Biography
Matt received a Bachelor of Science in Aeronautics and Astronautics degree from MIT in June 2010, and immediately began pursuing his Masters degree in the same. His areas of work include research into passive flow control, compression technology, and tradespace exploration with an emphasis on time-dependent analysis.

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Related Publications
Fitzgerald, M.E., Ross, A.M., and Rhodes, D.H., "A Method Using Epoch-Era Analysis to Identify Valuable Changeability in System Design," *9th Conference on Systems Engineering Research*, Los Angeles, CA, April 2011.

Fitzgerald, M.E., and Ross, A.M., "Mitigating Contextual Uncertainties with Valuable Changeability Analysis in the Multi-Epoch Domain," *IEEE Systems Conference 2012*, Vancouver, Canada, March 2012. (submitted)

Fitzgerald, M.E., and Ross, A.M., "Sustaining Lifecycle Value: Valuable Changeability Analysis with Era Simulation," *IEEE Systems Conference 2012*, Vancouver, Canada, March 2012. (submitted)

Valuation Approach for Strategic Changeability (VASC)

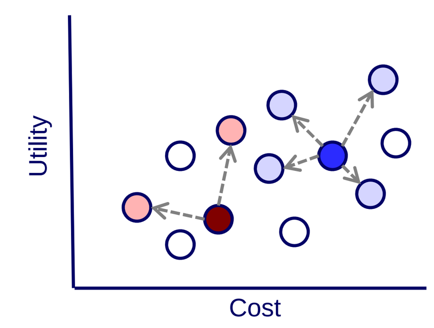
Matt Fitzgerald, S.M. in Aeronautics and Astronautics (expected in 2012)

Advisors: Dr. Adam Ross, Prof. Daniel Hastings

VASC

Qualities of a good changeability metric:
- Dataset ***independence*** – a design's score in a metric is unaffected by the set of other designs in consideration
- ***Universal*** scale – a score of X in one context is objectively the same as a score of X in another context
- Accounts for both ***magnitude*** (value gained) and ***counting*** (multiple options) value

Why VASC? Because determining ***valuable changeability*** is difficult:
- Counting versus Magnitude value tension
- Difficulty comparing effectively with passive robustness
- Common value metrics often violate one or both of dataset independence and universal scale



Counting vs. Magnitude value: does **red** or **blue** have more valuable changeability? Neither number of end states nor size of increase is enough to say for sure!

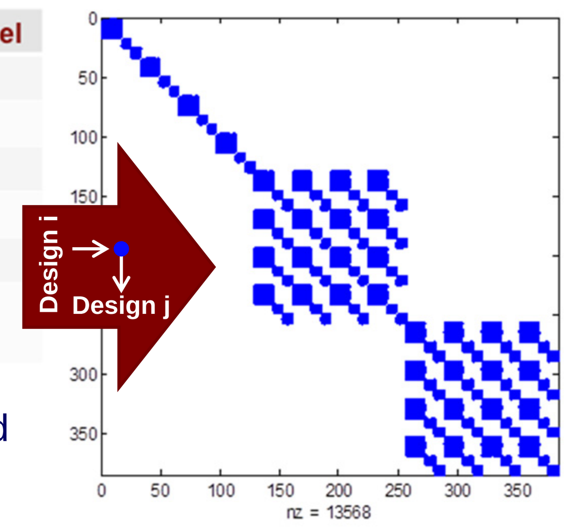
Lack of a single metric to encompass all of the desired information about changeability suggests the ***potential value of an organized changeability evaluation method*** using a suite of metrics and visualizations, thus motivating the development of VASC

1 Setup Data for Epoch-Era Analysis

The data set must have appropriate features for the creation of a ***design-differentiating epoch set***:
1. Define alternative preference sets and/or context variables
2. Enumerate them into a full epoch space
3. Evaluate any objective functions of interest (e.g., multi-attribute utility) for each considered design in each epoch

Transition rules defining the effect of change mechanisms on the design variables must also be created. They can be combined into multi-arc transitions in a tradespace network as well.

#	Rule	Effect	DFC level
1	Engine Swap	Biprop←→cryo	0
2	Fuel Tank Swap	Change propellant mass	0
3	Engine Swap (reduced cost)	Biprop←→cryo	1 or 2
4	Fuel Tank Swap (reduced cost)	Change propellant mass	1 or 2
5	Change capability	Change capability	1 or 2
6	Refuel in orbit	Change propellant mass (no redesign)	2



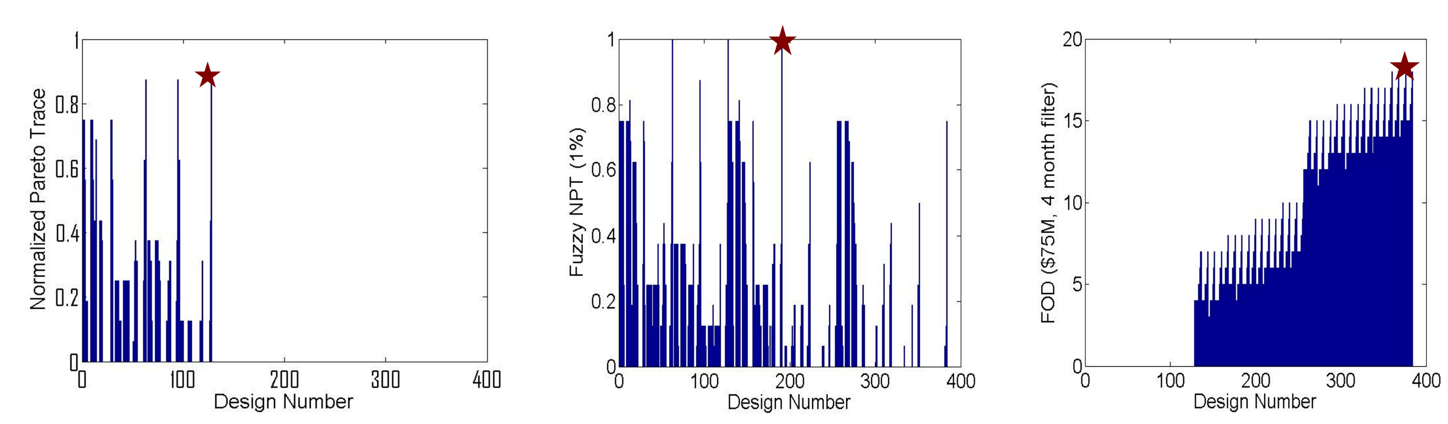
Space Tug transition rules, collapsed and combined into a tradespace ***full-accessibility plot***

2 Select Designs of Interest

A set of ***screening metrics*** can be used to identify key designs for further investigation. For example:

(fuzzy) Normalized Pareto Trace – NPT and fNPT identify passively value robust designs, which may become even more robust when considering their changeability

Filtered Outdegree – FOD identifies designs with a large number of change options, which heuristically have a high probability of having excellent value enabled by changeability

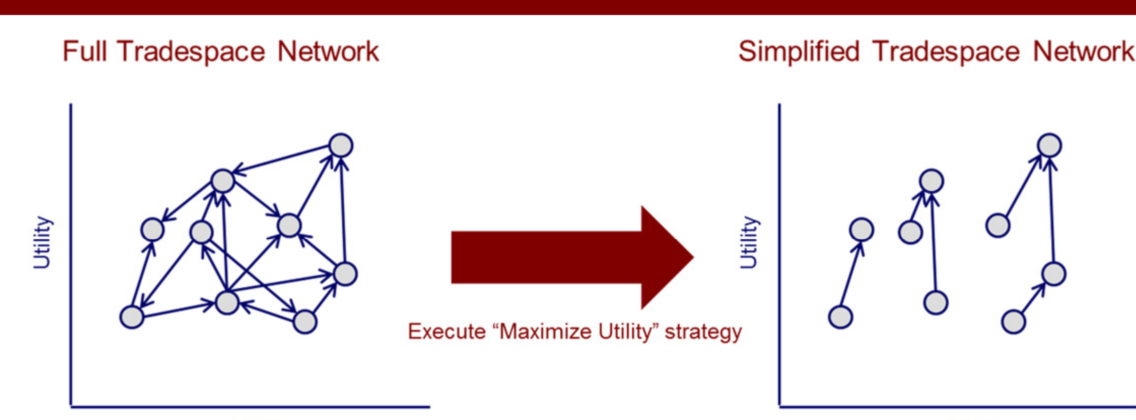


Example screening plots of NPT, fNPT, and FOD (in order) of a Space Tug case study, with promising designs of interest highlighted

3 Define Design Transition Strategies

A ***strategy*** is a statement of intent on how the stakeholder plans to utilize the changeability in the system. These can range from the simple (maximize utility at any cost) to the complex (objective dependent on current design and epoch, cost and time thresholds).

The end result of a strategy is the ability to ***determine the chosen transition arc*** (change mechanisms and end state) for each design in each epoch. Multiple strategies can (and should) be defined and evaluated, as they can have a significant effect on experienced value.



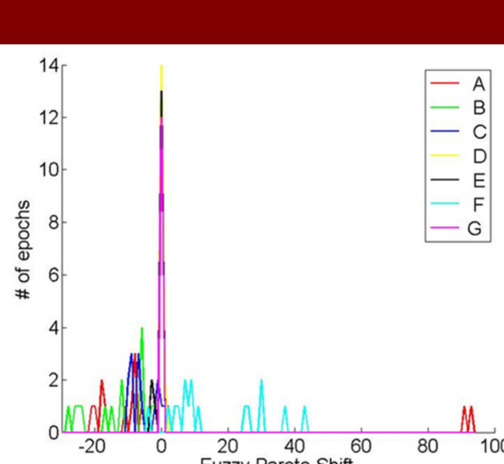
Simplification of tradespace network using a strategy: the one remaining arc is evaluated for *magnitude* value, and *counting* value comes out across all epochs

4 Multi-epoch Changeability Analysis

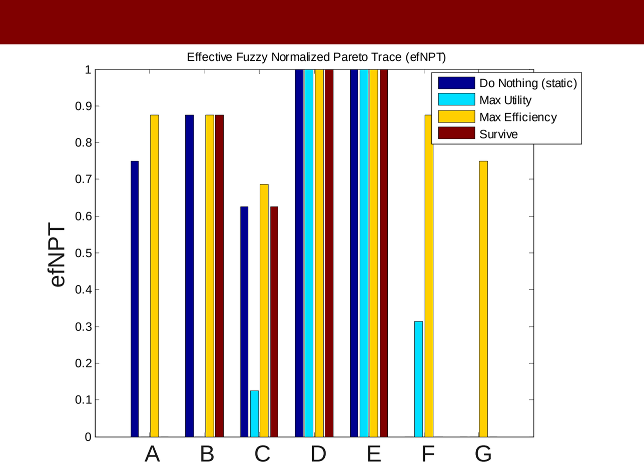
This step involves investigating the changeability of the designs of interest ***across the epoch space***

Fuzzy Pareto Shift – FPS quantifies the change in cost-utility efficiency across the strategically selected transition arcs. A design's FPS is presented as a distribution across the epochs, to provide a grasp of the relative frequency of different performance levels

Available Rank Increase – ARI allows for a simple comparison of potential change mechanism value by showing the best utility rank accessible via each rule.



Example FPS distribution plot for a Space Tug case study



Effective version of fNPT (efNPT) is calculated by considering transition end state rather than initial state, compared between designs of interest and strategies

5 Era-level Changeability Analysis

This step involves ***era construction and simulation*** to sample potential lifecycles for the system. The sampling of epochs for an era can be simply randomized or context-variable ordered, and epoch duration can also be pulled from a distribution.

Lifetime value metrics such as ***average FPN***, ***revenues***, and ***accumulated utiles*** can be collected and compared between designs. ***Removal weakness*** studies can quantify the criticality of a change mechanism to design value

	Rule 1	Rule 2	Rule 3	Rule 4	Rule 5	Rule 6
A	2.1%	93.9%	0.0%	0.0%	0.0%	0.0%
B	0.0%	94.3%	0.0%	0.0%	0.0%	0.0%
C	0.0%	92.8%	0.0%	0.0%	0.0%	0.0%
D	0.0%	80.9%	0.0%	0.0%	0.0%	0.0%
E	0.0%	0.0%	0.0%	96.8%	31.5%	0.0%
F	0.0%	0.0%	0.0%	0.0%	0.0%	100.0%
G	0.0%	0.0%	0.0%	0.0%	0.0%	98.4%

-DFC tradeoff	Design	+DFC tradeoff
N/A	D	+$544M initial cost, +$34B profit over 10 years
-$80M initial cost, -$4B profit over 10 years	E	+$80M initial cost, +$21B profit over 10 years
-$384M initial cost, -$20B profit over 10 years	F	N/A

Other outputs include ***transition rule usage likelihoods*** for each design over their lifetime and ***cost/benefit tradeoffs*** of adding or removing mechanisms

VASC can be repeated for a different set of designs of interest or change mechanisms, allowing for iterative refinement of design/option selection

Contributions

New metrics for valuing aspects of design changeability and change mechanisms
- FPN, FPS, ARI, eNPT, efNPT, Removal Weakness

An ***organized, repeatable method*** for investigating valuable system changeability (VASC)

Considers efficient ***multi-arc transitions*** and the corresponding value derived from rule coupling

Next Steps

Application to a third case study, with new features: ***Satellite Radar System***
- Dramatically larger design and epoch spaces
- Lifecycle Phase-dependent change mechanisms (i.e., Design, Build, Test, Operate)

Development/refinement of VASC for ***non-tradespace applications***
- Potentially new valuable changeability metrics for mechanisms with infinite end states

For more information, please visit: http://seari.mit.edu