SAND2010-3734C

Using System of Systems Modeling and Optimization in Weapon System Design and Acquisition

Sandia National Laboratories

June 14, 2010

Liliana Andrade

Tamara J. Brown

Craig Lawton

Nadine Miner

Sandia is a multi-program laboratory operated by Sandia Corporation, a Lockheed Martin Company, for the United States Department of Energy under contract DE-AC04-94AL85000

Sandia National Laboratories

Briefing Overview

- Background
- Problem Statement
- Methodology
- Sample Problem
- Summary

Sandia National Laboratories

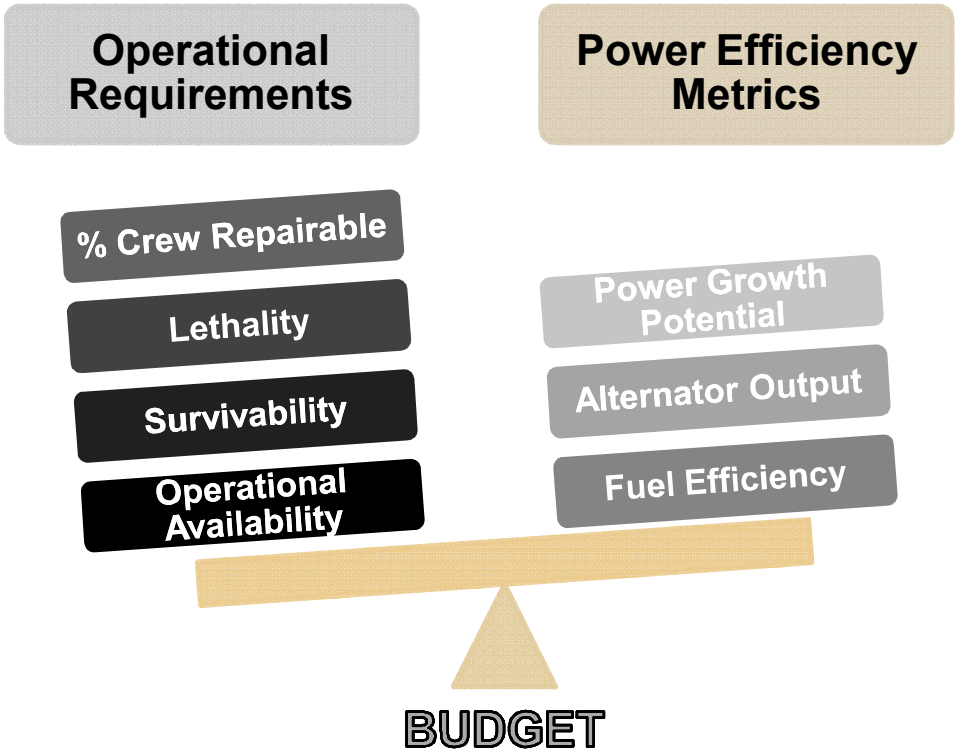
Background

- Recent government leadership initiatives to improve energy environment, and sustainability management
- Acquisition priority
  - Procuring more energy efficient fleets
- Understand tradeoffs between often competing objectives
  - Energy efficient solutions
  - Operational performance
  - Cost

Sandia National Laboratories

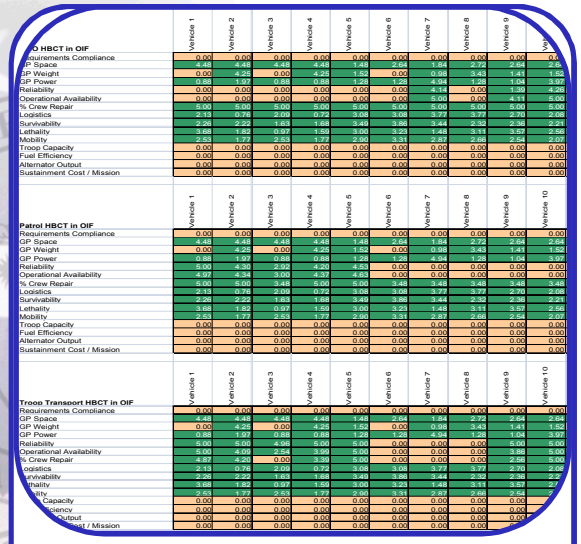
Problem Statement

- Acquire a more energy efficient fleet that can meet operational requirements at the best possible cost



Sandia National Laboratories

Methodology

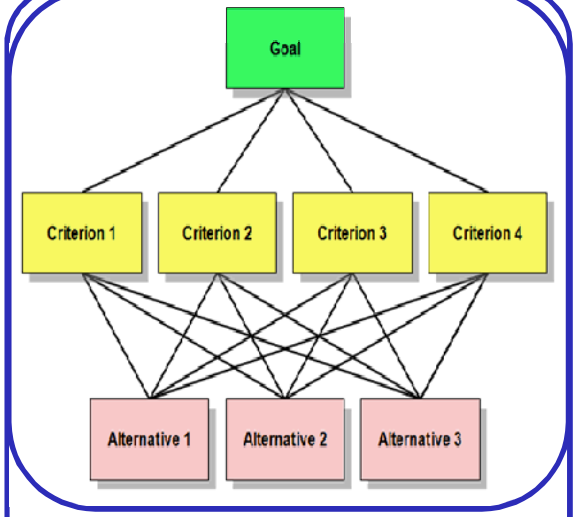


	Vehicle 1	Vehicle 2	Vehicle 3	Vehicle 4	Vehicle 5	Vehicle 6	Vehicle 7	Vehicle 8	Vehicle 9	Vehicle 10
HBCT in OIF										
Requirements Compliance	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
GP Space	4.48	4.48	4.48	4.48	1.48	2.64	1.84	2.72	2.64	2.64
GP Weight	0.00	4.25	0.00	4.25	1.52	0.00	0.98	3.43	1.41	1.52
GP Power	0.88	1.97	0.88	0.88	1.28	1.23	4.94	1.28	1.04	3.97
Reliability	0.00	0.00	0.00	0.00	0.00	0.00	4.14	0.00	1.39	4.48
Operational Availability	0.00	0.00	0.00	0.00	0.00	0.00	5.00	0.00	4.11	5.00
% Crew Repair	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00
Logistics	2.13	0.76	2.09	0.72	3.08	3.08	3.77	3.77	2.70	2.08
Survivability	2.22	2.22	1.63	1.68	3.40	3.89	3.44	2.89	2.89	2.22
Lethality	3.68	1.82	0.97	1.59	3.00	3.23	1.48	3.11	3.57	2.56
Mobility	2.53	1.77	2.53	1.77	2.00	3.31	2.97	2.66	2.54	2.07
Troop Capacity	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Fuel Efficiency	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Alternator Output	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Sustainment Cost / Mission	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

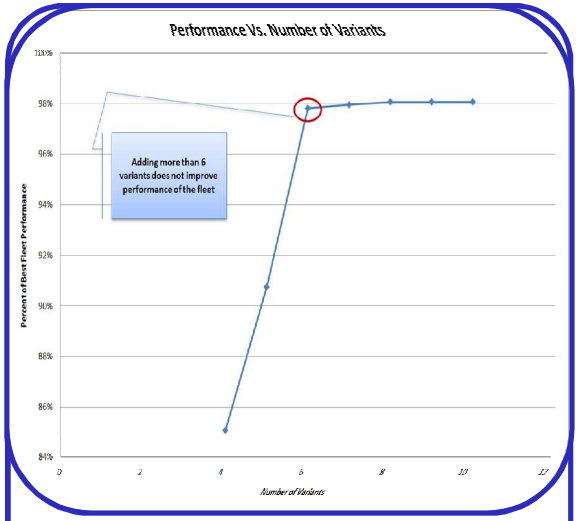
	Vehicle 1	Vehicle 2	Vehicle 3	Vehicle 4	Vehicle 5	Vehicle 6	Vehicle 7	Vehicle 8	Vehicle 9	Vehicle 10
Patrol HBCT in OIF										
Requirements Compliance	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
GP Space	4.48	4.48	4.48	4.48	1.48	2.64	1.84	2.72	2.64	2.64
GP Weight	0.00	4.25	0.00	4.25	1.52	0.00	0.98	3.43	1.41	1.52
GP Power	0.88	1.97	0.88	0.88	1.28	1.23	4.94	1.28	1.04	3.97
Reliability	5.00	4.30	2.02	4.20	4.53	0.00	0.00	0.00	0.00	0.00
Operational Availability	4.97	4.34	3.00	4.37	4.65	0.00	0.00	0.00	0.00	0.00
% Crew Repair	5.00	5.00	3.48	5.00	5.00	3.48	3.48	3.48	3.48	3.48
Logistics	2.13	0.76	2.09	0.72	3.08	3.08	3.77	3.77	2.70	2.08
Survivability	2.22	2.22	1.63	1.68	3.40	3.89	3.44	2.89	2.89	2.22
Lethality	3.68	1.82	0.97	1.59	3.00	3.23	1.48	3.11	3.57	2.56
Mobility	2.53	1.77	2.53	1.77	2.00	3.31	2.97	2.66	2.54	2.07
Troop Capacity	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Fuel Efficiency	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Alternator Output	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Sustainment Cost / Mission	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

	Vehicle 1	Vehicle 2	Vehicle 3	Vehicle 4	Vehicle 5	Vehicle 6	Vehicle 7	Vehicle 8	Vehicle 9	Vehicle 10
Troop Transport HBCT in OIF										
Requirements Compliance	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
GP Space	4.48	4.48	4.48	4.48	1.48	2.64	1.84	2.72	2.64	2.64
GP Weight	0.00	4.25	0.00	4.25	1.52	0.00	0.98	3.43	1.41	1.52
GP Power	0.88	1.97	0.88	0.88	1.28	1.23	4.94	1.28	1.04	3.97
Reliability	5.00	5.00	4.98	5.00	5.00	0.00	0.00	0.00	5.00	5.00
Operational Availability	5.00	4.09	2.54	3.99	5.00	0.00	0.00	0.00	3.88	5.00
% Crew Repair	4.97	4.20	0.00	3.39	5.00	0.00	0.00	0.00	2.58	5.00
Logistics	2.13	0.76	2.09	0.72	3.08	3.08	3.77	3.77	2.70	2.08
Survivability	2.22	2.22	1.63	1.68	3.40	3.89	3.44	2.89	2.89	2.22
Lethality	3.68	1.82	0.97	1.59	3.00	3.23	1.48	3.11	3.57	2.56
Mobility	2.53	1.77	2.53	1.77	2.00	3.31	2.97	2.66	2.54	2.07
Troop Capacity	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Fuel Efficiency	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Alternator Output	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Sustainment Cost / Mission	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Quantitative Analysis of Performance Attributes



Qualitative Assessment based on SME/User criteria



Optimize fleet management and acquisition based on constraints

- **Within a single framework, provide a tool that allows for optimum fleet management**

Sandia National Laboratories

Analysis Architecture

Quantitative Analysis

- Alternator Output
- Fuel Efficiency
- Operational Availability
- Survivability

Qualitative Assessment

- Assign relative importance to performance parameters

Optimization

- Budget
- Variants
- Acquisition Rules

Sandia National Laboratories

Optimization Model Formulation

- *Objective:* Based on weighted performance values (both operational and energy efficient metrics), what is the proper fleet composition of vehicles by variant and how should they be allocated to BCTs and missions?

- *Subject To:*
  - Budget available per period (including price/volume discounts, fixed costs)
  - Number of unique variants of vehicles allowed in the fleet
  - Performance requirements (operational, energy efficient)
  - Theatre, BCT, and Mission requirements
  - Assumptions of existing fleet

- *Key output:*
  - Number of vehicles by variant to purchase (and/or re-purpose) over time
  - Assignment of vehicles by theater, BCT and mission over time

Model Assumptions

- Initial inventory = 10,000 vehicles
  - Need 23,436 to outfit 58 Brigades
    - 30 HBCT
    - 8 SBCT
    - 20 IBCT
- 10 performance parameters
  - Operational Requirements
  - Energy Efficiency Metrics
- 16 vehicle variants available
  - Acquisition Cost
  - Fixed cost to acquire a new variant
  - Volume price discounts
- Theaters (Training, Deployment)
- Missions (Patrol, MCO, Troop Transport, Convoy)

Sandia National Laboratories

Scenarios Examined

- Suppose funds are unlimited and we can support all variants in the fleet – *"Ideal Fleet"*
- Suppose funds are very tight and we have to minimize the cost but we can support all variants in the fleet – *"Cheapest Fleet"*
- Tradeoff of performance vs. budget
- Tradeoff of performance vs. number of variants

Sandia National Laboratories

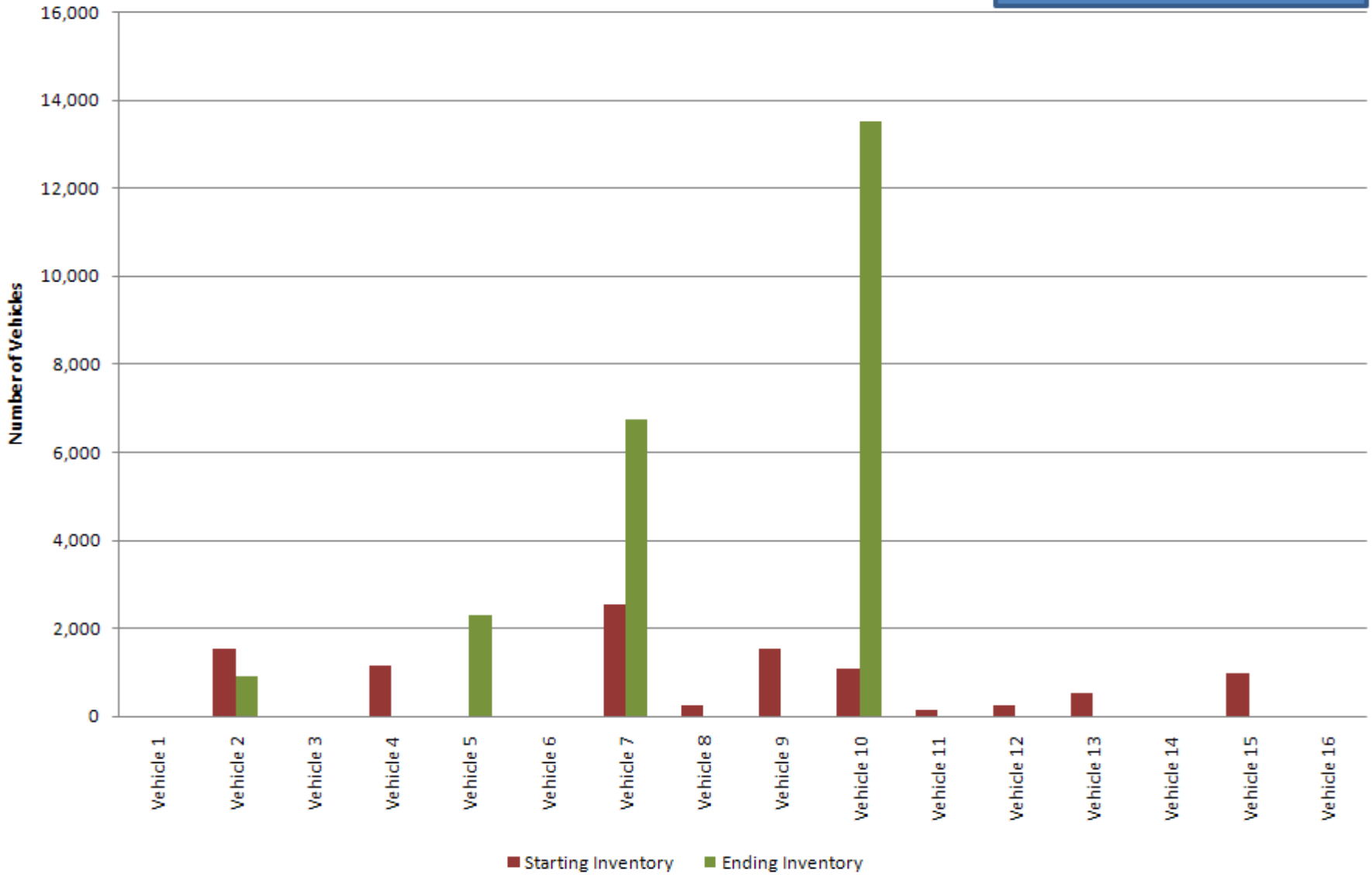
“Ideal Fleet”

Budget: Unlimited

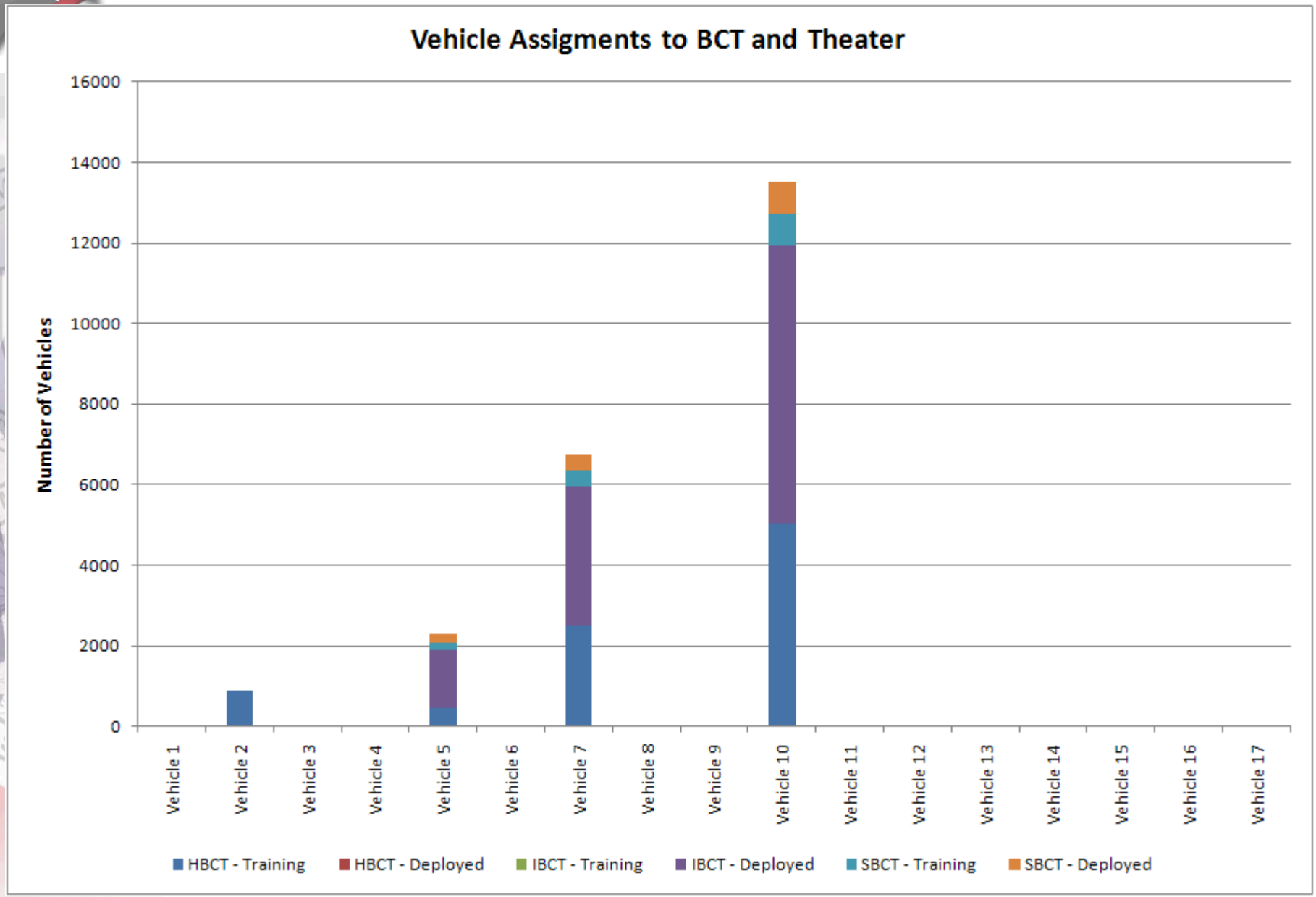
Number of Variants: 16

Ideal Fleet:
Initial Vs. Optimal Inventory

5,454 Retired Vehicles
18,892 Purchased Vehicles



Sandia National Laboratories



Sandia National Laboratories

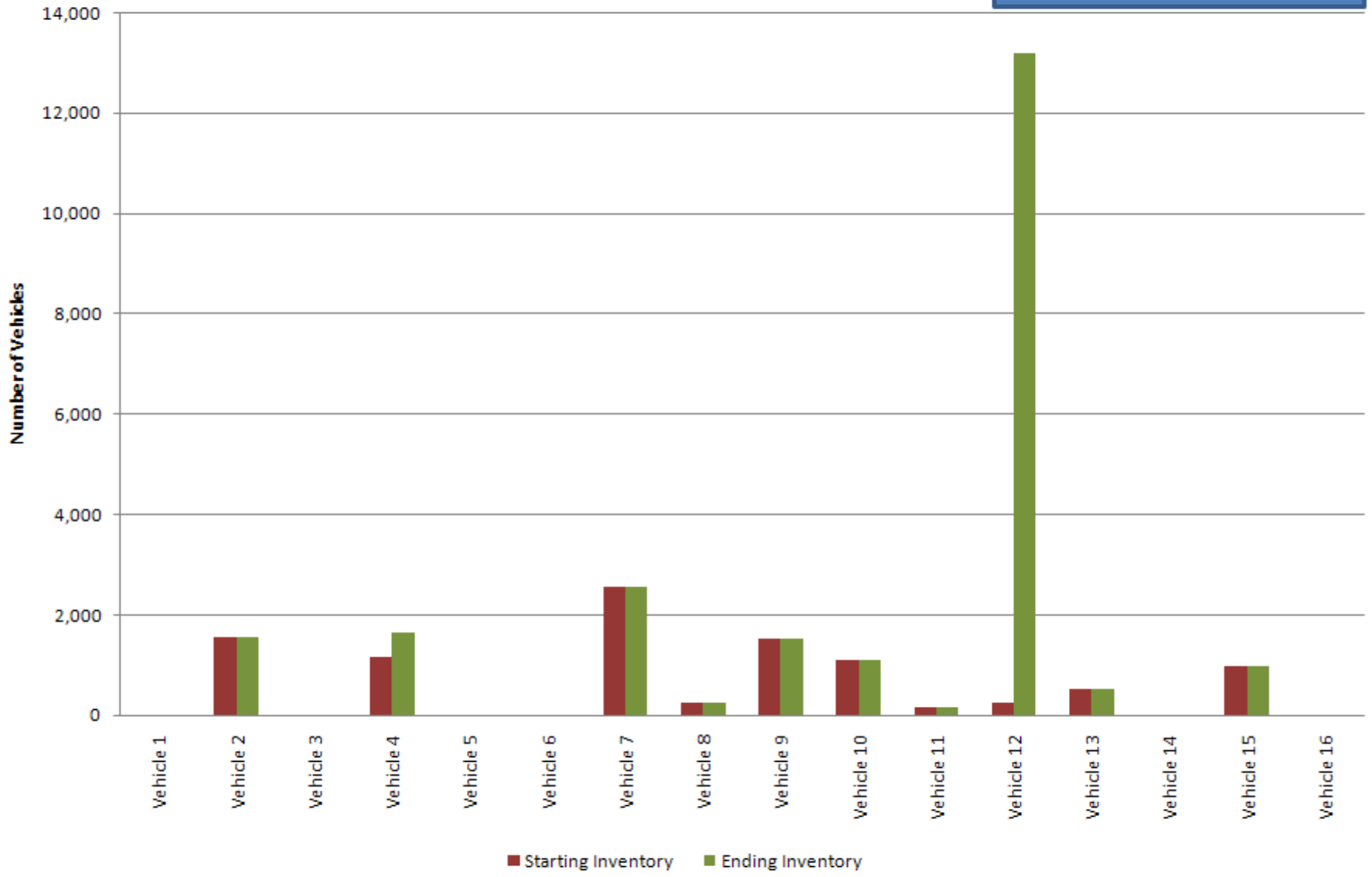
“Cheapest Fleet”

Budget: $5.18B

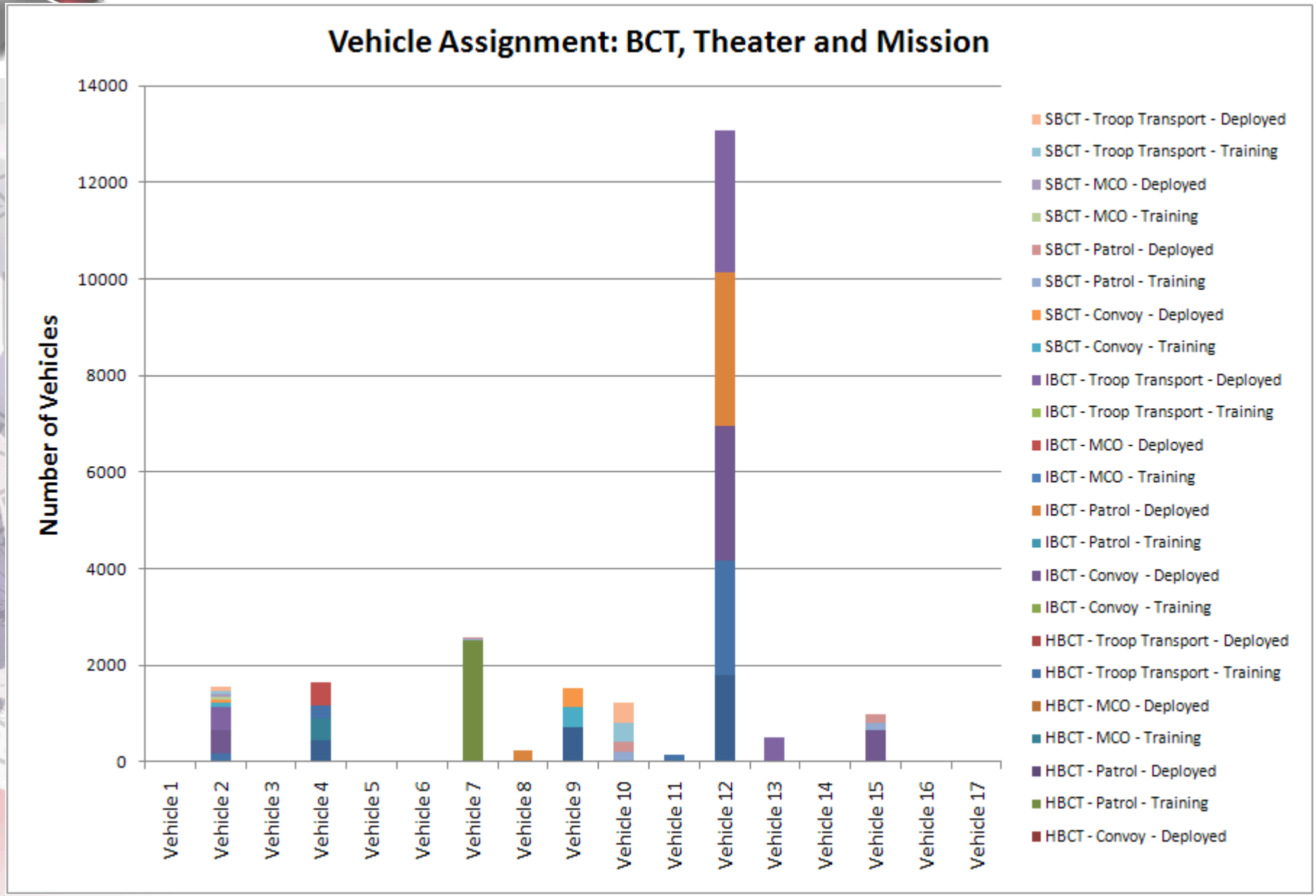
Number of Variants: 16

Cheapest Fleet:
Initial Vs. Optimal Inventory

0 Retired Vehicles
13,436 Purchased Vehicles



Sandia National Laboratories



Sandia National Laboratories

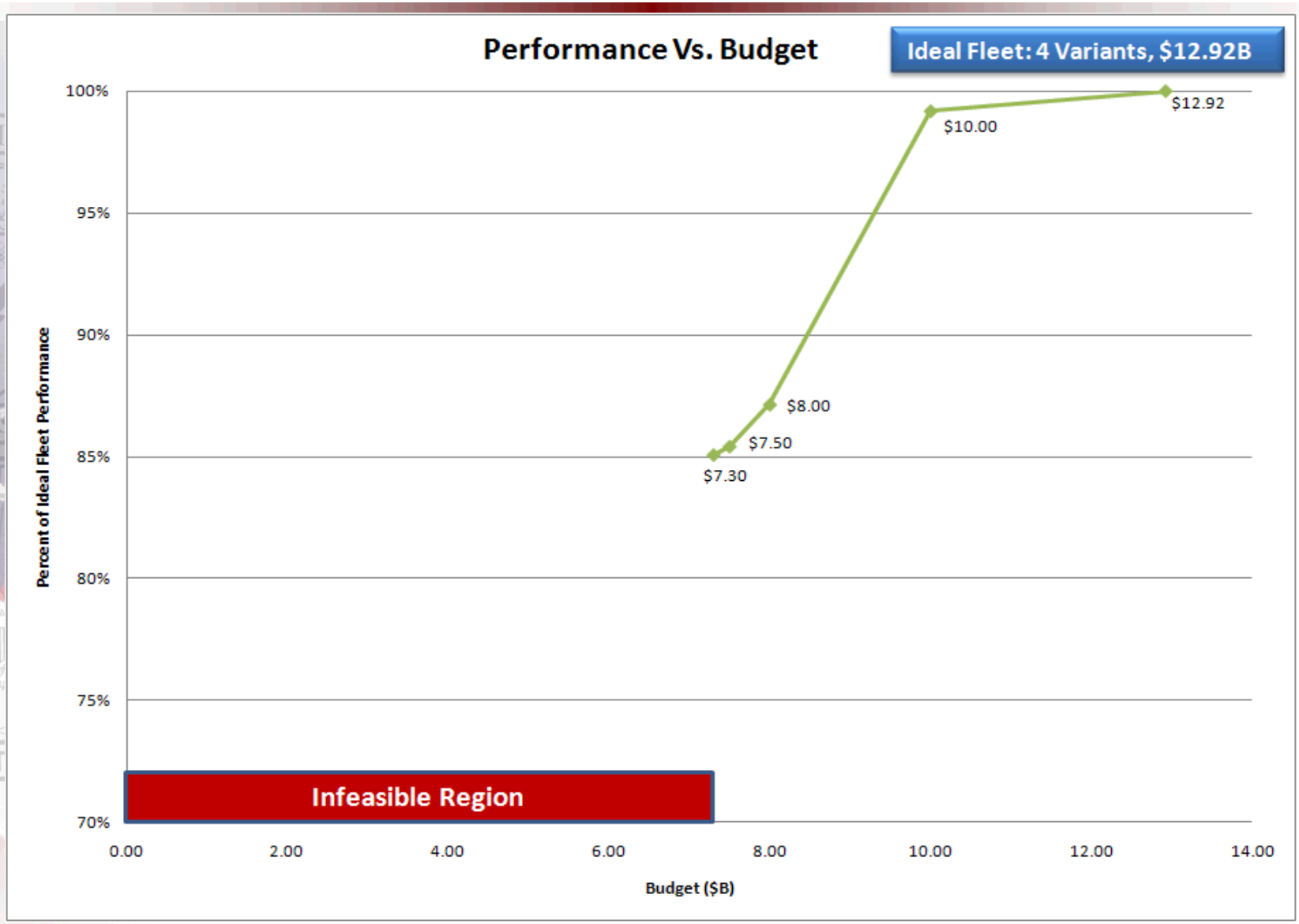
Tradeoff Frontier
Performance Vs. Budget

Budget: Variable

Number of Variants: 4

Sandia is a multi-program laboratory operated by Sandia Corporation, a Lockheed Martin Company, for the United States Department of Energy under contract DE-AC04-94AL85000

Tradeoff: Performance vs. Budget



Sandia National Laboratories

Tradeoff Frontier
Performance Vs. Number of Variants

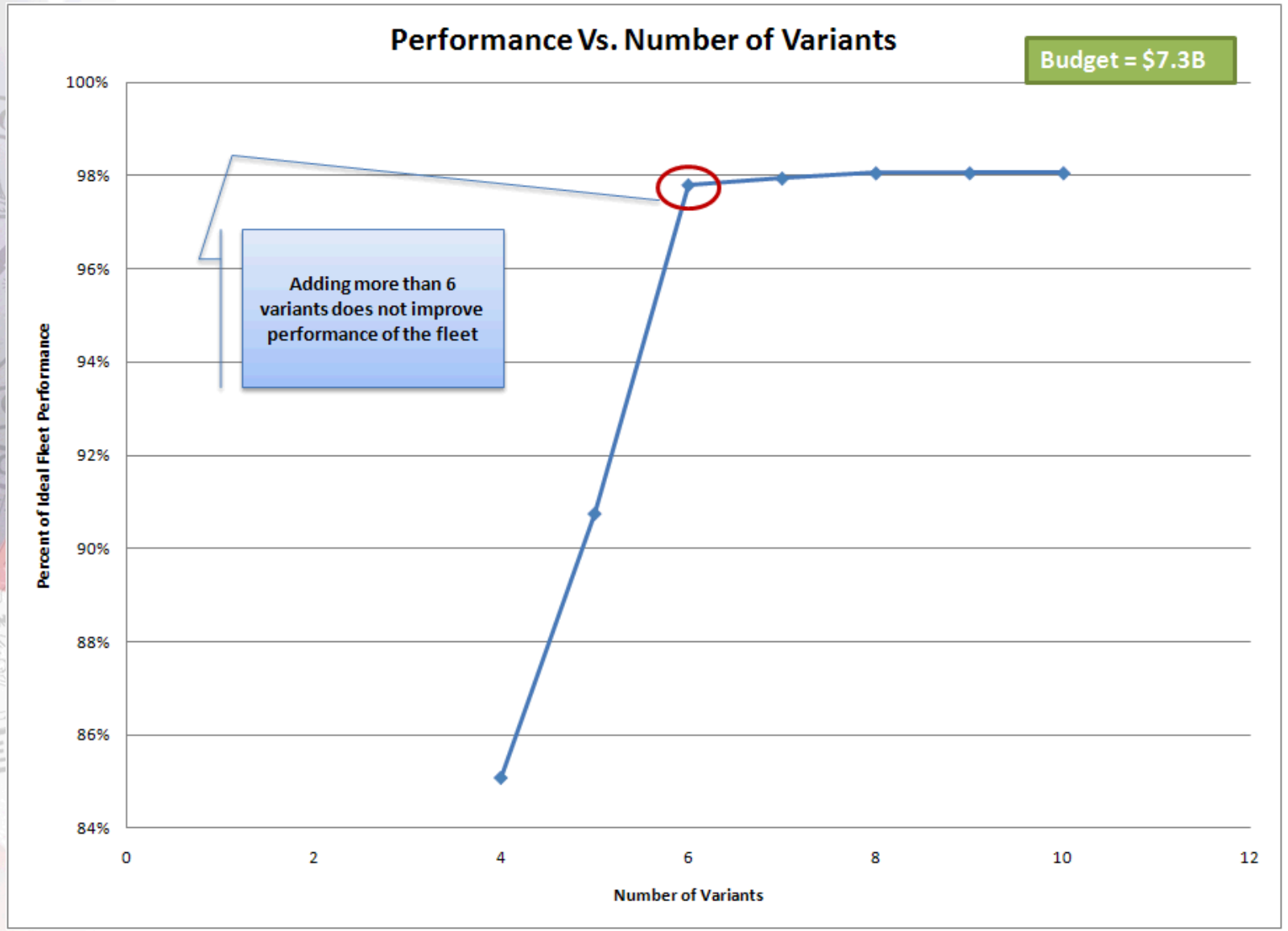
Budget: $7.3B

Number of Variants: Variable

Sandia is a multi-program laboratory operated by Sandia Corporation, a Lockheed Martin Company, for the United States Department of Energy under contract DE-AC04-94AL85000

Sandia National Laboratories

Tradeoff: Performance vs. No of Variants



Sandia National Laboratories

Summary

- This analysis framework incorporates
  - Quantitative analysis of performance parameters
  - Qualitative assessments from SME about relative importance of model parameters
  - Optimization capability to evaluate tradeoffs
- With increasing scrutiny

Sandia National Laboratories

QUESTIONS?

Sandia National Laboratories

Liliana Andrade

landrad@sandia.gov, 505-284-8482

Sandia is a multi-program laboratory operated by Sandia Corporation, a Lockheed Martin Company, for the United States Department of Energy under contract DE-AC04-94AL85000

Sandia National Laboratories