US ARMY RDECOM

U.S. Army Research, Development and Engineering Command

Engineered Resilient Systems: A Practical Armament Example and Study

19th Annual NDIA Systems Engineering Conference

ARMAMENT RESEARCH, DEVELOPMENT AND ENGINEERING CENTER
PICATINNY ARSENAL, NJ

TECHNOLOGY DRIVEN. WARFIGHTER FOCUSED.

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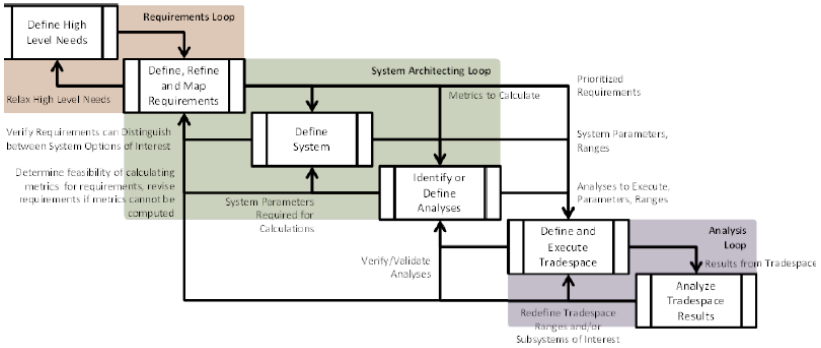
ERS Tradespace Analysis

ENGINEERED RESILIENT SYSTEMS
DEPARTMENT OF DEFENSE
T R A D E S P A C E



- **Define**
  Users describe the needs, the analyses to assess whether or not the needs are met, and the system(s) being designed to satisfy those needs
- **Execute**
  Users set conditions for and manage/monitor the execution of the integrated engineering models
- **Analyze**
  Users assess the information generated by the execution of the models to improve their mental models of the problem and the system of interest

MBSE
Model Based Systems Engineering

MDAO
Multidisciplinary Design Analysis and Optimization

MCDM
Multi Criteria Decision Making

- **Discover what building engineered resiliency means to Armaments**
- **Learn how to utilize ERS Tradespace Tools to support Army RDT&E projects**
- **Investigate Integrated Model Based Engineering best practices (MBE & MBSE)**
- **Advance Multi-Objective Decision Analysis methodology and tool**

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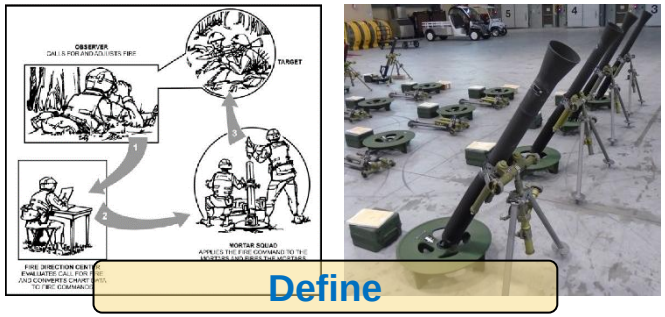
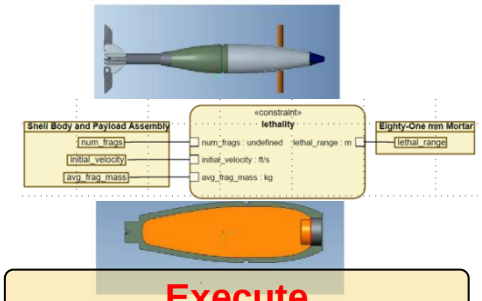
Background
Mortar Munition Case Study

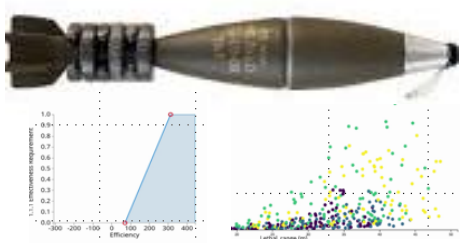
Goal	To utilize ERS Tradespace software tools to implement ARDEC SE best practices utilizing an Integrated Model Based Engineering approach on RDT&E projects
What	Proof of Concept to exercise Engineered Resiliency in Munitions Systems Design
Scope:	Leverage Mortar Domain System Model example and executable physics based models to generate multi-objective Tradespace analysis for optimized system performance (lethality, effectiveness, cost)



Define



Execute



Analyze

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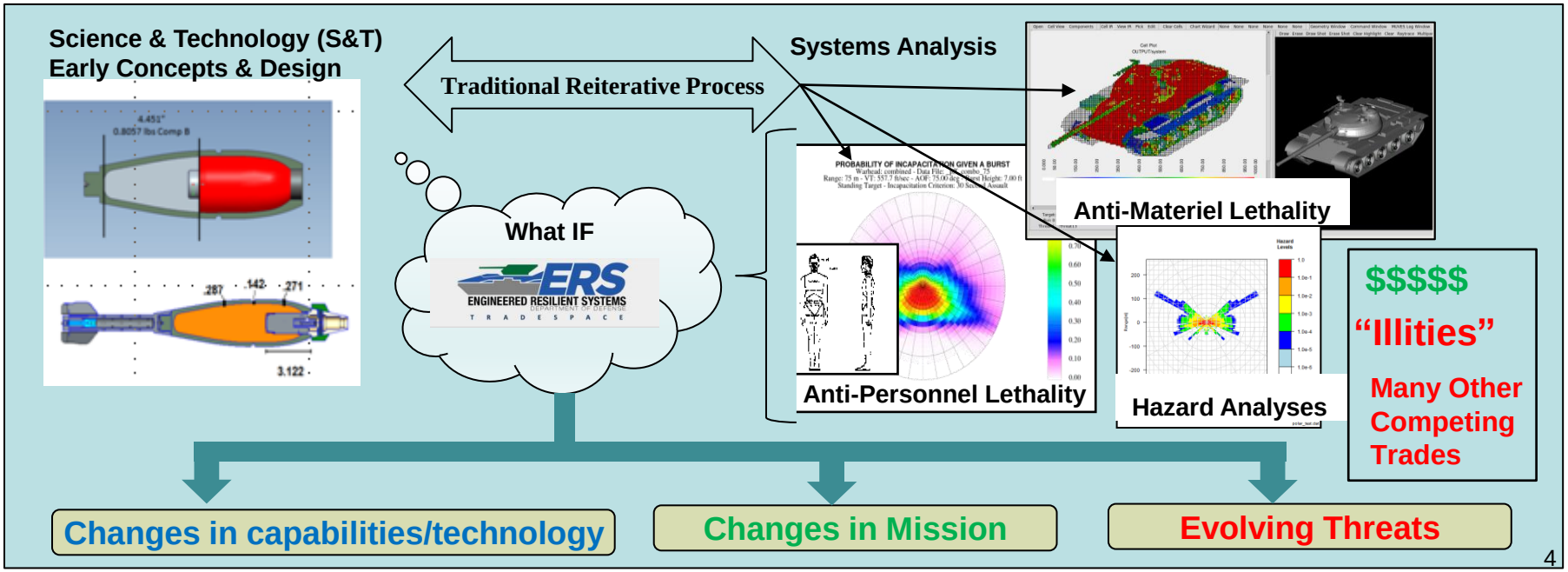
Building Resiliency into Munitions System Design

Can the use of ERS methods, processes, and tools improve the Systems Engineering design process?

- Better understand the exchange and integration of the Systems Model Concept
- Capture rationale from Concept Feasibility Studies
- Capture and link engineering analysis to support Requirements Analysis and Architecture Design Phases
- Improve the identification and prioritization of SE Trade Analysis

Tradespace analysis for an optimized and resilient munition



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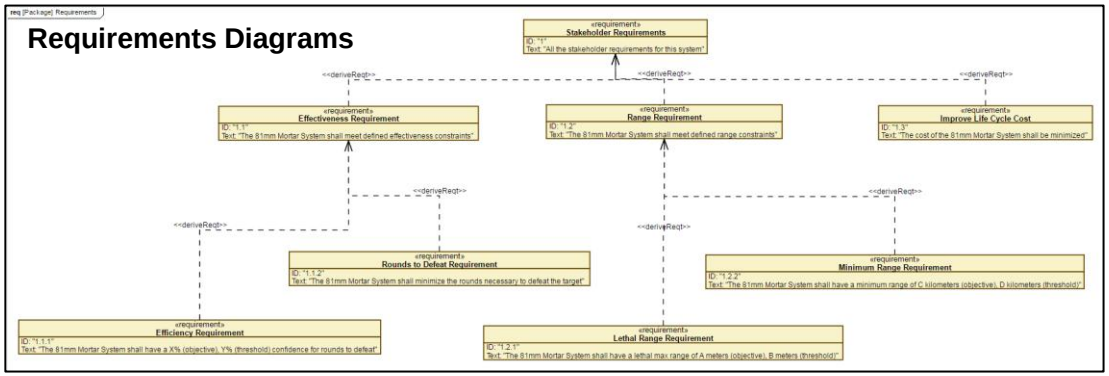
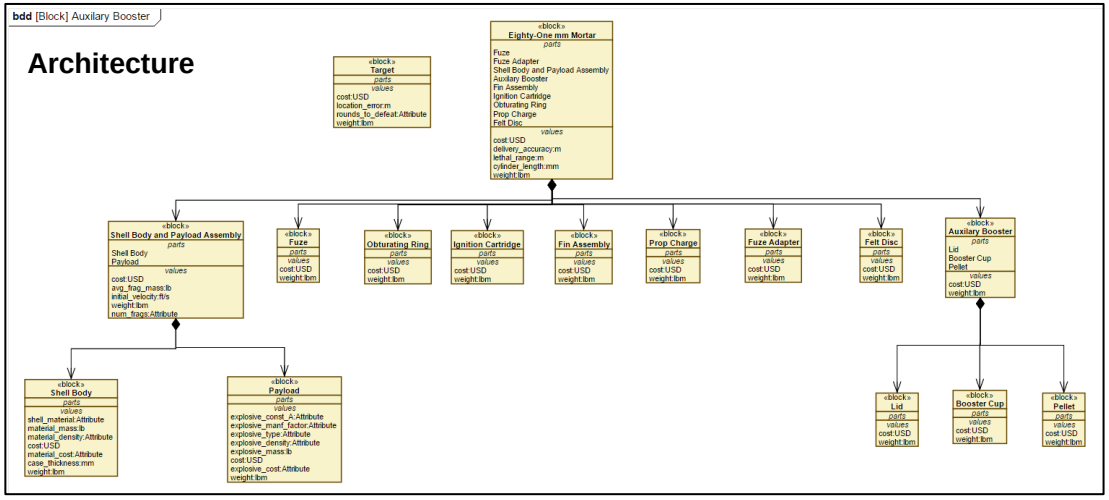
Trade Define: Model Based SE

Science & Technology (S&T)
Early Concepts & Design

Component
Fuze
Booster
Body
Payload **(Explosive Fill)**
Obturator
Ign. Ctg.
Inc. Cont.
Prop Chg.
Fin





Trade Define: Model Based Systems Engineering (MBSE) approach to conduct:

- Stakeholder Requirements Definition: Operational Requirements, CONOPS, MoEs/MoPs
- Requirements Analysis: Traceability, Visualize Relationships
- Architecture Design: Analysis to enable Tradespace Exploration, Conduct Systems Engineering Trade analysis, and Enable Multi-Objective Decision Analysis (MODA)

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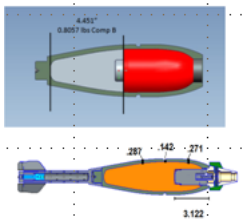
Trade Execute: Multidisciplinary Design Analysis and Optimization (MDAO) "The Process"

Early Concepts & Design



Shell Material

Explosive Type

Cylinder Length (mm)

Cylinder Thickness (mm)

Fragmentation Simulation Model

Material Attributes

Explosive Attributes

Cost Model

$$$$$

Unit Production Cost (USD)

Average Fragment Mass (grains)

Fragment Initial Velocity (ft/s)

Number of Fragments

Delivery Accuracy

Location Error

Lethal Area Simulation Model

Lethal Range Threshold (m)

RTD Simulation Model

Rounds to Defeat (30% confidence)

Key
Continuous Input
Discrete Input

- Modeling the Multidisciplinary Analysis Workflow
- Integrated multi-domain analysis into ERS execution

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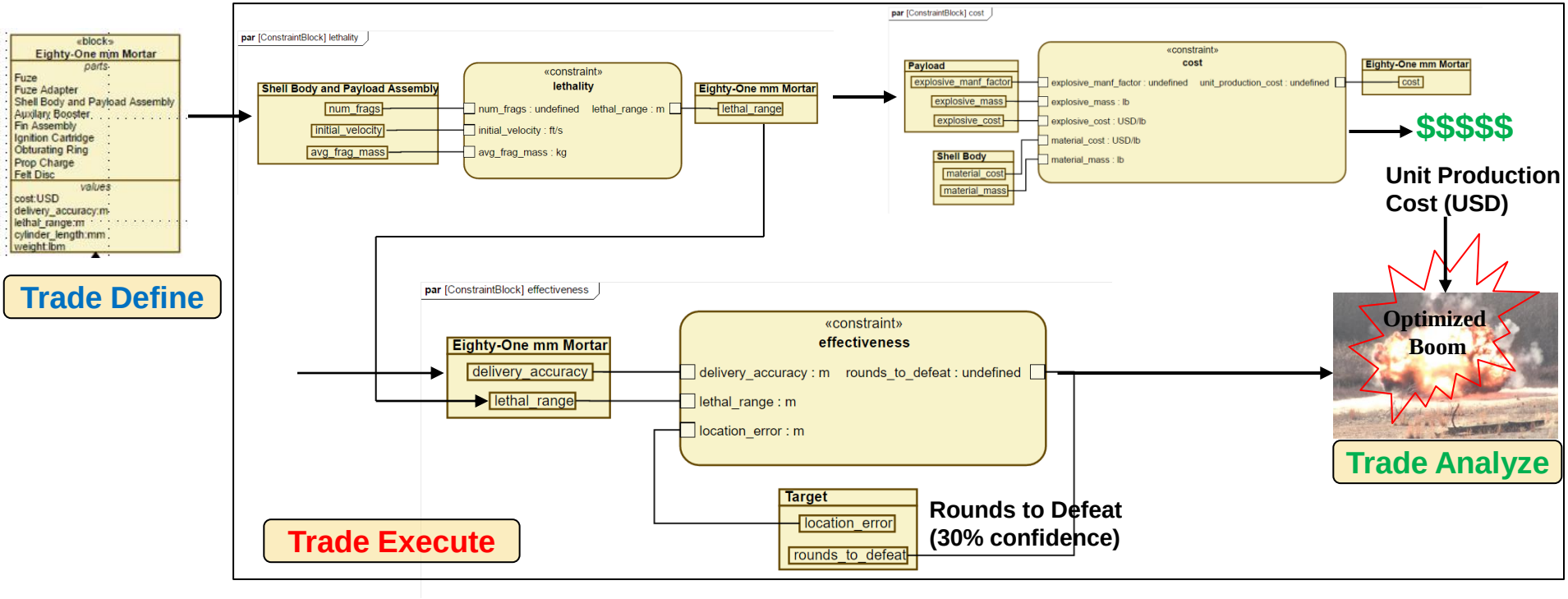
Trade Execute: MDAO Implementing "The Process" in ERS



Trade Execute: Model Based Systems Engineering (MBSE) approach to:

- Establish a Dynamic Model Execution Framework for your specific Problem Space/System of Interest (executable model)
- Comprehensive models/visualization of the multi-disciplinary system analysis process and workflow to analyze system level performance
- System Requirements, Architectures, Physical Design Space are all traced to enable System Analysis activities and SE Trades

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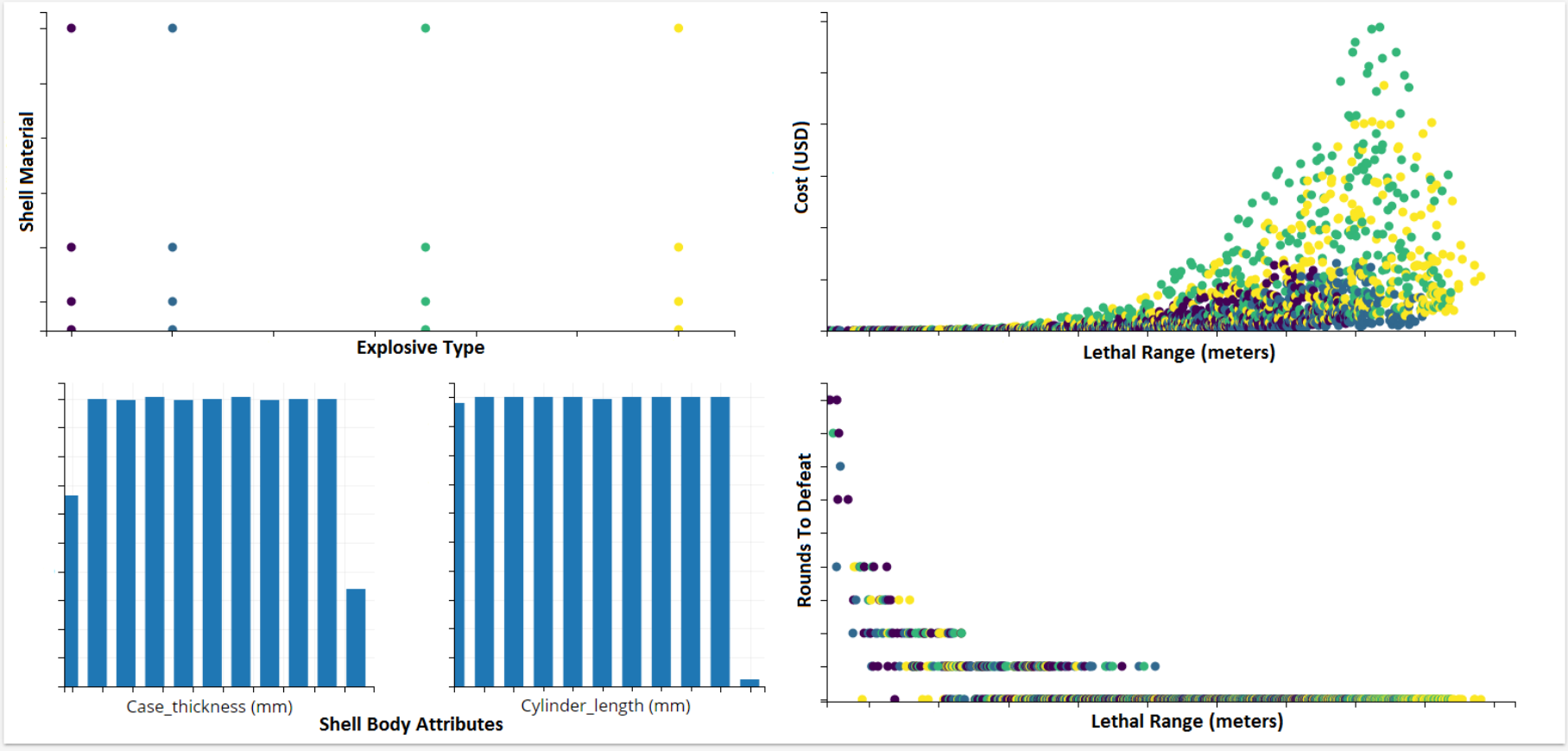
Trade Analyze: Tradespace Analysis



Trade Analyze: Across Multi-Criteria (system level requirement)

- Provides a powerful visualization workspace to quickly view analysis results across large tradespace
- Toolset includes histograms, scatterplots, boxplots, sensitivity analysis, etc.

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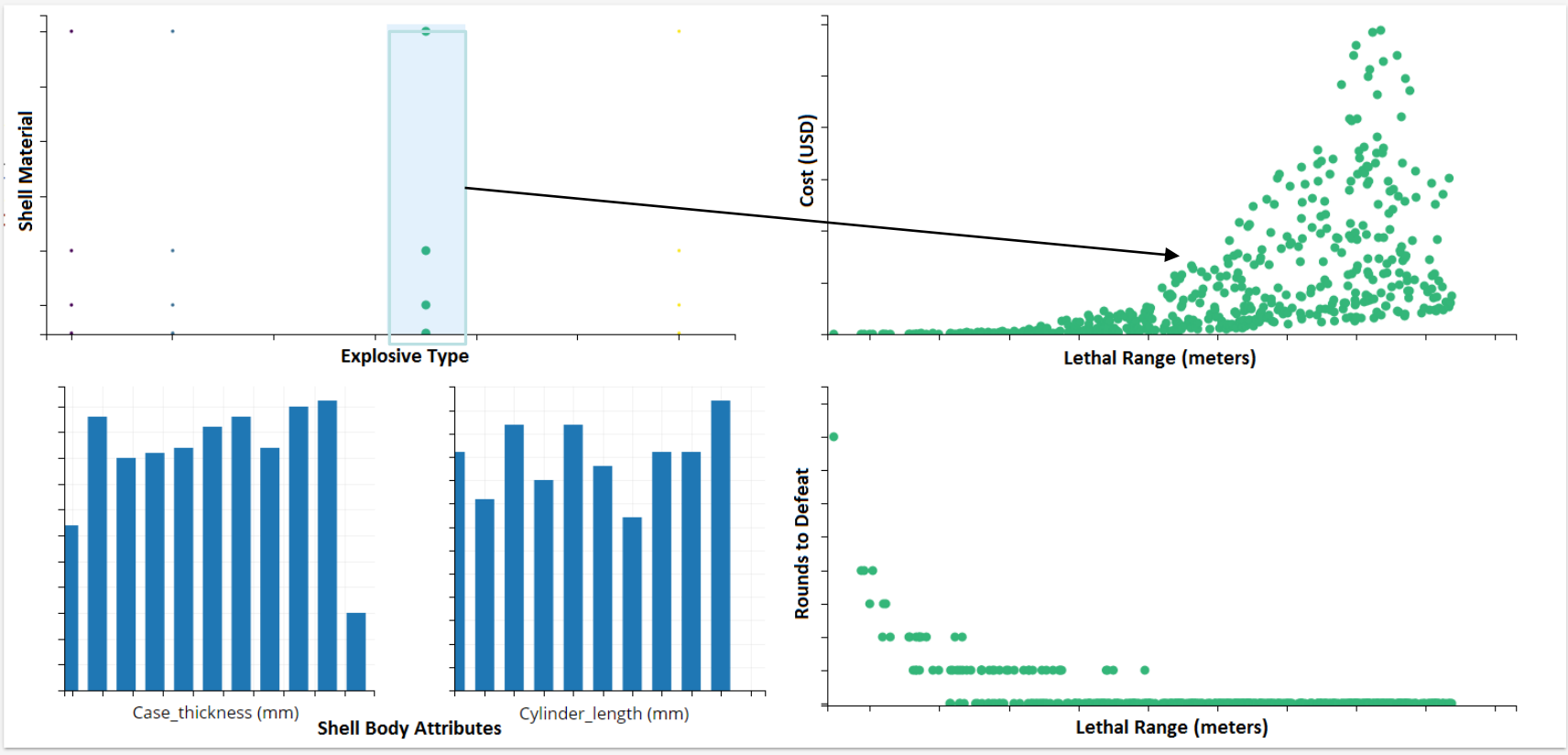
Trade Analyze: Tradespace Analysis



Trade Analyze: Focus on single criteria (individual requirement)

- Visualizations provide dynamic filtration tools
- Easily able to assess system relationships and behaviors

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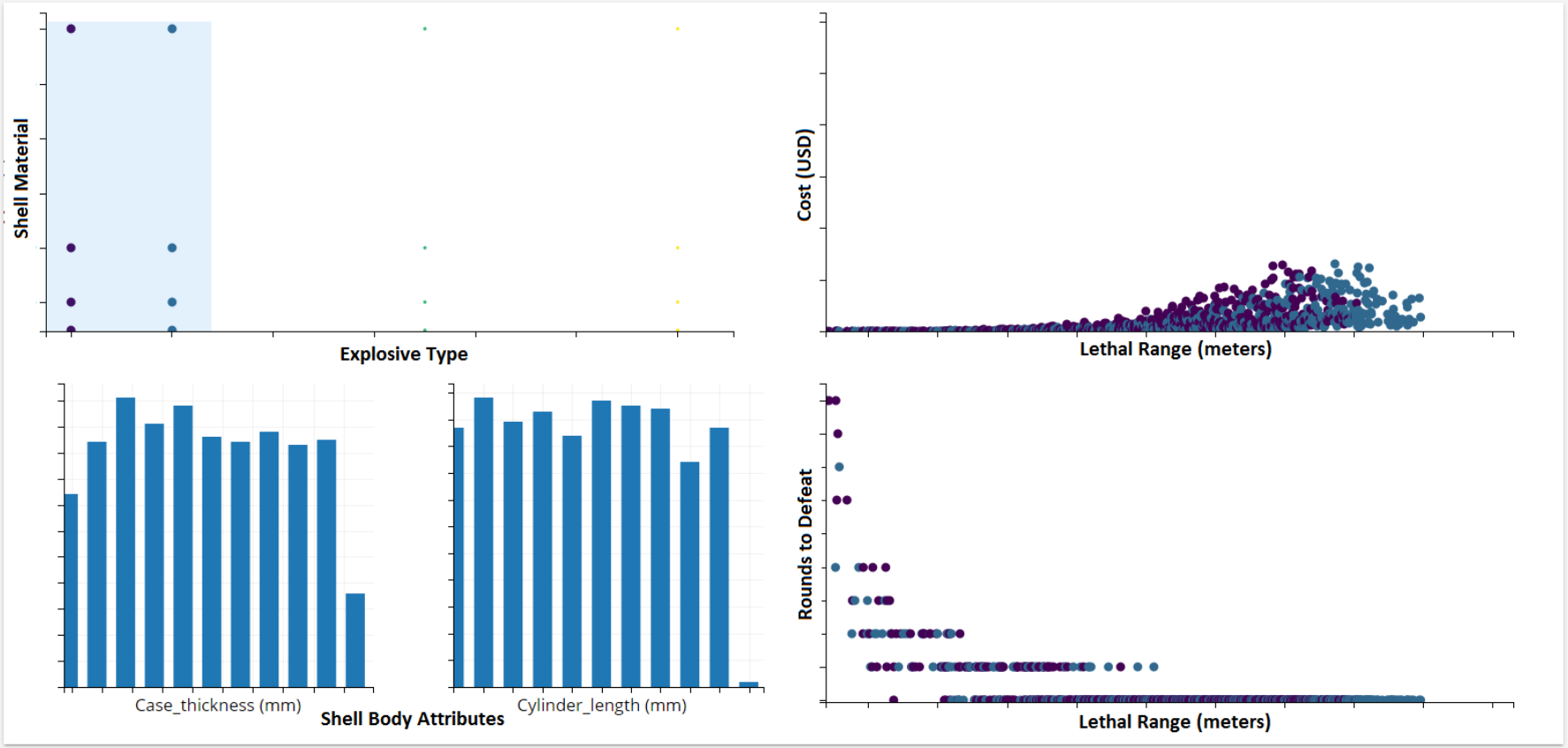
Trade Analyze: Tradespace Analysis



Trade Analyze: Multi-Criteria Decision Making (MCDM)

- Ability to generate probabilistic solutions versus point solutions
- Tools are feature rich and capable of superimposing constraints for ease of use
- High volume data sets on the order of 10^3 can be reduced to ~25

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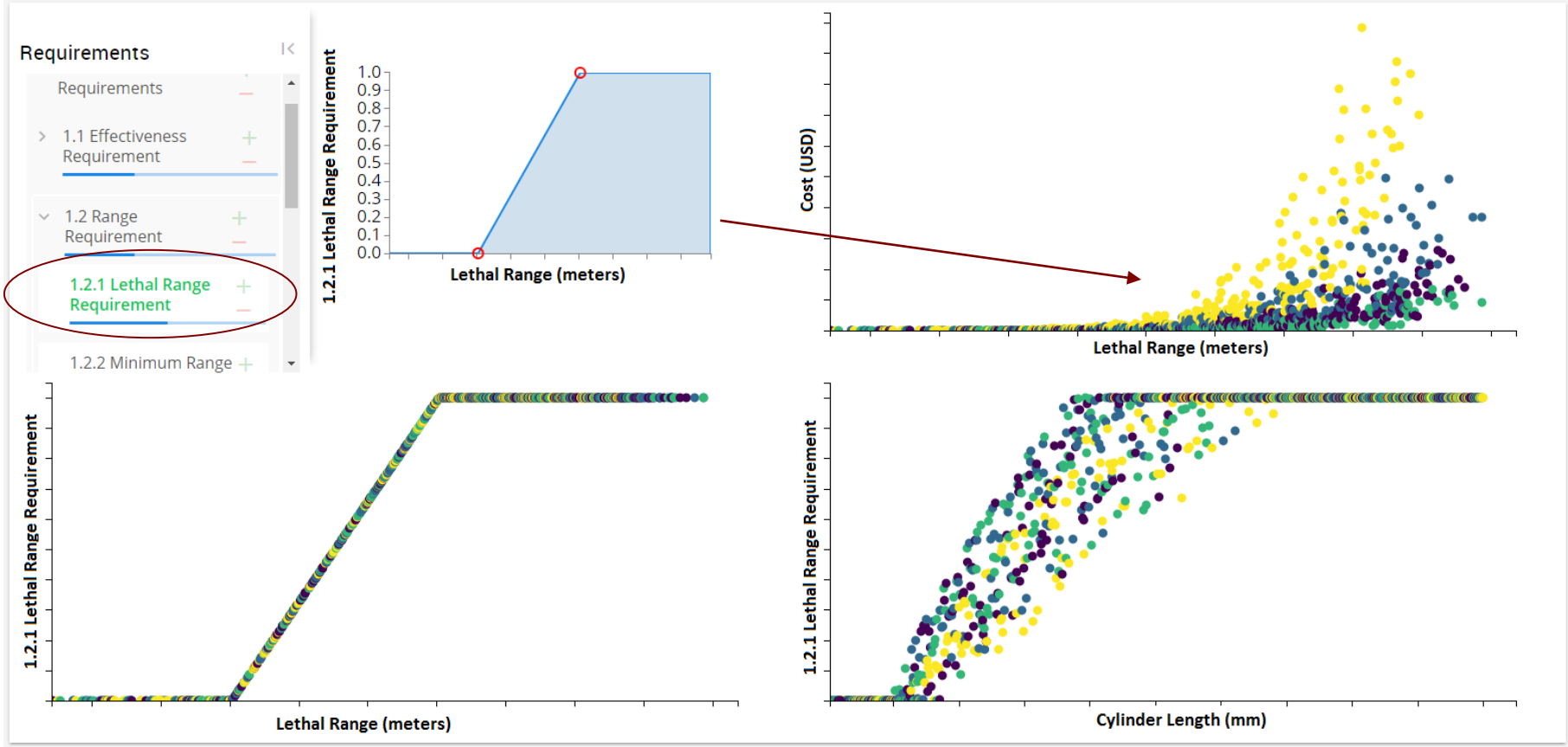
Trade Analyze: Tradespace Analysis



Trade Analyze: Individual Requirement

- Enables the ability to compare configurations against specific requirements
- Requirements can be adjusted and effects of changes are seen on dynamic plots

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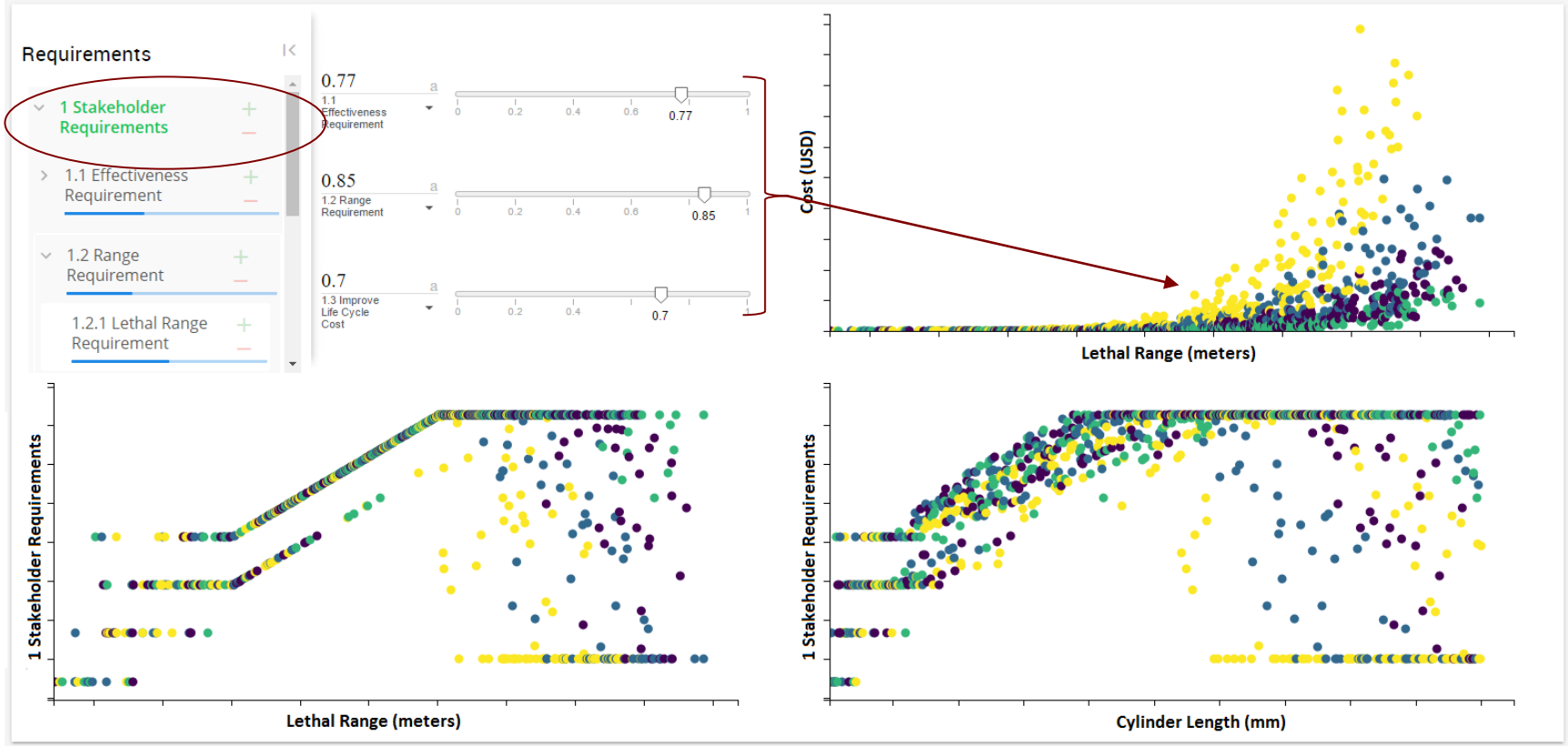
Trade Analyze: Tradespace Analysis



Trade Analyze: Set of Requirements (System Level)

- Full customization of weighted requirements is accessible
- Provides a view comparing various configurations ability to satisfy requirements

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Was the Boom Worth It?

- Modular Analysis & Tools to create reusable set of System Models
- Ability to integrate multi-disciplinary design analysis tools
- Powerful set of large Tradespace Analysis Tools
- Improves efficiency and reduce time to engineer concepts/designs to meet emerging requirements

"Systems engineering (SE) establishes the technical framework for delivering materiel capabilities to the warfighter…. SE also enables the development of engineered resilient systems that are trusted, assured, and easily modified (agile)." DAG Chapter 4

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What's Next

- Continue to partner with ERS Community & ERDC to continue research, development, and project pilots of ERS Tradespace Tools at ARDEC
- Implement Decision Management Process[1], algorithms, and visualization into ERS Multi-Objective Decision Analysis (MODA) tool set
- Project Pilots/Use Cases to demonstrate utility and gain lessons learned to prepare for "culture shock" (introducing new methods, tools, and integration)
  - Integrated Model Based Engineering (MBSE & MBE)
  - Preparing to break down stove pipes
  - Anticipate the learning curve and training
  - Tradespace Tools to ARDEC SE Workforce, "another tool in the SE Tool Kit"
- Explore the state of the art and untapped potential of ERS
  - Ability to generate a large Tradespace and powerful Execution and Visualization
  - Ability to integrate multi-disciplinary analysis and visually assess across multi-domains on the same playing field
  - Collaborative Web Based Tools

[1] Cilli, M., *Improving Defense Acquisition Outcomes Using an Integrated Systems Engineering Decision Management (ISEDM) Approach.* Ph.D. Dissertation. Stevens Institute of Technology, Hoboken, NJ, 2015

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Lessons Learned and Parting Thoughts

- ERS offers integration between traditional SE and ORSA Domains
  - Ability to effectively re-use MBSE Artifacts for Systems Analysis, Tradespace Analysis, & Decision Analysis.
  - Powerful set of tools to conduct dynamic analysis
  - Re-useable set of models for alternatives/variant analysis
- Ability to conduct large Tradespace exploration
  - Ability to develop probabilistic solutions versus point solutions
  - Encourages the use and need for additional and rigorous SE Trade Analysis
  - Supports informed decision making (give them the tool and they will come)
- Supports the Systems Model Concept
  - Full Traceability between requirements, architectures, and models
  - Enables IPT working in collaborative web integrated development environment

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