



ility Tradespace Analysis: Analysis of the Influence of Requirements Change on a System



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ility Tradespace Analysis



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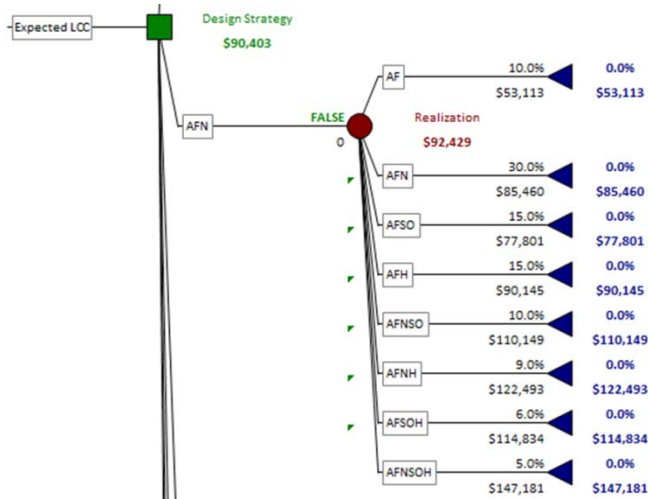
- Previous work at AFIT has focused on flexibility
 - Treat program baseline parameters (req'ts, production #'s, etc.) as stochastic variables
 - Use expected value of life cycle cost as a proxy measure for valuing flexibility
- Recent extensions/applications
 - Use epoch-era analysis as a framework for capturing future uncertainty
 - Initial application on Air Force T-X advanced trainer concept



Methodology

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- Developed decision tree map out design strategy and era possibilities



Epoch	Epoch Variables	Probability of Occurring
AF	AF	10%
AFN	AF + N	30%
AFSO	AF + SO	15%
AFH	AF + H	15%
AFNSO	AF + N + SO	10%
AFNH	AF + N + H	9%
AFSOH	AF + SO + H	6%
AFNSOH	AF + N + SO + H	5%



Analysis



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- Summary of LCC associated with design strategy and epoch realization

	Design Strategy					
Epoch	AF	AFN	AFSO	AFH	AFNH	AFNSOH
AF	\$48,236	\$53,113	\$51,695	\$50,627	\$55,533	\$58,787
AFN	\$85,861	\$85,460	\$89,320	\$88,252	\$89,482	\$95,003
AFSO	\$78,828	\$83,705	\$77,772	\$81,219	\$92,565	\$88,777
AFH	\$85,269	\$90,145	\$88,728	\$82,482	\$90,746	\$96,267
AFNSO	\$116,453	\$116,052	\$115,397	\$118,844	\$120,074	\$123,795
AFNH	\$122,894	\$122,493	\$126,353	\$120,107	\$118,553	\$127,458
AFSOH	\$115,861	\$120,737	\$114,804	\$113,074	\$121,338	\$125,031
AFNSOH	\$153,486	\$153,085	\$152,429	\$150,699	\$149,145	\$152,723

NOTE: All \$ figures BY13 in millions





Analysis



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- Decision tree recommended AF design strategy due to lowest expected LCC
- Expected LCC difference compared to AF design strategy
 - Driven by estimated LCC and probability of occurrence

	Design Strategy					
Design Strategy	AF	AFN	AFSO	AFH	AFNH	AFNSOH
AF	\$0	\$2,027	\$1,833	\$579	\$4,781	\$8,597

NOTE: All \$ figures BY13 in millions

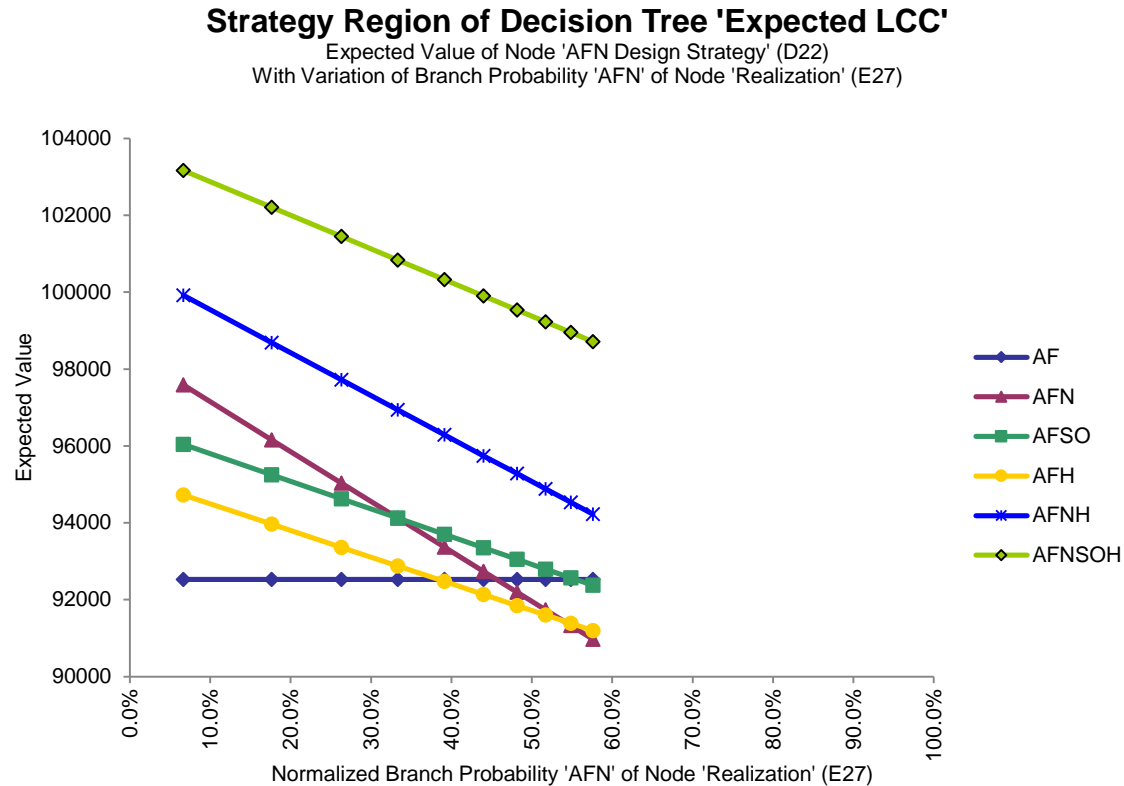


Sensitivity Analysis



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- One way AFN → AFN normalized branch probability

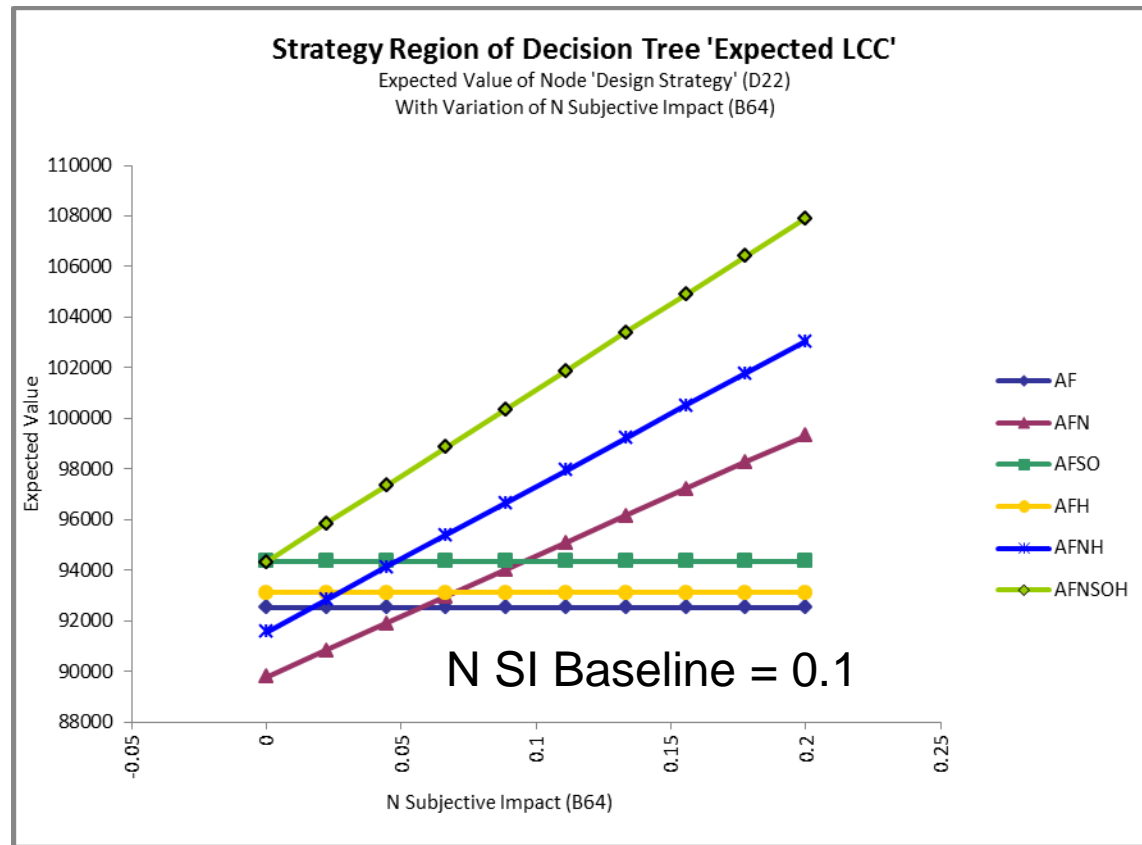




Sensitivity Analysis

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- One way N subjective impact





Results

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- Flexible Design Strategy favored when...
 - Probability of era occurring ↑
 - Subjective Impact ↓
 - Production and O&S Cost Modifiers ↓



Current Efforts



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- How do we improve on “subjective impact” factors relating a requirements change to design/production effort required to accommodate the change
- Product design literature provides some ideas for relating architectural constructs to meaningful impact factors
- Application to a flexible weapons (munitions) concept



Current Research Questions



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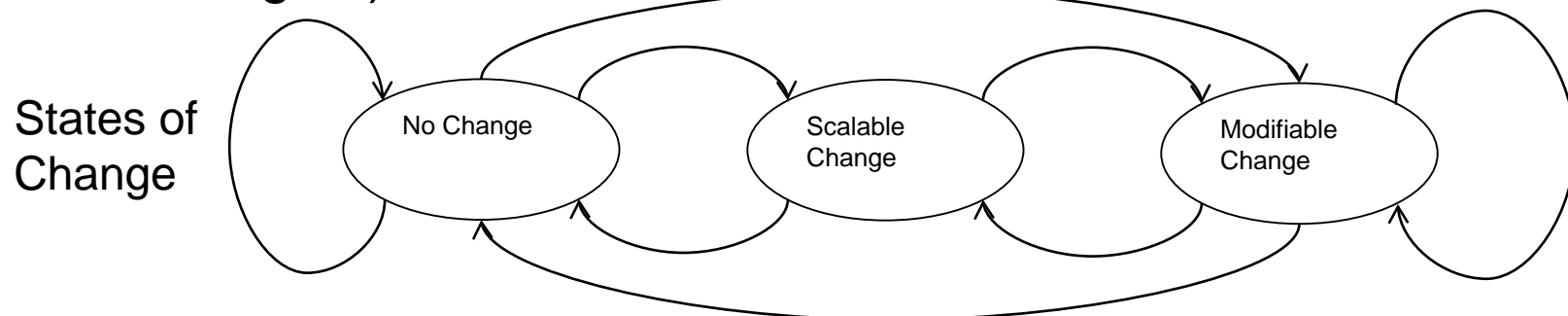
1. How does a type of requirements change impact a module/component?
2. How is the module/component impacted by a combination of requirement changes?
3. How does a type of requirements change impact the system?
4. How is the system impacted by a combination of requirement changes?
5. What strategy(ies) should be taken to mitigate the impact of change in the system?



Methodology

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- Baseline for Methodology: Martin & Ishii [2002], Generational Variety Index (GVI)
- Define system requirements, system/SoS architecture and a time period for input distributions
- Implement uncertainty into all inputs
 - Likelihood of requirement change in peacetime
 - Likelihood of requirement change in wartime
 - Non-homogeneous state transitions
 - Type of component change (scalable or modifiable) [Ross et al. 2008]
 - Impact of component change
- Analyze over multiple time periods (possible system lifecycle lengths)

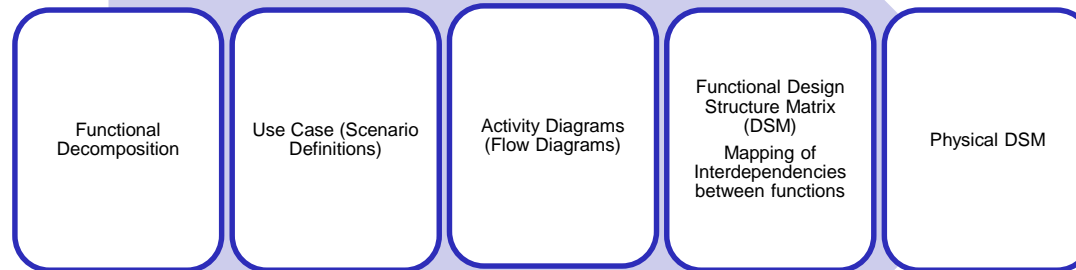




Gathering Model Inputs

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- Objective and Scope of the System
- System Architecture Development
 - Generate architectural alternatives from physical and functional DSM



- Input questions answered by the system architecture
 1. What are the types of requirements that the system supports?
 2. What system functions support the type of requirement?
 3. What modules/components perform each system function?
 4. If the type of requirement changed, does it cause a scalable and/or modifiable functional change?
 5. For a functional change, which modules/components are likely to be impacted, and do those changes drive changes elsewhere in the system

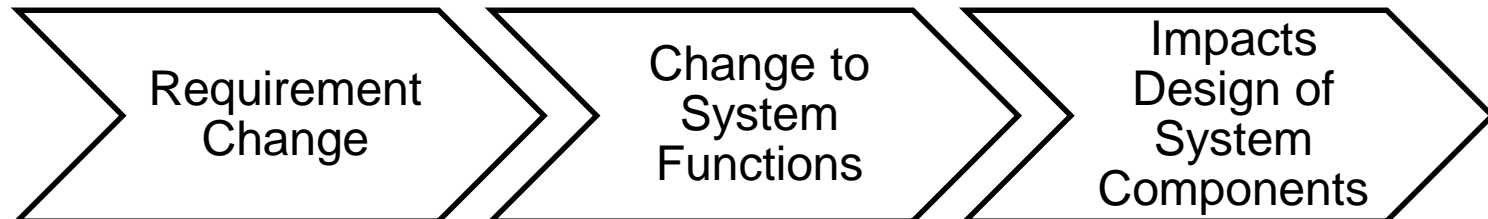


Gathering Model Inputs



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- Input questions answered by a Subject Matter Expert
 - As a result of a requirements change, what is the impact on the module/component of a scalable or modifiable functional change from each change state?
 - As a result of a requirements change, what is the probability that the module has a scalable or modifiable change from each change state?
 - What is a reasonable time period for a change to occur in the system?
 - What is the probability that a requirement will change in the defined time period from each change state?

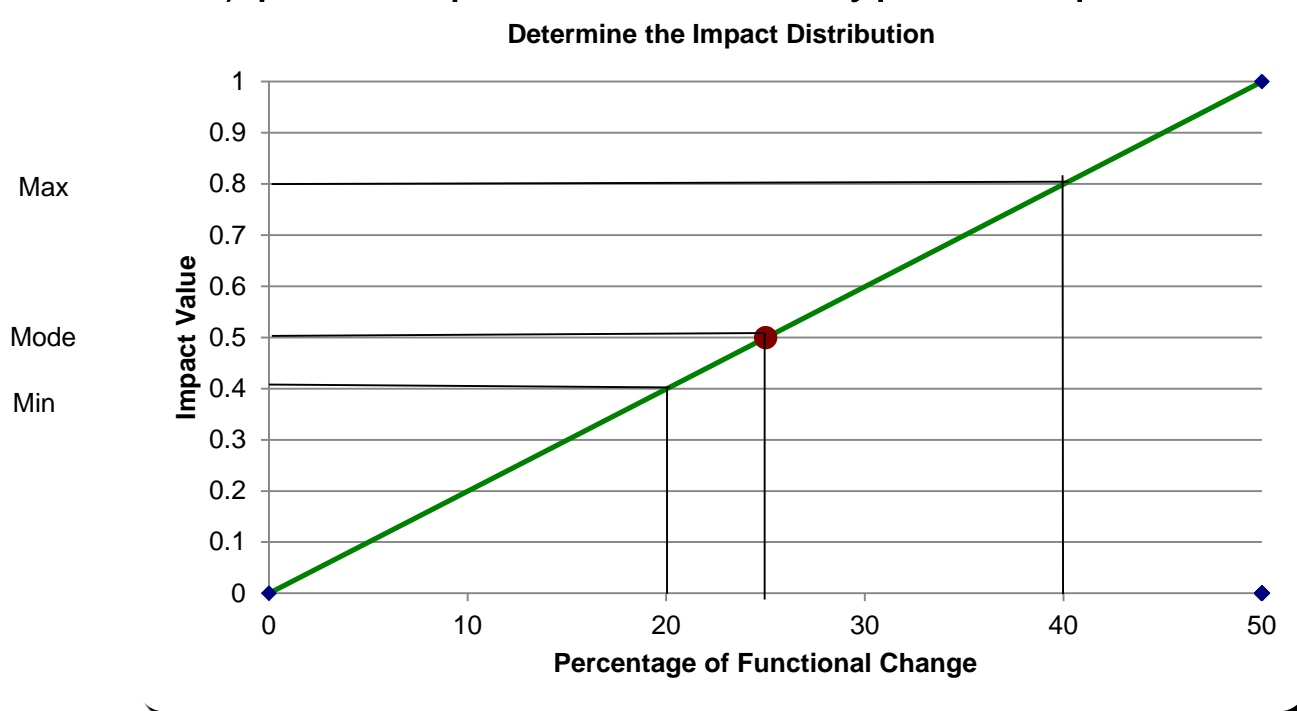




Impact Value

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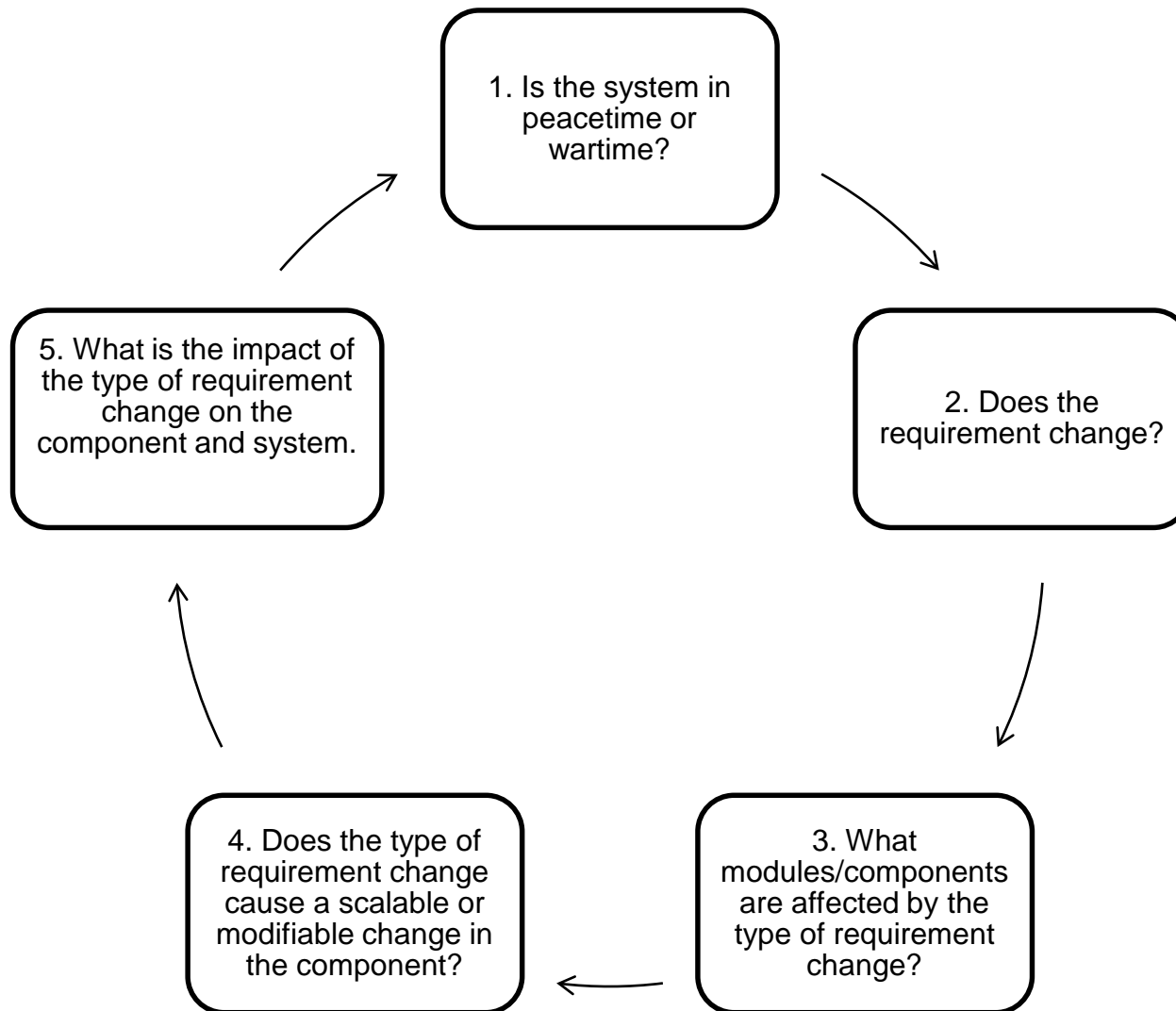
- A measure of “level of effort to change”
- Utilize methods similar to Decision Analysis to define component impact range and weights
- To elicit impact values, determine a triangular distribution (min, max, and mode) of percentage of functional change (scalable and modifiable) per component due to a type of requirements change





Model Formulation

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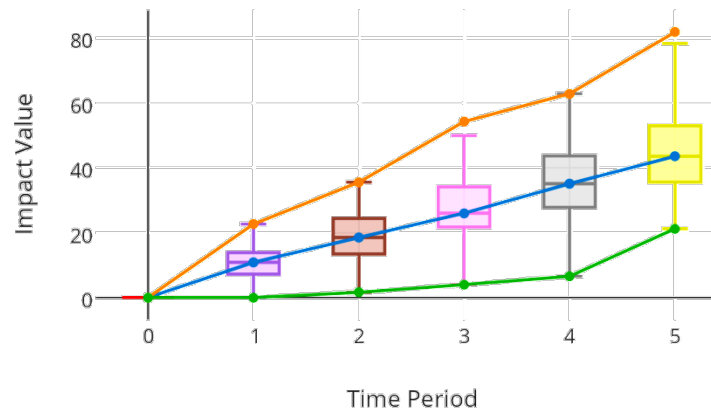


Results

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- Random walk (monte carlo) provides information on the cumulative impact (total, scalable, and modifiable) for how:
 - A type of requirements change impacts a module/component
 - The module/component is impacted by a combination of requirement changes
 - A type of requirements change impacts the system
 - The system is impacted by a combination of requirement changes

Random Walk Output Example





Status of Research



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- Develop preliminary system architecture that describes component functionality and information/resource flow
- Develop model that incorporates uncertainty into all inputs as described
- Determine how each uncertain input influences the Generational Variety Index results
- Incorporate flexible weapons concept as a case study to determine how the different types of requirement changes impact the system



Quantifying Tradespace



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- **Challenges**

- This current research provides relative value for ranking design options, but does not provide absolute resource (i.e., dollar) values suitable for cost analysis and budgeting actions
- Also precludes direct comparison to existing/legacy systems
- The DoD has no standard approach for developing credible cost estimates for a program “born flexible” – requirements must be fixed and the APB is assumed to be static



Quantifying Tradespace



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- **Stochastic Cost Estimating**

- Methodology intended to account for flexibility related to system *design* and *mission* execution
 - Flexibility related to *acquisition* might be possible as well, but not being evaluated by AFIT at this time
- Using AFRL flexible weapons concept as framework to develop estimating methodology
 - Modularized subsystems, standard interfaces, open system arch
 - Dynamic targeting, accuracy, and effects
- Concept
 - Develop range of estimates for each logical module of munition based on historical costs
 - Conduct sensitivity analysis to determine how sensitive the cost of each module is to variation in component types
 - Aggregate module costs and run Monte Carlo simulation



Future Work



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- Incorporate direct and indirect component change propagation into changeability analysis
 - Use cumulative result to further aid in performing architectural tradeoffs and resource allocation
- Incorporate the exogenous factors driving requirements change that impact the system
- Use methodology to determine impact of systems change at all levels (i.e. system of system) due to exogenous factors and/or “component” propagation
- Use impact analysis to inform cost estimation models
- Combine with other architecture evaluation/validation methods to close loop around architectural variations, mission effectiveness and cost effectiveness