

Using Multi-Objective Combinatorial Optimization to Inform Initial Requirement and Design Decisions

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2013 INFORMS Annual Meeting
October 6, 2013
Minneapolis, MN

Purpose and Briefing Overview

To provide a methodology overview of a Multi Objective Combinatorial Optimization used to inform initial requirements and design decisions. Discuss initial use of methodology and future work.

- **Background**
- **Understanding the Problem**
- **Multi-Objective Combinatorial Optimization**
- **Methodology**
- **Data & Analysis Structure**
- **Initial Use**
- **Future Work**

- **Customer:** Mr. Shatiel Edwards, PEO GCS
- **Team (SNL):** Alexander Dessanti, John Eddy, Jack Gauthier, Stephen Henry, Matt Hoffman, Hai Le, Darryl Melander, Adam Pierson, Liliana Shelton
- **Other team members:** Matt Cilli (ARDEC), Mike DiNunzio (TACOM), Booz-Allen Hamilton (BAH)

Background

- **Origins**

- **Acquisition Decision Memorandum:**

- **On November 3, 2010 the Under Secretary of Defense for Acquisition, Technology and Logistics signed the Directive for obtaining greater efficiency in defense spending**

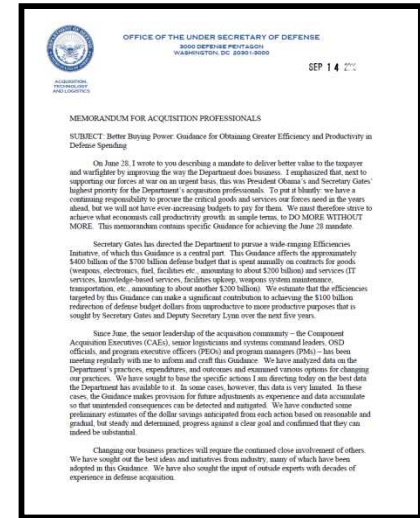
- **“The ability to successfully develop, build, and field a capable IFV within the department’s cost and schedule constraints is strongly dependent on aggressive exploration of the capabilities trade-space and the full range of alternatives prior to finalizing requirements...”**

- **Motivation**

- **Requirement for all new acquisitions (Milestone B)**

- **“You will present a systems engineering trade off analysis showing how cost varies as the major design parameters and time to complete are traded off against each other.”**

Customer, Mr. Shatiel Edwards (PEO GCS) tasked a multi-agency team with developing the methodology and tools necessary to apply this problem to the Ground Combat Vehicle (GCV)

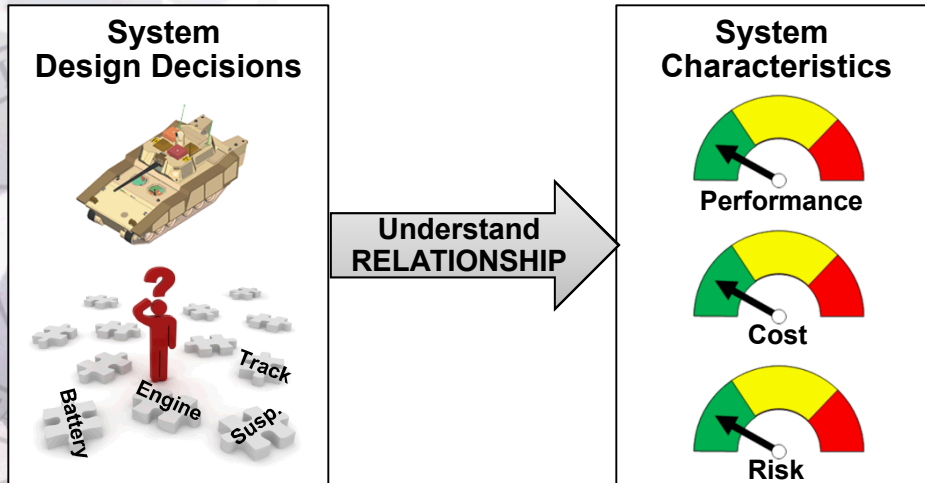


Objectives

- Deliver the warfighting capability we need for the dollars we have
- Get better buying power for warfighter and taxpayer
- Restore affordability to defense goods and services
- Improve defense industry productivity
- Remove government impediments to leanness
- Avoid program turbulence
- Maintain a vibrant and financially healthy defense industry

Obtain 2-3% net annual growth in warfighting capabilities without commensurate budget increase by identifying and eliminating unproductive or low-value-added overhead and transfer savings to warfighting capabilities. Do more without more.

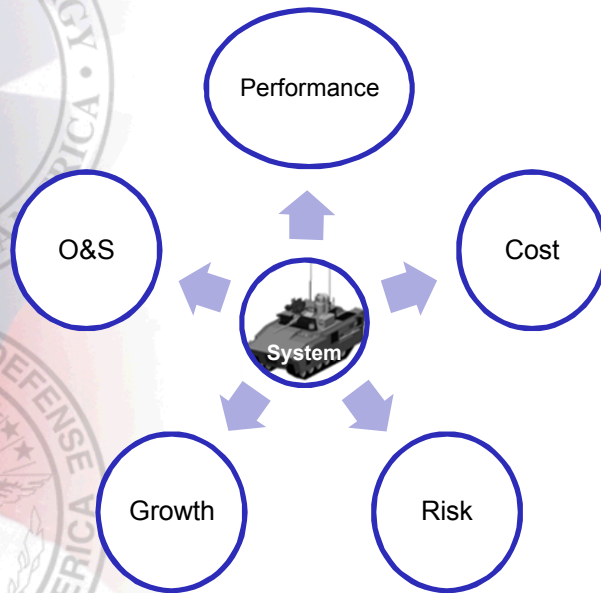
Understanding the Problem



- **System Decomposition**
 - Understand the parts of the system that are tradable
- **System Characteristics**
 - Model relationship between system design decisions and system characteristics
- **Challenges**
 - Multiple dimensions of importance
 - Number of possible solutions
 - Constraints
 - 2nd and 3rd order interactions
 - Dependencies

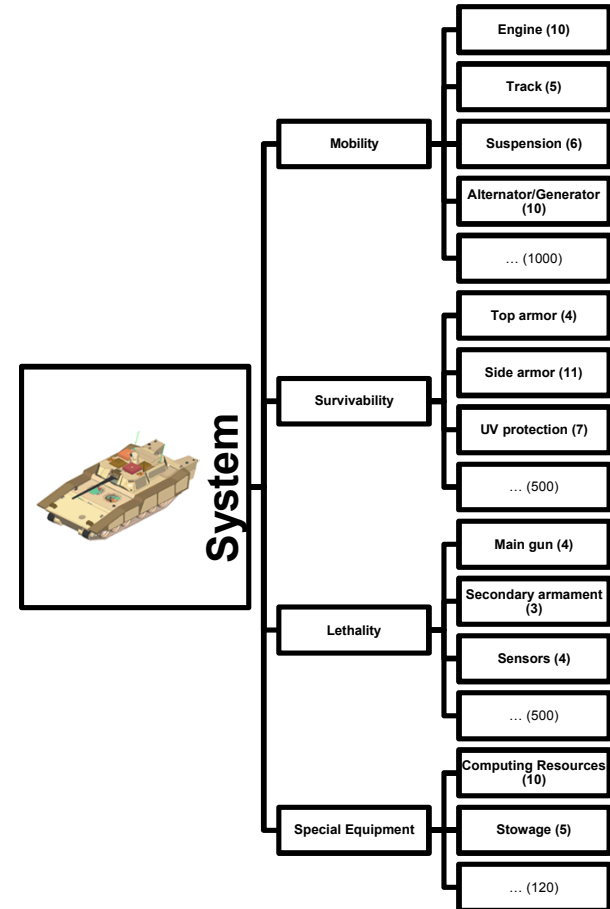


Multi-Objective, Combinatorial Optimization



Multi-Objective

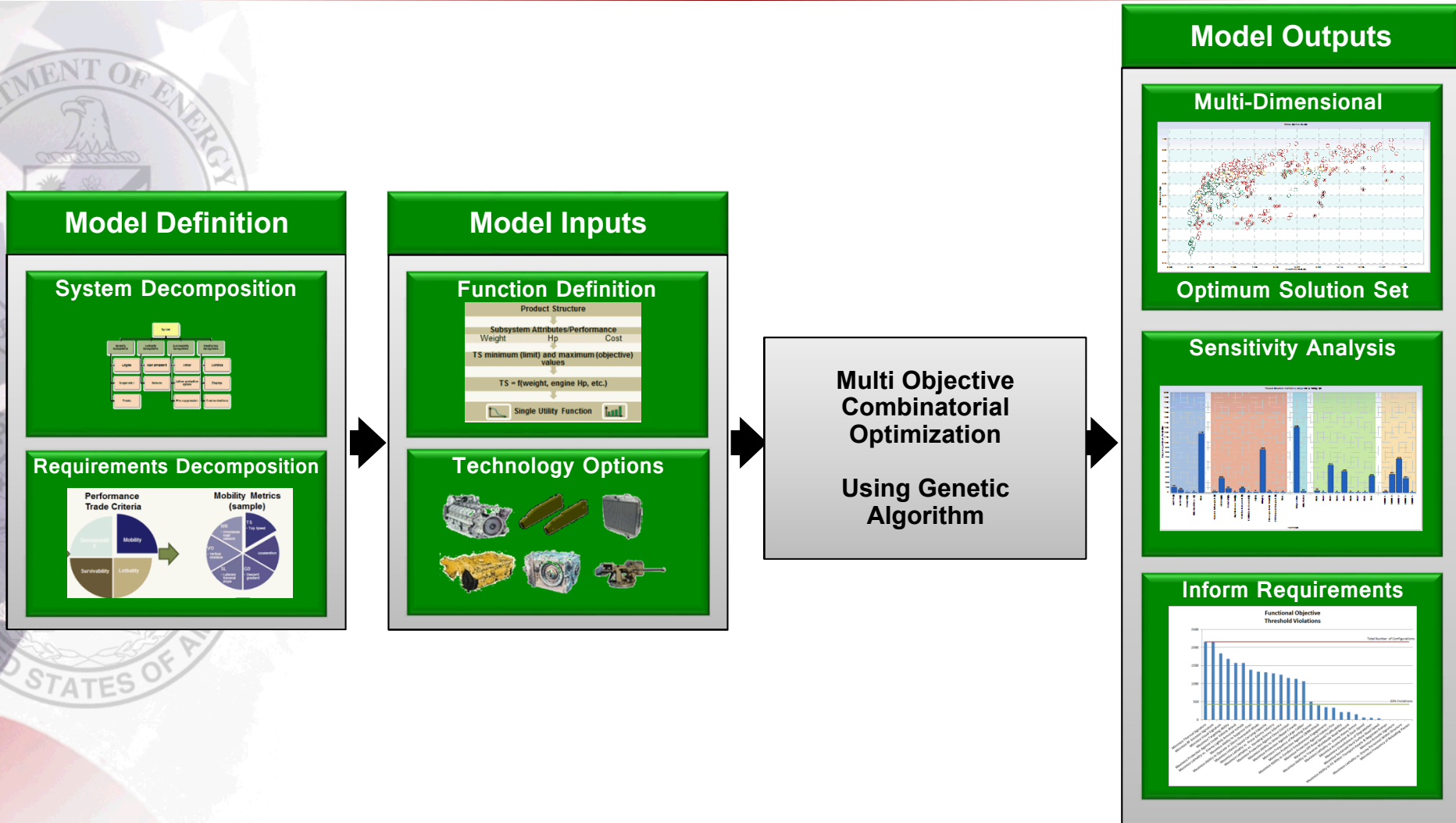
- Multiple dimensions of interest
- Opposing objectives
- Different stakeholders have different interests



Combinatorial Optimization

- What are the best “things” to pick for a system design?
- Possible number of solutions 9.31×10^{19}

Methodology

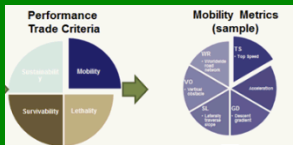


Model Definition

System Decomposition



Requirements Decomposition



Model Inputs

Function Definition

Product Structure			
Subsystem Attributes/Performance			
Weight	Hp	Cost	
TS minimum (limit) and maximum (objective) values			
TS = f(weight, engine Hp, etc.)			

Single Utility Function

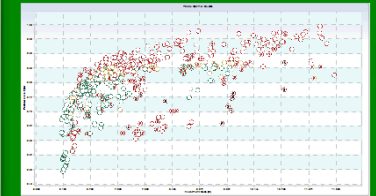
Technology Options



Multi Objective
Combinatorial
Optimization
Using Genetic
Algorithm

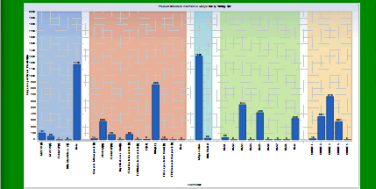
Model Outputs

Multi-Dimensional

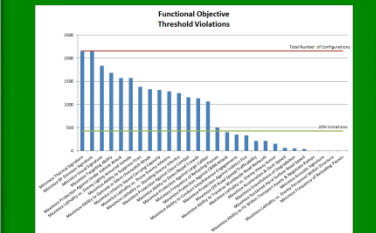


Optimum Solution Set

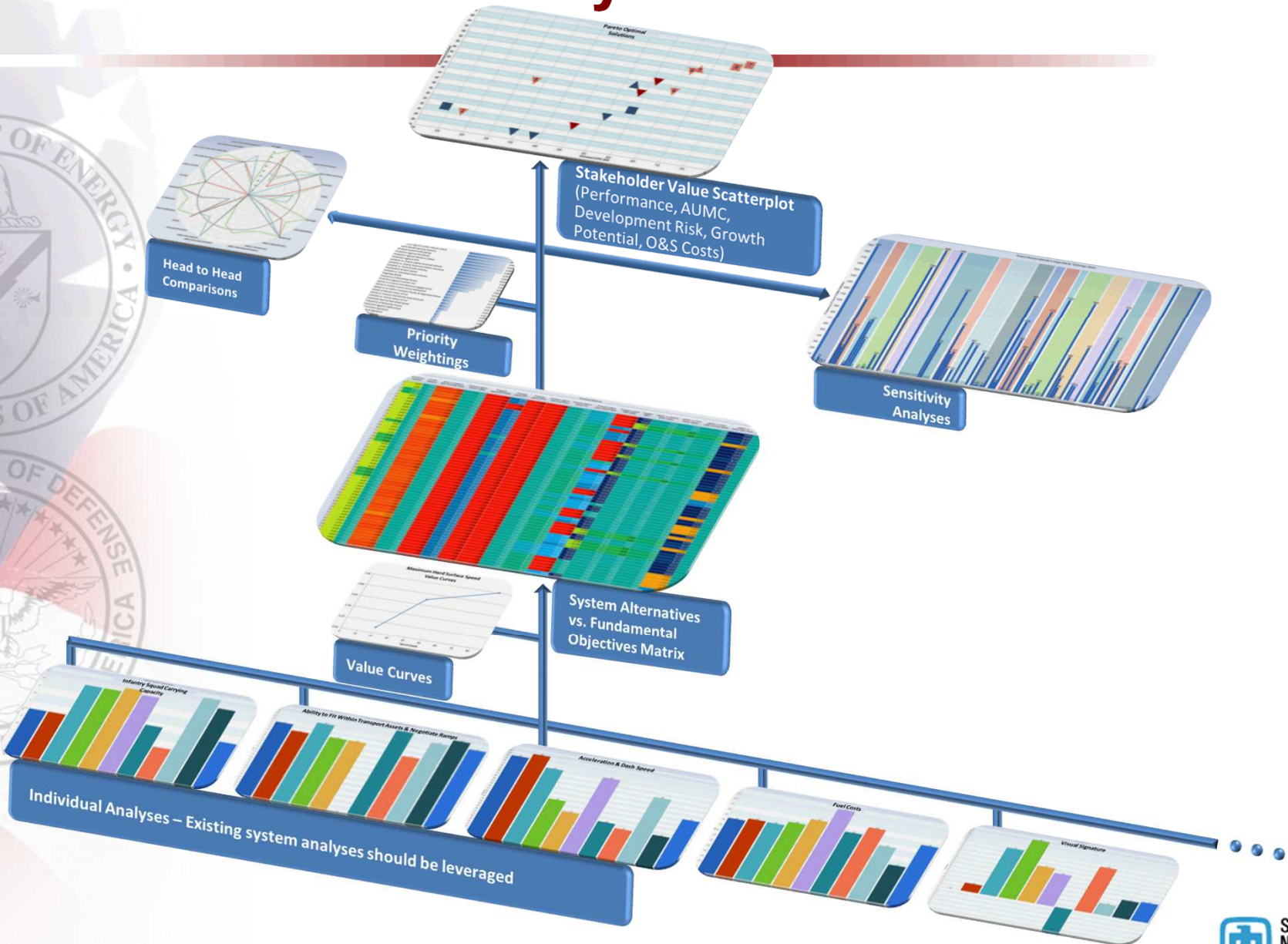
Sensitivity Analysis



Inform Requirements



Data & Analysis Structure

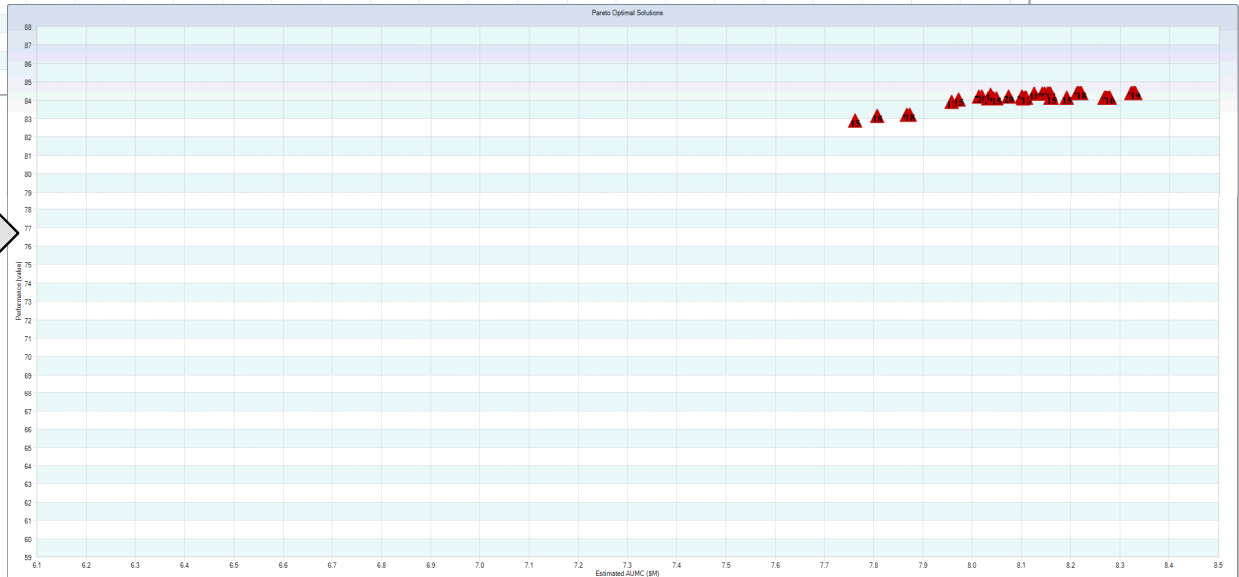
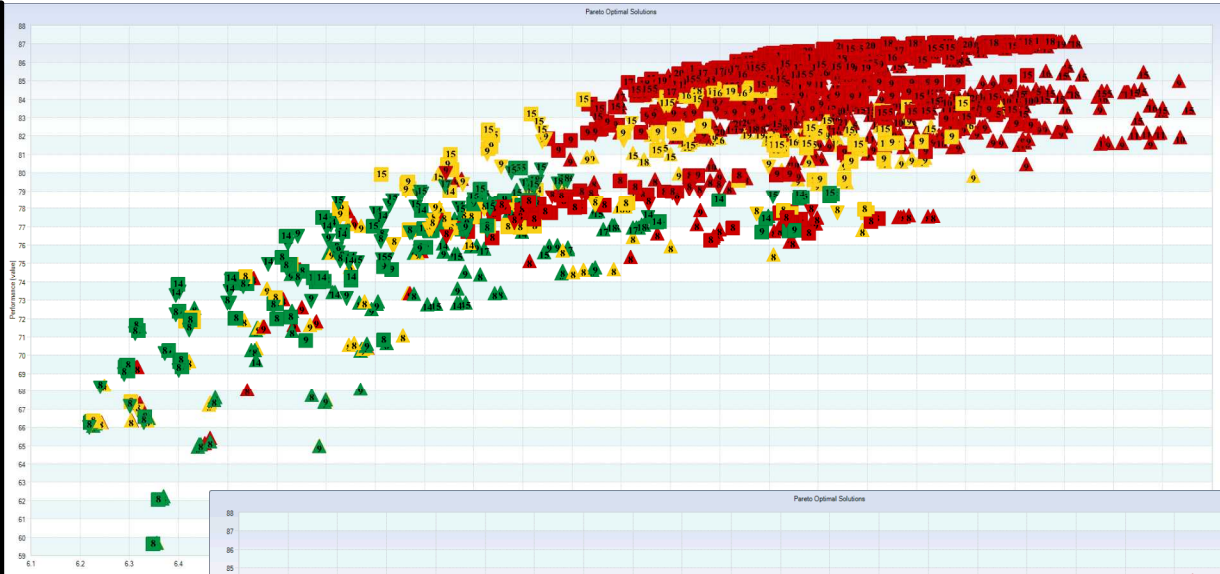


Initial Use: Informing Requirements

O&S Cost:
20 yr cost (\$M)

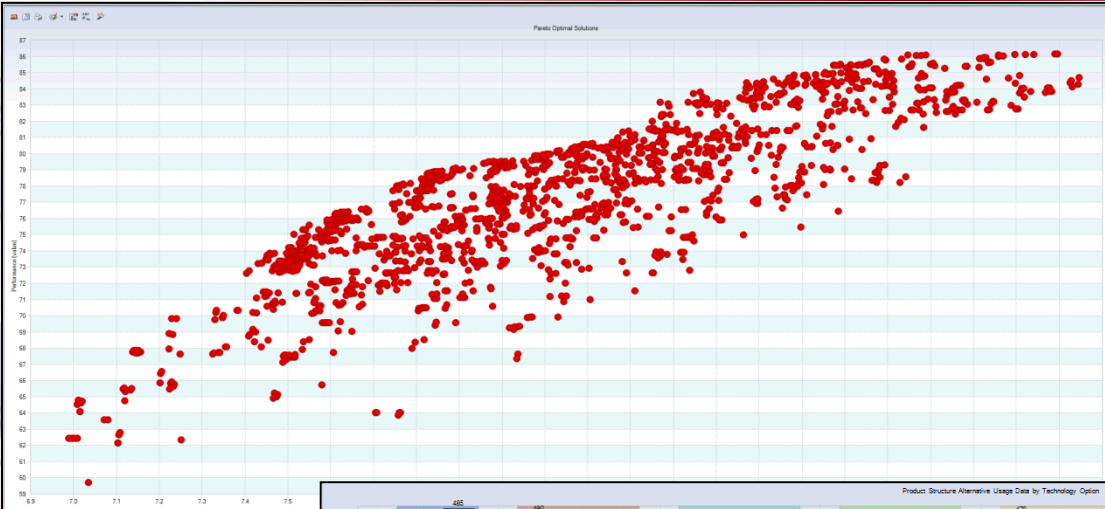
Growth:
△ High
□ Moderate
▽ Low

Risk:
● High
● Medium
● Low

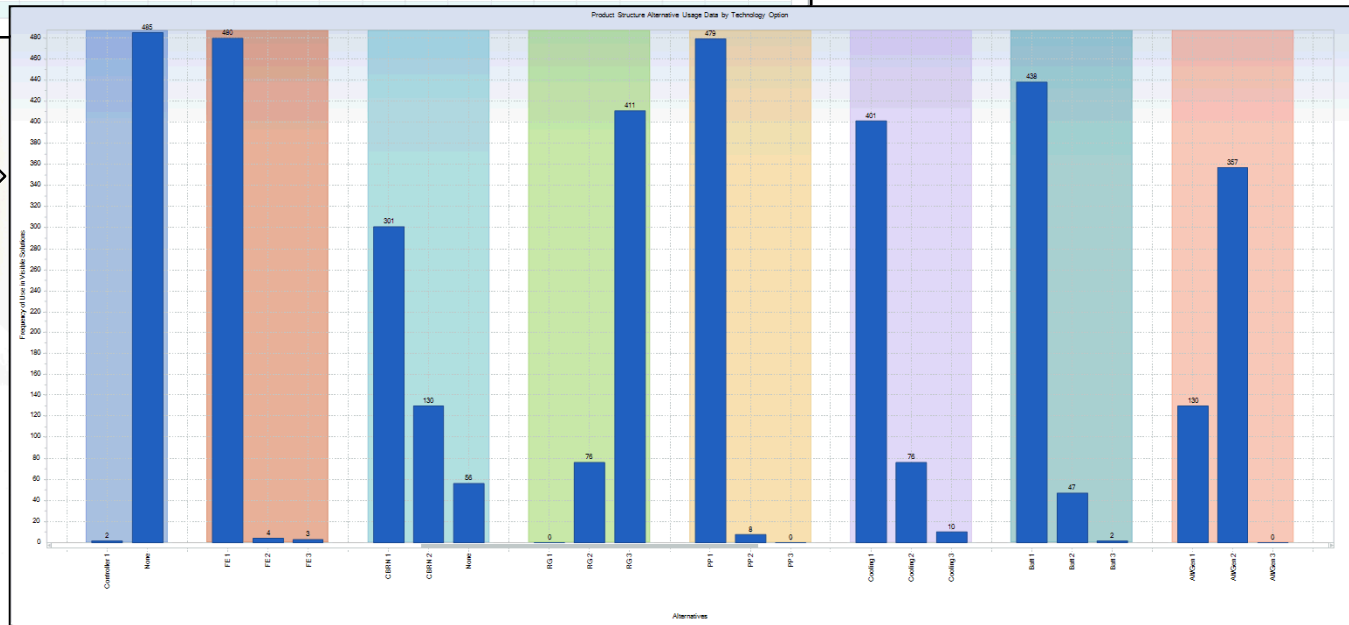


- What is the current ability to meet requirements?
- How much does it cost?
- What other tradeoffs are made in order to meet all requirements?

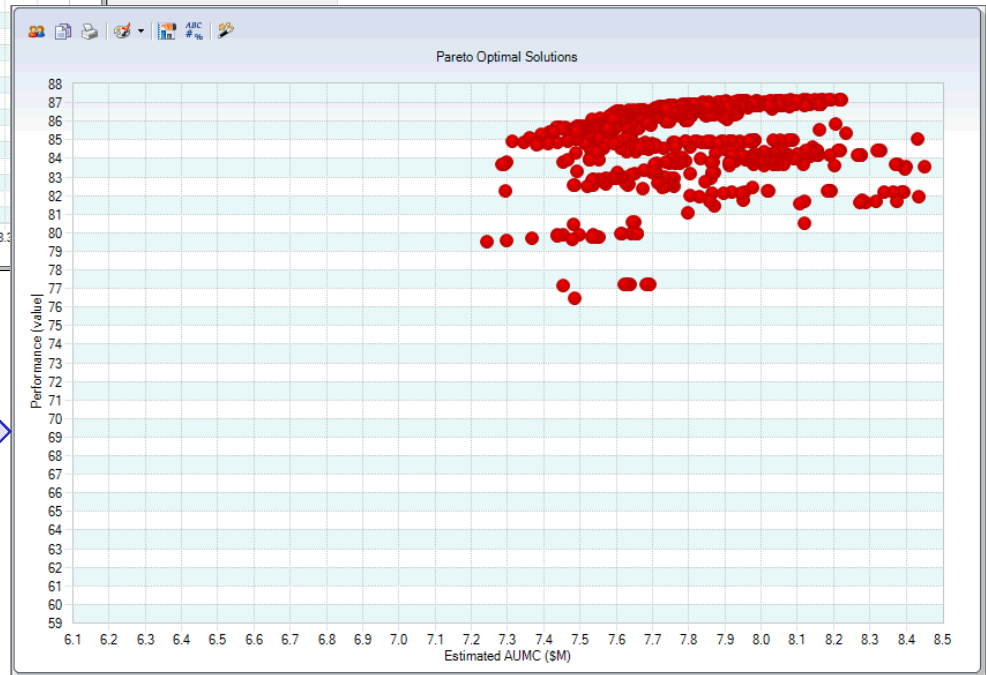
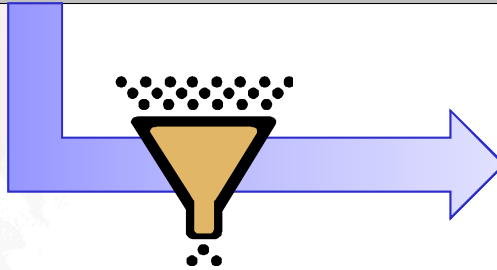
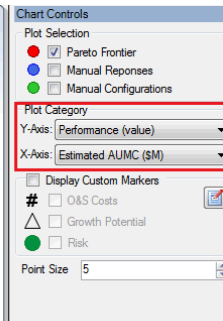
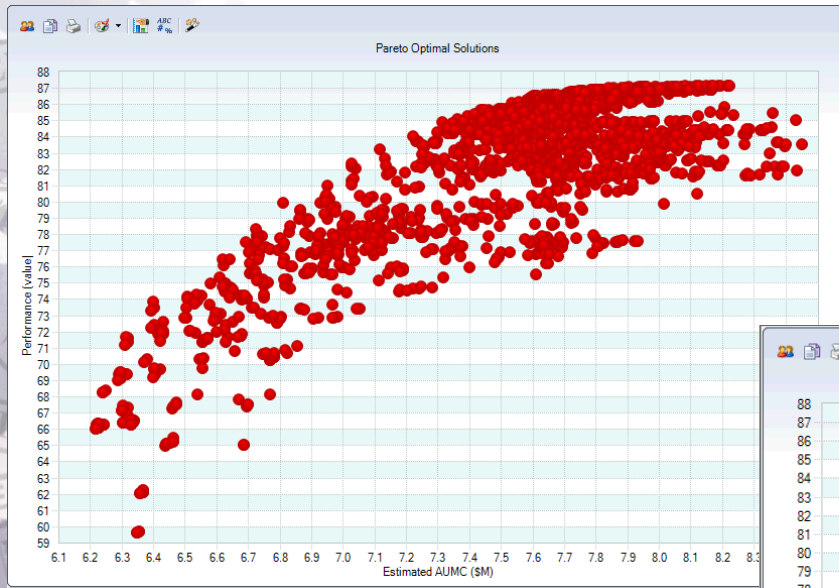
Initial Use: Inform Design Decisions



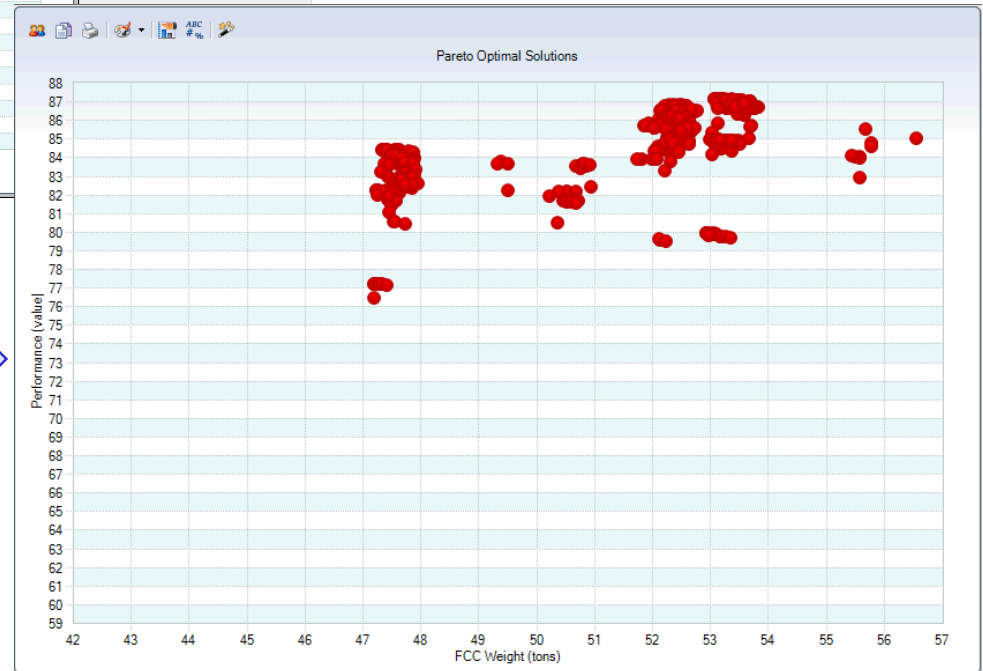
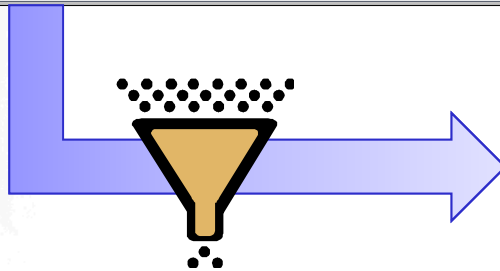
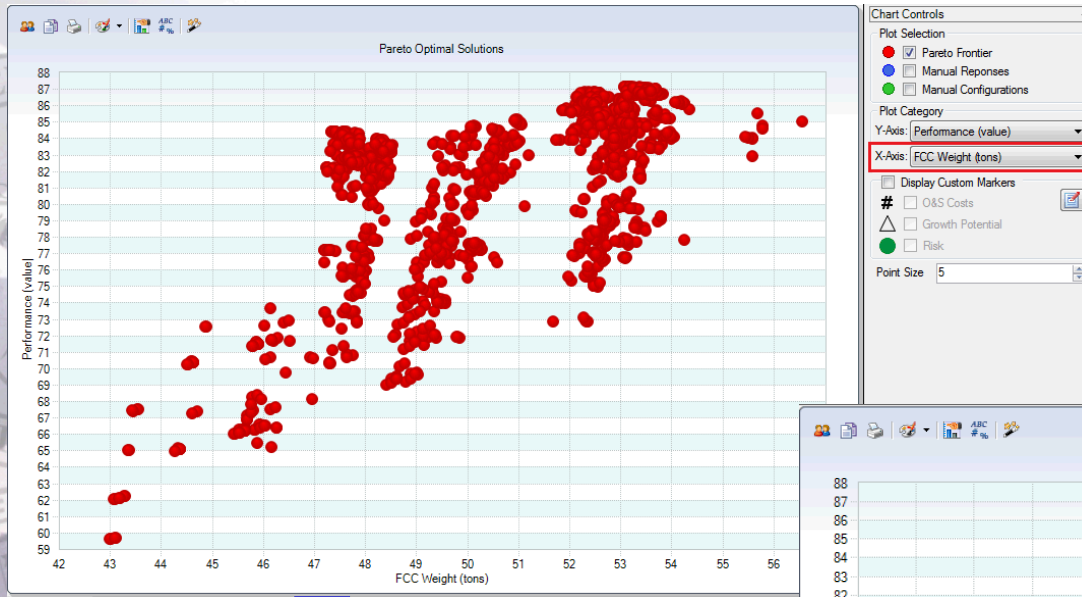
- What are the most commonly selected technologies?
- Are there any technologies left out of the solution set?
- How sensitive is the solution set to the selection of certain technologies?



Initial Use: Technology Tradeoffs



Initial Use: Technology Tradeoffs



Future Work

- **We have been successful applying this methodology to the design of a single platform...**
 - **Ground Combat Vehicle (GCV)**
 - **Bradley Vehicle**
 - **Armored Multi-Purpose Vehicle (AMPV)**
 - **Paladin Integrated Management (PIM)**
- **Future Work...**
 - **Optimizing a family of platforms**
 - **Take commonality among platforms into account**
 - **Optimizing base camps**
 - **Their function is very different from a vehicle**
 - **No formal requirements documents**
 - **Different sizes**
 - **Different environments**
 - **Different support structures (operational)**