Generating Design Spaces

**Tradespace exploration paradigm:** Going from considering 1) point designs; 2) local points with trades; 3) Pareto Front; to 4) full tradespace, to explore enough data to generate multi-dimensional insights about the relationship between what is asked for (needs) and what is possible (alternative designs).

**Generating alternatives with design variables:** Alternatives can be off-the-shelf choices or new designs that can be customized to drive value; each design concept can be represented by a design vector (a set of design variables that parameterize that concept and are factors within the designer’s control).

**Scoping the design space:** Specifying scope sets constraints on the study, including resources needed, potential cost, expected schedule, and expertise needed. Scoping must balance breadth and depth.

**Picking a set of alternatives to evaluate:** Enumeration lists range and steps for each design variable (input requirements for evaluation models), while sampling is selecting a subset of designs to evaluate.

**Example sampling techniques:** Many techniques exist for sampling (e.g. random sampling and DOE techniques such as full factorial, Latin hypercubes, one at a time, etc.) and must balance resource constraints for model execution versus coverage of the design space.

Evaluating Design Spaces

**Considerations for models for tradespaces:** Evaluative models and value models must be scalable and applicable across many alternatives (i.e. the design space). Developers must consider sensitivity of the outputs to assumptions, as well as the fidelity of the models.

**Additional considerations for models:** Using models for decision making often involves
interaction between mental models and constructed models. Mental models (e.g. what we have in our heads) and constructed models (e.g. what we explicate in software and tools) each make predictions about how an alternative will perform. Model credibility must be considered and is a function of how trustworthy and truthful a given model is to support decision making.

**Evaluative models:** Performance and cost: These models have design variables as input and performance and cost attributes as output; they typically can be verified once ground truth is available.

**Evaluative models:** X–TOS case study: Used DVM to identify design drivers and key relationships and a DSM to structure relationships between model inputs and outputs.

**Evaluative models:** Space Tug case study: Lists the equations used in the study for each attribute, intermediate variable, and design variable, including parametric performance models and cost models.

**Fidelity of evaluative models:** Choice of fidelity level should be explicit and balance factors including: resources available for model development and execution, breadth of design space, level of detail of design needed for decision making, fidelity of other linked models, and smoothness of outcome space.

**Verification and validation (V&V):** Verification is whether something complies with its specification ("Are you building it right?"), whereas validation is whether something meets the needs of stakeholders ("Are you building the right thing?"). V&V applies to both models used and design alternatives selected.

**Tradespace Representations, Visualizations, and Interactions**

**Challenges of multidimensional representations:** Key dimensions for tradespace exploration include information dimensionality (number of metrics), multiple perspectives (different stakeholders’ goals and interpretations), temporal representations (metrics changing over time), and depth of detail (design abstraction). Cognitive and perceptual limits impact how to effectively gain insights across these.

**Canonical and novel interactive representations:** Canonical plots: cost–benefit scatterplots, zoomed scatterplots, scatterplot matrices, plot by mission, plot by context, distribution of metrics, time–sequenced plots. Interactive plots: scatterplots (select, pan, zoom), specifying favorites, exploring preferences via altering value models, exploring designs with range setting, filtering and brushing.
**Example tradespace visualizations:** Using questions to select and guide use of representations (*What are the best designs? How easily can we meet our attribute requirements? What are the design drivers for the different missions? How does change in operating environment change cost-benefit tradeoffs?*)

**Overview of visual analytics:** Harnessing the computational power of a computer with the insight and intelligence of a human makes visual analytics a powerful approach for the type of exploratory data analysis needed in large tradespace exploration activities.

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**Key Figures this Week**

Week 3: Generating and Evaluating Alternatives > Generating Design Spaces

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**TRADESPACE EXPLORATION PARADIGM**

![Diagram of tradespace exploration paradigm with axes labeled Utility and Cost.](image)
Week 3: Generating and Evaluating Alternatives > Evaluating Design Spaces

**DESIGN-VALUE LOOP PERSPECTIVE**

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**Generating Tradespace Data**

Week 3: Generating and Evaluating Alternatives > Tradespace Representations, Visualizations, and Interactions
Week 3: Generating and Evaluating Alternatives > Tradespace Representations, Visualizations, and Interactions

STYLES OF REPRESENTATION

Example Tradespace Visualizations

Cost–benefit scatterplot with each point as an alternative