

**ADVANCED COLLABORATIVE SYSTEM
OPTIMIZATION MODELER (*ACSOM*)**
(A.K.A. Armored Combat System Optimization Modeler)
&
SEARCH, EXPLORE AND LEARN (*SEaL*)
EXTENSION

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Decision and Risk Analysis
Systems Engineering
General Dynamics Land Systems
Sterling Heights, Michigan

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Overview

- ACSOM Whole-system Trade Capabilities
- ACSOM's Application Example - Large Program Trade Study
- Extensions to Force on Force
- Enhanced Capability (SEaL) – Large Bid Program Example

Recognition

Mr. Dave Strimling, the father of ACSOM:

- 1) 2006 US National Defense Industrial Association (NDIA) Ferguson Award for Excellence in Systems Engineering
- 2) 2006 General Dynamics Technology Excellence Award
- 3) 2006 General Dynamics Engineer of the Year Award

Mr. Steve Rapp, for SEaL extension to ACSOM:

- 1) 1987 MORS Award – Thesis Most Likely To Improve National Defense, Naval Postgraduate School
- 2) 1989 ORSA/TIMS MAS Koopman Prize

DRA Team:

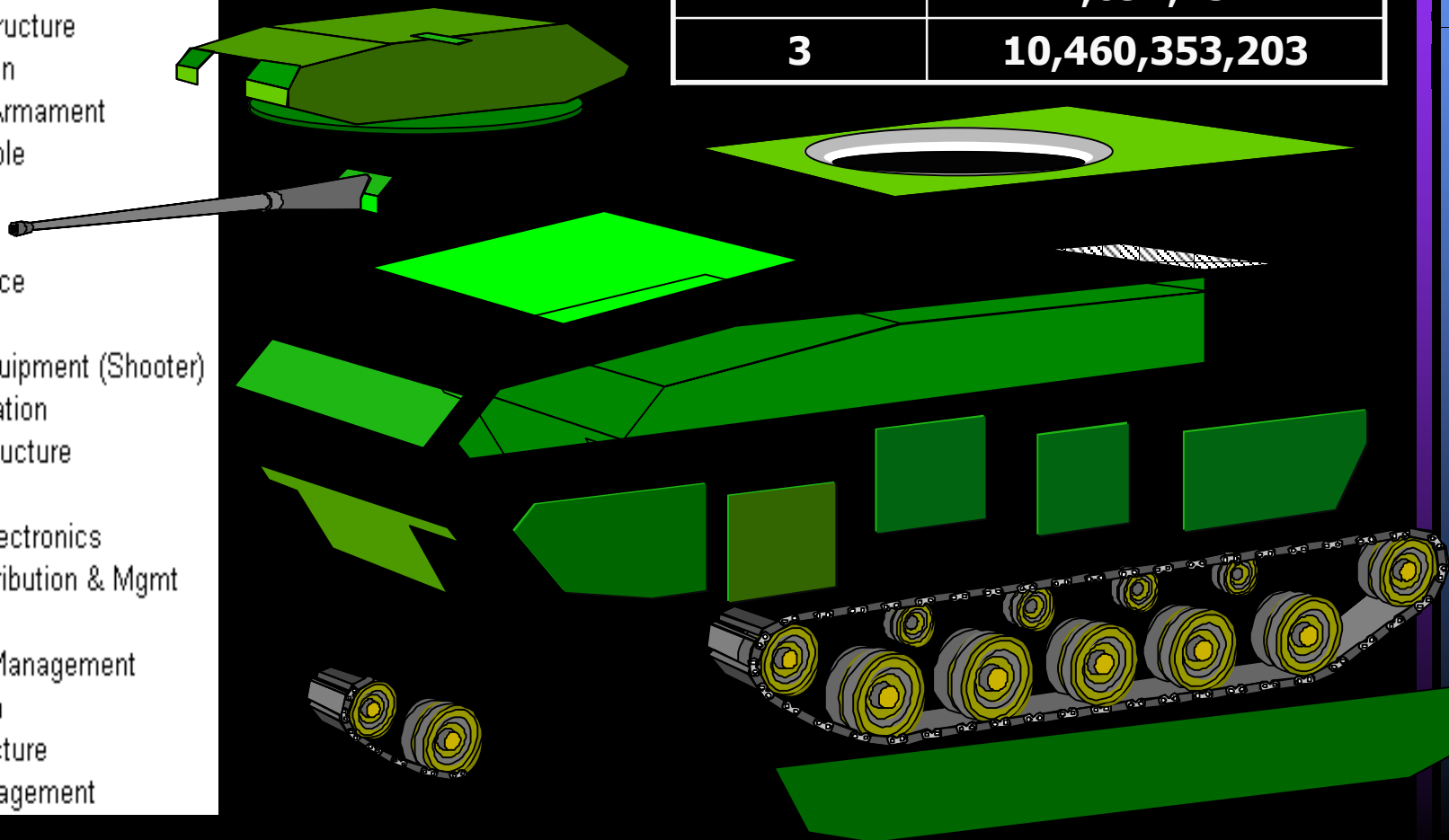
2007 Ground Combat Systems PEO – Certificate of Appreciation

The Whole-system Design Problem

21 SUBSYSTEMS

AFES
Armor
Chassis Structure
Crew Station
Defensive Armament
Dismountable
ECS
Fuel
Hit Avoidance
Lighting
Mission Equipment (Shooter)
Mission Station
Mission Structure
NBC
Platform Electronics
Power Distribution & Mgmt
Propulsion
Signature Management
Suspension
Turret Structure
Water Management

Options per subsystem	Theoretically Possible Subsystem Combinations
2	2,092,152
3	10,460,353,203



ACSOM and SEaL

1). A Set of Balanced, Feasible, Non-dominated, Whole-system Design Solutions

2). displayed so that **System Performance** and **Allocation Thresholds** can be assessed,

3). all done within minutes by using a non-specialized PC.

Considers **Full Spectrum** of Subsystem Options

Prevents Infeasible Combinations of Subsystems

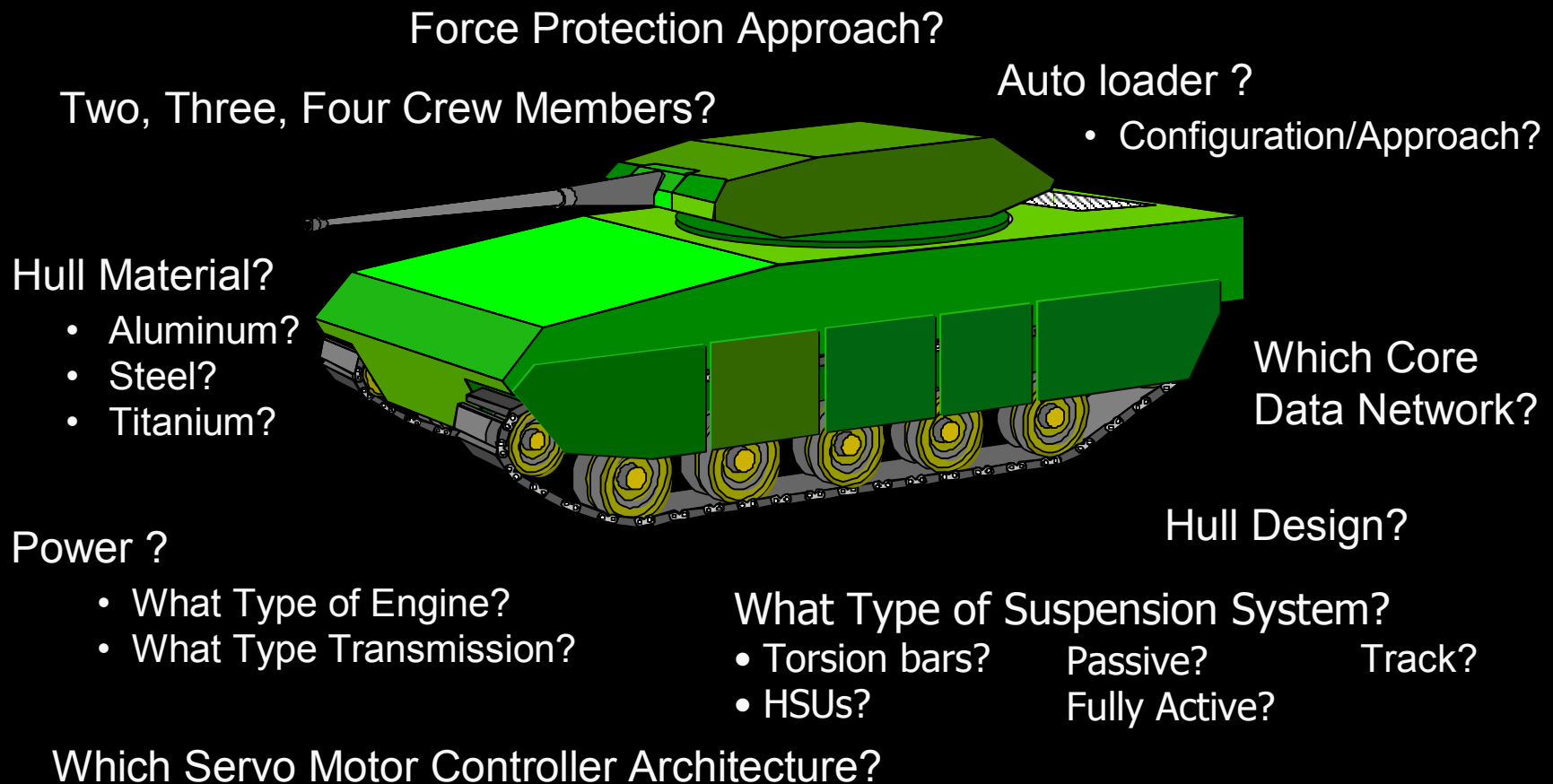
Finds a set of **Balanced Solutions**, Performance *versus* Burdens

4). SEaL provides a direct solve extension to ACSOM that finds a single vehicle alternative by using multi-objective optimization balancing all criteria

Considers All to Make the Whole

Full Spectrum

Numerous Subsystems with a multitude of options for each



Incorporates Interactions

Prevents Infeasible Combinations

Prerequisite

SubSys 1

Opt.

X
Y
Z

○
is required in
order to select

○
is incompatible
with

○
is inseparable
from

SubSys 2

Opt.

A
B
C
D

- Auto loader design
A and D require Hull
design Y

Incompatible

SubSys 1

Opt.

X
Y
Z

○
is required in
order to select

○
is incompatible
with

○
is inseparable
from

SubSys 2

Opt.

A
B
C
D

- Suspension option Y
(torsion bars) will not
work with engine
option D (diesel) . . .
space claim

Co-requisite

SubSys 1

Opt.

X
Y
Z

○
is required in
order to select

○
is incompatible
with

○
is inseparable
from

SubSys 2

Opt.

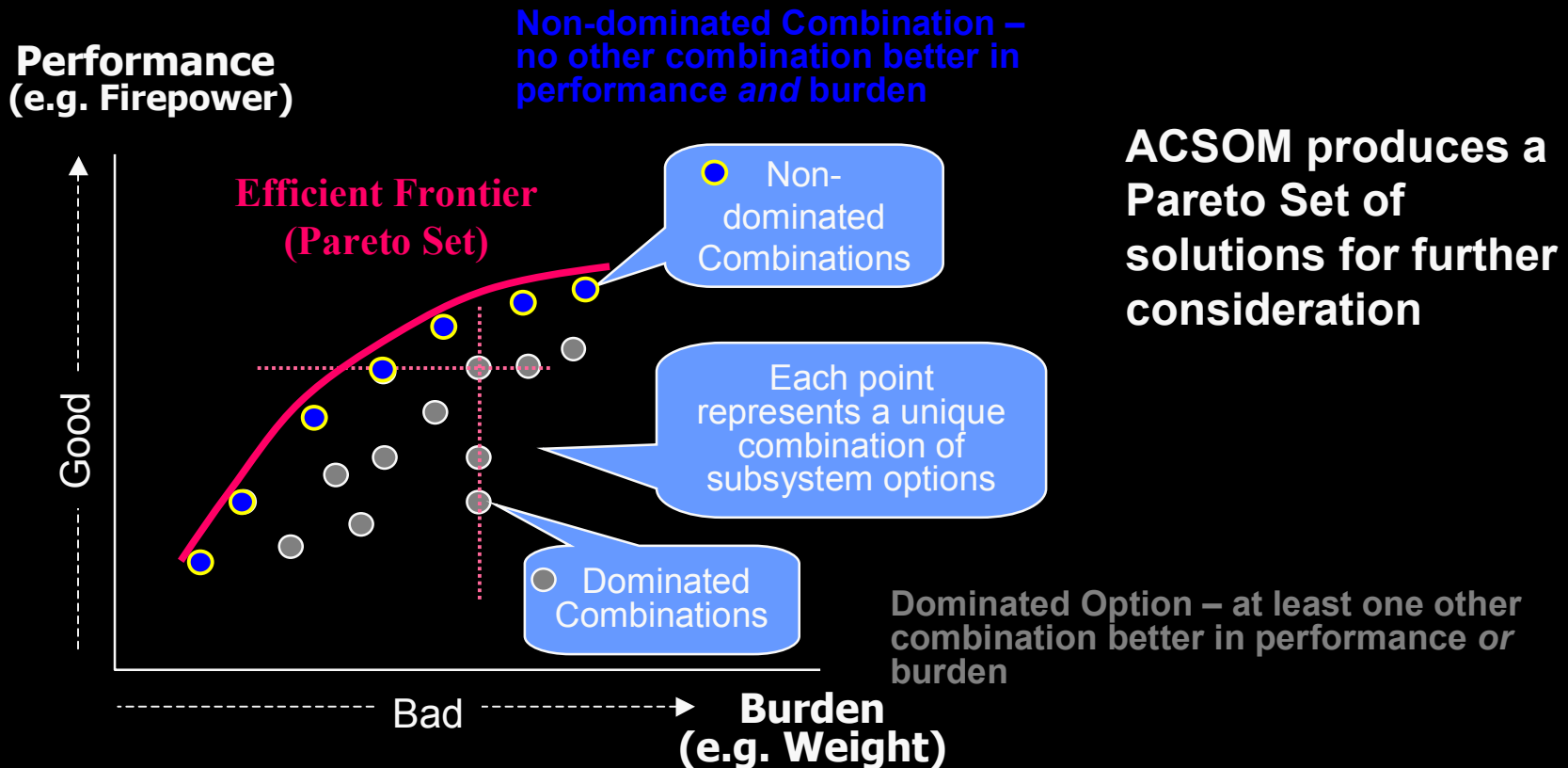
A
B
C
D

- Frame Structure option
Y and Armor option D
must be selected
together

Balances the Possibilities

Balance

Consider only balanced solutions



Balances the Possibilities (more detail)

Best Balance

1

Select feasible combinations of subsystem options that:

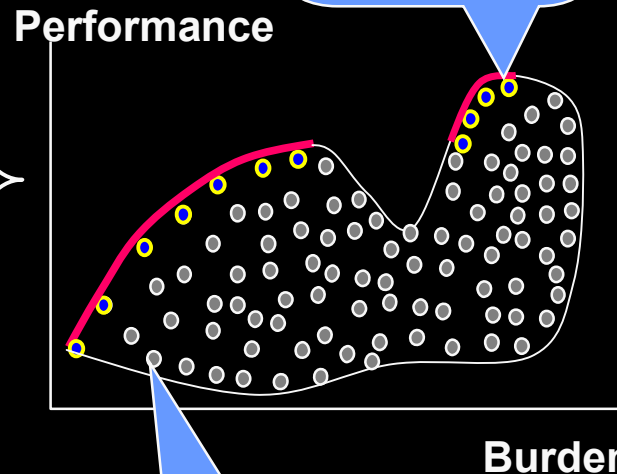
Maximizes Performance Score

Σ

Speed * w_1
Acceleration * w_2
Fuel Efficiency * w_3
Ride Quality * w_4
Rate of Fire * w_5
SIGMAN * w_6
Survivability * w_7
Maint. Ratio * w_8
FOV * w_9



Performance



Burden

• Dominated Combinations

2

Minimizes Burdens

Life Cycle Cost
Risk
Power
Thermal
Weight (lbs.)
MTBSA, etc.

ACSOM Needs

1. Identification of subsystems
 2. Options within each subsystem
 3. Option interactions
 4. Performance metrics associated with each subsystem
 5. Values and utility functions for performance metrics
 6. Burden values
-

ACSOM Gives

1. Solutions Table
2. Values Table
3. "What-If" Tool

Subsystem	Subsystem Option
Suspension	Torsion Bar
Suspension	HSU
Suspension	Hybrid
Propulsion	Diesel
Propulsion	Turbine
Propulsion	Warp
Turret	Main Gun
Turret	Main Gun and Aux Gun
Hull Material	Titanium
Hull Material	Steel
Hull Material	Composite
Hull Material	Adamantium

Brief Example

Vs.

Lifecycle Cost	Weight	Risk
-------------------	--------	------

Considers Only the Plausible

Allocation Achievement

Four subsystems considered

Solutions Table

Performance Score

Balance against LCC, Weight, and Risk

Solution	Suspension	Propulsion	Turret	Hull Material	MUF	Lifecycle		
						Cost	Weight	Risk
2	Torsion Bar	Turbine	Main Gun	Titanium	0.89	303000	14000	2.2
3	Torsion Bar	Diesel	Main Gun	Titanium	0.76	240000	20000	2
5	Torsion Bar	Turbine	Main Gun	Steel	0.72	301000	16000	1.6
1	Torsion Bar	Diesel	Main Gun	Steel	0.62	238000	22000	1.4
6	Hybrid	Turbine	Main Gun	Composite	0.59	378578	12780	1.95
4	HSU	Turbine	Main Gun	Steel	0.51	343000	15600	2

6 Solutions

Too Costly!

Too Heavy!

- Weight to be no greater than 20,000 lbs
- LCC to be no greater than \$300K
- Risk to be no greater than 2.0

Shows the Details

Data		Color		!		Color Key: Good				OK		Poor					
RANK MODE		3 COLOR		Performance Metrics						Burden Metrics							
				Ride Quality		Mobility		Lethality		Survivability		Weight		Risk		Lifecycle Cost	
Solution ID		MUF															
2		0.890		3		3		1		1		2		5		4	
3		0.760		3		4		1		1		5		4		2	
5		0.720		3		3		1		2		4		2		3	
1		0.620		3		4		1		2		6		1		1	
6		0.590		2		2		1		3		1		3		6	
4		0.510		1		1		1		4		3		4		5	

Subsystem	Subsystem Option	1	2	3	4	5	6	
Suspension	Torsion Bar	1	1	1	0	1	0	66.7%
Suspension	HSU	0	0	0	1	0	0	16.7%
Suspension	Hybrid	0	0	0	0	0	1	16.7%
Propulsion	Diesel	1	0	1	0	0	0	33.3%
Propulsion	Turbine	0	1	0	1	1	1	66.7%
Propulsion	Warp	0	0	0	0	0	0	0.0%
Turret	Main Gun	1	1	1	1	1	1	100.0%
Turret	Main Gun and Aux Gun	0	0	0	0	0	0	0.0%
Hull Material	Titanium	0	1	1	0	0	0	33.3%
Hull Material	Steel	1	0	0	1	1	0	50.0%
Hull Material	Composite	0	0	0	0	0	1	16.7%
Hull Material	Adamantium	0	0	0	0	0	0	0.0%

Answers What-if Questions

What-If Tool

			Survivability	Mobility	Ride Quality	Lethality	Lifecycle Cost	Weight	Risk
Select A Pareto Alternative:	2	LOAD	0.4	0.15	0.1	0.24	303000	14000	2.2
Subsystem	Option		Survivability	Mobility	Ride Quality	Lethality	Lifecycle Cost	Weight	Risk
Suspension	Torsion Bar		0.18	0.10	0.10	0	78000	1200	0.5
Propulsion	Turbine		0	0.05	0	0	190000	8000	0.3
Turret	Main Gun		0	0	0	0.24	25000	1800	0.6
Hull Material	Titanium		0.22	0	0	0	10000	3000	0.8
			0.40	0.15	0.10	0.24	303000	14000	2.2

What-If Tool

			Survivability	Mobility	Ride Quality	Lethality	Lifecycle Cost	Weight	Risk
Select A Pareto Alternative:	2	LOAD	0.32	0.16	0.17	0.24	345000	13600	2.6
Subsystem	Option		Survivability	Mobility	Ride Quality	Lethality	Lifecycle Cost	Weight	Risk
Suspension	HSU		0.10	0.11	0.17	0	120000	800	0.9
Propulsion	Turbine		0	0.05	0	0	190000	8000	0.3
Turret	Main Gun		0	0	0	0.24	25000	1800	0.6
Hull Material	Titanium		0.22	0	0	0	10000	3000	0.8
			0.32	0.16	0.17	0.24	345000	13600	2.6

Successful Use Across Program Variants

Program Vehicle Variants								
Perf. Metrics	12	13	12	14	13	12	14	15
Sub-systems	6	6	12	14	13	7	14	15
Theor. Comb.	3,584	1,792	1,792	20,160	10,752	4,928	32,256	10,752
Burden Metrics	7	7	7	7	7	7	7	7

Burden Metrics

AUPC
Cost Risk
Tech Risk
Power
Thermal
Weight
Reliability

Subsystems

Ammunition Handling
Signature Management
Propulsion
Suspension
Defensive Armament
Structure and Armor
Water Purification

Performance Metrics

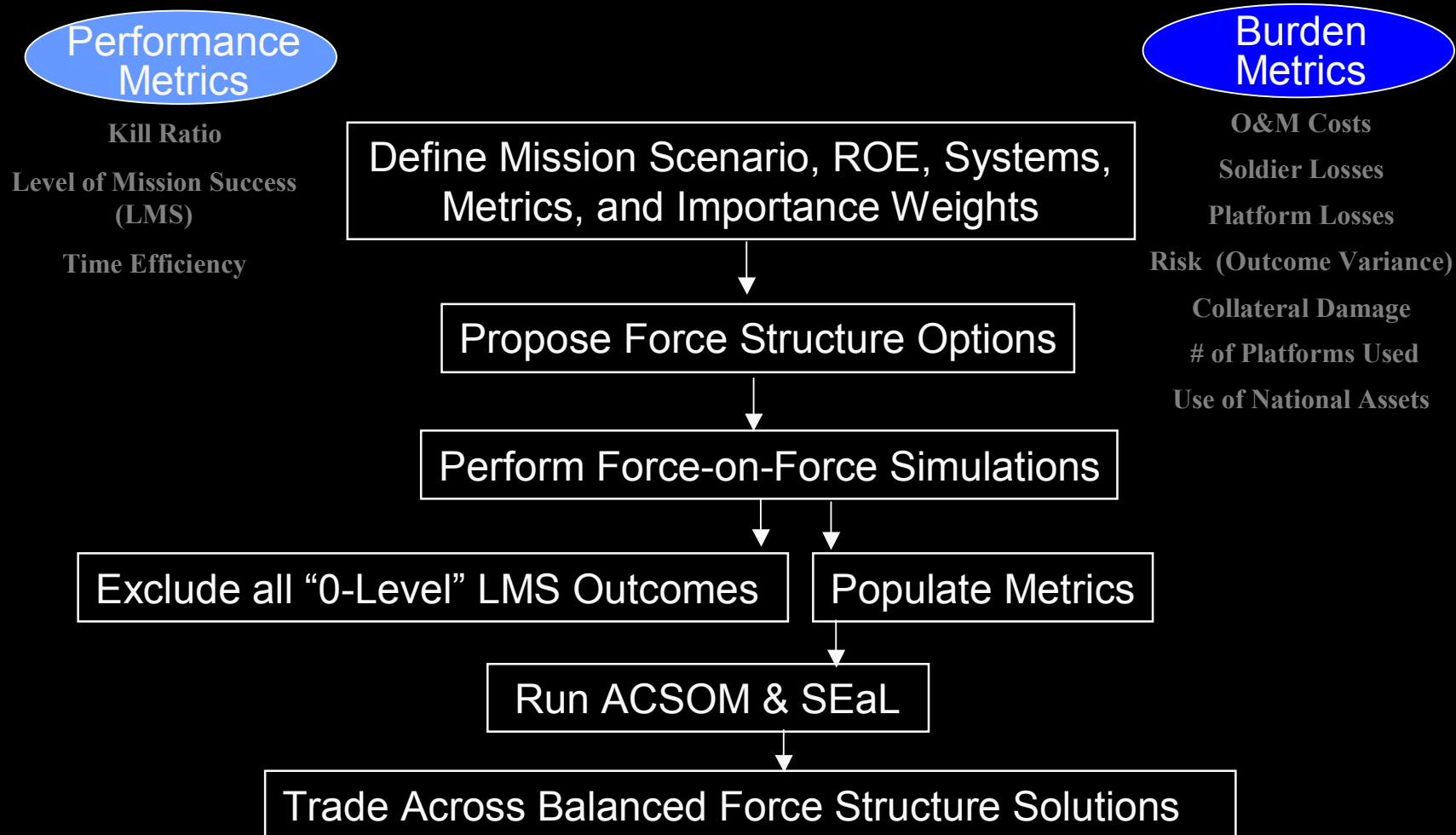
Primary Road Speed
Cross Country Speed
Acceleration
Mission Fuel Cons.
Susp. Ride Quality
Skirt Coverage
Pk Against Target
Signature Management
Ammunition Vulnerability
Water Purification
Rate of Fire
Multi-Hit Distance

Gave Insight to the Program

- **Best subsystem option for one variant wasn't necessarily best common option - trade off across family for commonality – drove actual program policy change**
- **Assess alternatives with respect to customer's allocation priority**
- **New metric weights easily incorporated and impact seen**
- **New metric values (better information) easily incorporated and impact seen**

Can Assess Force Structure

Provide balanced system of systems within a specified mission scenario



Enhanced Capability - SEaL

First – Single Criteria Optimization

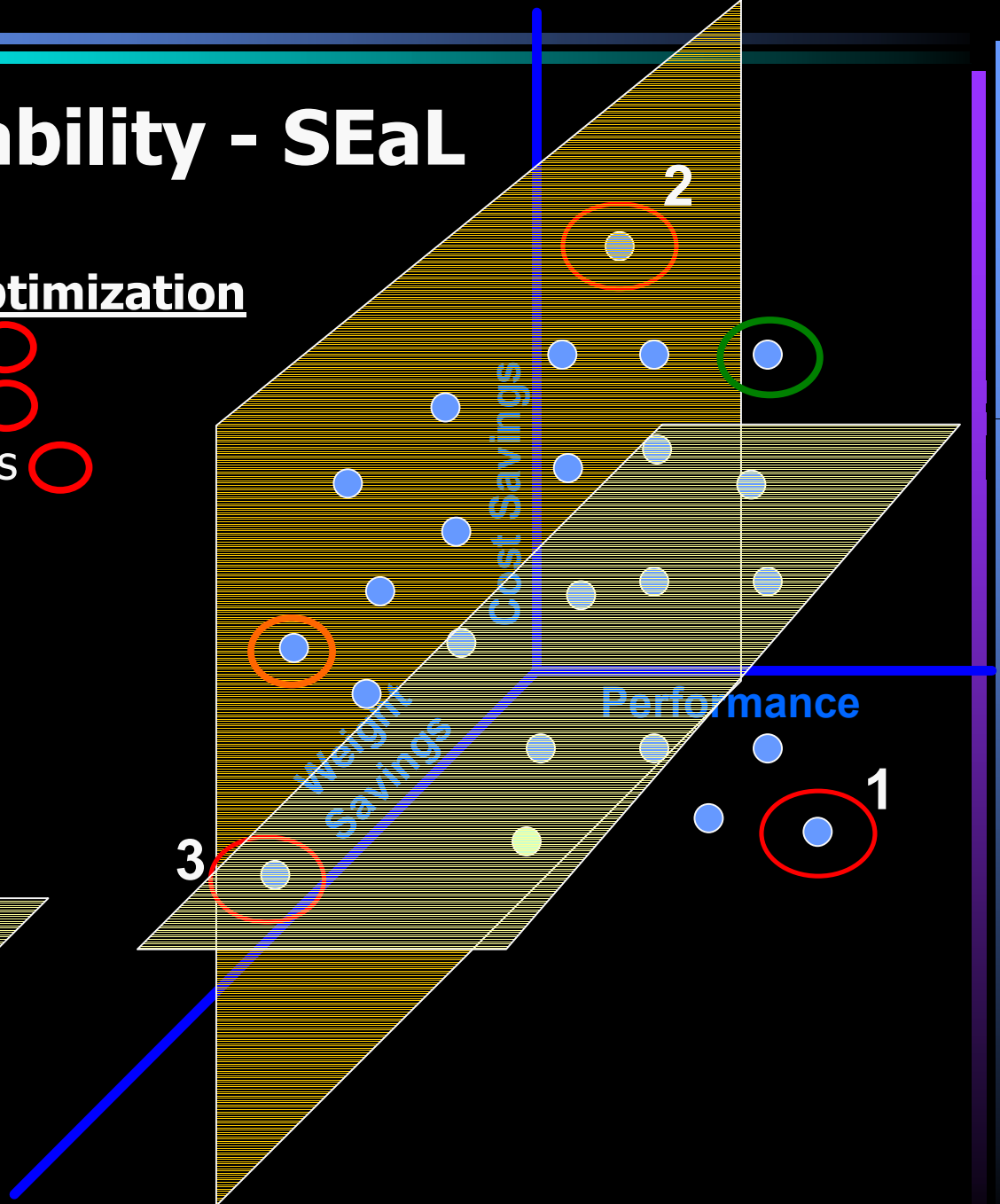
1. Find Best Performance ○
2. Find Best Cost Savings ○
3. Find Best Weight Savings ○

Second

4. Create Lower Bound For Performance
5. Find Best Cost in Reduced Trade Space

Third

6. Create Lower Bound For Cost Savings
7. Find Best Weight in Reduced Trade Space



SEaL Results

Burdens					Subsystems				
Sol #	MUF	Cost	Weight (lbs)	Description	Armor	Drivetrain	Engine	Structure	Suspension
1	0.6429	\$134,500.00	14422	Max MUF	Aluminum Upper/Lower	Hi Tech	High Output	Monocoque	Conventional - Beefed Up
2	0.3821	\$66,250.00	15035	Min Cost	Cheaper Aluminum	Baseline	Base +50 HP	Baseline	Baseline
3	0.4772	\$151,000.00	11636	Min Weight	Al Lower/ High-Hard Upper	Hi Tech	High Output	Monocoque	Baseline
4	0.6022	\$104,500.00	14722	MUF > .6, Min Cost	Aluminum Upper/Lower	Baseline Improved	Base +50 HP	Monocoque	Conventional - Beefed Up
5	0.5974	\$92,250.00	12263	MUF > .55, Cost < 110000, Min Weight	Al Lower/ High-Hard Upper	Baseline Improved	High Output	Monocoque	Conventional - Beefed Up

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Finds a set of **Balanced Solutions**, Performance *versus* Burdens