Implementing Set-Based Design in DOD Acquisitions

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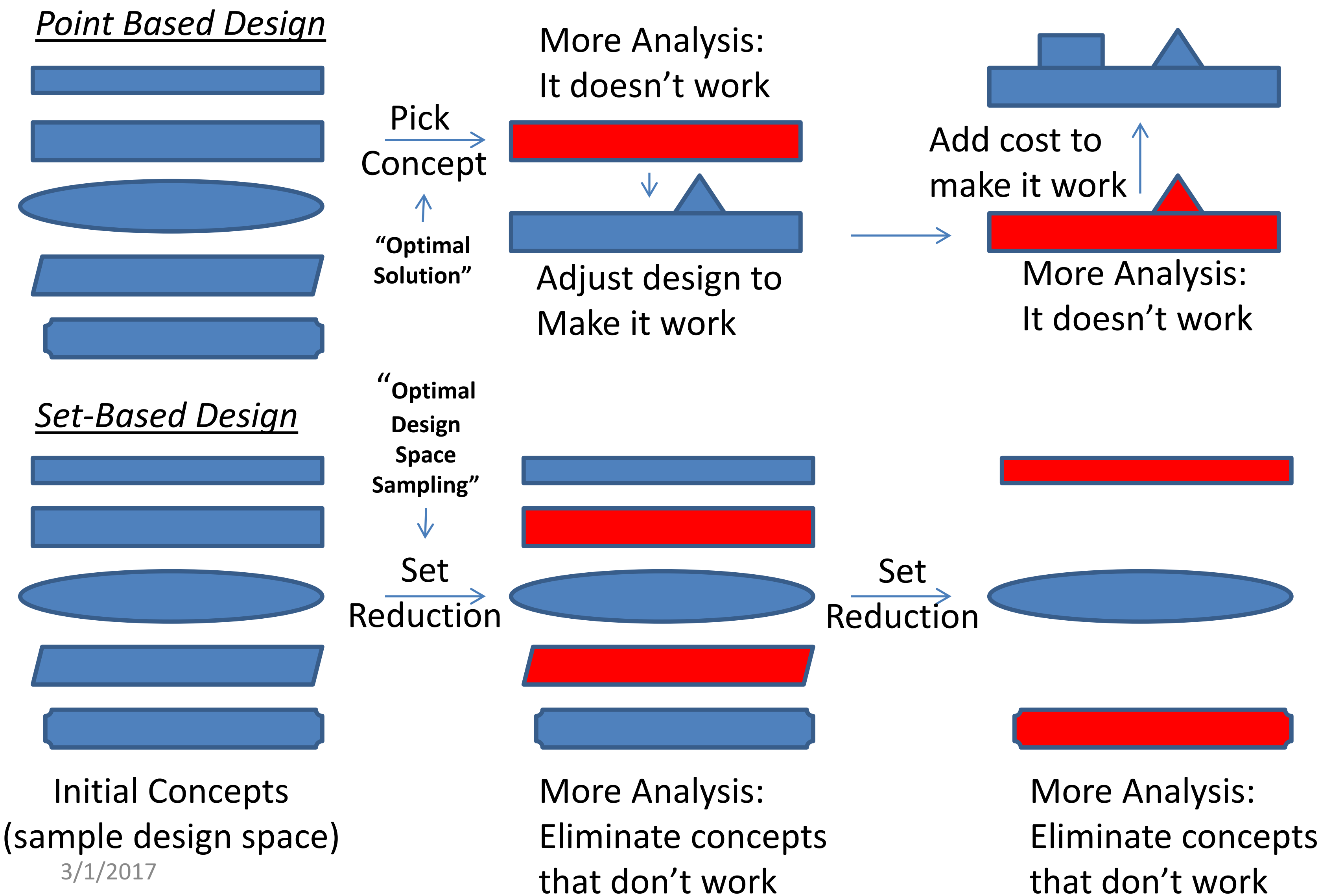
Point Based vs Set-Based Design



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

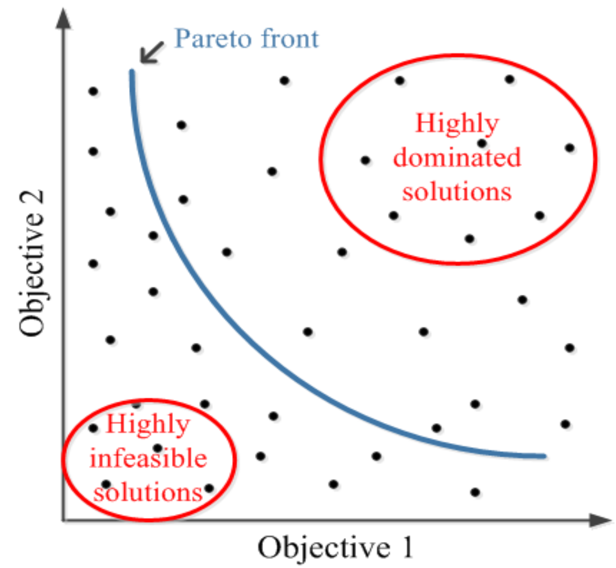
What is the Design Problem?

- 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

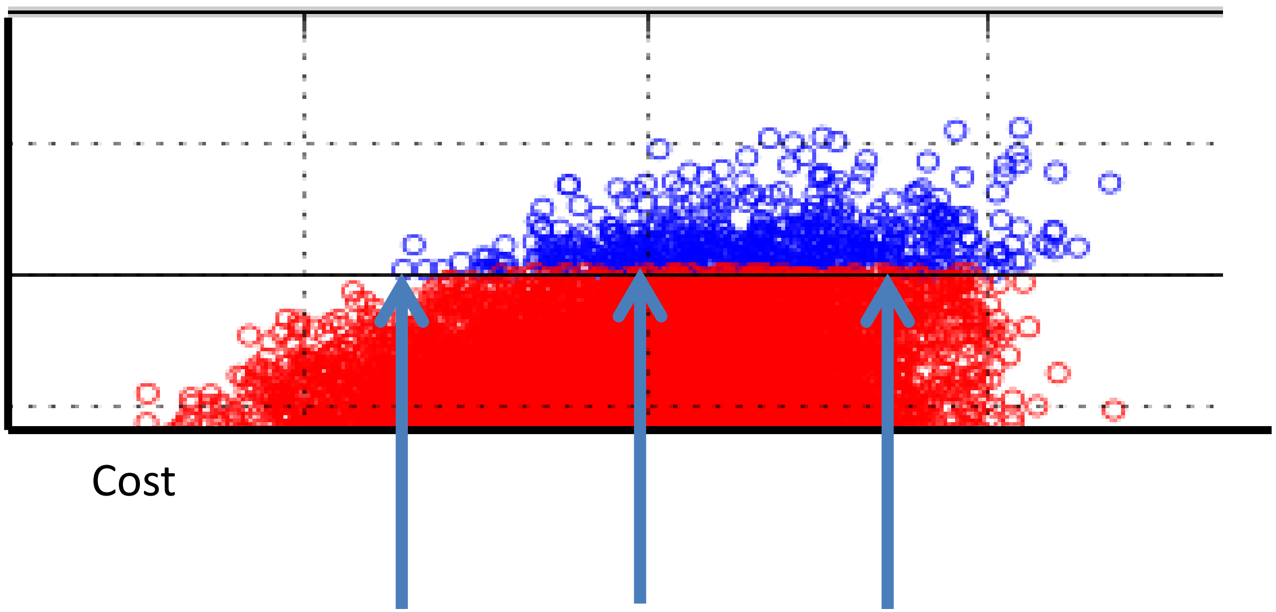


McKenney, Thomas, and David Singer, "Set-Based Design," SNAME (mt) Marine Technology, July 2014, pp. 51-55.

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



If this configuration is Viable, then this is the ideal representative cost

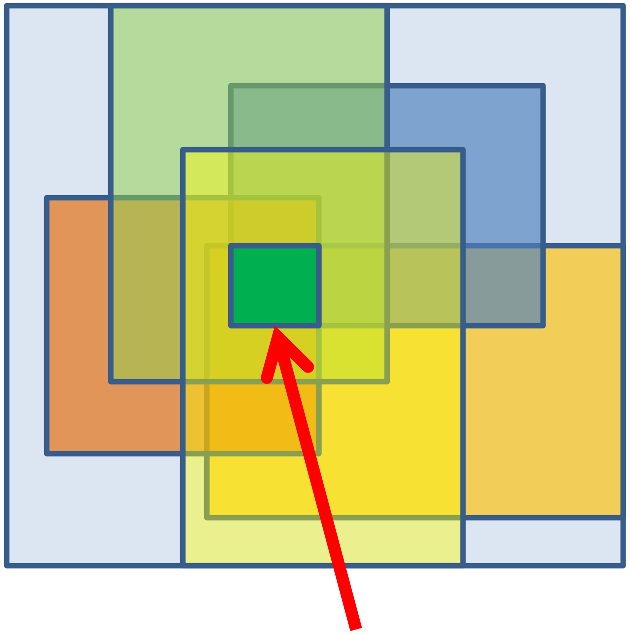
Many configuration options for this cost

Even more configuration options for this cost

Preparing for concept exploration:

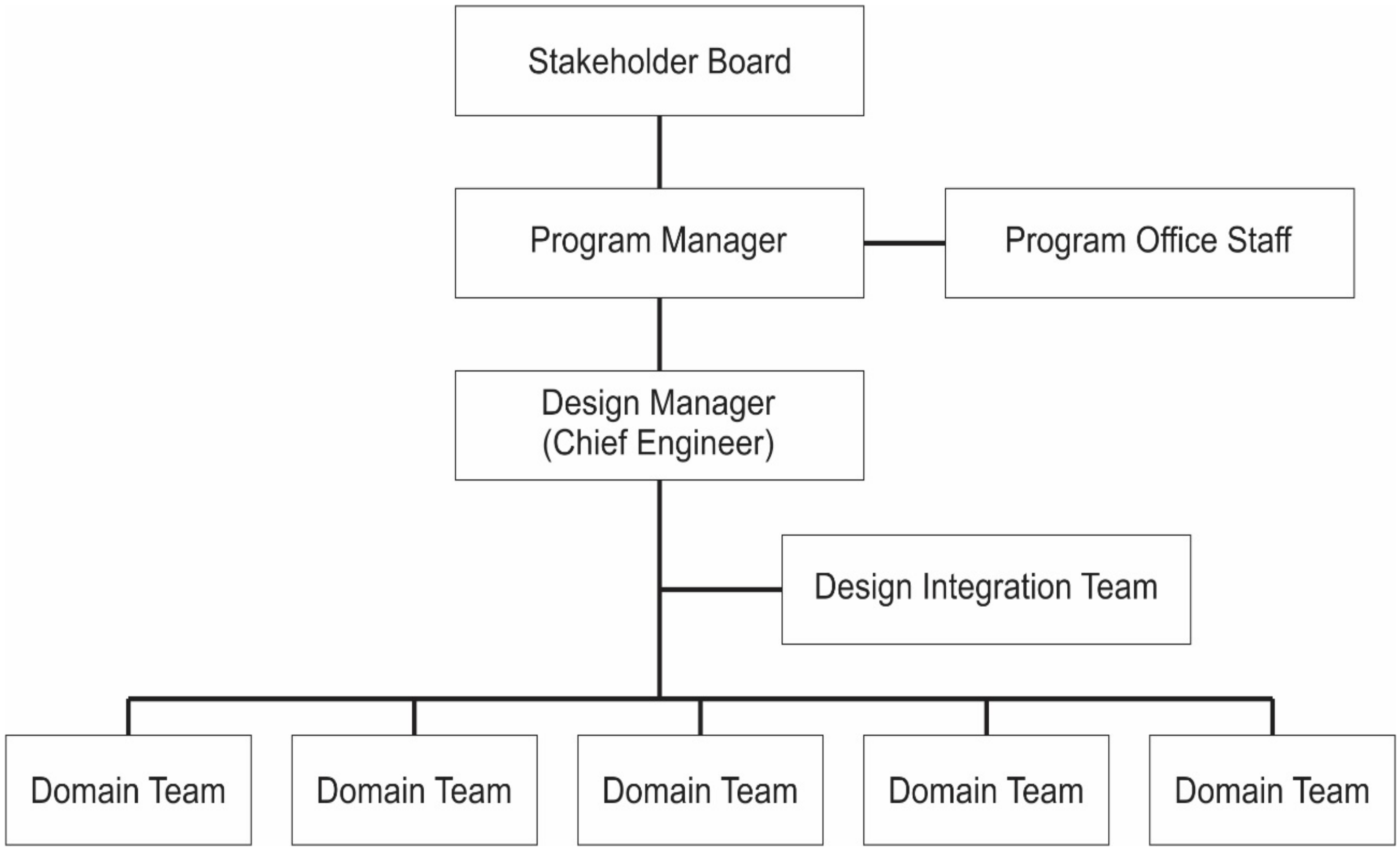
Design the Design Process

- 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



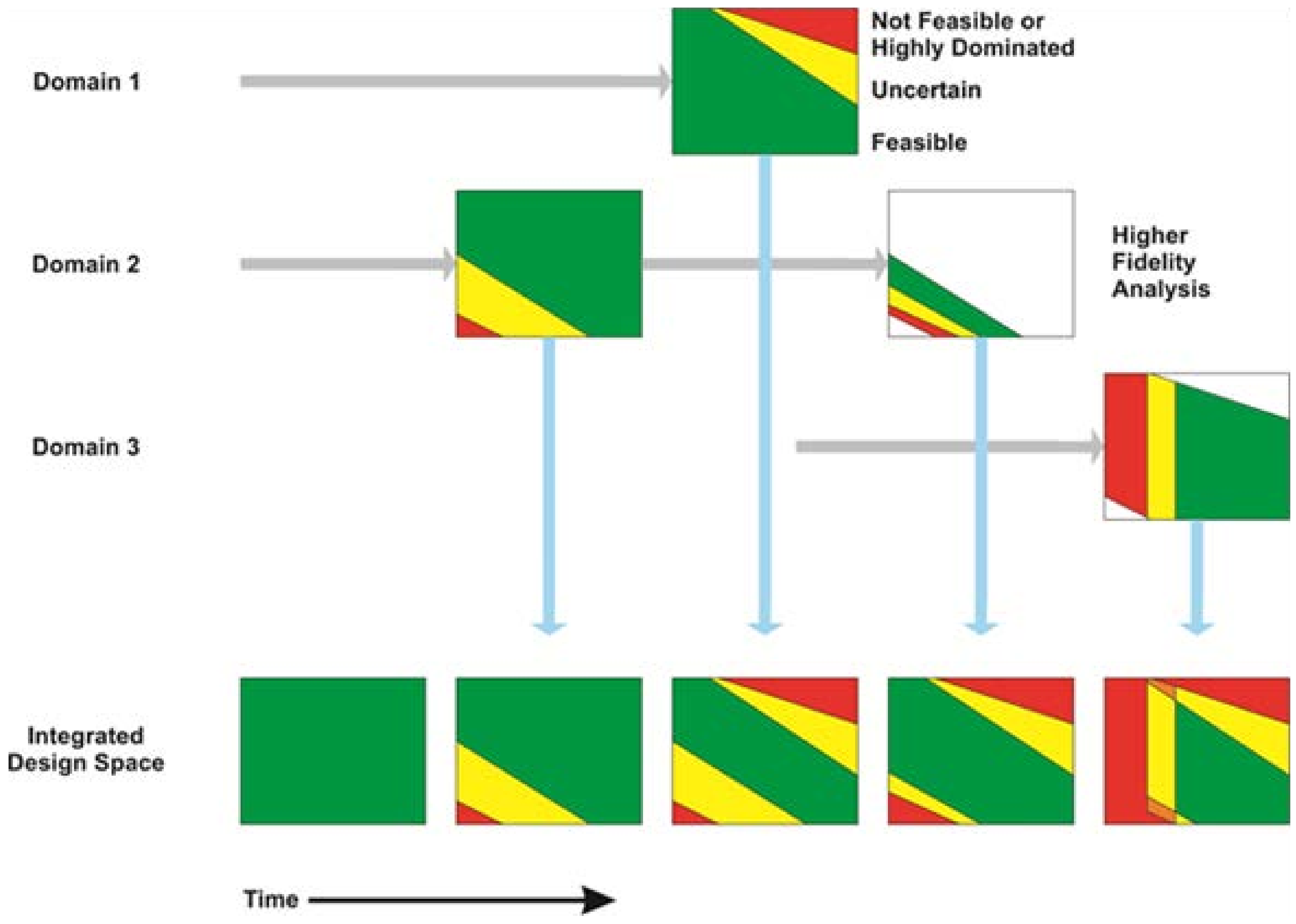
Intersect Analyses results to define Feasible Design Space for a capability concept

Design Team



Stakeholder Board
Program Manager
Program Office Staff
Design Manager
(Chief Engineer)
Design Integration Team
Domain Team
Domain Team
Domain Team
Domain Team
Domain Team

SBD Execution



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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.