Tradespace: Informed Decision-making for Acquisition

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Tradespace - the set of processes, program and system parameters, attributes, and characteristics required to satisfy mission profile

**Trade space**
- The space spanned by completely enumerated design variables

**Point-based design**
- Single
- Learning Points
- Adjust
- Iterate if required

**Set-based design**
- Advanced analytics allow engineers to investigate more thorough design solutions sets
ERS Tradespace Concept

ERS CLOUD COMPUTING ENVIRONMENT (CCE)

10,000x Improvement in productivity in Analysis of Alternatives

Efficiently discover key performance parameters (KPPs)

HPCMP and S&T Resources

Currently Applied ERS Advanced Tradespace Analytics

DEFINE

• Early concept tool
• Functional / component breakdown
• Explore tradespace edges

Expand Tradespace Fully

Performance Assessments
Performance Metrics

High-fidelity Models
Parameter Sweeps: Design Variations

ANALYZE

• Highly computational
• Sifts through millions of designs
• Refined set of specifications for viable design solutions
Tradespace Exploration Processes

**Seeding**
- High-Fidelity Simulations
- Historical Data

**Performance Modeling**
- physics-based models analyze new designs
- known designs are used in formulating the tradespace

**Systems Properties “ilities”**
- evaluated in various performance scenarios
- analyzed from a systems perspective
- assessed in the context of possible operational missions

**Mission Modeling**
- Systems Properties “ilities”

**Tradespace Creation “Define”**
- Performance Modeling

**Tradespace Analysis “Partition”**
- Exclusion
- Selection
- Comparison

Tradespace is gradually narrowed
Globally optimum solutions are revealed
Remaining designs are compared and contrasted
Decision Analysis: Integrated Processes with Trade Analytics

Mission Effectiveness

Program Constraints

Models & Data

Physics-Based Designs

Expertise & Management

Design Space

All Alternatives

Must Criteria

Want Criteria

Solution

Possible Alternatives

Mission-Level Simulations

Set-Based Design

The space spanned by completely enumerated design variables

Advanced analytics allow engineers to investigate more thorough design solutions sets
Technical Requirements of Data-Driven Decisions Tools

- Have a traceable history
- Utilize cutting edge search and decision analytics

Visualize trades between dominant variables and requirements

Allow novice and advanced data exploration

Trace Requirements and link systems to output

Quickly find dominant variables

Tradespace tools must:
Ontology Models: Consistency in System Communication

Original system breakdowns by ontologies or SysML, along with requirements, are tied to the tradespace

- Inserts greater accuracy and verification into the analytic processes
- Passing the metadata gives us insight into how to analyze the data
- Direct mapping via SysML → WBS → MILSTD-881C (soon 881D) is an OSD-CAPE requirement
Data Metrics

Humans
10s

PC
1000s

Web
100000s

HPC
Billions

Size of Tradespace

Complexity

Today

Tomorrow

Spark

Hadoop

Distribution A
Beta-Release Status:

- Supplied acquisition community a web-based environment for storing, visualizing and analyzing data
- Allowed for access and annotation by multiple parties for any given location;
- Provided the base for a collaborative decision support environment.
  - Gaps in previous environments forced point-based design methodology.
- Successfully supported MBSE and data filtering
  - Previously available MBSE were expensive and resource heavy – requiring local resources and administrative personnel, required expensive licensing agreements.
The FY17 Beta Release of TradeAnalyzer to a number of DoD Users resulted in important lessons and changes

• Use of ParaView Web - generating interactive visualizations of large data-sets and annotation capabilities

• Role Based Access Control (RBAC) needed to execute R-Scripts in a secured environment; implementation in a complex collaborative environment is challenging.

• Working on secure authentication mechanisms that couple with customers local access control policies is an ongoing and important DoD issue.

ERS Tradespace development is now focusing on the user-oriented approach in preparation for DoD-wide implementation and adoption
Available Plotting Options

- **Histogram**: A diagram consisting of rectangles whose area is proportional to the frequency of a variable and whose width is equal to the class interval.
- **Scatter Plot 2d**: A graph in which the values of two variables are plotted along two axes, the pattern of the resulting points revealing any correlation present.
- **Scatter Plot 3d**: A graph in which the values of three variables are plotted along three axes, the pattern of the resulting points revealing any correlation present.
- **Clustering 3d**: A graph in which the values of three variables are plotted along three axes, with a mesh alpha clustering overlay.
- **Surface Plot 3d**: Surface plots are diagrams of three-dimensional data. Rather than showing the individual data points, surface plots show a functional relationship between a designated dependent variable (Y), and two independent variables (X and Z).
- **Contour**: A contour plot is a graphical technique for representing a 3-dimensional surface by plotting constant z slices, called contours, on a 2-dimensional format.
- **Heatmap**: Graphical representation of data where the individual values contained in a matrix are represented as colors.
- **Correlation Matrix**: Graphical representation showing the correlation coefficients between sets of variables.
- **Parallel Coordinates**: A common way of visualizing high-dimensional geometry and analyzing multivariate data.
- **Pareto Front**: A framework for partially exploring a set of “options” with multi-dimensional outputs assuming a very weak “desirability” partial ordering which only applies only when one processes is better (or at least as good) for all the outputs. It is useful for reducing a set of candidates prior to further analysis.
Updates to Architecture

- Web Hosted
- Access Control
- Collaboration
  - Shared Notebooks
  - Shared Data
- Versioning
- Analytic Packages
- Scalable
- Portable
- Reproducible
- Distributed
  - Spark
  - Hadoop

Relevant ERS Talk

10:40 - Resilient Tools: Building an Agile Framework for the Analysis of Environmental Impacts on Military Systems
Dharhas Pothina, PhD - ERDC
Network Access

ERS USERS

- ERS Internal
- Development Environment
- Source Control (GitLab)
- ERS Software Team
- External Interface Tools
- Pingfederate (Authentication)

EXTERNAL INTERFACE

- Trusted Systems (White Listed)
- External Developers
- External Access
  - Port 443
  - Trusted Systems

HPC.MIL

- Access Req
- Separate HPC Accounts
- Trusted Systems
- (White Listed)

Cloud Specifications

- 4 GPU have been added to the 96-processor cores, 2.0TB RAM, 42 TB storage

PING provides:
- Two-factor authentication
- Single sign-on
- Accepts multiple industry standards

Active Directory (AD)
AD manages database of valid users

External .mil access is white listed

INDUSTRY COMPUTING INTERFACE

- ECCA hosting SOAP/REST Service Interfaces
- Industry Model
- API

SOURCE CONTROL (GitLab)

ERS SEGMENT on the DREN erdc.dren.mil

USER’S ENVIRONMENT

Browser Access Port 443

Trusted Systems (White Listed)
Questions
What is a Tradespace

• Tradespace is the space spanned by completely enumerated design variables. It is the potential solution space.

• Tradespace can also be defined as the set of processes, program and system parameters, attributes, and characteristics required to satisfy mission profile.

• The enumeration of a large tradespace helps prevent designers from starting with point designs while allowing them to investigate more thorough design solutions sets.
ERS Tradespace Analytics support Collaborative Processes

Previous Design Successes, Lessons-learned

Needs (…ilities)
- Manufacturability
- Affordability
- Reliability
- Sustainability
- Usability
- Testability
- Etc.

HPCMP Resources

S&T Resources, Research

Rapid, Reconfigurable Systems

Acquisition Solutions

Lifecycle Data

Mission Data

Trade Space Analysis

Mission Context

Physics-based models

Enterprise Web Portal

Training

Acquisition

Engineering

Cost Analysis

T&E...