Improving Acquisition with Set-Based Design

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Set-Based Design (SBD)

Set-based design is founded on three key principles

- Defining an appropriate design space
  - Consider multiple large "sets" of alternatives
  - Consider what is feasible with respect to the customers and engineering voices
  - Communicate through sets or boundaries
- Integrating sets by intersection
  - Seek conceptual robustness (where sets overlap)
  - Infusing multiple conceptual perspectives
- Establishing feasibility before commitment
  - Reduce the trade-space in deliberate and informed manner (design flexibility / cost / risk / etc.)
  - Requirements trade-space is reduced based on operational value and risk
  - Design trade-space is reduced based on feasibility and value (capacities / schedule / etc.)

Set-Based Design methodology enables informed design decisions

Set-Based Design vs. Conventional Design

Set-Based Design	Conventional Design
Allows *constraining* decisions to be made later, after sufficient information is gathered. Decisions which remove parts of the trade-space, where changes to the decisions would result in significant additional cost in the future.	Attempts to Lock-in the design as early as possible in order to prevent blocking the engineering process
Provide varying solution architectures to enable trades on requirements (i.e. performance, capability), resources (i.e. cost, schedule), and provide flexibility/robustness in the process to requirement change.	Provide single point solution based on early assessments of requirements
Improve breadth and depth of knowledge of the wider trade-space, with increased traceability to decision makers on how the viable configurations were determined	Focus on increasing detailed understanding of the trade-space within the locked-in design space.
Reinforce confidence in final recommendations with a pattern of reproducible defensible artifacts in support of the decision process, specifically before highly *constraining* decisions.	Design efforts are in support of the initially identified candidate solution

What are the Perceived Barriers to Using Set-Based Design?

- Time Required to Analyze the Full Trade-space is Excessive
  - SBD is described as carrying tens or hundreds of thousands of designs forward in parallel
  - Physics-based simulations can take considerable time

- Quantity of Data Generated from Full Trade-space Exploration is too Large to Analyze and Maintain
  - Large multi-faceted data
  - Tools have processing limits
  - Difficult to maintain traceability

- Additional Analysis is Cost Prohibitive
  - Engineers are already busy
  - Requires investment in new skills and capabilities

Time Required to Analyze Full Trade-space is not too Excessive?

- Automated analytical framework leverages computing power to allow for exploring large sets of candidate solutions.

ACV (2013)	SSCTF (2014)	SMI (2016)
Explored 1M+ combinations across 27 trade studies in 9 months.	Explored 16M+ combinations in ~6 months.	Explored 1.5M+ combinations across 16 architectures in 3 months.

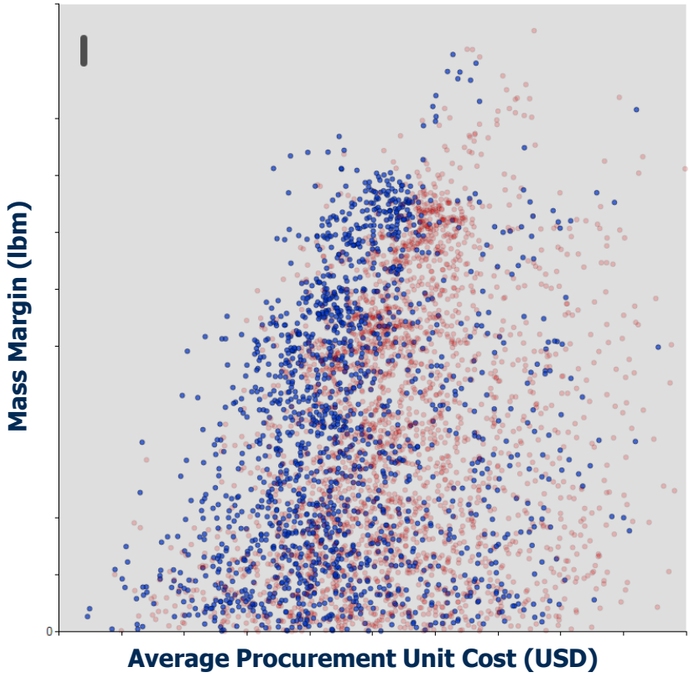
- Automated analytical framework allows for quick Design and V&V iterations.

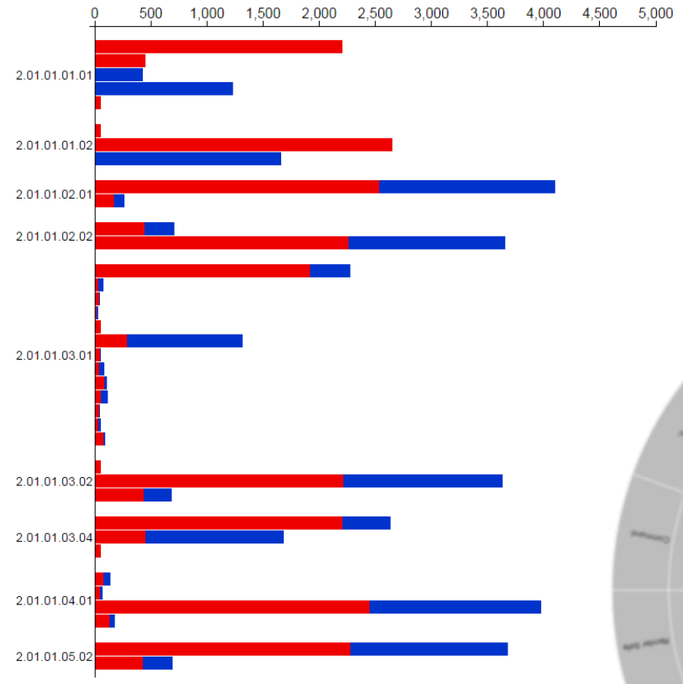
ACV	→	SSCTF	→	SMI
3-4 days		30-40 hours		30-40 minutes

Quantity of Data Generated from Full Trade-space Exploration <u>is not too</u> Large to Analyze

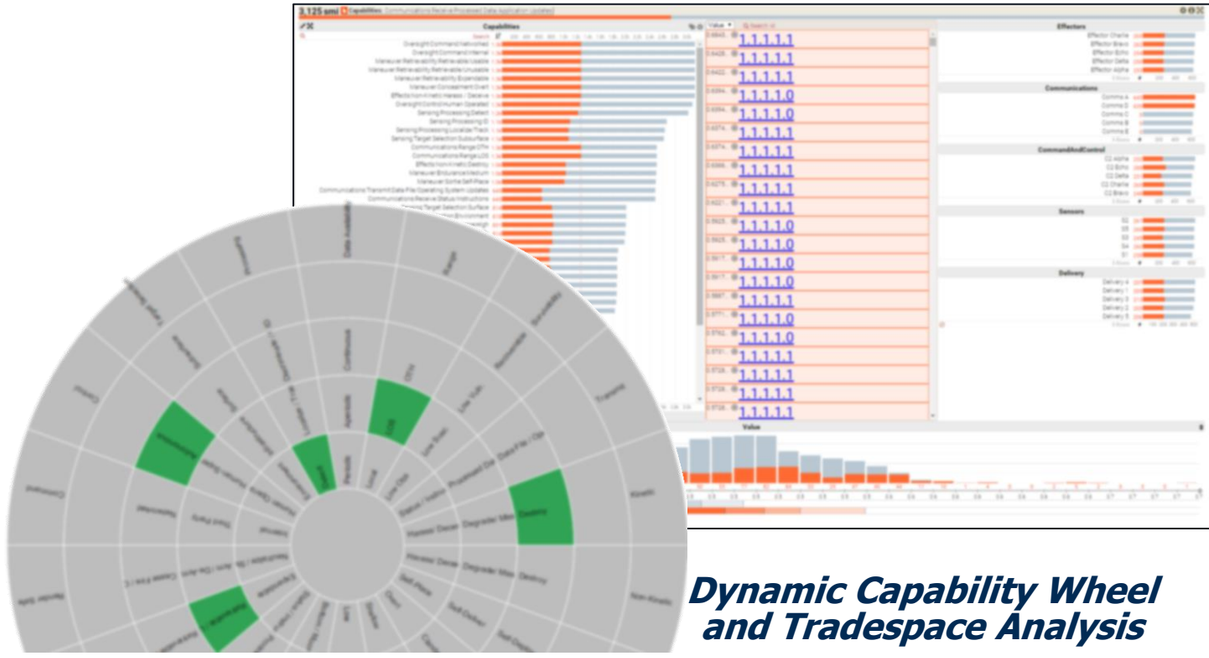
- Custom visualizations allow decision makers to efficiently interact with data.
- Automated data analysis prunes the trade-space.

ACV





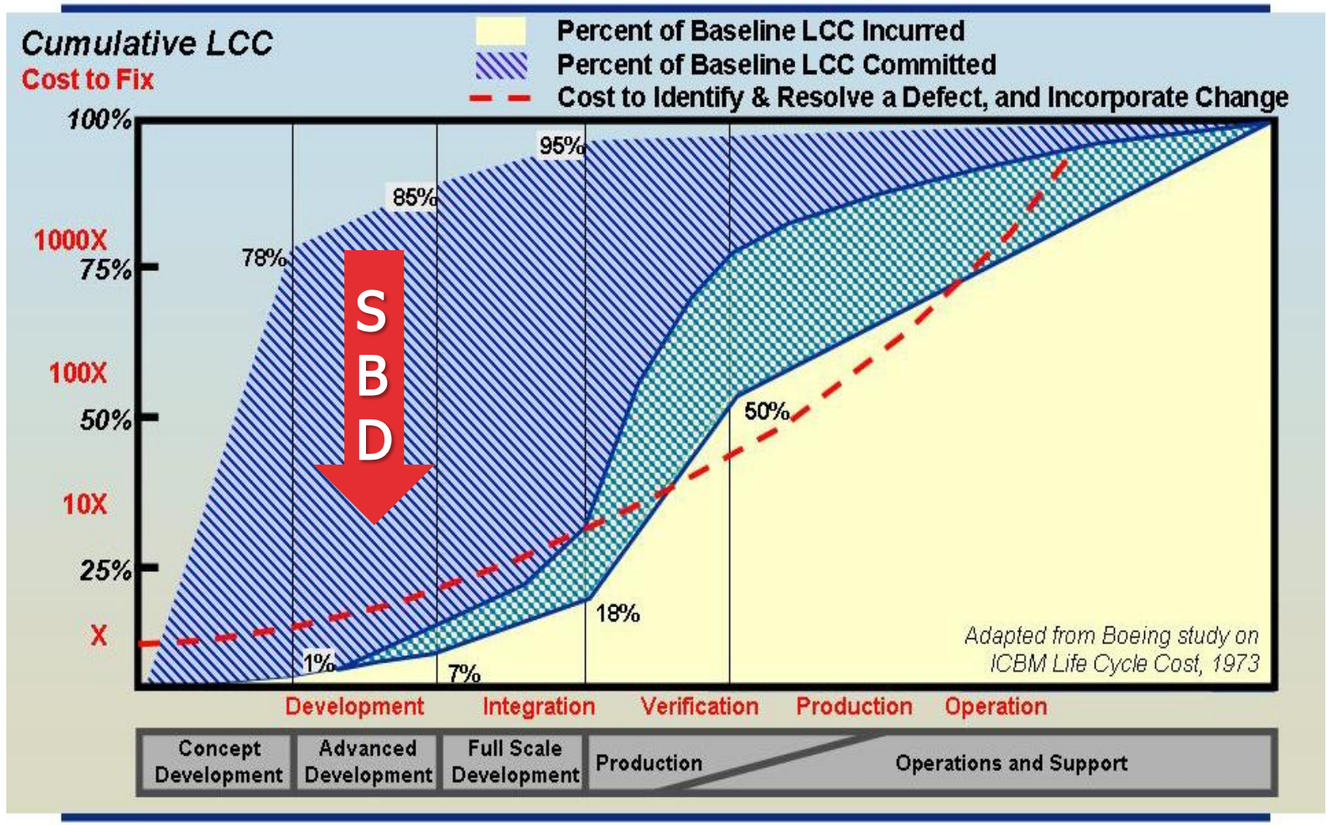
SMI



Dynamic Capability Wheel and Tradespace Analysis

Additional Analysis is not Cost Prohibitive

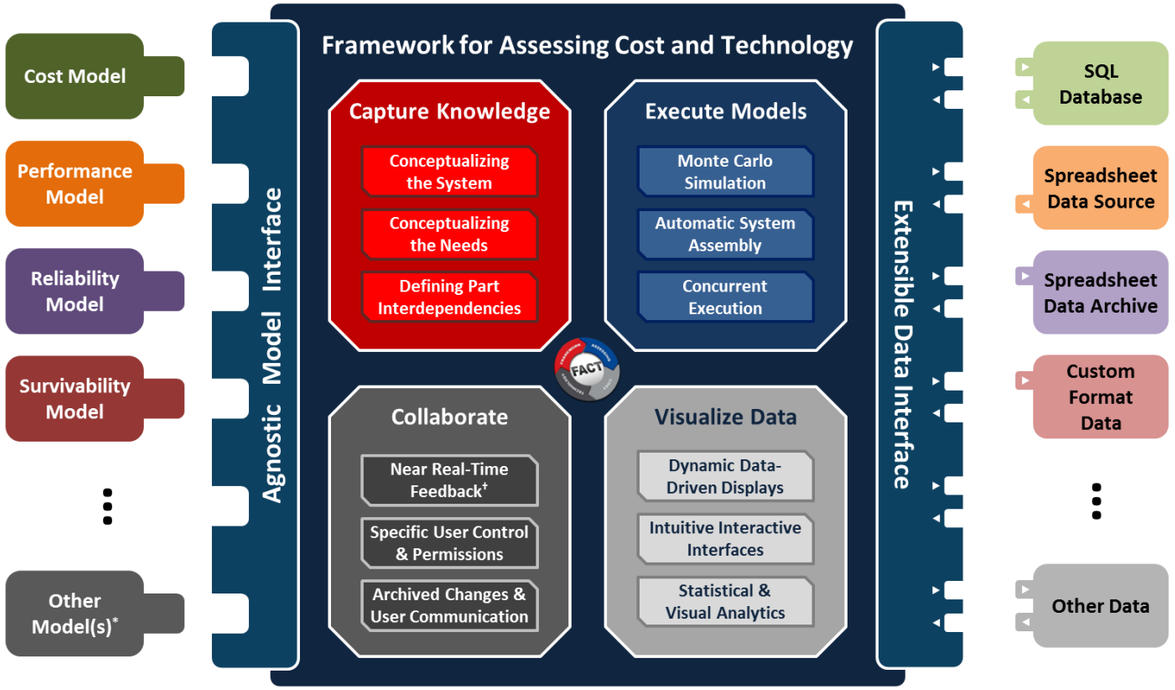
- Set-Based Design (SBD) promotes good Systems Engineering practices.
- Delaying *constraining* decisions postpones cost commitment and allows decisions to be informed by superior data.



Ref: Loren, J.R., "Next-Generation Air Force Systems Engineering: An Integrated Life-Cycle Approach to Development, Test and Sustainment," USAF Test and Evaluation Days, Destin, Florida, AIAA 2007-1680, 13-15 February 2007.

Framework for Assessing Cost & Technology (FACT)

- Processes large data sets through integrated Modeling and Simulation
- Provides data integration, processing and concise visuals of data relationships and solution alternatives
- Allows users to understand and rapidly assess interdependencies between requirements, components, and variables of large and complex data sets
- Allows decision makers to explore the trade-space and compare alternatives
- Allows leaders to maintain and manage an evolving requirements sets
- Proven effective in supporting SBD methodology and processes



FACT supports SBD by integrating and executing multiple models, databases, & information sets to produce actionable solution alternatives to aid decision makers

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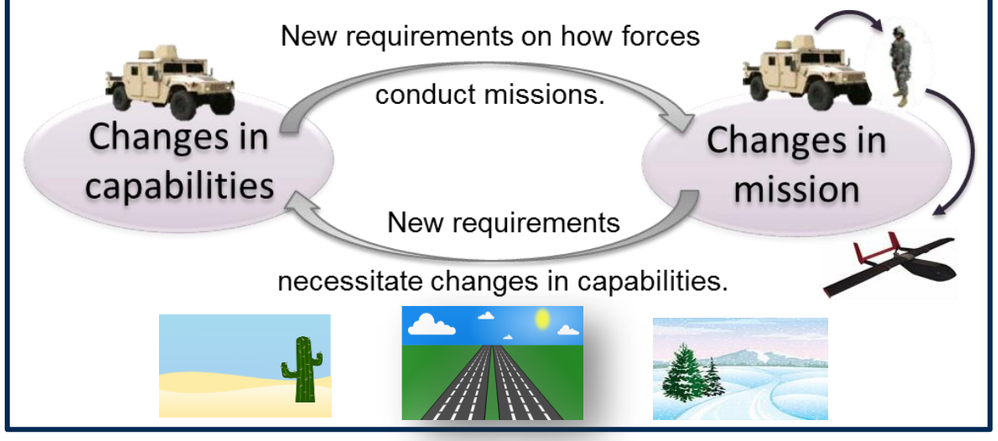
Collaborative Systems Engineering Tools for Resilient Systems

The Problem

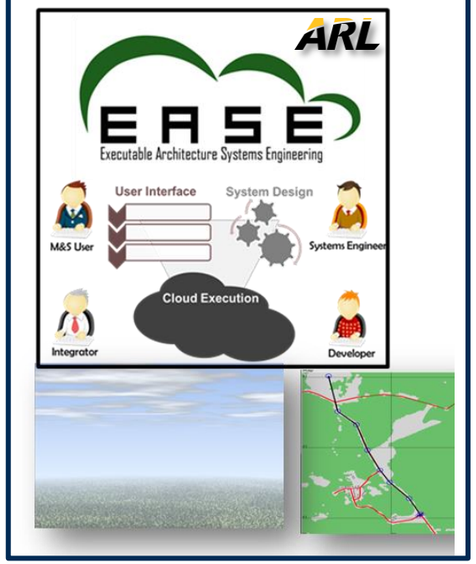


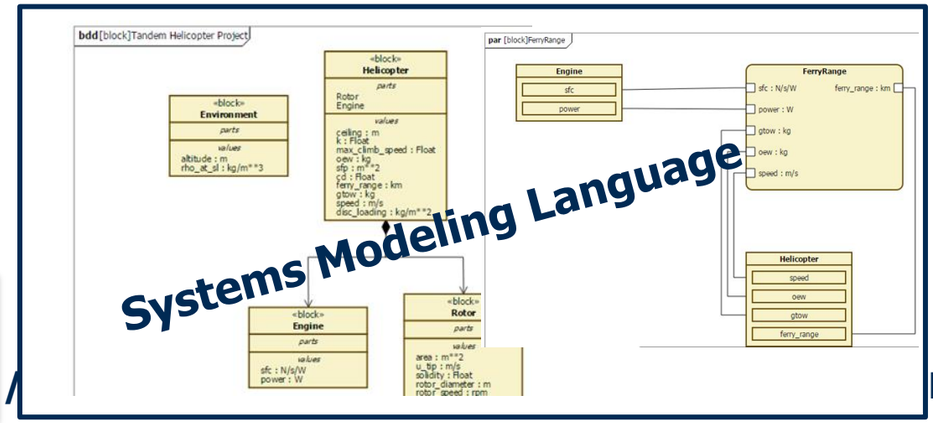
- **Engineered Resilient Systems**: Supporting DoD CoI through Army/ERDC
- **Model Based Systems Engineering:** web-based, collaborative tools and a modular framework
- Integrated with **High Performance Computing** assets at DoD Centers
- **Building on USMC Investment:** building on a multi-year USMC investment in the Framework for Assessing Cost and Technology (FACT)

Improved Acquisition & Development for Sustained System Effectiveness

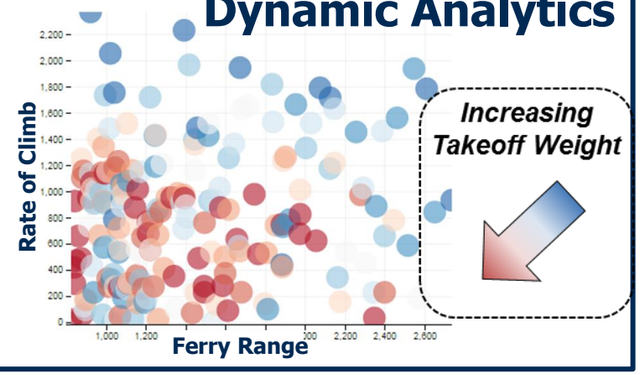
Collaborative Tradestudies

Operational "Futures"





Dynamic Analytics



What is a Smart Mine?

TRADITIONAL
Cold War
Rudimentary
Uncontrolled
Immobile
One Effect ("Boom")
Destructive
Overt
Limited depths
Many sorties

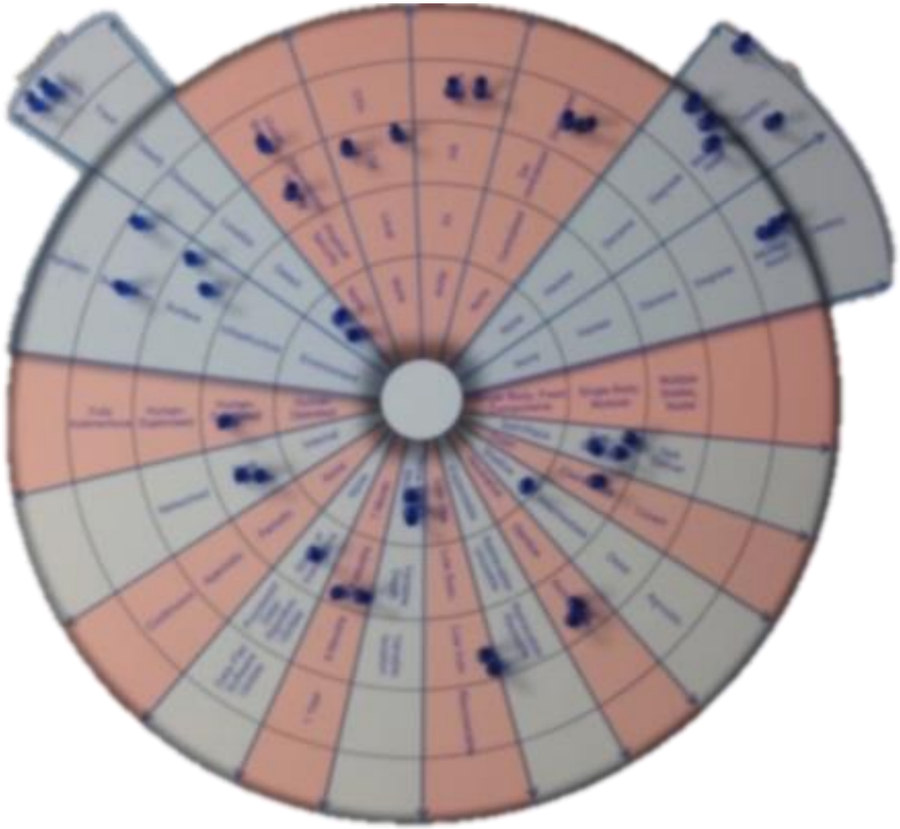
Smart Mine effort brings offensive mining into 21st Century

SMART MINE
Modern Warfare
Sophisticated
Controlled
Asymmetric
Multiple Effects
Disruptive
Robust
Variable Depth
Few sorties

Smart Mine Process

1. Collect information
   - What Capabilities Are Possible?
   - Fleet Survey
     - Scenario-Based Evaluation (Wargame)
     - Determine Which Capabilities Are Important to Users
   - Market Survey
     - NR&DE Submitted Potential Components (Effectors, Sensors, Communications, Vehicles)
     - Excel Spreadsheet Format

Capability Gameboard



Smart Mine Process

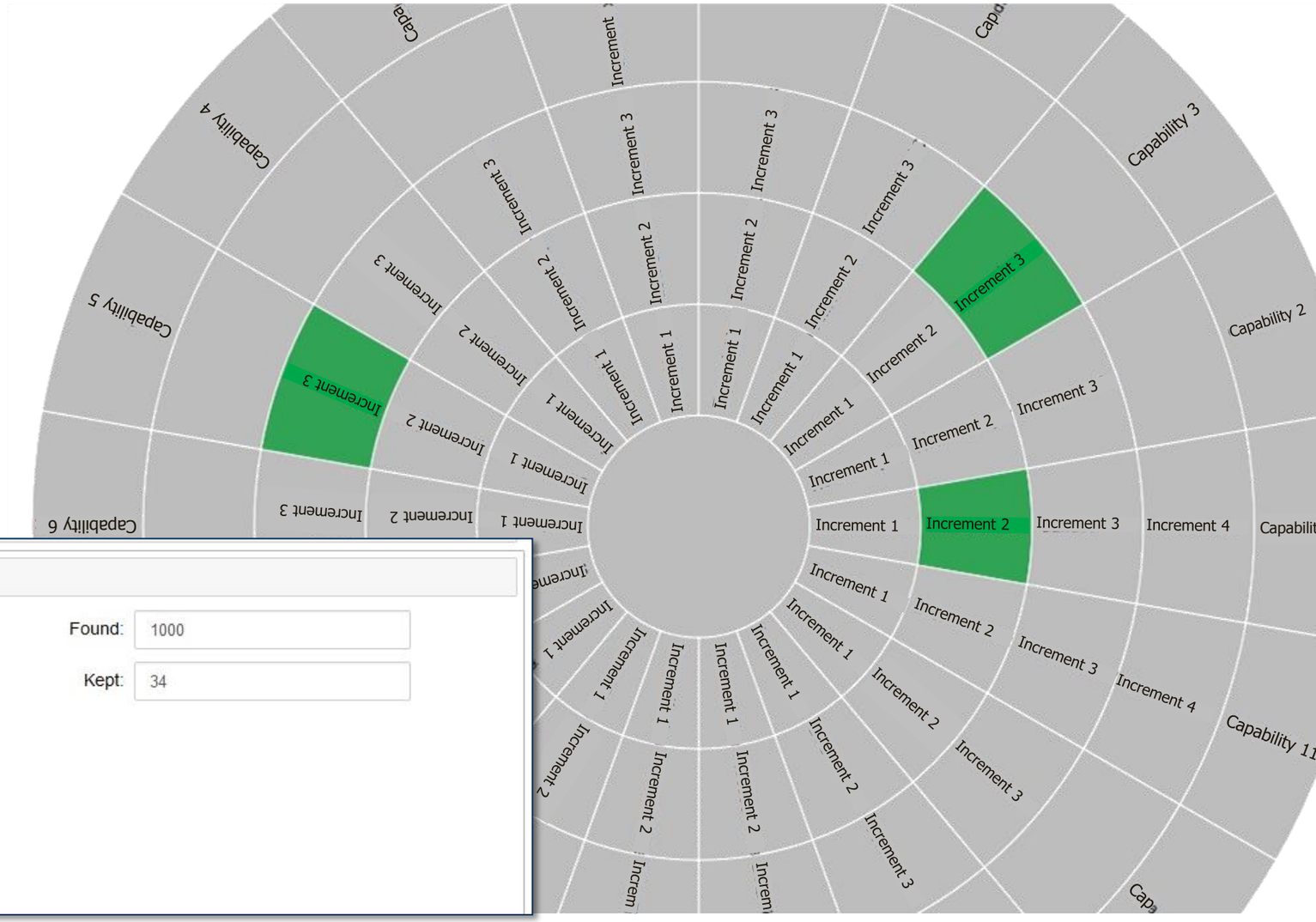
2. Generate and Evaluate Alternatives
   - Explore Complete Tradespace
     - Generate Random Configurations for Each System Architecture Concept and Sort by Average Value
   - Focus on Highly-Valued System Architectures
     - Randomly Generate ~1M Configurations
     - Effectors (2), Sensor (1), Communications (1), and Delivery (1)
   - Evaluate Attributes of Each Configuration (Value, Weight, Cost, Carrying Capacity, etc.)
   - Custom Software Written in Python Using Jupyter Notebook Environment
   - Cost Estimation Performed Using SEER Model

Note: Logos presented here are for informational purposes only and do not apply or constitute DoD endorsement.

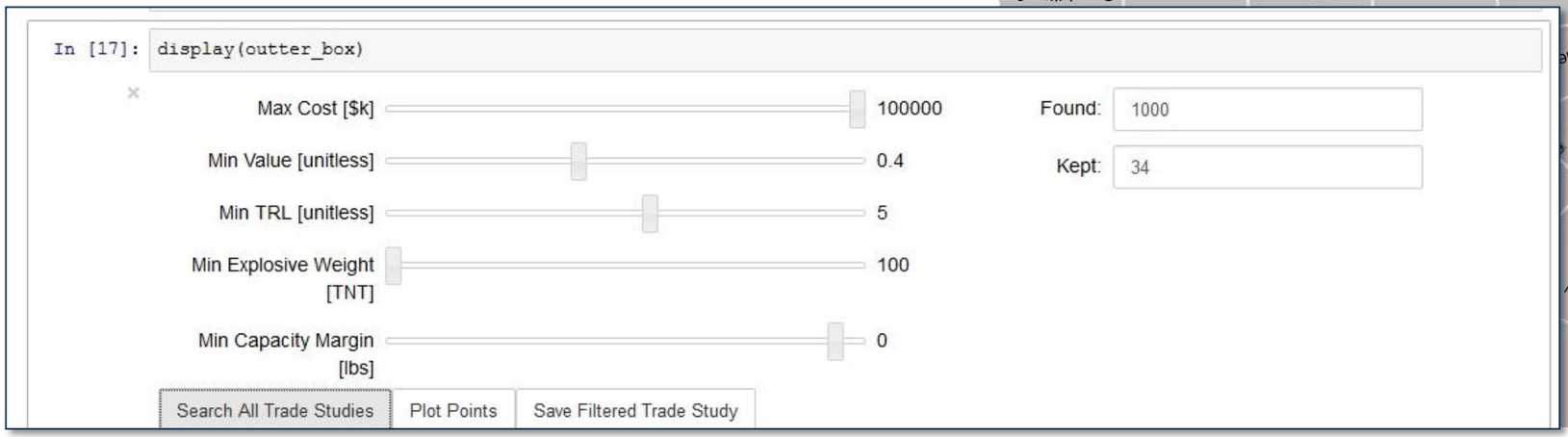
Smart Mine Process

3. Visualize and Filter
   - Filter Systems by Capabilities or Attributes
   - Determine Which Configurations Are Feasible

Filter By Capability Concepts



Filter By Attributes

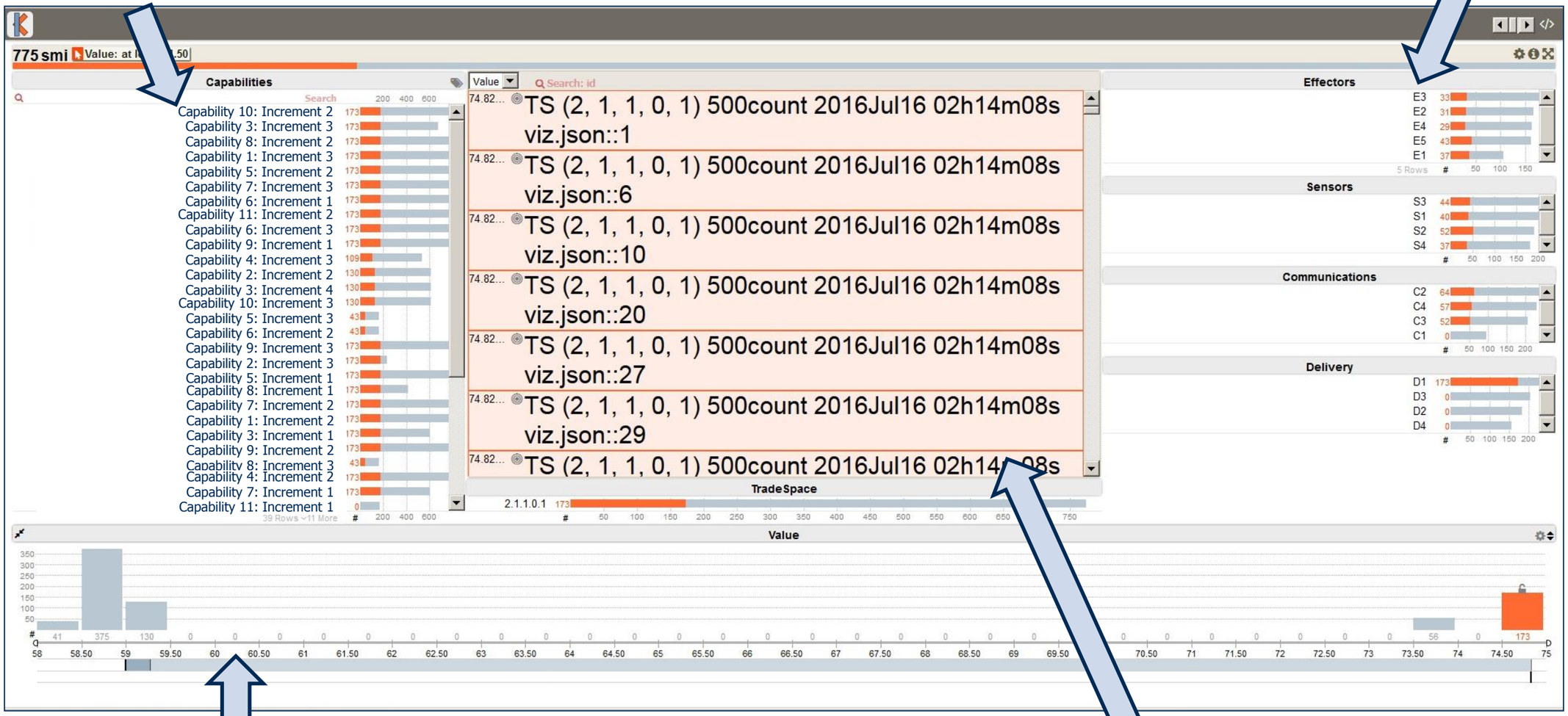


SMI Visualizations

Capability Histograms

SMI Dashboard

Component Histograms



Value Histogram

Sorted Configuration List

Impacts of Set-Based Design

- Build Trust
  - Rapid V&V instills confidence in the input data, models, and analysis results.
- Continuous Learning
  - Leverage the automated analytical framework and computing resources to search the tradespace round the clock.
  - Maintain trades throughout entire decision making process.
- Powerful Visualizations
  - Decision makers make more informed decisions through inspection of interactive visualizations
  - Gain insight into reasonable thresholds and objectives requirements

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