

Implementing Set-Based Design in DOD Acquisitions

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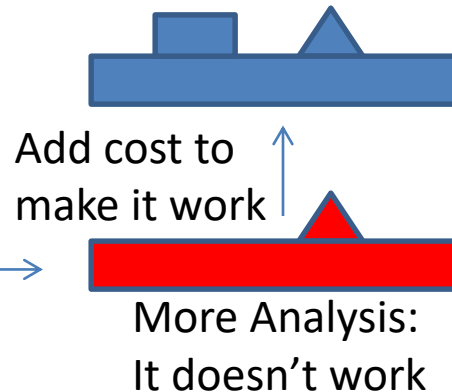
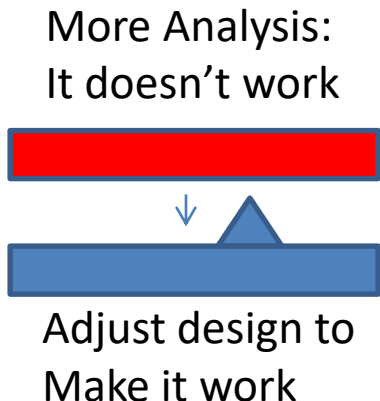
Point Based vs Set-Based Design

Point Based Design



Pick
Concept →

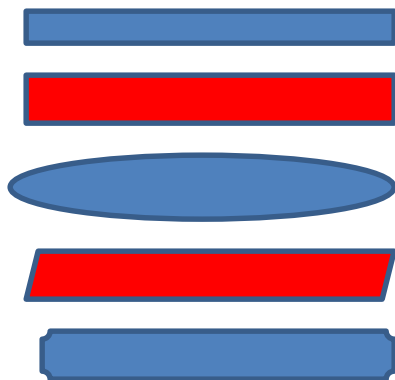
↑
"Optimal
Solution"



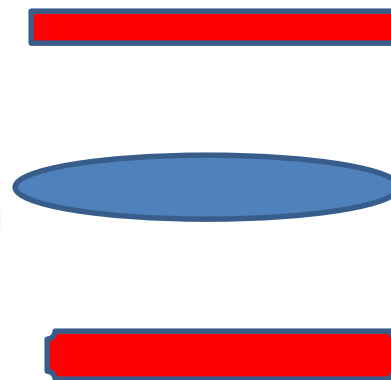
Set-Based Design



"Optimal
Design
Space
Sampling"
↓
Set
Reduction →



Set
Reduction →



Initial Concepts
(sample design space)

3/1/2017

More Analysis:
Eliminate concepts
that don't work

More Analysis:
Eliminate concepts
that don't work

Principles of Set-Based Design (SBD)

- Understand the design space
 - Identify feasible regions within a wide set of boundaries
 - Explore tradeoffs by designing and analyzing multiple alternatives
 - Communicate sets of possibilities
- Integrate by intersection
 - Have specialists consider a design from their own perspective
 - Work in parallel asynchronously
 - Look for intersections of feasible sets – Eliminate infeasible
 - Impose minimum (maximum) constraint – Eliminate dominated
 - Seek conceptual robustness – Diversity
- Establish feasibility before commitment
 - Narrow sets gradually while increasing detail or scope of analysis
 - Stay within set once committed (Unless new knowledge indicates otherwise)
 - Control by managing uncertainty
 - DOCUMENT ALL SET REDUCTIONS

Make robust data-driven decisions

What is the Design Problem?

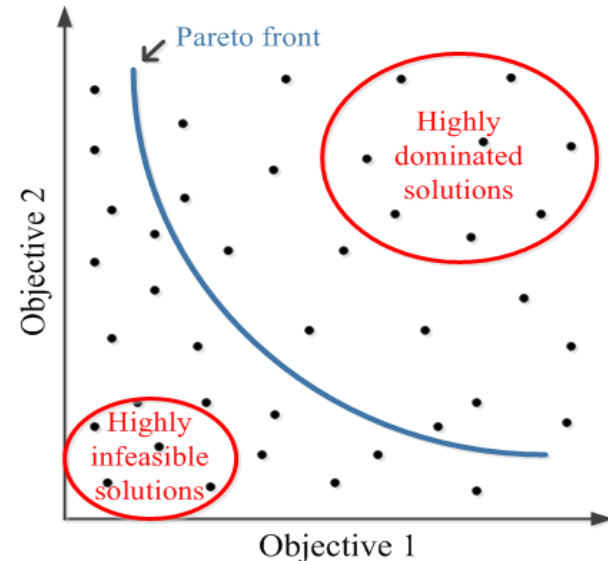
- Pre-Milestone A: Concept Exploration
 - What is the set of operational requirements for which a system can be built over a desired time period for a desired amount of funds to achieve a desired operational value?
 - Designing Requirements
 - Examples: ACV and SSCTF
- Milestone A to Milestone B: Preliminary & Contract Design
 - What is the best set of specifications for procuring a system to achieve the desired operational requirements within the desired time period and cost constraints?
 - Designing Specifications
 - Example: SSC

Both may use SBD as a “Design Method” but will have different “Design Processes”

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 within the requirement space, not the configuration level
- Cost for a given set of requirements should be based on a diverse set of feasible configurations
 - Avoid common mode failures
 - Reflect undecided requirements
 - Reflect undecided implementation



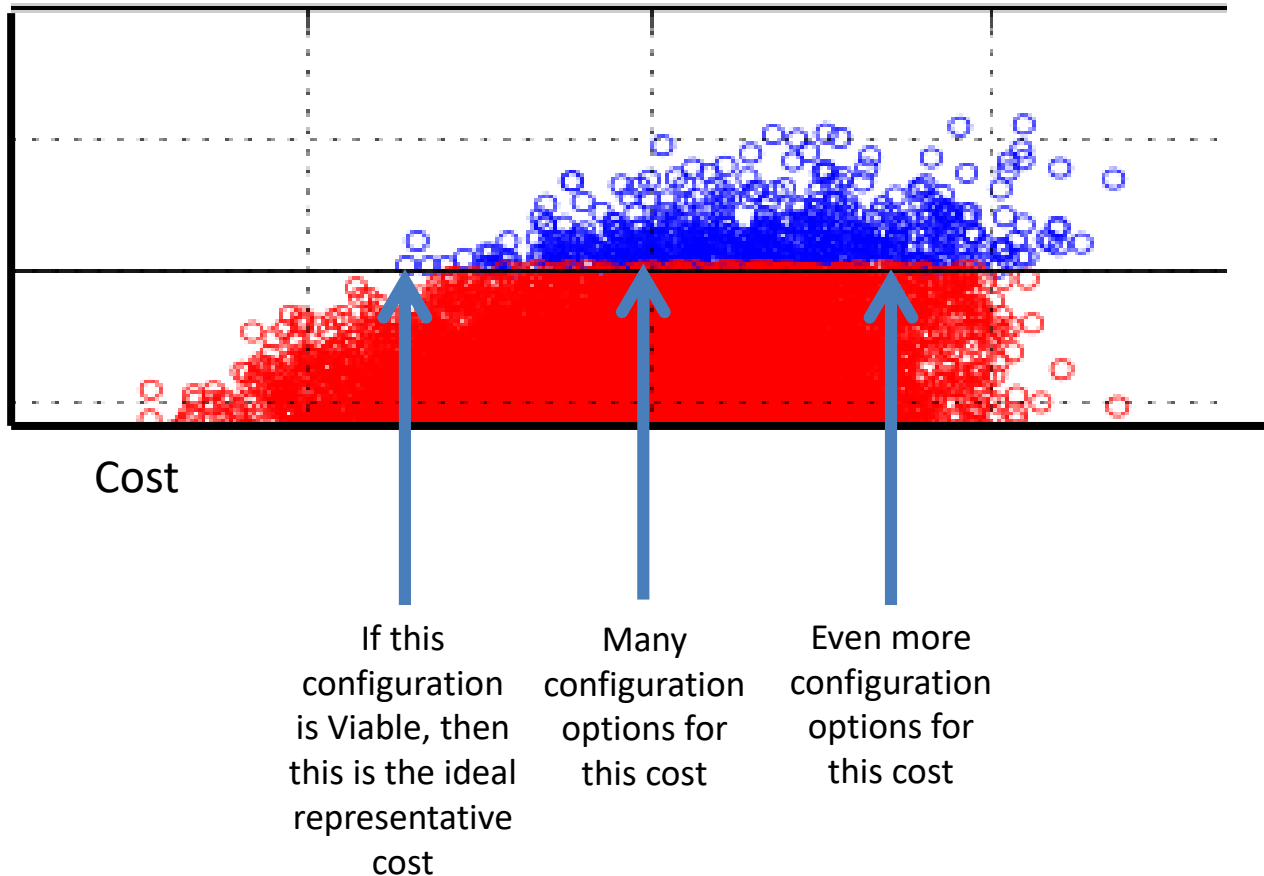
McKenney, Thomas, and David Singer, "Set-Based Design," SNAME (mt) Marine Technology, July 2014, pp. 51-55.

Systematically Eliminate

- Highly Dominated Solutions
- Not Feasible Solutions

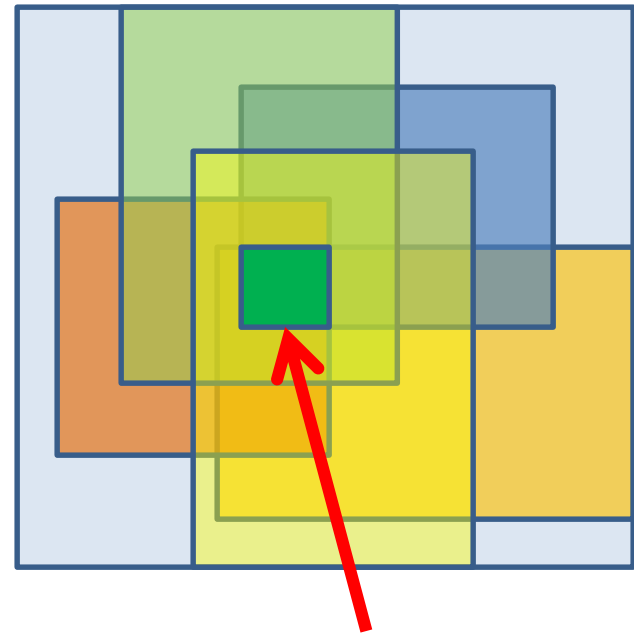
What is a good representative cost?

Answer: The lowest cost for which the risk that all feasible configurations with a lower or equal cost are not viable is low.
The risk is evaluated via a Diversity Metric



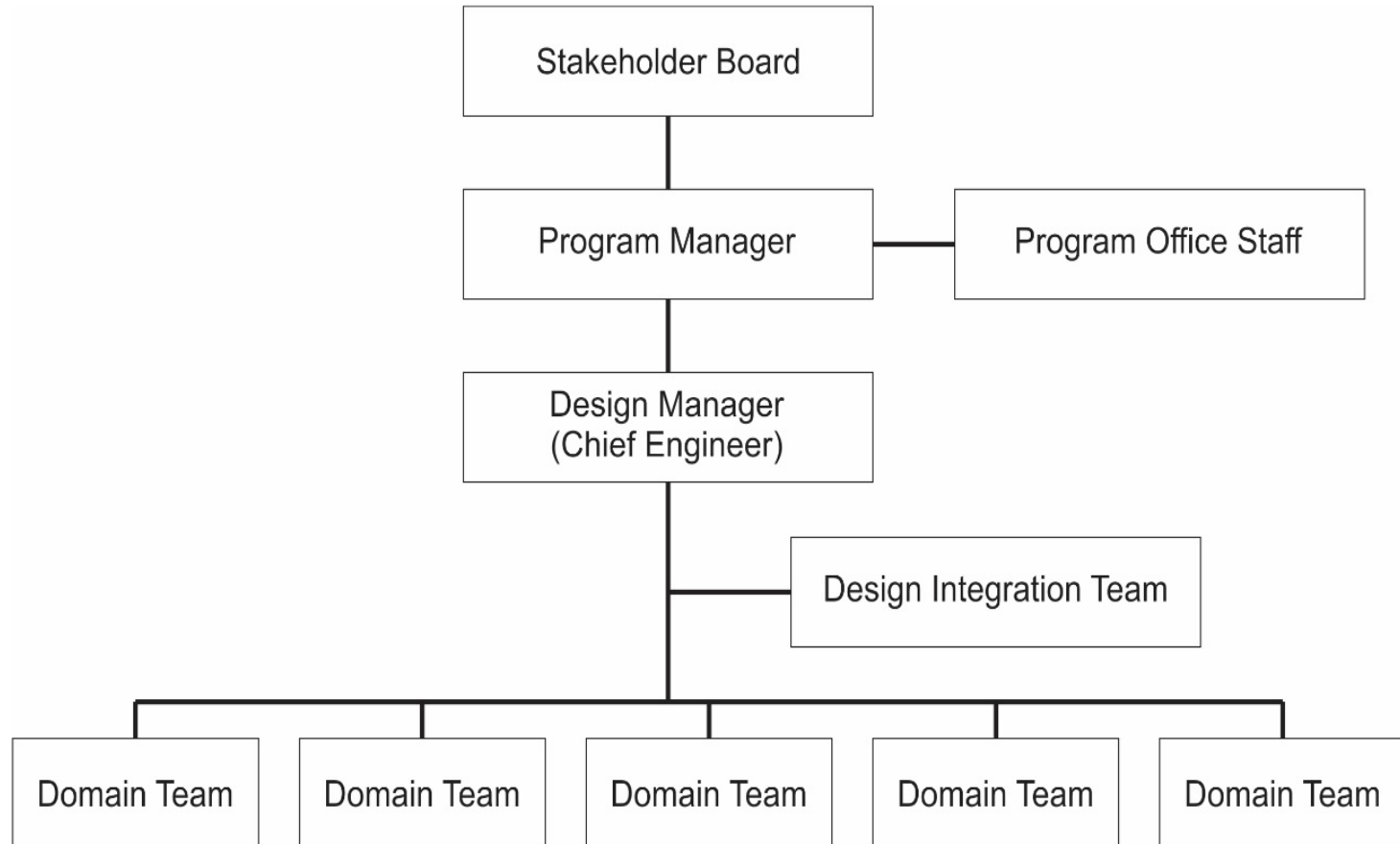
Preparing for concept exploration: Design the Design Process

- Understand the requirements trade space:
 - Fact of Life: just do it (ship must float)
 - Low Impact: assume value and address later
 - Medium Impact: assume baseline and treat as an incremental change
 - High Impact: explore the design space
- Understand the types of analysis domains needed:
 - Technical Feasibility and cost
 - Acquisition Feasibility
 - Military Effectiveness
 - Affordability
- Develop methods to intersect the results of the analyses from the different domains
 - If a configuration is infeasible in one domain, it is infeasible
 - Can strategically order analyses to reduce design space early
- Develop methods to compare attributes of the sets of feasible configurations for each capability concept across all the capability concepts
 - Representative cost based on diversity

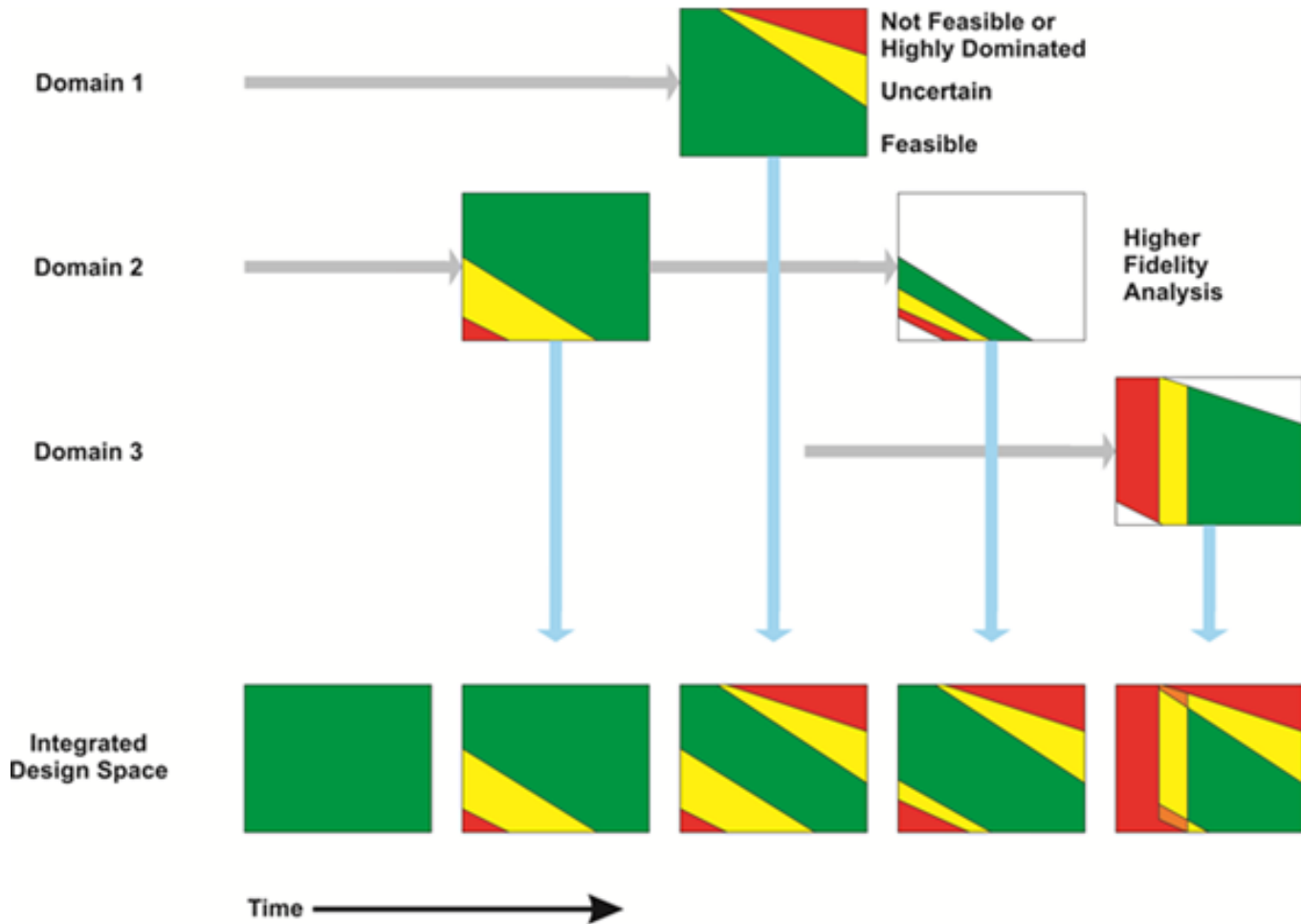


Intersect Analyses results to
define Feasible Design Space
for a capability concept

Design Team



SBD Execution



Set-Based Design Examples

- Past
 - (1980's to present) Toyota Product Development
 - (2008) SSC: Ship to Shore Connector (Preliminary Design)
 - (circa 2009) planned to use for CG(X) (Preliminary Design)
 - (2013) ACV: Amphibious Combat Vehicle (Requirements)
 - (2014) SSCTF: Small Surface Combatant Task Force (Requirements)
 - (2016) SMI: Smart Mine Initiative (Requirements)
- Ongoing / Future
 - Future Surface Combatant (Requirements)
 - Force Architecture Studies (Requirements)
 - Large Surface Combatant (Preliminary Design)
- When to use ...
 - A large number of variables
 - Tight coupling among variables
 - Technologies and design problems not well understood – learning required for a solution

Key Take Aways

- Set Based Design (SBD) is a methodology: The way design alternatives are understood, analyzed and selected.
 - Implemented through Design Processes
 - Enabled by Design Tools (typically within a Model Based Systems Engineering Environment)
- **The key idea is that decisions are systematically made (and documented) to eliminate regions of the design / requirements space.**
 - Easier to show something is not the answer than prove something is best
 - The final answer is chosen from the design space remaining after all the potential solutions that aren't the answer are eliminated.
- SBD methodology can apply to Capability/Requirements Development and Design Development
- SBD demonstrated its power to inform senior Flag/General Officer decisions regarding requirement space, design space, and technical and programmatic risks.
- SBD does not make decisions, it informs decisions ... most importantly, it preserves decision space for leadership until the time is right
 - Make decisions when knowledge is sufficient.
 - Avoid “re-making” decisions or back-tracking.