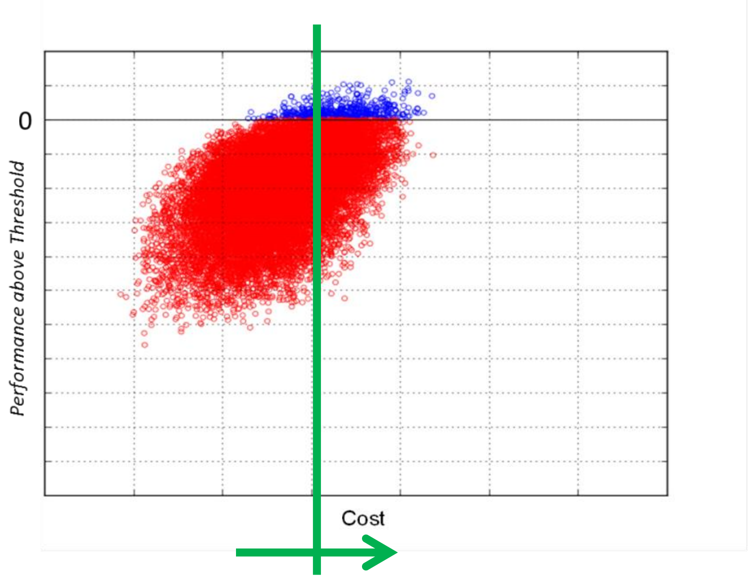
Develop Representative Costs



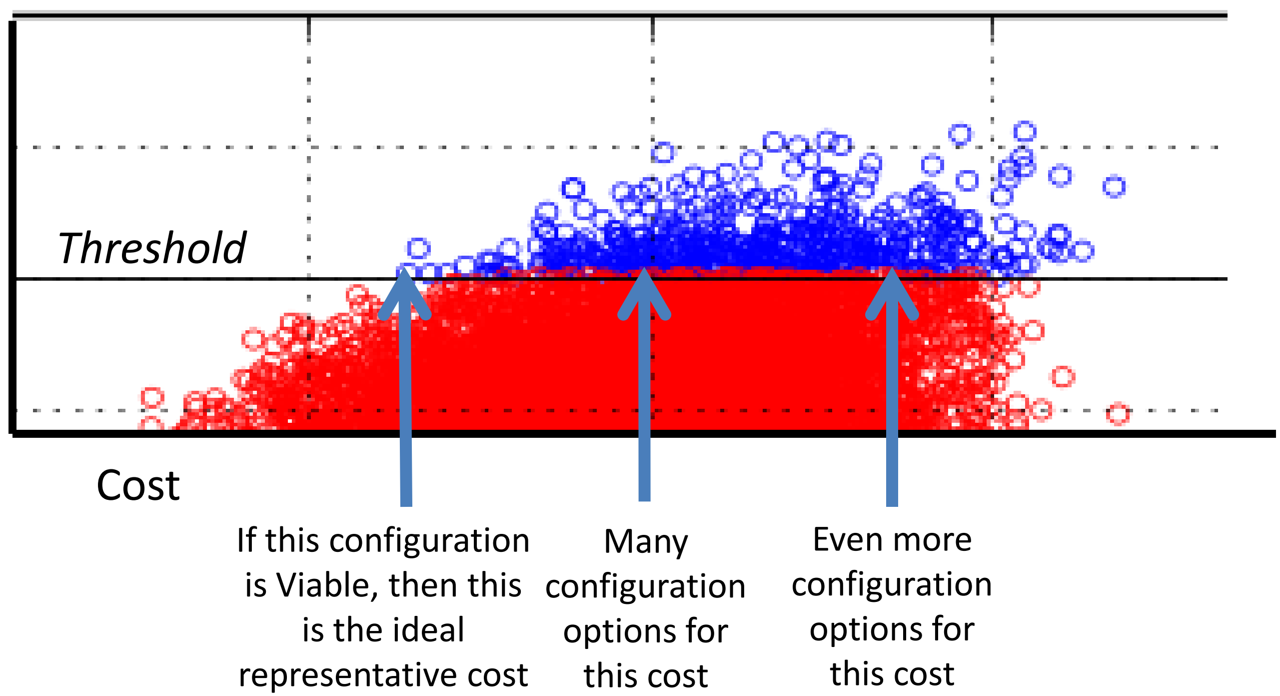
- A representative cost is developed for each capability concept based on the set of feasible configurations.
- Representative costs should be comparable among different capability concepts.
  - Diversity Metric is an enabler
- Representative costs should be presented as ranges
  - Uncertainty in technical solution
  - Uncertainty in cost modeling



How far to move the line?

What is a good representative cost?

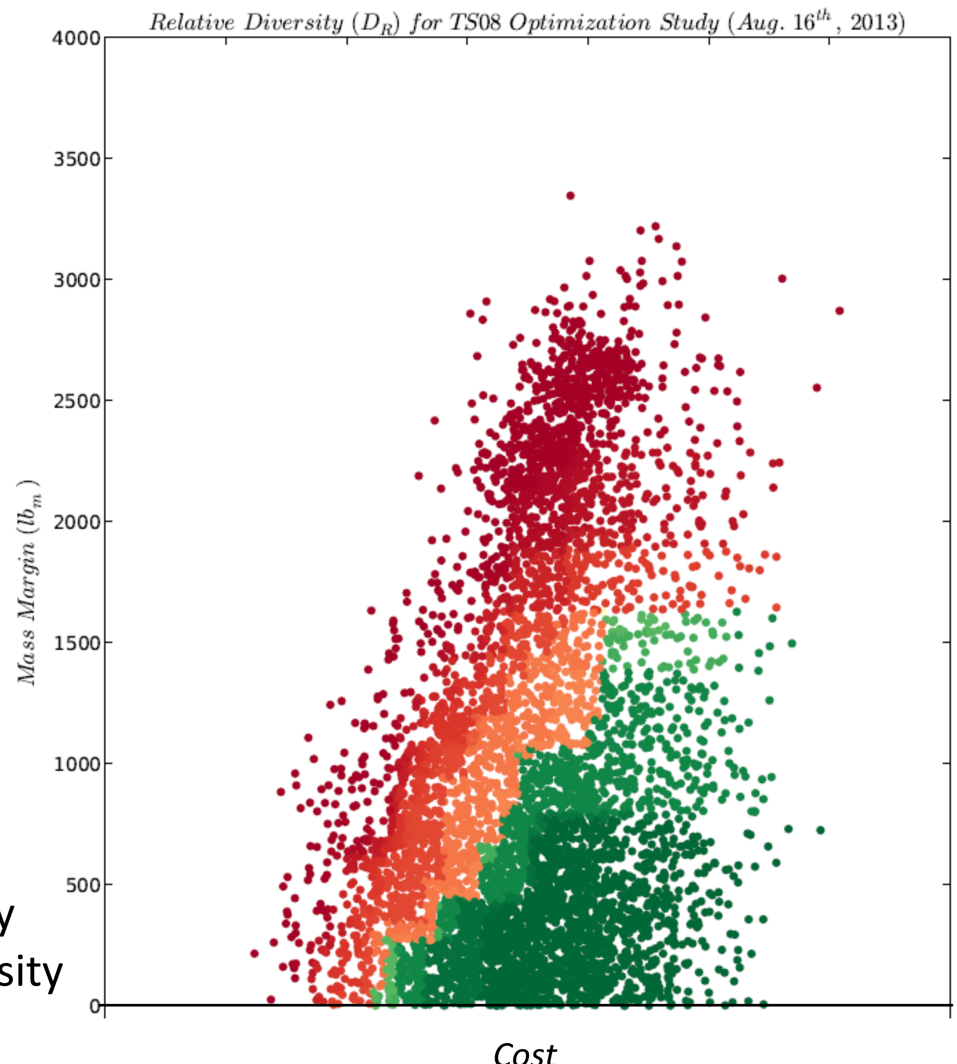
Answer: The lowest cost with a low risk that all feasible configurations with a lower or equal cost are not viable.
(or alternately, the lowest cost where there is a high probability that at least one feasible configuration of equal to or less cost is viable)
The risk can be evaluated via a Diversity Metric



Diversity Metric

- Measures how different the feasible configurations within a set of configurations are from each other
  - Higher diversity implies a lower risk that all feasible configurations below a specified cost are not viable
- Based on a set of “Diversity Variables”
  - A subset of the “Design Variables”
  - Aligned with degree of risk

Diversity metric used in ACV study



Red is lower diversity
Green is higher diversity

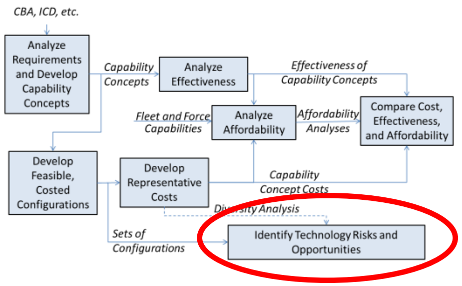
Note: this diversity metric considered the Mass Margin

Comparing Capability Concept Cost

Compare ranges of cost
Do not compare point designs!

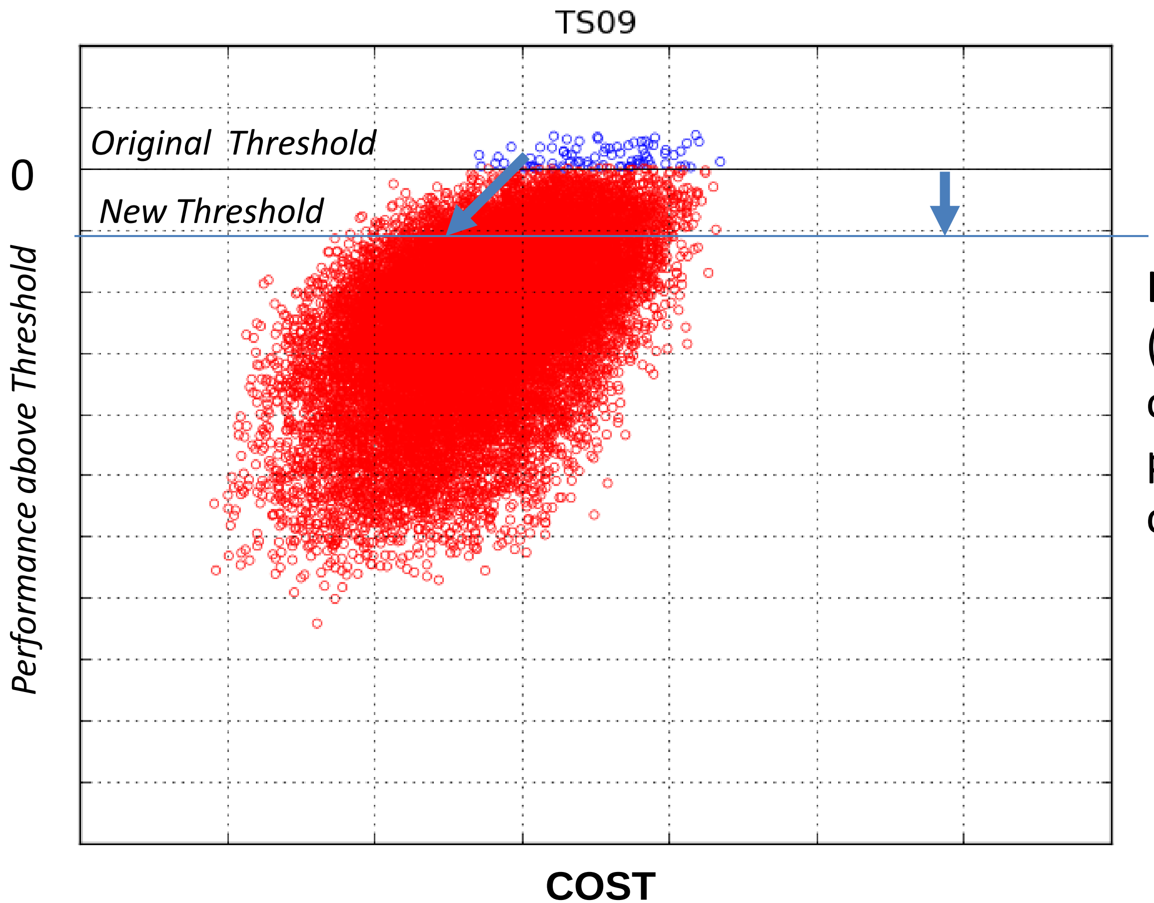
Cost Ranges account for uncertainty in technical solution (set of feasible points) and Cost Estimating Relationship (CER) uncertainty

Identify Technology Risks and Opportunities



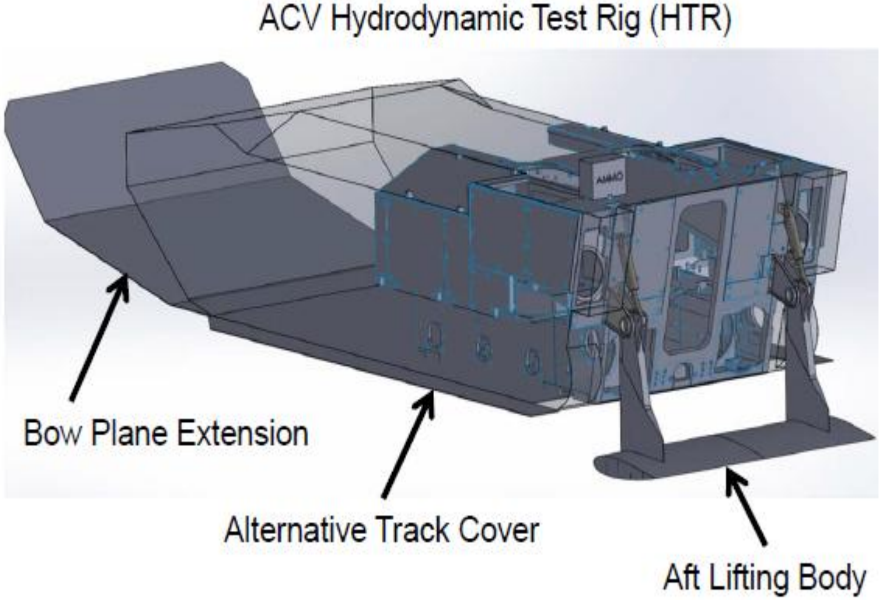
- Analysis of configurations and diversity identifies technology risk and opportunity possibilities
- An Innovation Team can use these insights to seek out promising technology opportunities.

Insight

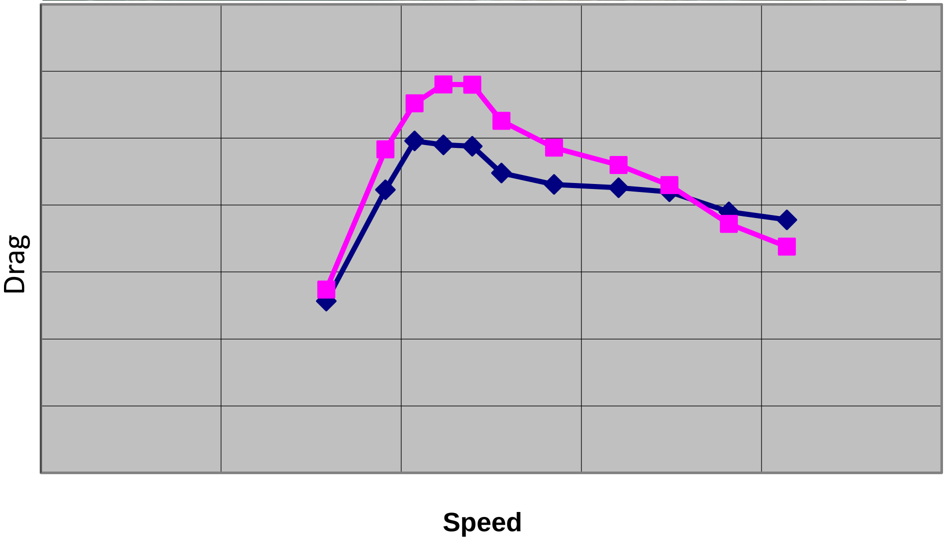


Lowering Threshold (constraint) enables cost reduction or possibly increasing capability

Technology Opportunity (ACV)



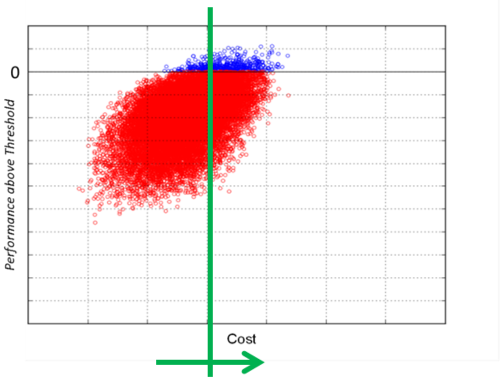
Need to test at full-scale to confirm



Model Testing: Aft Lifting Body Reduced Drag

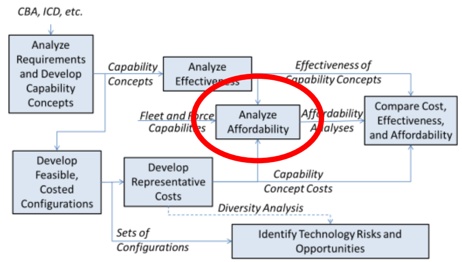
Using a Diversity Metric to identify Ship Design Technology Risks and Opportunities

Diversity Variable	Number of Configurations to meet Diversity criteria
AAW suite	40
SUW suite	43
ASW suite	51
Weight Equation	54
Deckhouse Material	57
Propulsion Architecture	119
Main Engine Power	153
Hogging Constant	164



Risks and Opportunities: Concentrate near term design activity on understanding these options

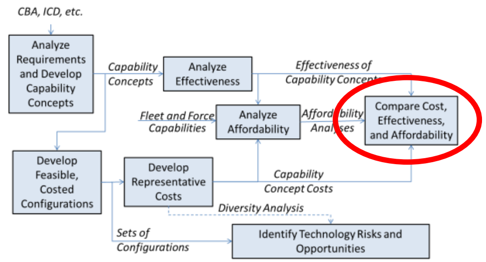
Assess Affordability



- Establishing value of capability with respect to cost
- Part of Portfolio Analysis
  - Navy-wide considerations
- May include user feedback to prioritize capabilities
  - Resource constrained war games

ACV Workshop conducted at Ellis Hall on 9-11 July 2013 to gain feedback

Compare Cost, Effectiveness and Affordability



- Intersect the findings of
  - Effectiveness Analysis
  - Affordability Analysis
  - Cost and Feasibility Analysis
- Highlight Technology and Risk Opportunities

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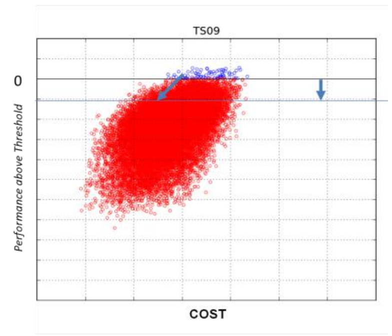

Key Points

- Make comparisons at the Capability Concept Level
- Base representative cost estimates and performance on the set of feasible configurations for a given Capability Concept
- Save time by having specialists work in parallel and integrate their work using set-based design methodology
  - Systematically eliminate regions of the design space based on analysis
- Gain insight from feasible and infeasible configurations

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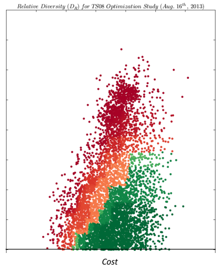
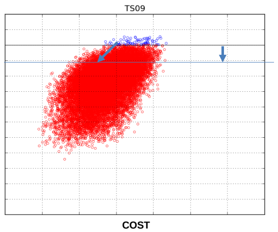
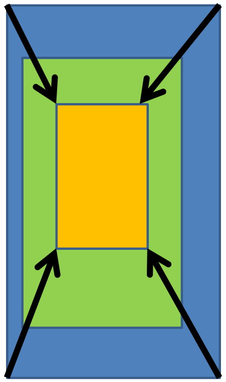


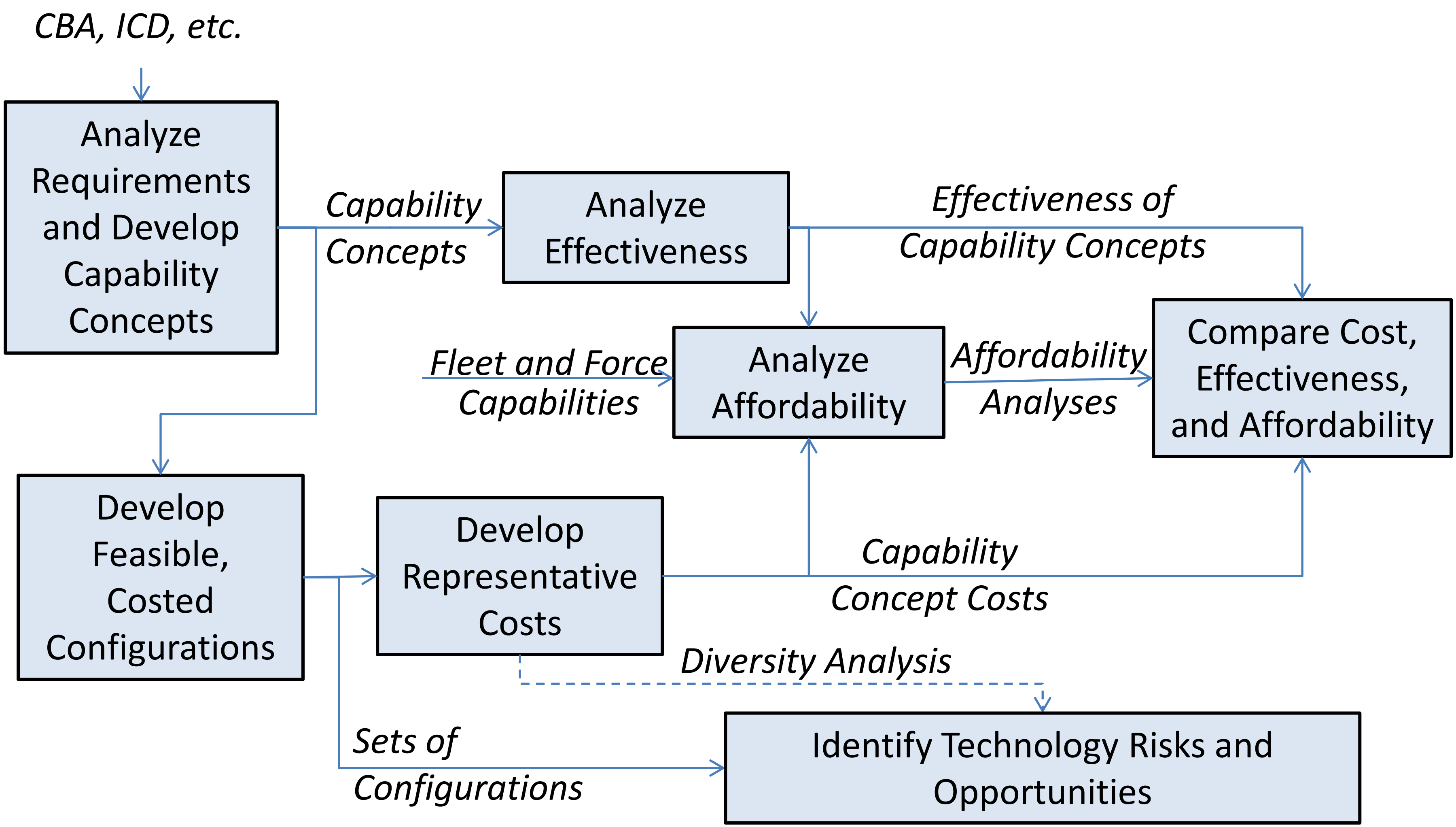




Synergy Between Tools & Approach

- Tools without an approach are of little value.
- An approach without the necessary tools cannot be executed.
- Our CPES approach requires a pragmatic combination of innovative approach and capable tools.

Reference Concept Exploration Process



References

- Norbert Doerry, Mark Earnesty, Carol Weaver, Jeff Banko, Jim Myers, Danny Browne, Melissa Hopkins, Santiago Balestrini, "Using Set-Based Design in Concept Exploration," presented at SNAME Chesapeake Section Technical Meeting, Army Navy Country Club, Arlington VA, September 25, 2014.
- Dr. John Burrow, Dr. Norbert Doerry, Mark Earnesty, Joe Was, Jim Myers, Jeff Banko, Jeff McConnell, Joshua Pepper, and COL Tracy Tafolla, "Concept Exploration of the Amphibious Combat Vehicle," Presented at the SNAME Maritime Convention, Houston, TX, October 23, 2014.
- Dr. Norbert Doerry, "Measuring Diversity in Set-Based Design," Presented at ASNE Day 2015, Arlington VA, March 4, 2015.
- Matt Garner, Dr. Norbert Doerry, Adrian MacKenna, Frank Pearce, Dr. Chris Bassler, Dr. Shari Hannapel, and Peter McCauley, "Concept Exploration Methods for the Small Surface Combatant," presented at the World Maritime Technology Conference 2015, Rhode Island Convention & Omni Hotel, Providence, RI., Nov 3-7, 2015.

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