



Engineered Resilient Systems Tradespace Enabled Decision Making

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Tommer R. Ender, PhD
Electronic Systems Laboratory
Georgia Tech Research Institute
tommer.ender@gtri.gatech.edu

Simon R. Goerger, PhD
Engineer Research & Development Center
US Army Corps of Engineers
simon.r.goerger@erdc.dren.mil

Christopher McGroarty
Simulation and Training Technology Center
Human Research and Engineering Directorate
Army Research Laboratory
christopher.j.mcgroarty.civ@mail.mil

Eric Spero
Vehicle Applied Research Division
Vehicle Technology Directorate
Army Research Laboratory
eric.spero.civ@mail.mil

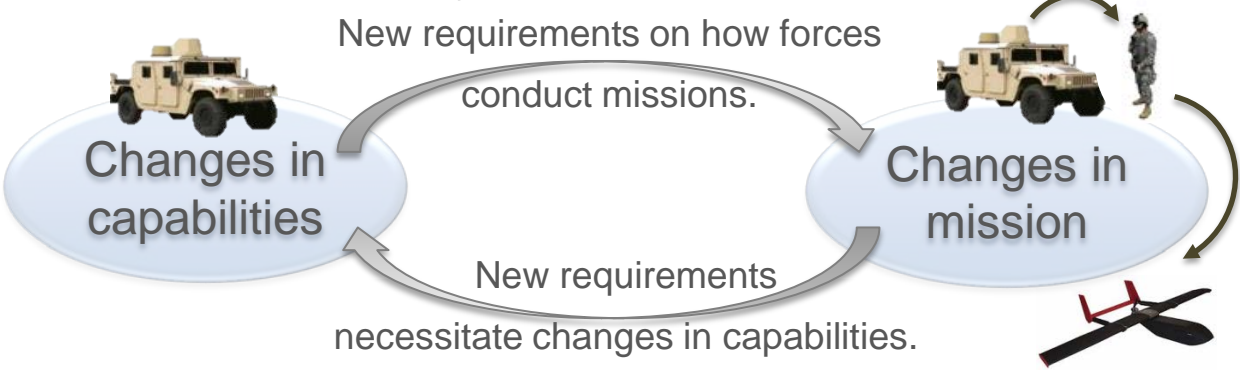




Motivation: Resilience over the System Lifecycle

No one system can meet future, unspecified requirements and capabilities across its lifecycle, therefore design choices must be made

The operational reality:



– Our goal –

Enable systems engineers to design and analyze more effectively and rationally in support of Pre-Milestone A Tradespace Analysis.

Has led to:

“ERS will empower pre-materiel analysis with significant impact on:

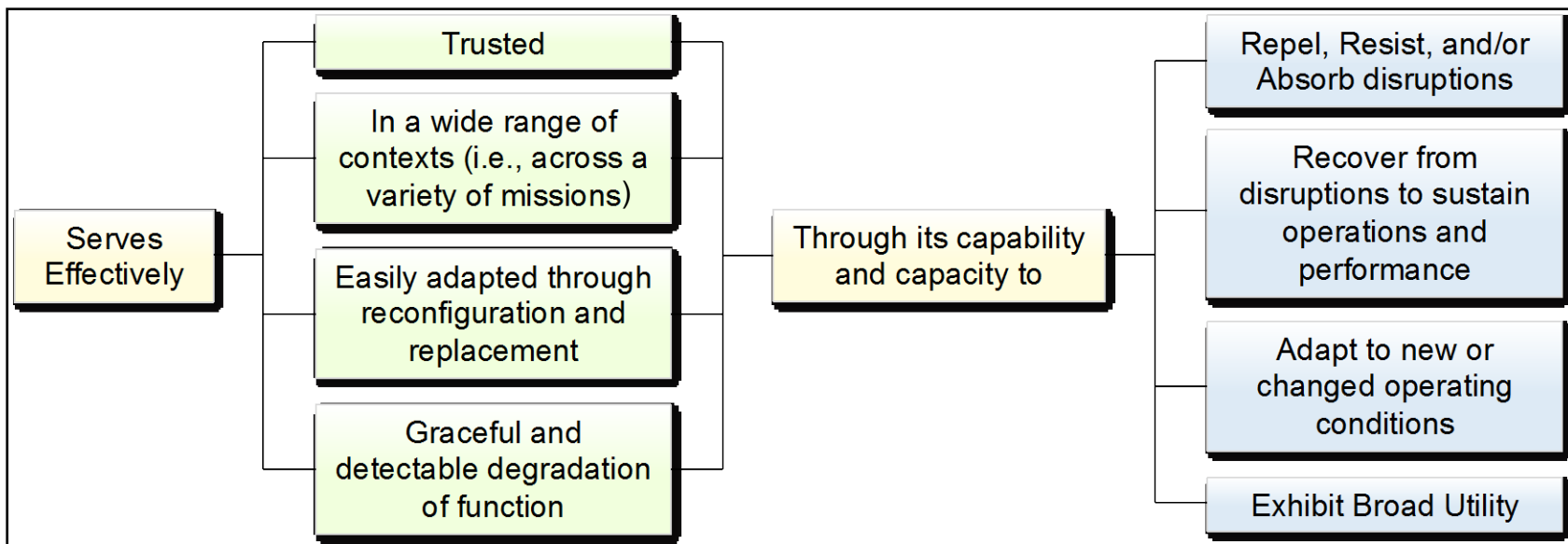
- Requirements Generation*
- Analysis of Alternatives*
- Lifecycle Intelligence”*

~ Dr. Jeffery Holland, ERS Overview Dec 2013



Definition of Resiliency

- ✓ Trusted and effective out of the box
- ✓ Can be used in a wide range of contexts
- ✓ Easily adapted through reconfiguration and replacement
- ✓ Graceful and detectable degradation of function





Tradespace Analysis for Early-Stage Design

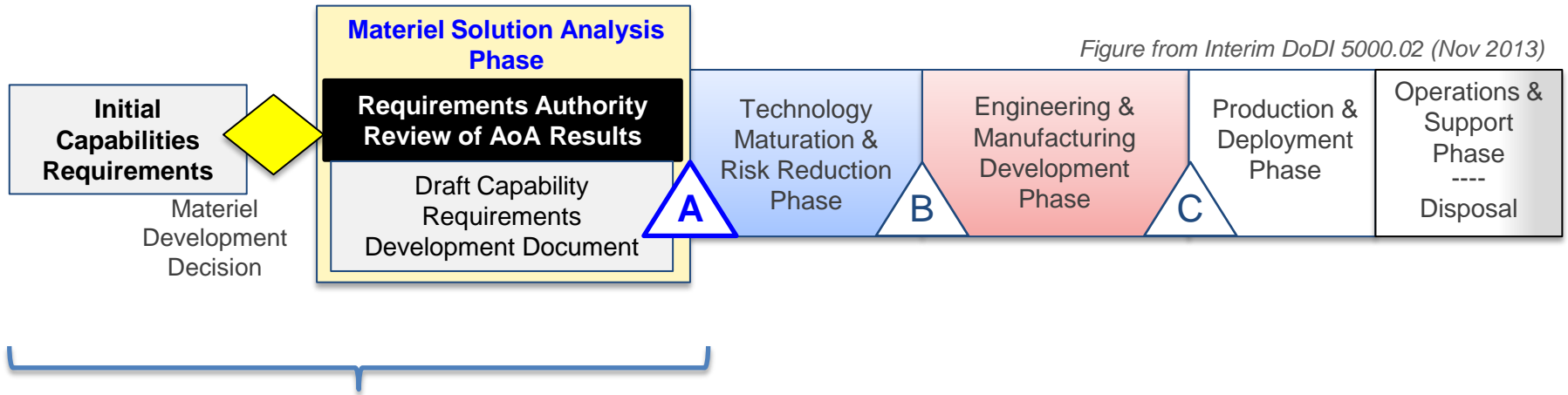


Figure from Interim DoDI 5000.02 (Nov 2013)

Objectives

- Identify, develop, and integrate a **design space analysis environment and integrated workflow**
- Investigate how to **operationalize formalisms** into measureable and executable constructs
- ... to support **Pre-Milestone A** Tradespace Analysis

Purpose

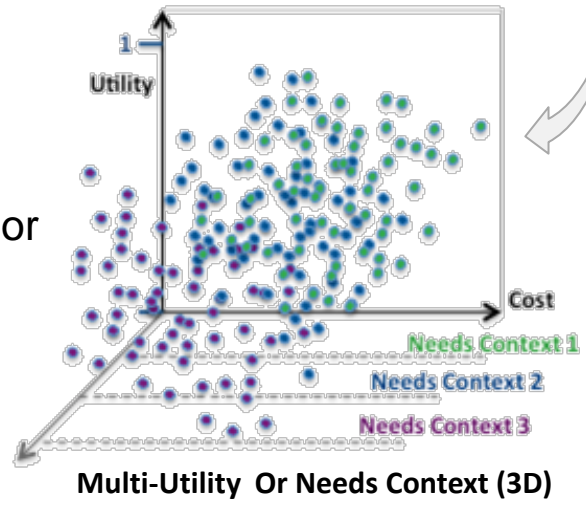
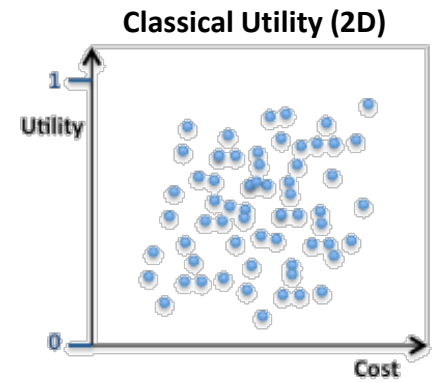
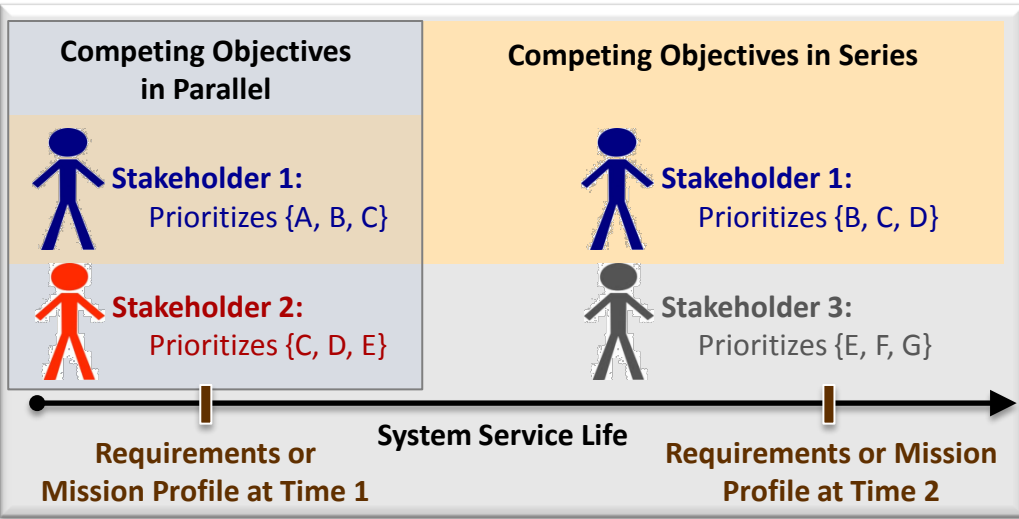
- To support investigation and comparison of new methods and constructs for design exploration*
- To create flexible, rationally guided analyses in a way that allows the customer to quantify and visualize the impact of various requirements*

Source: Sitterle, V.B., Curry, M.D., Freeman, D., Ender, T.R., "Integrated toolset and workflow for tradespace analytics in systems engineering," Proceedings of the 24th INCOSE International Symposium, 30 June to 3 July 2014.



Needs Context Analysis

Evaluate Design Alternatives according to their capabilities and characteristics as 'valued' by Stakeholders

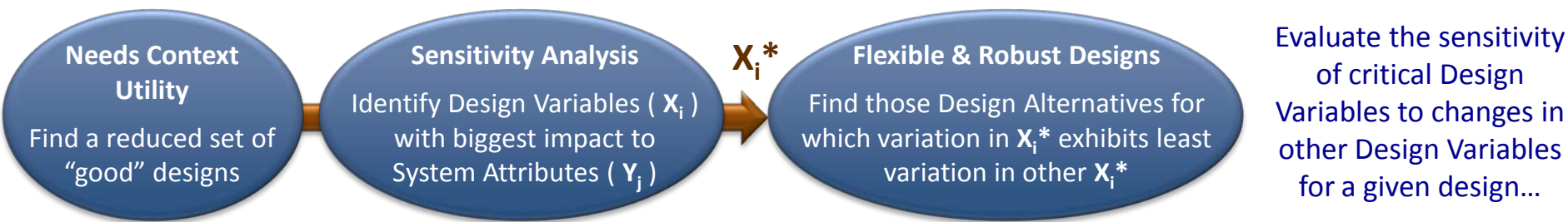


- Enables analysis across **Stakeholders** & **Mission Profiles** that necessitate different objectives
- Helps capture **Resiliency** of a system design across competing or changing requirements
- Addresses '**Robustness**' of system capabilities using a **Broad Utility** construct.
- Scaled against **Objective and Threshold** requirement levels (**Key Performance Parameter concept**) to promote comparability across analyses



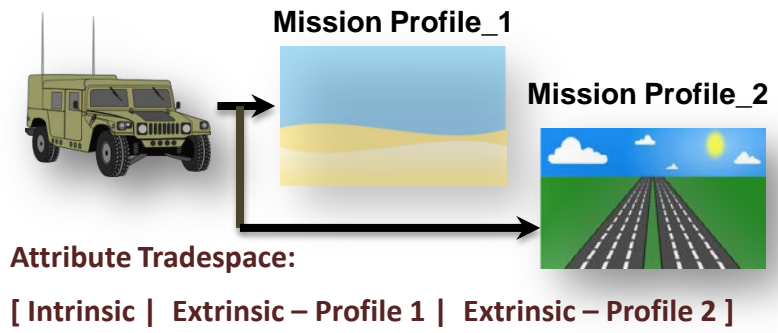
Risk in the Engineering Process

- Evaluate risk associated with initial engineering design selections or later changes of key system components



Begin to paint a proxy picture of how an Engineering Change will impact the entire system design.

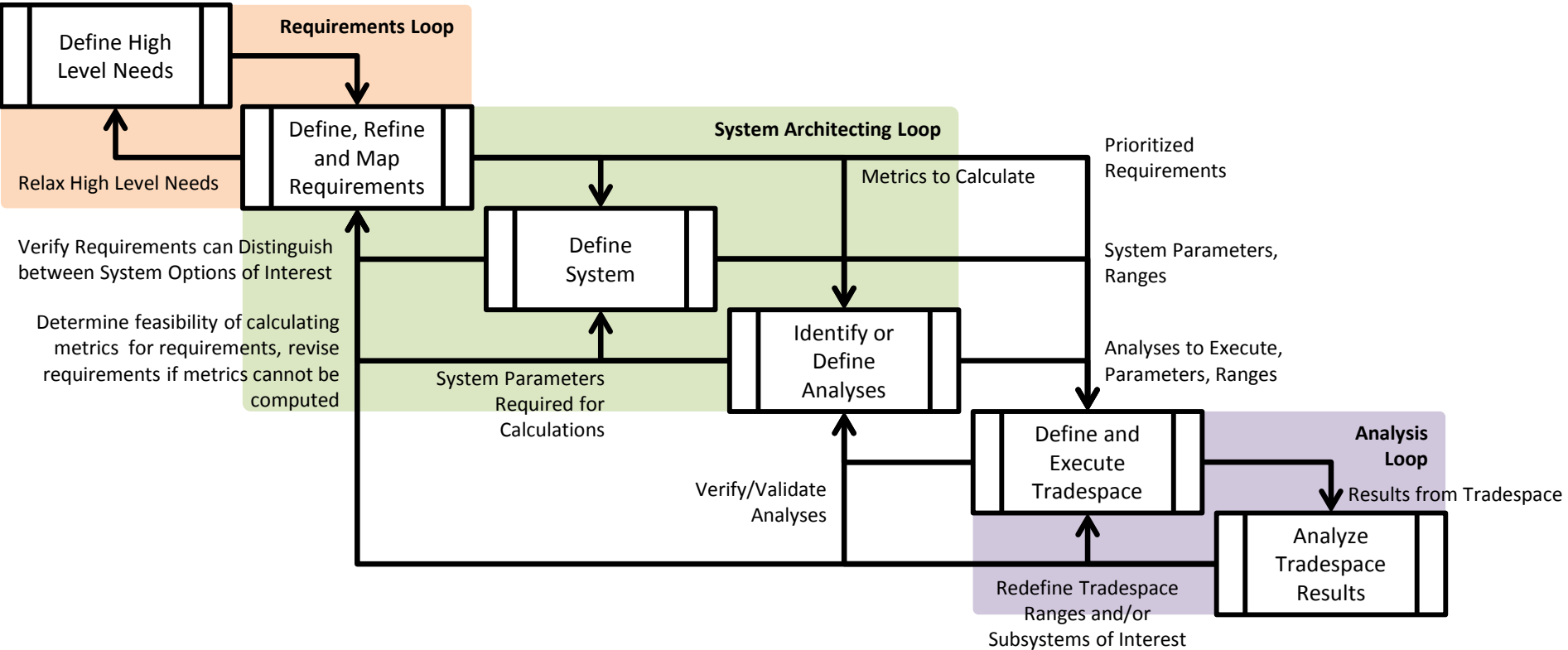
- Evaluate dimensions of Resiliency one at a time; design workflow to support analytical synthesis
- Next, mature the concept of context to include operational & environmental characteristics; adds dimension to Tradespace and takes a step toward a profile or topography of Resiliency





Networked Workflow through a Design Space Environment

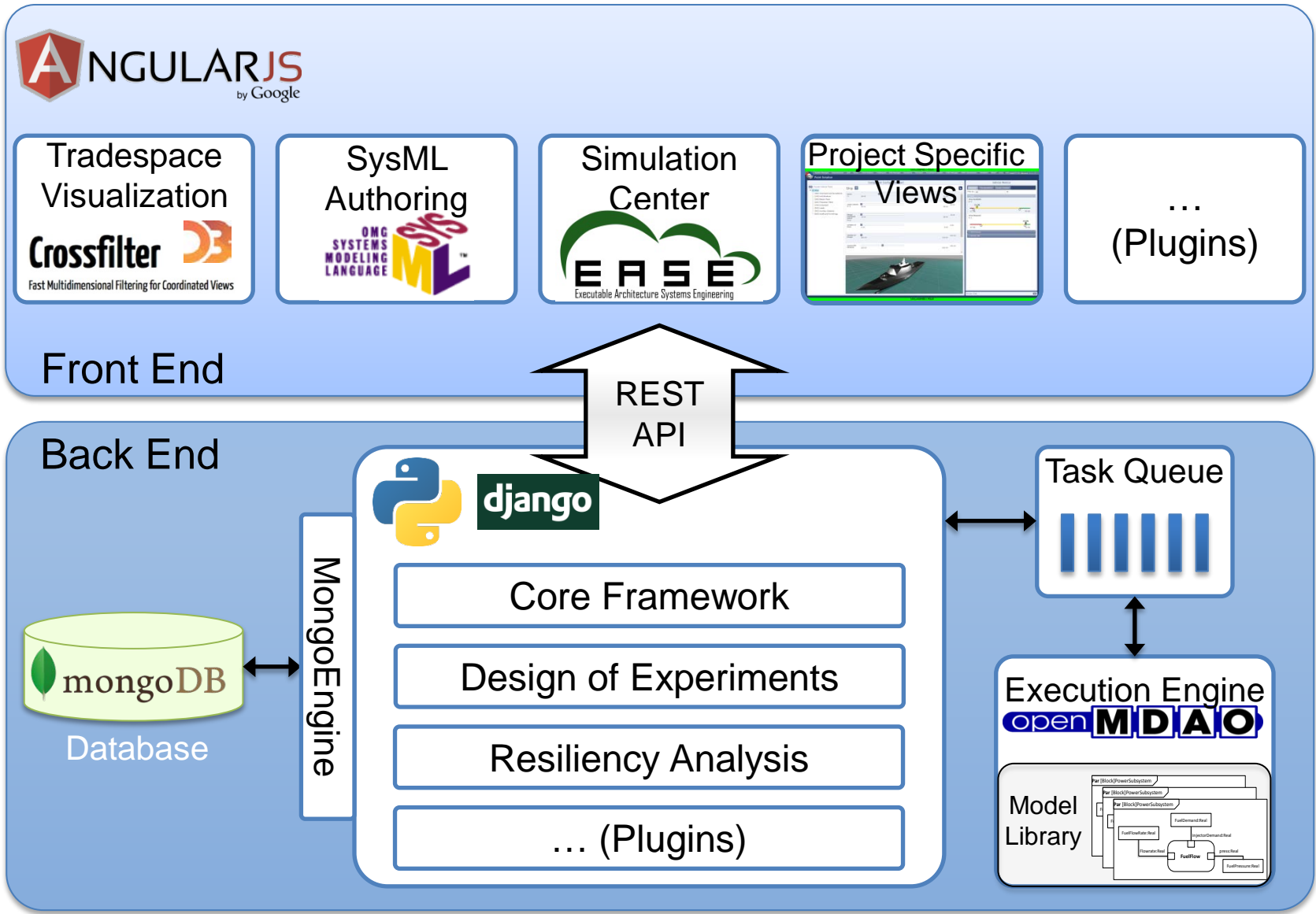
Generalized Systems Engineering Workflow showing the set of all Systems Engineering Use Cases



A use case has a specific path through the networked workflow. Driving the tool development with the generalized workflow helps ensure we can meet the requirements of *future* use cases.

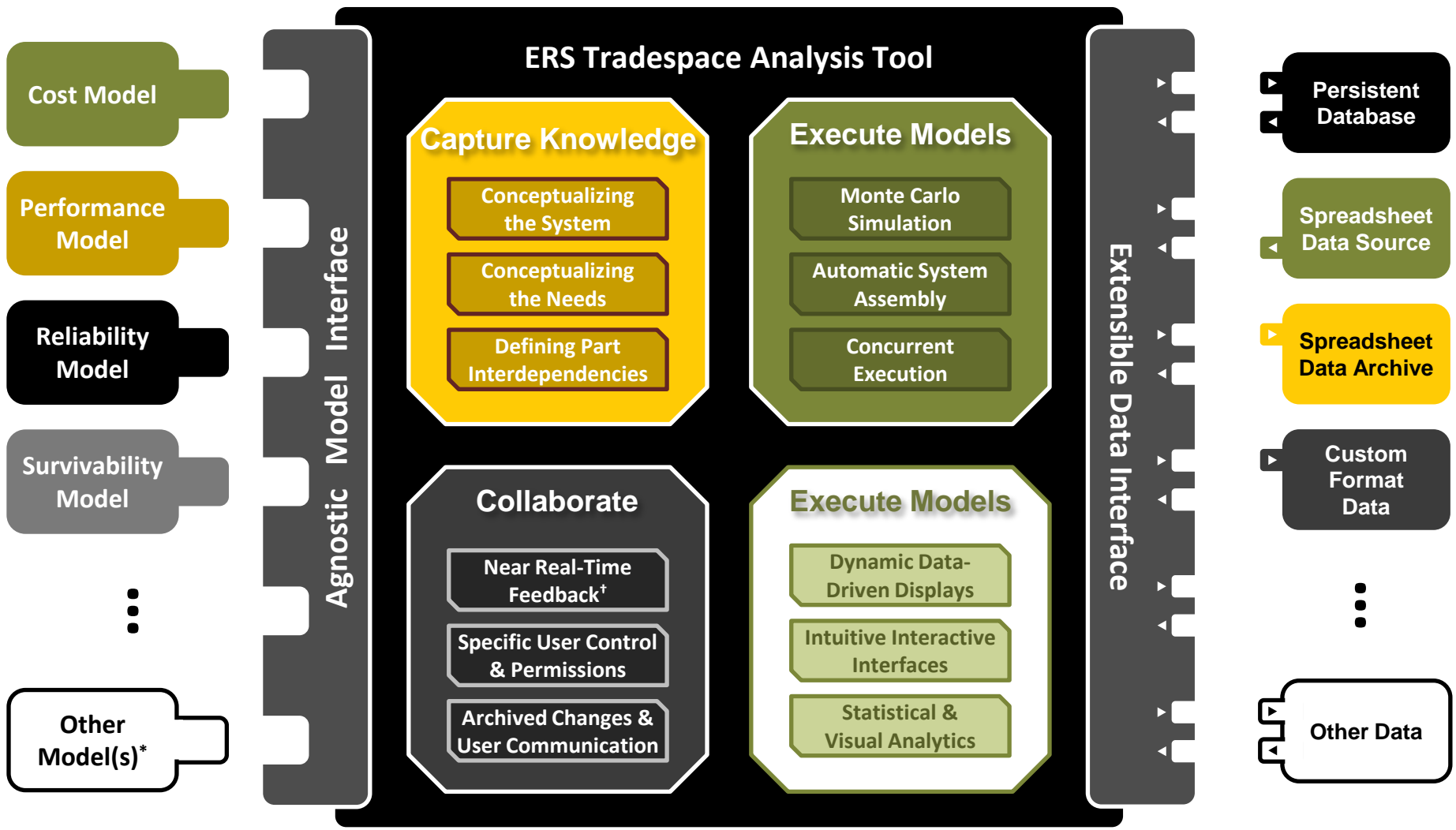


ERS Tradespace Analysis Tool: Software Architecture





Tradespace Capabilities

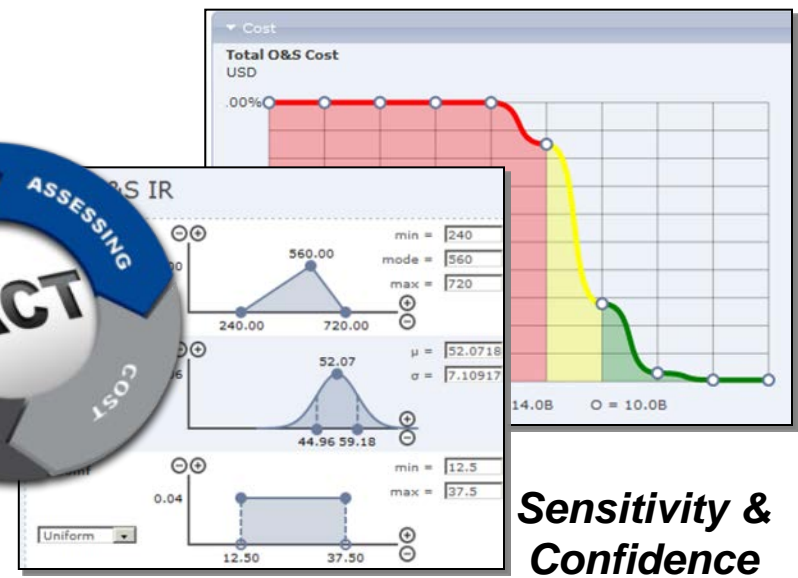
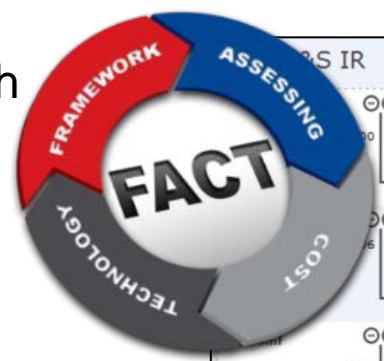


* There can be multiple models within these generic categories, e.g., cost models for both the life cycle and acquisition, each being its own "peg"
[†] Requires integrated models to be executable in near real-time



Leveraging USMC Investment in Collaborative MBSE

- **Collaborative Development:** browser-based tool enables analysis as a web service
- **Performance:** “black box” approach to performance models integration through metadata interface
- **Cost:** acquisition cost estimating relationships and trusted Operations & Sustainment cost model
- **Model Based Sys Eng (MBSE):** conforms to SysML and accepted systems engineering standards



Sensitivity & Confidence Analysis

Dynamic System Comparison

	Alternative 1	Alternative 2
Land Range at Cruise 300.00 400.00	243.83 mi	409.58 mi
Max Swim Speed 8.00 12.00	7.89 mph	10.30 mph
Max Water Speed at 1' SWH 8.19 17.48	3.47 knot	5.31 knot
Minimum HP Required to Maintain S 727.65 300.00	670.20 hp	603.21 hp

Collaborative In- Browser 3-D Manipulation





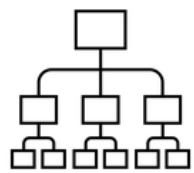
Web-enabled Collaborative Tradestudies

TRADESPACE Define Execute Analyze Visualize Home About Contact

Enable informed decisions | Empower AoA and requirements generation | Visualize more trades in less time

ERS TRADESPACE

Start Trading »



Define

Define your system of interest through authoring SysML Block Definition and Parametric Diagrams. Populate your database of system options with off-the-shelf and notional parts. Set your system KPPs and KSAs as requirements.

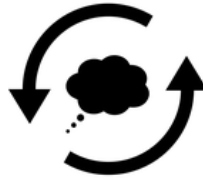
- SysML Authoring
- System Manager
- Requirements



Execute

Execute trade studies using set distributions, sampling available system options or defining Designs of Experiment.

- Trade Studies
- Design of Experiments



Analyze

Analyze a configuration using the Point Solution Sandbox or Sensitivity Analysis.

- Point Solution
- Sensitivity Analysis



Visualize

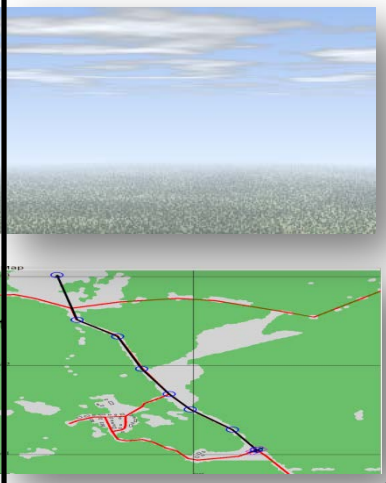
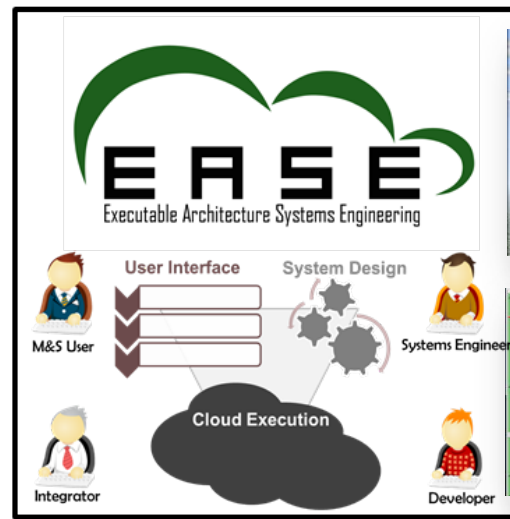
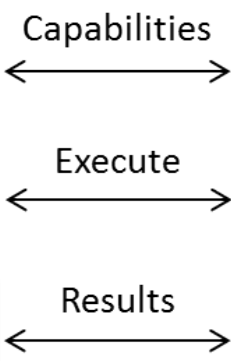
Visualize and explore the results of your trade study and DoE executions using box & whiskers, probability graphs, scatterplot matrices, and coordinated interactive views. Compare solutions and measure against requirements.

- Visualization Builder
- Solution Comparison



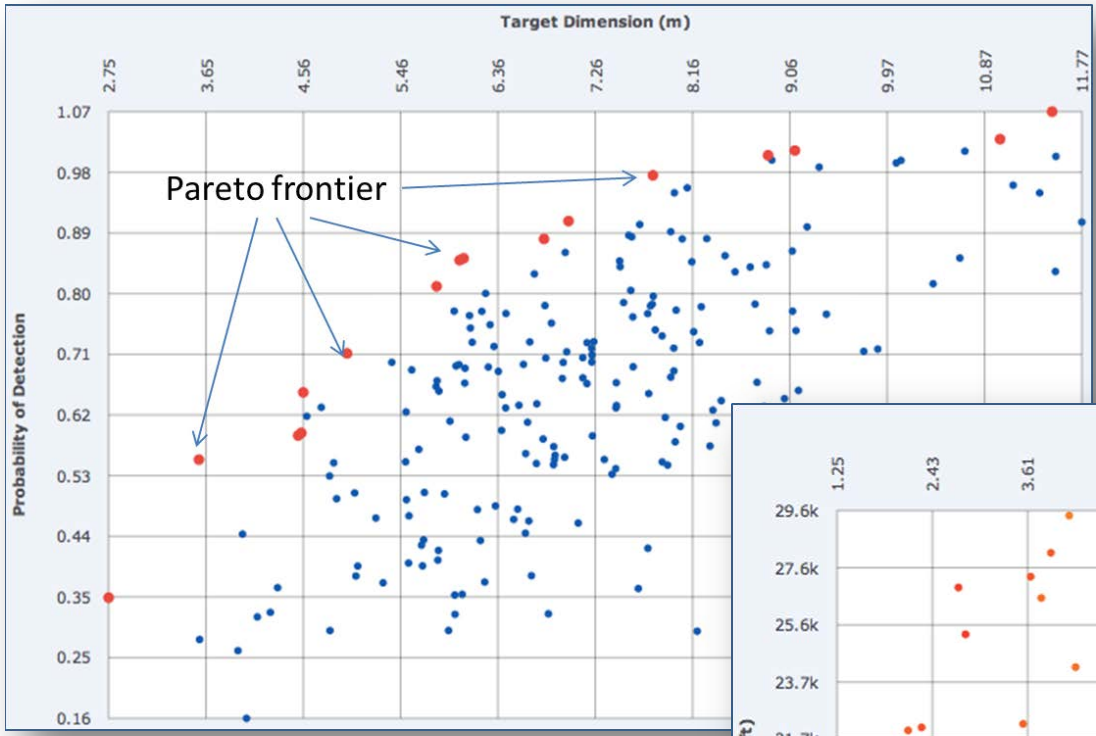
Interfacing Tradestudies with Simulation Operational Scenarios

- Executable Architecture Systems Engineering (EASE)
 - Links analytical, experimental and training objectives with the technical complexity of Modeling & Simulation
 - Explore operational aspects of the analytical questions in simulation
- ERS effort develops interface between MBSE/Tradestudies and Army Research Lab investment in executable, cloud-computing resources
- Enables evaluation of MoE's based on scenarios



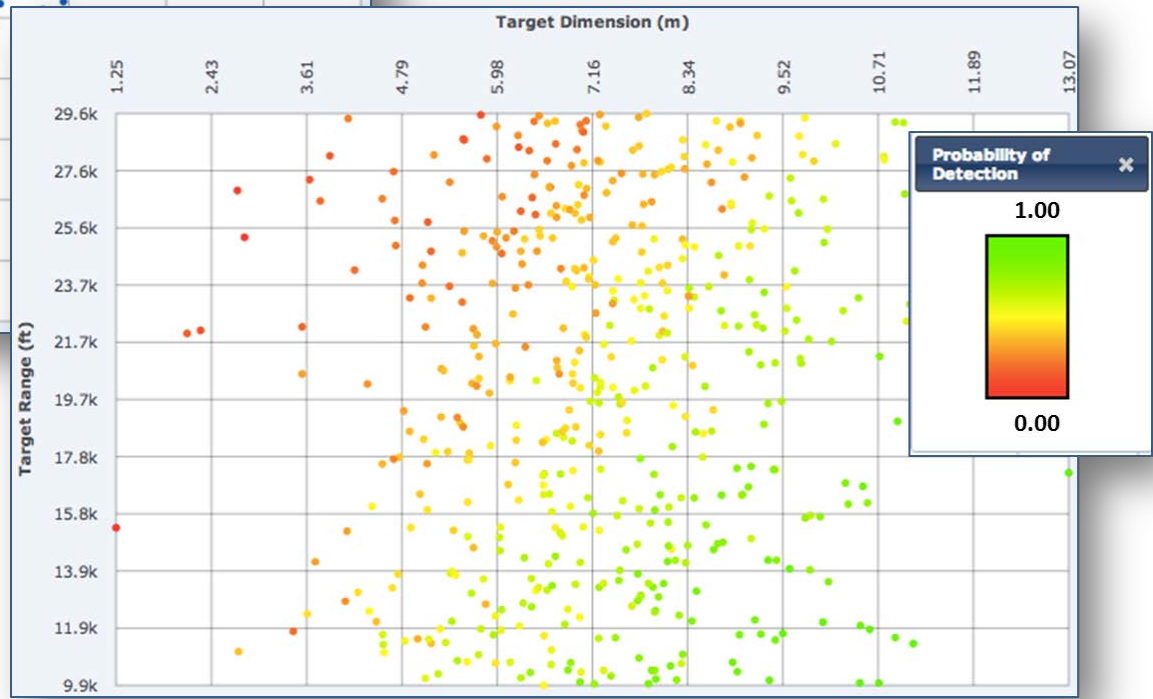


Early Tradespace Results



- Tradestudy execution generates numerous design options for evaluation against various threats
- Pareto frontier illuminates the “non-dominated” design trades

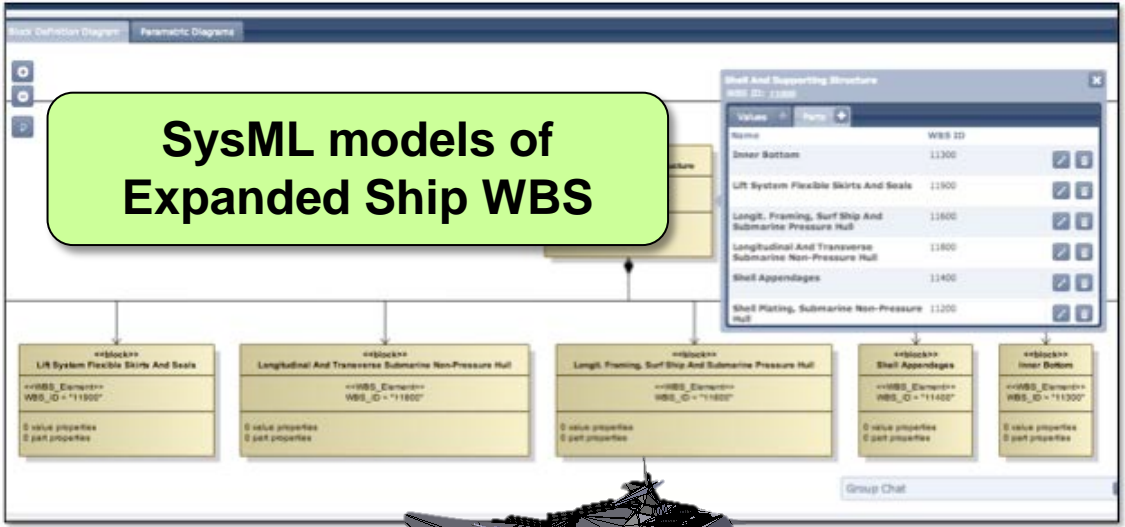
- Heat map can be used to identify those threat characteristics against design options that meet given Probability of Detection thresholds and objectives





ERS Ships: Tradespace Proof of Concept

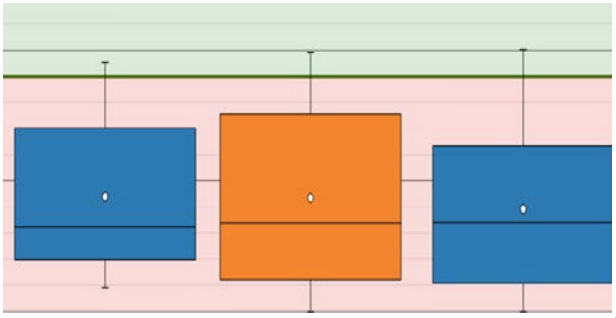
SysML models of Expanded Ship WBS



Browser friendly 3-D based on NSWCCD CAD models



Robust Design Driven Evolution of Parameters



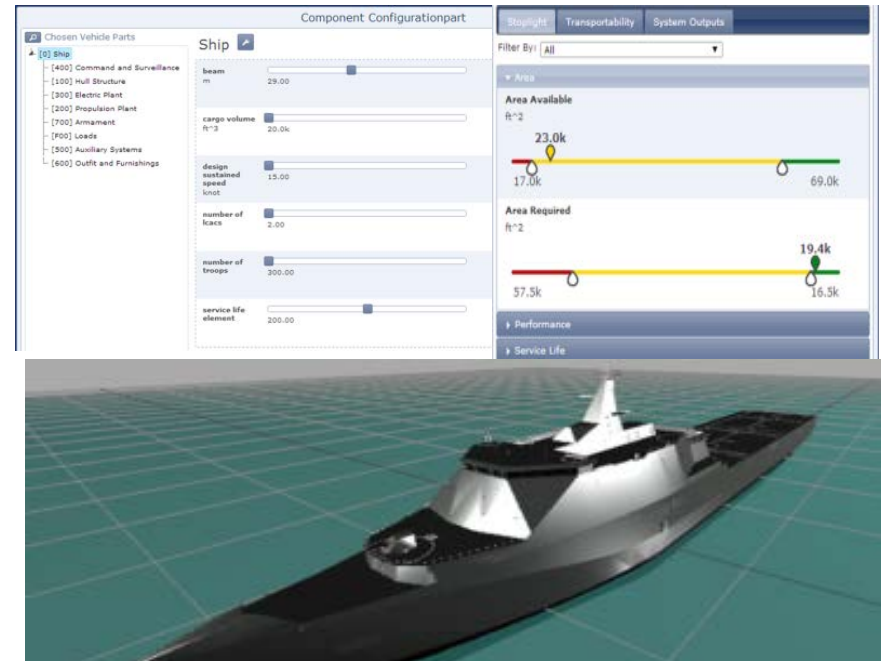
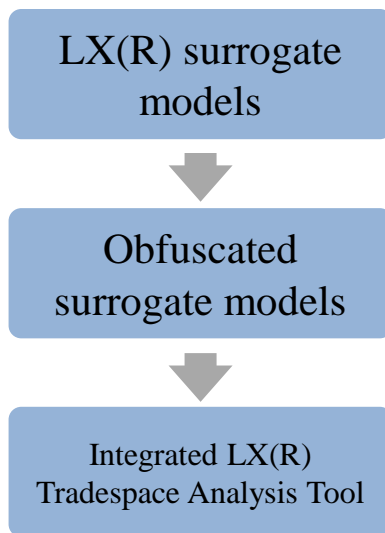
ERS-Ships: LX(R) “Firedrill” Study

LX(R) Program Objective

- Build 11 amphibious ships to replace aging fleet of Landing Ship Dock
- Must be more cost effective than the San Antonio (LPD-17) program

ERS LX(R) Study Objective

- Support NAVSEA in analyzing tradespace for LX(R)
- Process improvement: learn how to support tradespace analysis for current and relevant projects





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