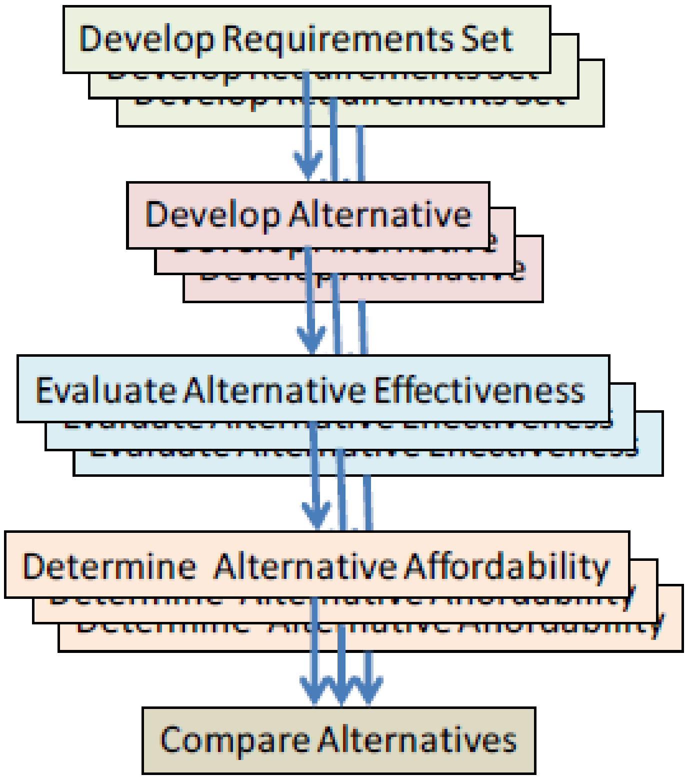
Using Set-Based Design in Concept Exploration

Norbert Doerry, Mark Earnesty, Carol Weaver, Jeff Banko, Jim Myers, Danny Browne, Melissa Hopkins, and Santiago Balestrini

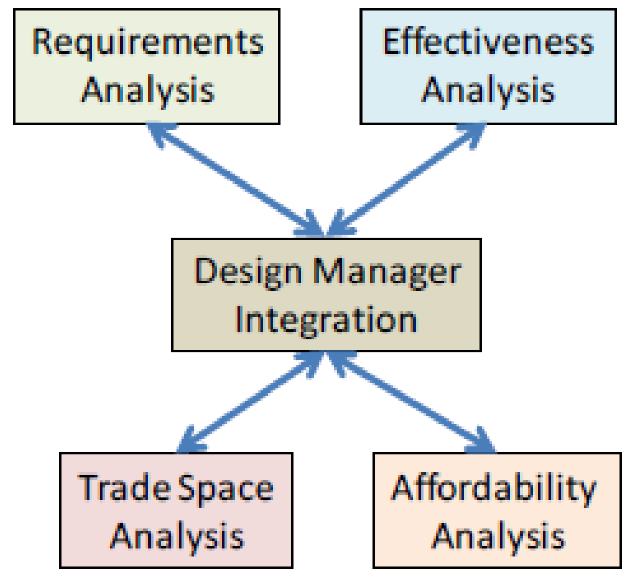
Study Approach
(Traditional vs. Set-Based Design)

Traditional Approach



Serial Process – takes longer

Set-Based Design Approach



Parallel Process – faster

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 shows 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
- Configurations currently deemed Feasible may prove not to be Viable due to future analysis or testing

Feasible Concept

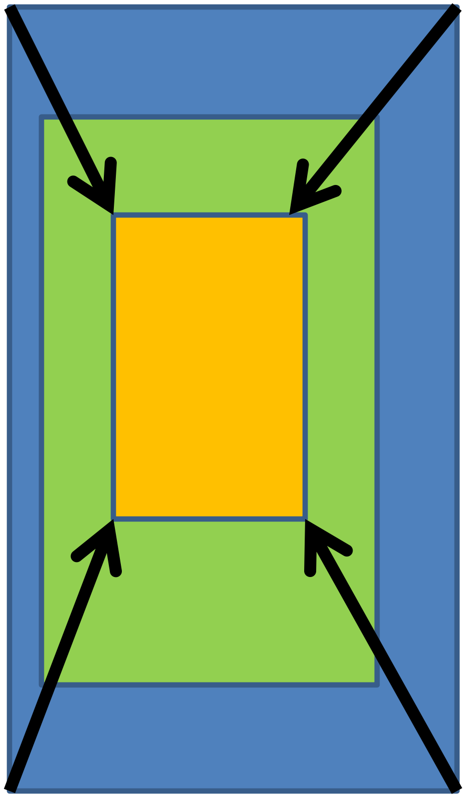
- A Capability Concept with sufficient feasible configurations of sufficient diversity such that the risk that none of the feasible configurations are viable is low

Diversity

- A metric of the degree to which the feasible configurations within a design region are different from each other
- High diversity implies lower risk

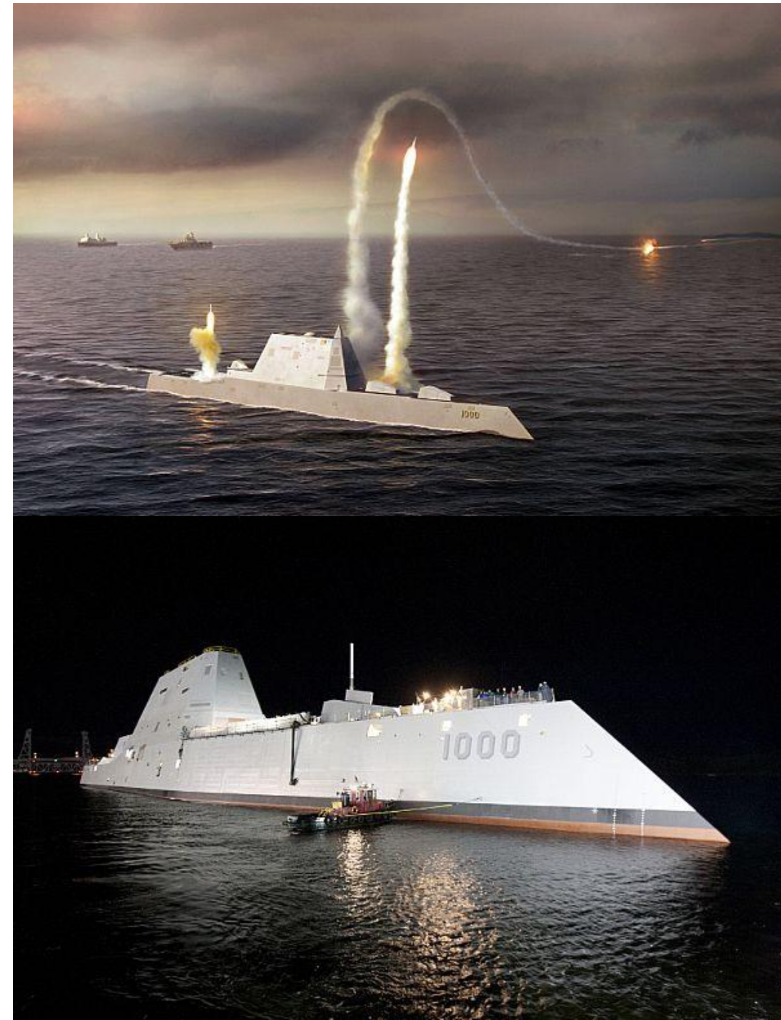
Set Based Design

- Consider sets of configurations (Design Space) rather than point designs for each Capability Concept
  - Enough feasible configurations of sufficient diversity indicates a feasible 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
- THE END RESULT IS A SET OF FEASIBLE CONFIGURATIONS: NOT A POINT DESIGN
  - Base "representative cost" for a Capability Concept on the set of feasible configurations, not any one point design.
- Make decisions at the Capability Concept / Design Alternative level, not on specific point designs – Don't decide too soon!

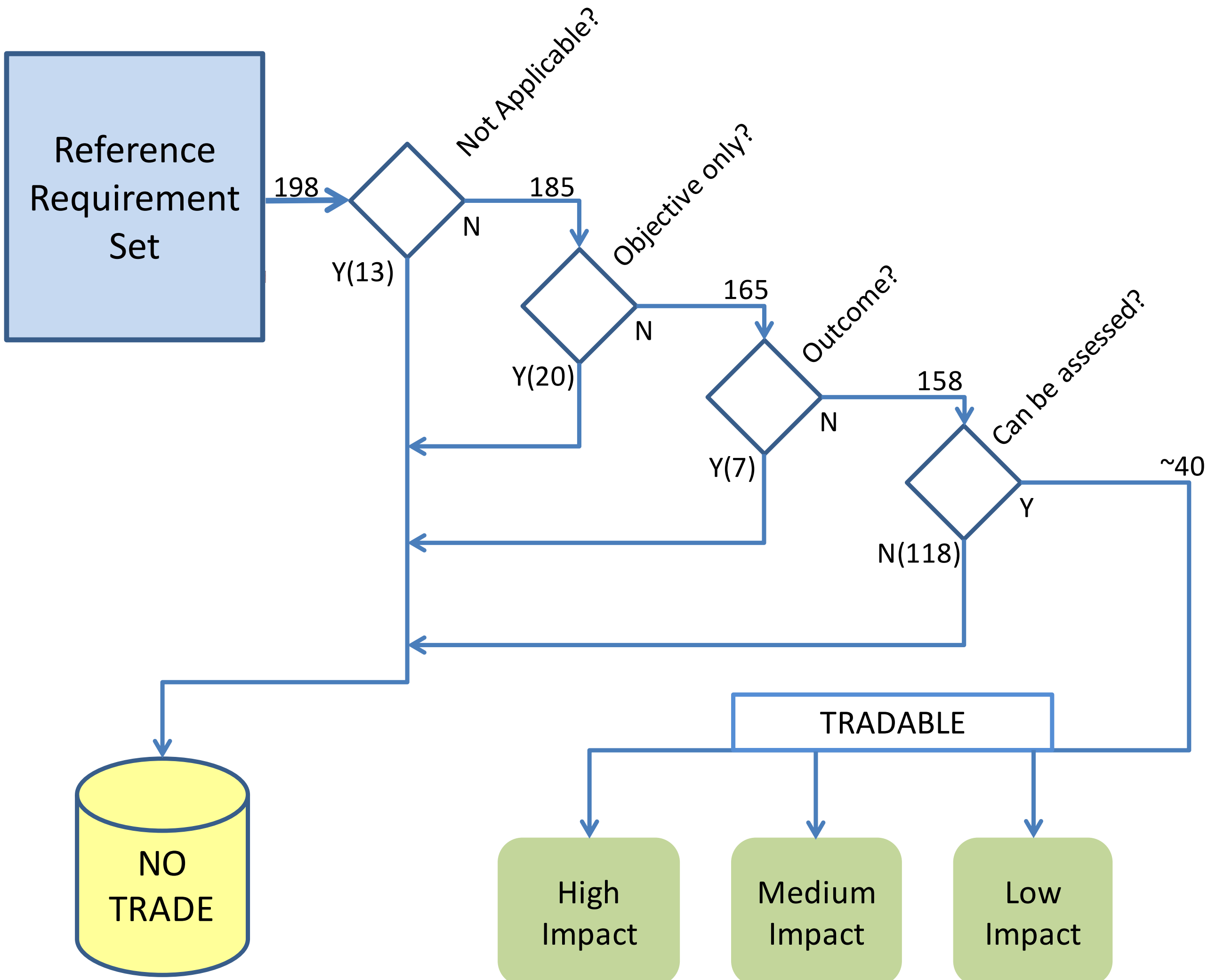


Viability vs Feasibility

- 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



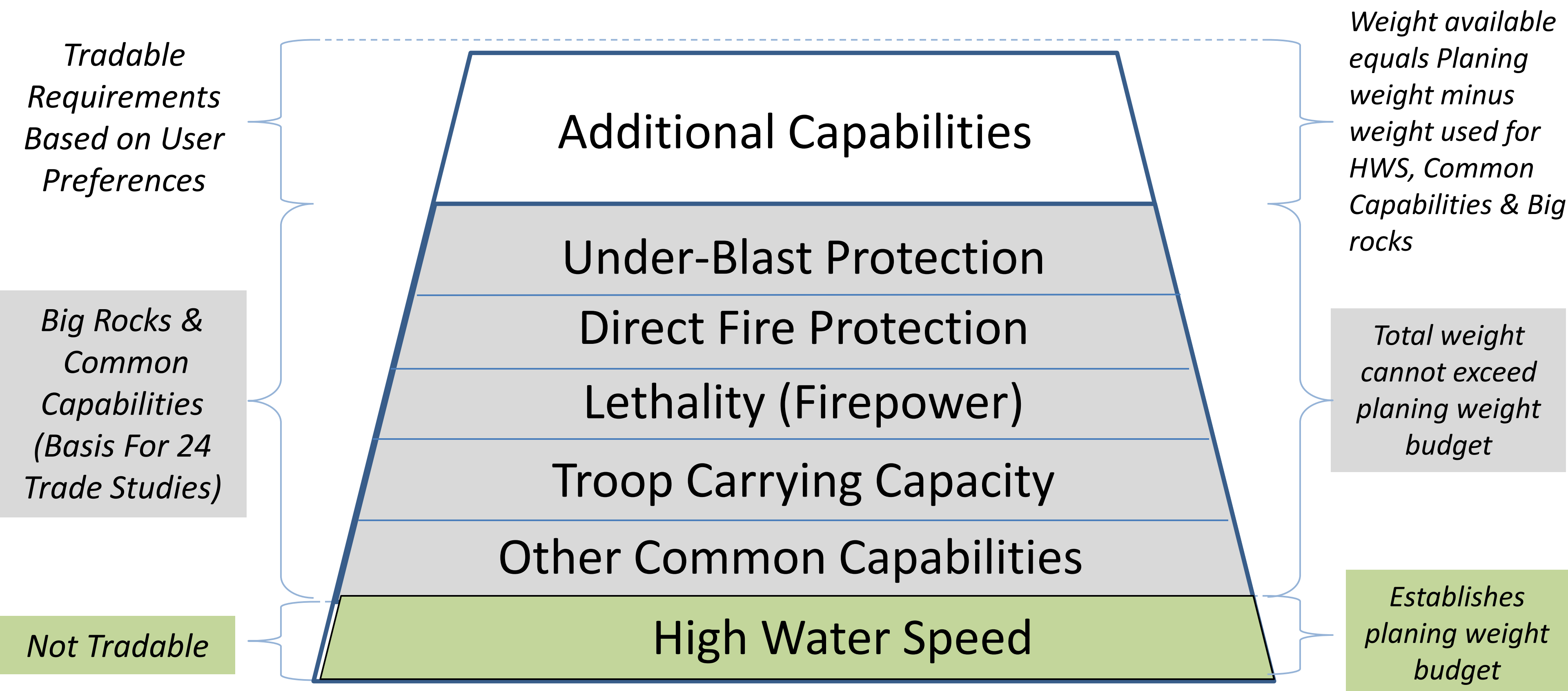
Tradable Requirements



Defining Capability Concepts

- Develop multiple Capability Concepts based on different combinations of High Impact Tradable Requirements
  - Choose to gain an understanding of the interactions of these High Impact Tradable Requirements
- Develop excursions to understand impact of Medium Impact Tradable Requirements
  - Assume (but verify) that impact is relatively constant across the set of Capability Concepts
- Defer consideration of Low Impact Tradable Requirements

ACV Capability Partitioning



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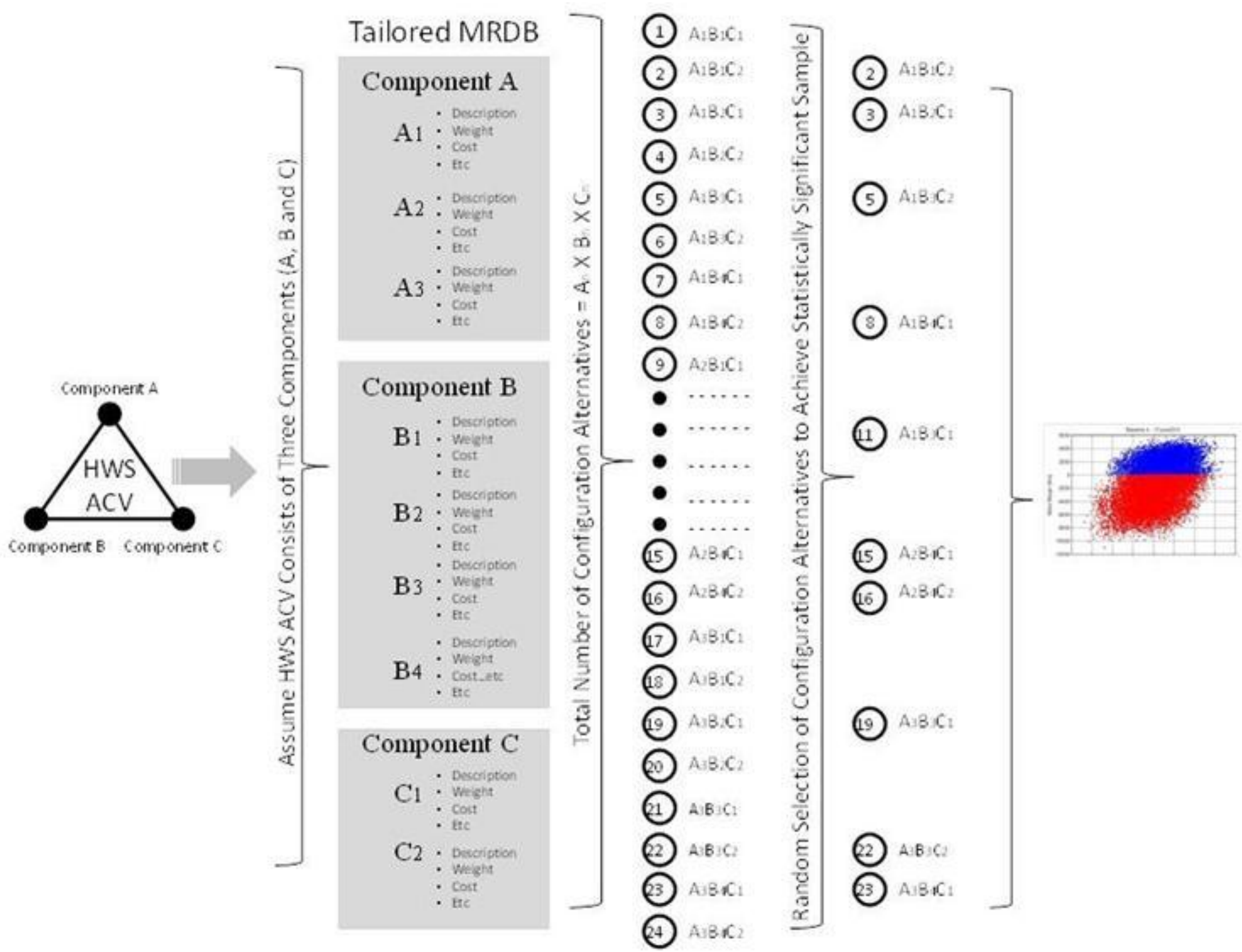
Configuration Modeling

- Market Research Database
  - Document component cost and technical data
  - Use a well defined Work Breakdown Structure (WBS)
  - Base on information provided by Industry (if possible)
    - Data traceability retained
  - Trace capability concept requirements to component selection
- System Modeling Tool
  - Use data from the Market Research Database
  - Calculate parameters needed to establish feasibility
  - Other technical parameters needed by the Cost Model
  - Assumptions documented in a Ground Rules & Assumptions (GR&A)
    - Best Practice: Incorporate the GR&A into the Study Guide
- Cost Model
  - Calculate acquisition and lifecycle cost estimates
  - Assumptions documented in GR&A

Engaging Industry

- Use industry to develop Configuration Modeling data
  - Information from industry can provide alternate solutions, confirm existing data, update existing data, and/or fill in missing data.
  - Data must be closely scrutinized to ensure it is fully understood:
    - Dry weight vs wet weight
    - Continuous rating or peak rating
    - Does it meet environmental requirements? (shock, vibe, EMI, etc)
    - Technical Maturity
- Best practice is to use a dedicated team to engage industry through means such as Requests for Information (RFI)

Assembling a Configuration



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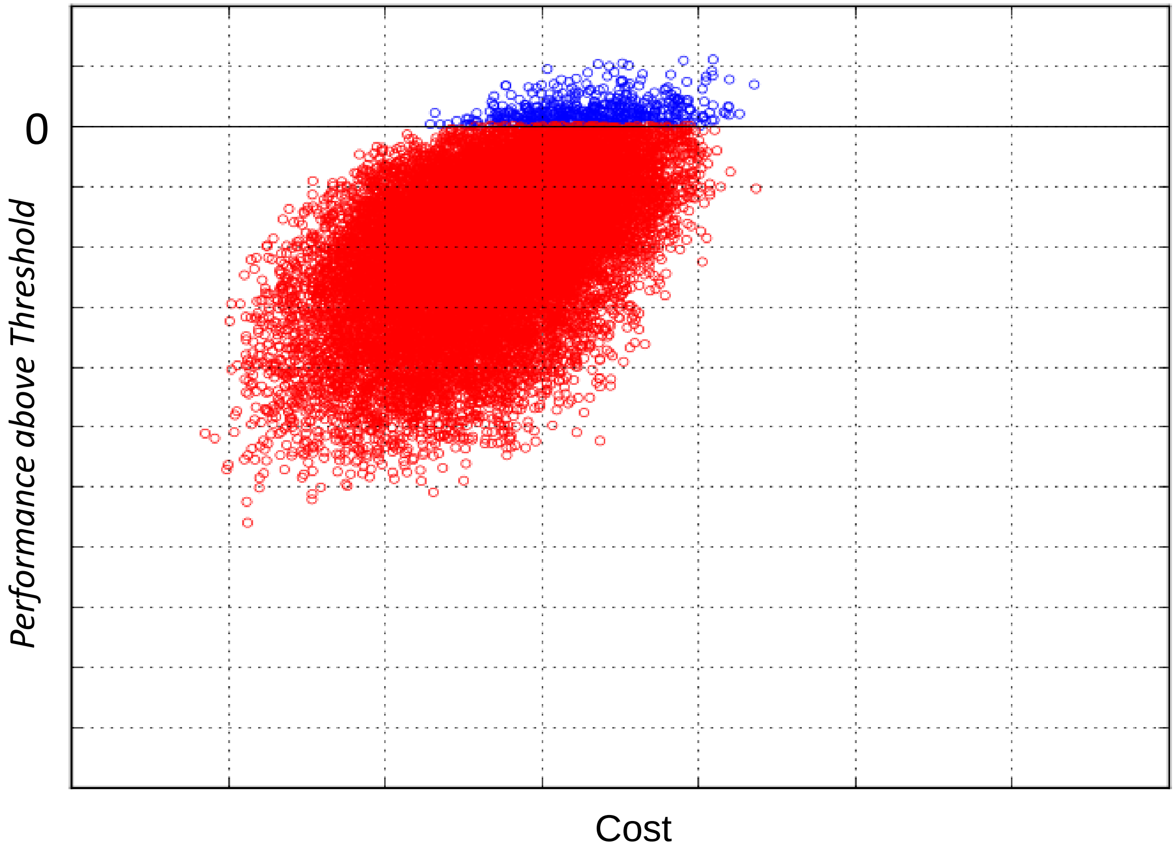
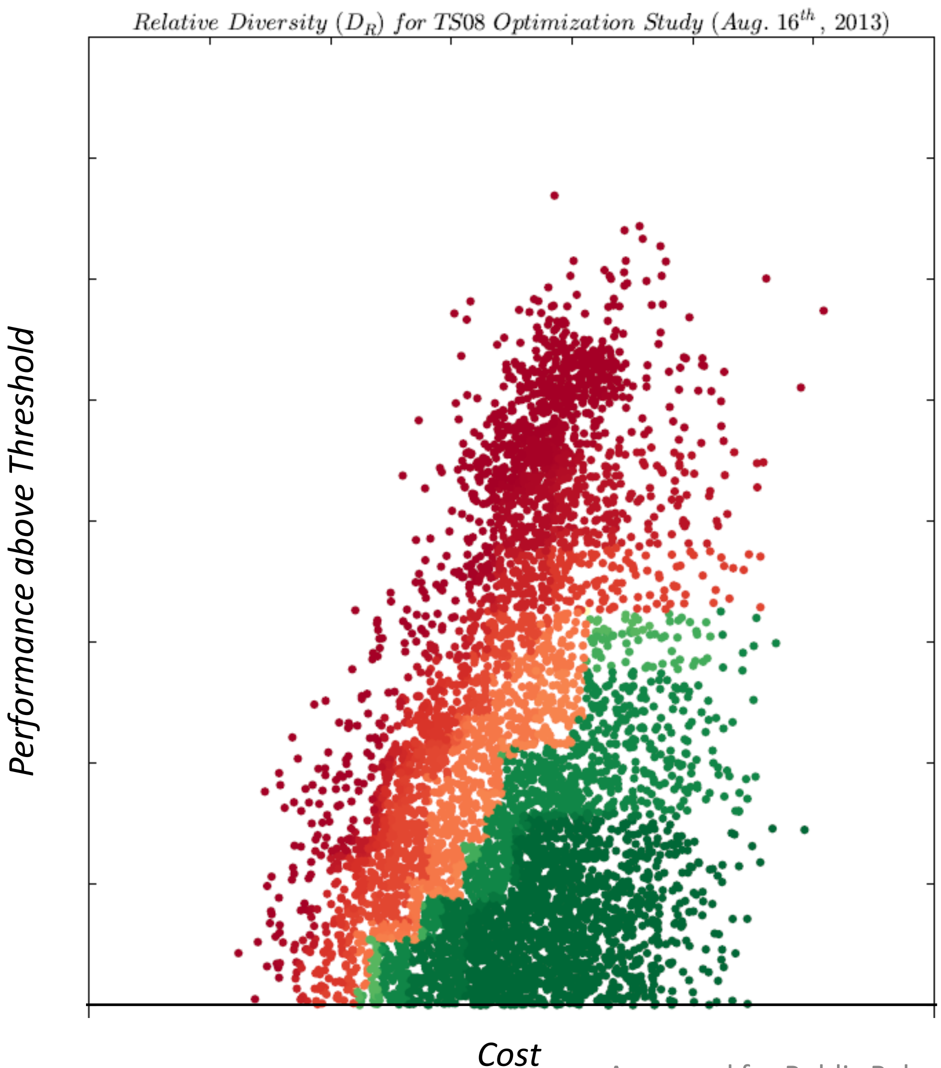
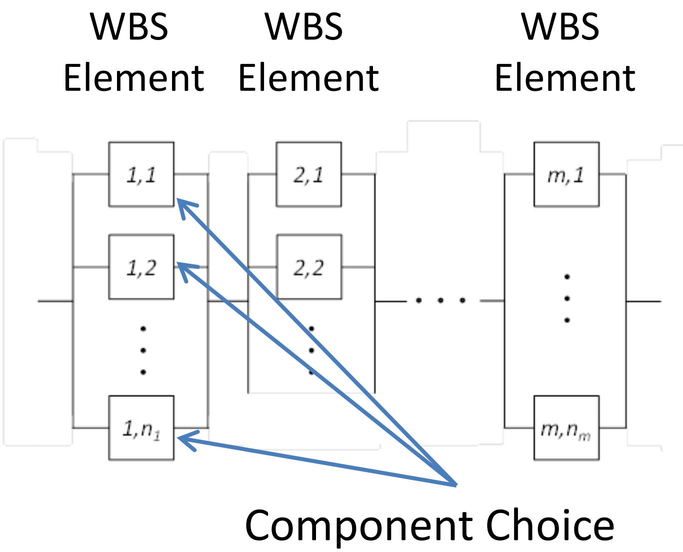
Scatter Plot



Diversity





N_i = total number of component choices in feasible design space

n_i = total number of component choices in the area to left of and above the evaluated point

M = total number of WBS elements

$$D_R = \frac{\prod_{i=1}^{m}\left(1-\frac{1}{2^{n_i}}\right)}{\prod_{i=1}^{m}\left(1-\frac{1}{2^{N_i}}\right)}$$

Comparing Capability Concepts Technical Risk

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**
"C" Under-Blast Protection; Weapon "Y"	**Feasible**	**Feasible**	**Feasible**	**High Risk Feasibility**
"C" Under-Blast Protection; Weapon "Z"	**High Risk Feasibility**	**Not Feasible**	**Not Feasible**	**Not Feasible**
"D" Under-Blast Protection; Weapon "X"	**High Risk Feasibility**	**Not Feasible**	**Not Feasible**	**Not Feasible**
"D" Under-Blast Protection; Weapon "Y"	**High Risk Feasibility**	**Not Feasible**	**Not Feasible**	**Not Feasible**
"D" Under-Blast Protection; Weapon "Z"	**Not Feasible**	**Not Feasible**	**Not Feasible**	**Not Feasible**

Comparing Capability Concepts Effectiveness

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

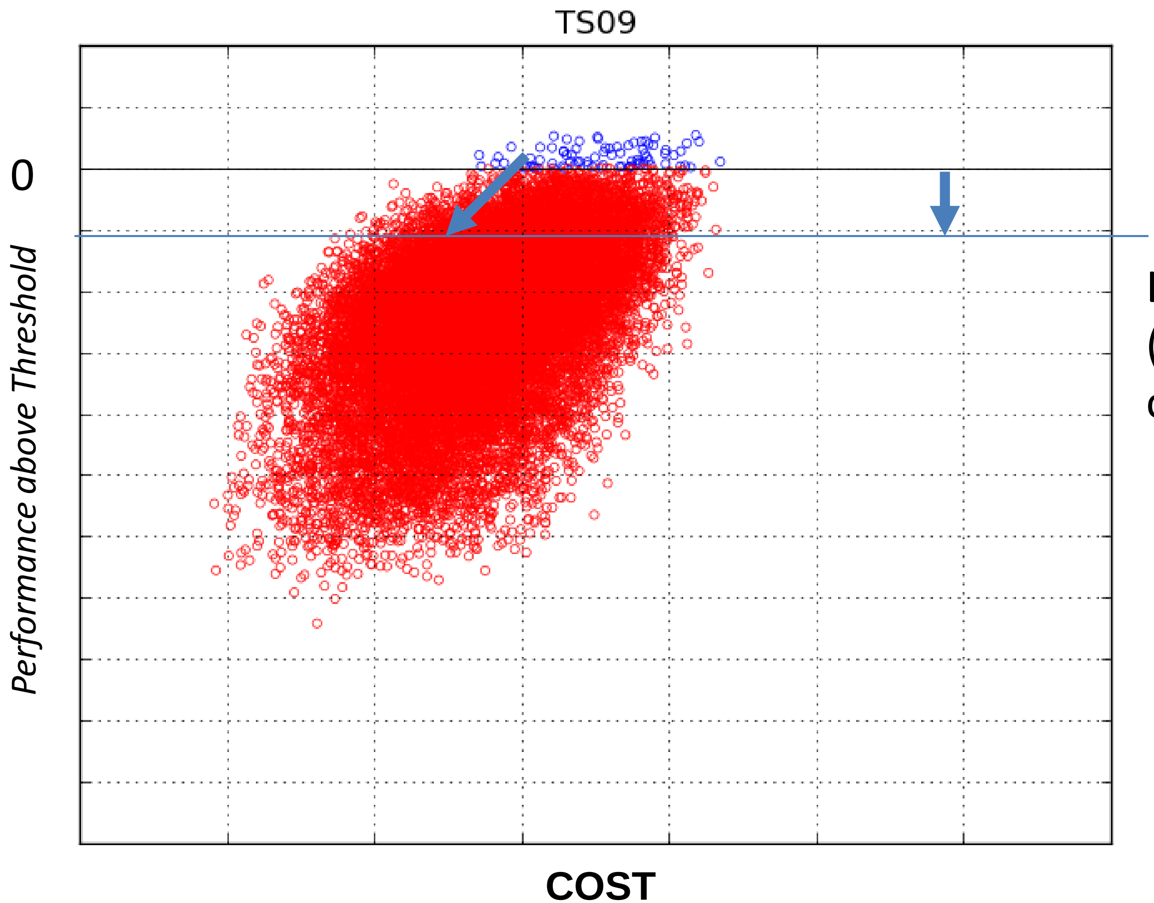
Performance / Effectiveness Metrics

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

Insight



Lowering Threshold (constraint) enables cost reduction

Flexibility and Modularity

Flexibility

- Exact value of a requirement not yet determined
  - A range for the value is established.
- Time when requirement will be determined specified
  - Short Term: Before MS A
  - Mid Term: Within 1 year after MS A
  - Far Term: Before MS B
- Design must affordably accommodate range of requirement until the value is established.
- Enables deferring decision until more is known about the impact of the requirement on cost and value.

Modularity

- Ability to inherently meet the current threshold and accept the modularity impacts in order to grow to the final desired capability
- Categories:
  - Field: modules selected and changed out in the field
  - Depot: modules changed out in a depot environment
  - Variant: design modularity; variant with high commonality ordered for production, but not designed to be modified later.
- Modularity requirements documented in pairs:
  - Threshold requirement at Initial Operational Capability (IOC)
  - Modularity features for future upgrades

Key Points

- Make comparisons at the Capability Concept Level
- Base cost estimates and performance on the set of feasible configurations for a given Capability Concept
  - Any one configuration may not be viable
- Save time by having specialists work in parallel and integrate their work
  - Integrate by systematically eliminating regions of the design space based on analysis
- Use diversity metrics to gain confidence in concept feasibility
- Gain insight from feasible and infeasible configurations

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