Using ERS Tools for Trade Space Exploration of Military Ground Vehicles

With an Iterative Concept Development and Performance Analysis Process

Dr. Matt Castanier*, Mr. Andy Pokoyoway, Mr. Gary Bronstetter

US Army Tank Automotive Research, Development, and Engineering Center (TARDEC)

Abstract ID: 19035 *** Lead author contact info:** 586-282-8461 <matthew.p.castanier.civ@mail.mil>

NDIA Systems Engineering Conference
Springfield, VA 27 OCT 2016

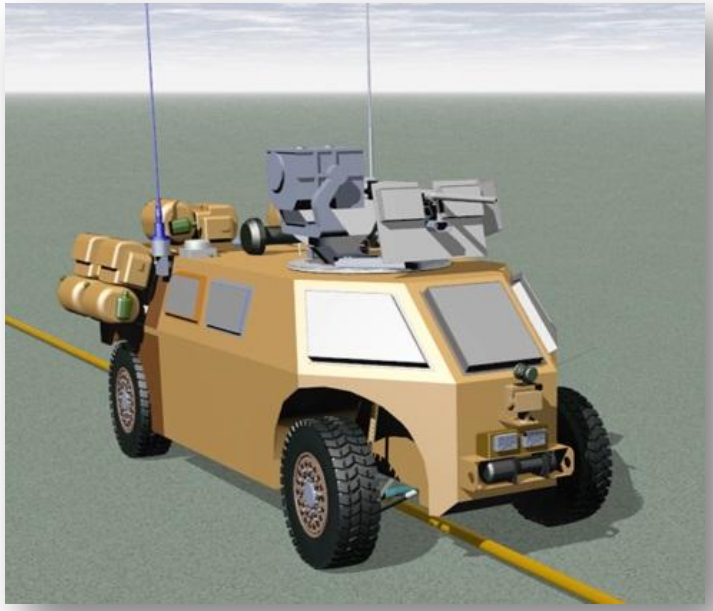
Background and Motivation

- Performing multidisciplinary design optimization of a military ground vehicle is extremely challenging
- Setting the requirements (defining the optimization problem to be solved) is an even greater challenge
- There is a need for a collaborative, flexible platform for performing **trade space exploration**
  - Vary requirements to evaluate performance payoff
  - Iterate on the requirements-concept-analysis process

ERS LRV Trade Space Exploration Project

Objectives

- Learn, evaluate, and provide feedback to developers of **CREATE-GV and ERS Tools**
- Apply these tools to the **LRV notional concept vehicle** to perform **trade space exploration**



CREATE-GV: Computational Research and Engineering Acquisition Tools and Environments – Ground Vehicles

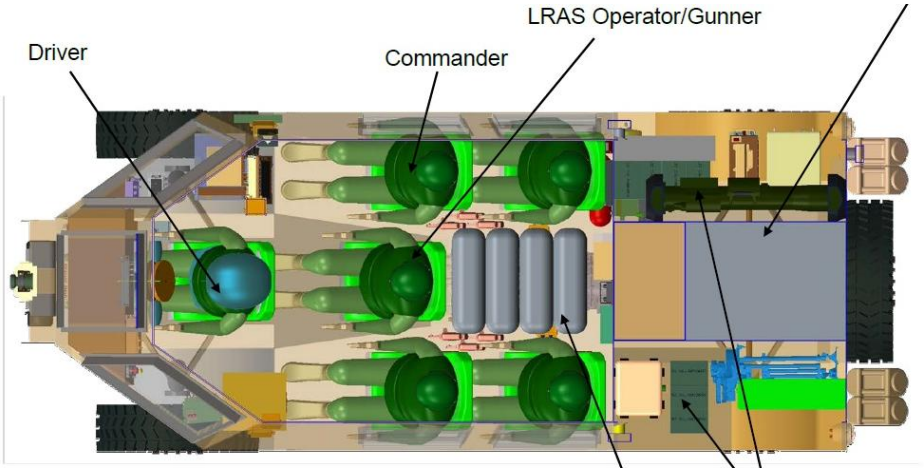
ERS: Engineered Resilient Systems

LRV: Light Reconnaissance Vehicle

LRV – A Notional Concept for a New-Start Vehicle

Notional concept was initially developed based on these requirements:

- Crew of 6
- Power for 96-hour mission
- Silent watch, silent move
- Advanced reconnaissance & surveillance equipment package
- CH-47 internal transport and sling-load transport



Initial LRV Concept

Operational Mode
(Full Combat Capability)
~7 tons

CH-47 Internal Transport Mode
~5 tons

Trade Space Analysis During Concept Phase

Some early lessons learned…

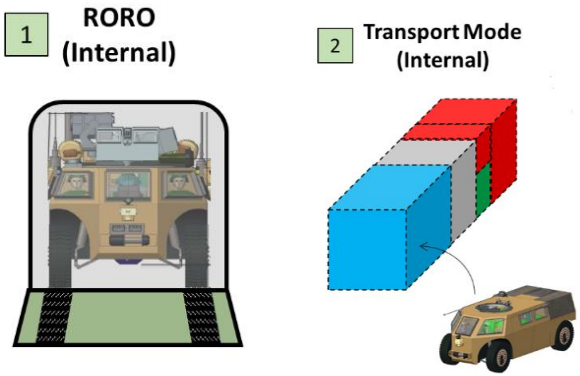
- Much of the trade space analysis is effectively carried out during the initial concept phase
  - When developing the CAD model

- Relatively few requirements dominate the initial layout, space and weight claim studies
  - For the LRV, the internal transportability requirement had a particularly strong effect

- This has a profound effect on the remaining trade space
  - Before a more complete analysis is performed

Revisiting Transportability Requirement

- Based on discussions with warfighter customer* on actual needs, the transportability requirement was relaxed
  - * TARDEC Emerging Concepts Office (ECO)
- Internal transport no longer strictly required
  - Sling-load-only allowed
  - Relaxes size, weight, and packaging constraints
- Sling-load configurations allow:
  - Improved blast protection (V-belly armor, floating floor, higher standoff)
  - Increasing occupant space
  - Adding canine space



Trade Space Exploration Process

Reviewed initial concept & requirements

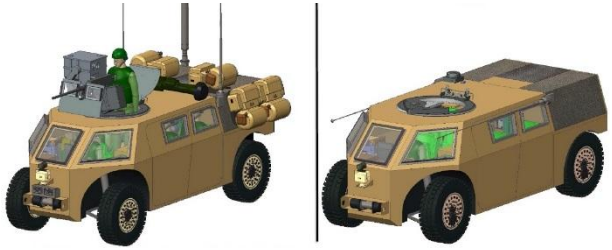
Performed analysis to build trade space

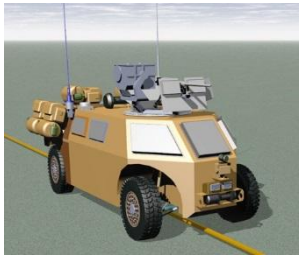
Revisited concept & varied requirements

Performed analysis to expand trade space

Generated new design set = new concept

Iterative Concept-Analysis Loop





LRV Trade Space Definition

Design Variables

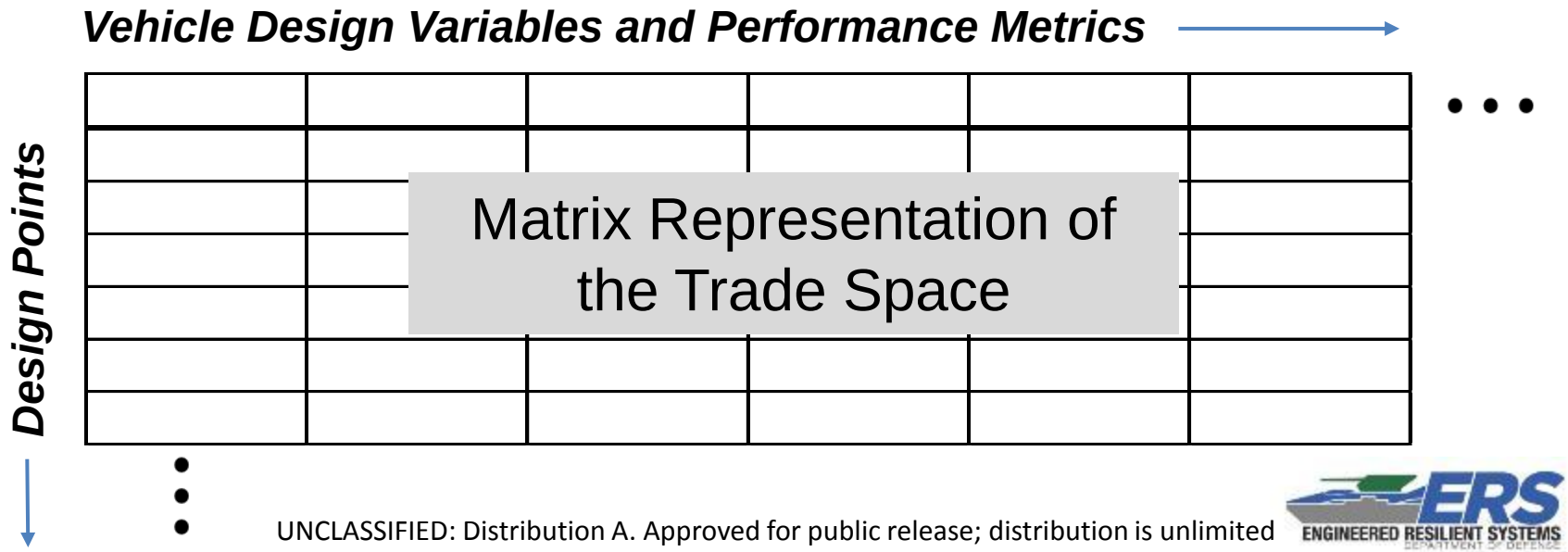
- Max Weight
- Vehicle Height
- Vehicle Length
- Vehicle Width
- Center of Gravity (CG) Height
- CG Fore-Aft Location
- Wheelbase
- Track Width
- Armor Weight
- Tire Type
- Suspension Stiffness
- Suspension Damping
- Mounted Weapon Type
- Surveillance Equipment

Performance Metrics

- On-Road Speed
- Off-Road Speed
- Max Sandy Grade
- Off-Road No-Go %
- Soft-soil mobility
- Surveillance
- Crew Size
- Rollover resistance
- Silhouette
- Engine power density
- Survivability
- Transportability
- Lethality

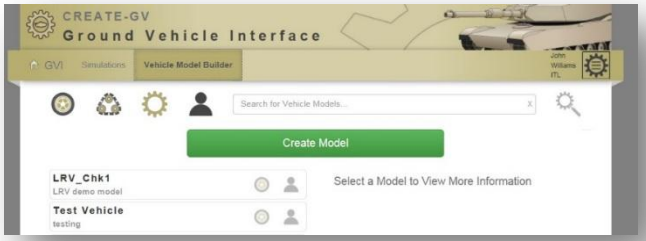
Trade Space: Matrix Representation

- **Columns: Design Dimensions**
  - Design variables
  - Design objectives (performance metrics)
- **Rows: Design Points**
  - Sampled values of design variables
  - Corresponding values of performance metrics



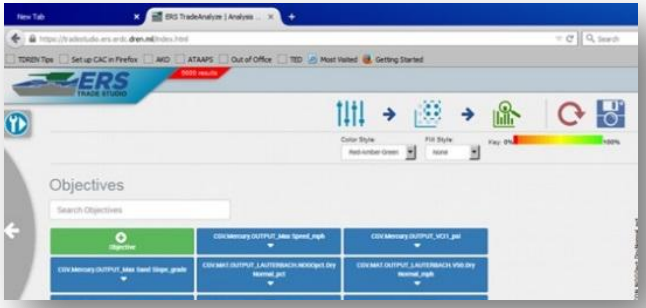
CREATE-GV and ERS Tools

CREATE-GV Tools



- **Ground Vehicle Interface (GVI):** User interface providing simplified and intuitive access to other CREATE-GV tools and HPC resources
- **Mercury:** Physics-based M&S tool for mobility, including dynamic simulation of ground vehicles and multi-physics simulation of terrain mechanics
- **Mobility Analysis Tool (MAT):** Computational tool used in combination with Mercury for producing mobility performance metrics for systems engineering and trade space exploration

ERS Tools



- **TradeBuilder:** Tool for building and assembling trade space from simulation results and/or models to perform analyses
- **TradeAnalyzer:** Tool that provides a collaborative workspace for loading the trade space, assigning weights to metrics, ranking designs, and post-processing and visualizing results

ERS ENGINEERED RESILIENT SYSTEMS

Mobility Analysis with CREATE-GV Tools

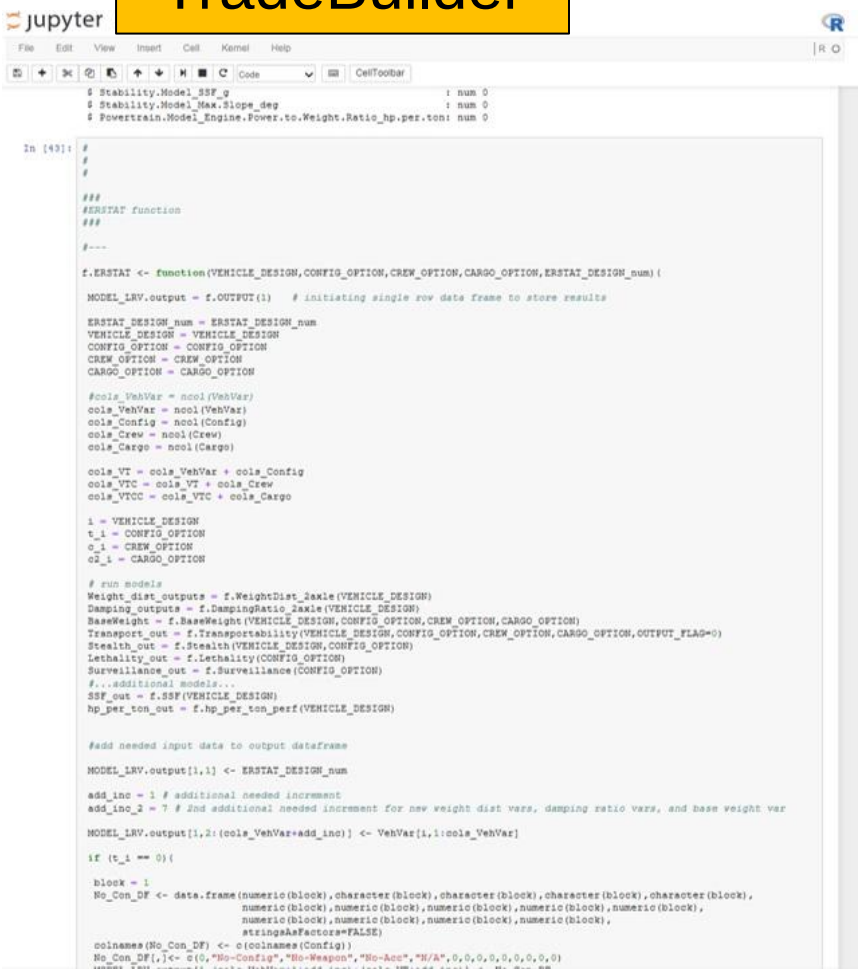
CREATE-GV simulations yield mobility performance metrics:

- VCI1: *soft soil mobility performance metric*
- Max Sand Slope: *steepest grade for sandy hill climb test*
- NOGO%: *percent of terrain that is highly restricted WRT vehicle mobility*
- Max Speed: *on-road speed metric*
- V50 Speed: *off-road speed metric*

ERS TradeBuilder Modules for the LRV

- **Mobility**: Import CREATE-GV simulation results
- **Transportability**: Assess CH-47 transport mode options
- **Visibility**: Calculate silhouette profile
- **Survivability**: Assess armor weight
- **Lethality**: Ranking of mounted weapon
- **Surveillance**: Ranking of mounted surveillance system
- **Power Density:** Ratio of HP to weight
- **Stability**: Rollover resistance metric
- **Crew:** Crew size + canine go/no-go

TradeBuilder



Trade Space Construction in ERS TradeBuilder

CREATE-GV	
1	On-Road Speed
2	Off-Road Speed
3	Max Sandy Grade
4	Off-Road No-Go %
5	Soft-soil mobility

ERS TradeBuilder	
1	Surveillance
2	Crew
3	Stability
4	Silhouette
5	Power density
6	Survivability
7	Transportability
8	Lethality

Performance Metrics imported from result files

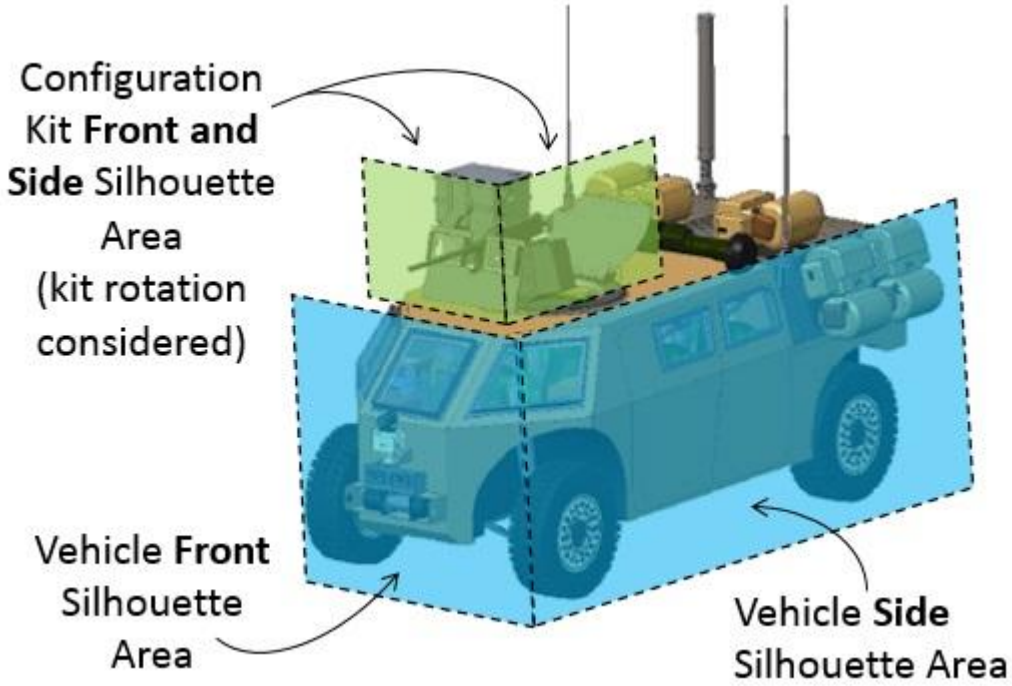
Performance Metrics evaluated in ERS TradeBuilder

Design Variables

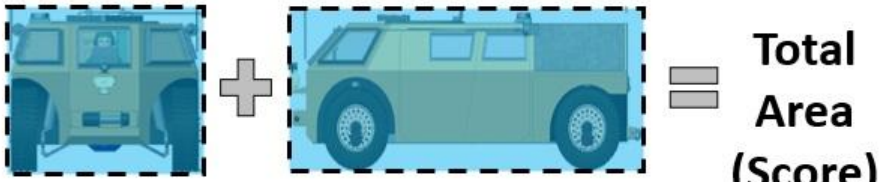
#	H	L	W	…											
1	H_1	L_1	W_1												
2	H_2	L_2	W_2												
3	H_3	L_3	W_3												
4	H_4	L_4	W_4												

Designs

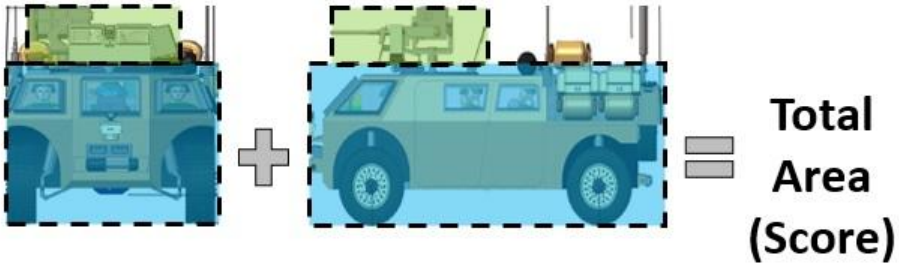
Visibility Analysis in ERS TradeBuilder



Silhouette Area - No Configuration Kit :

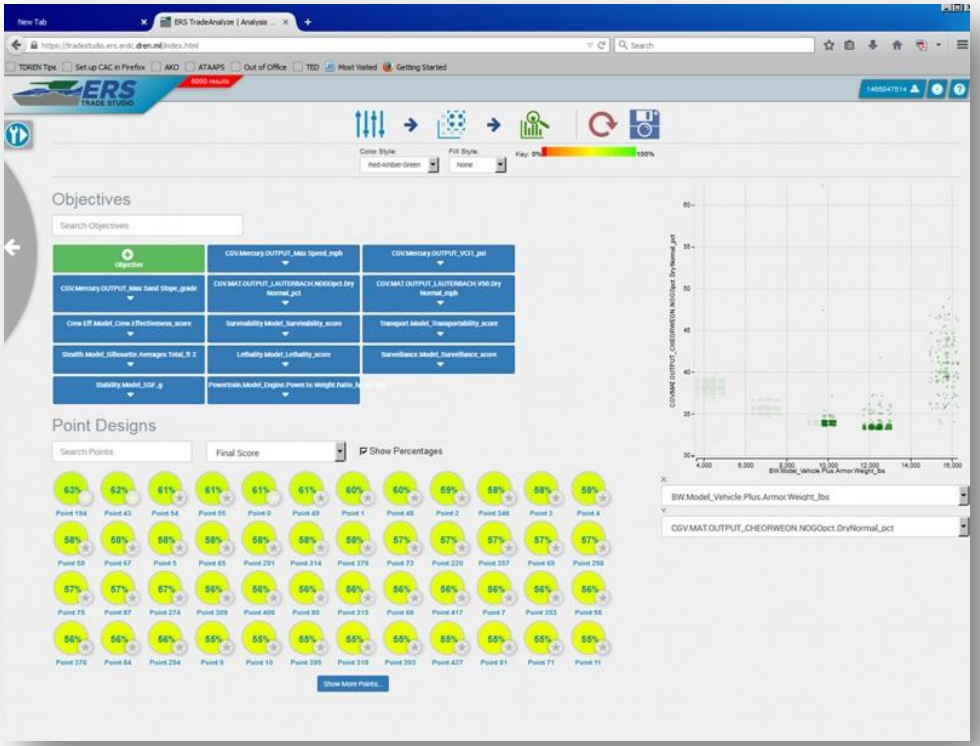


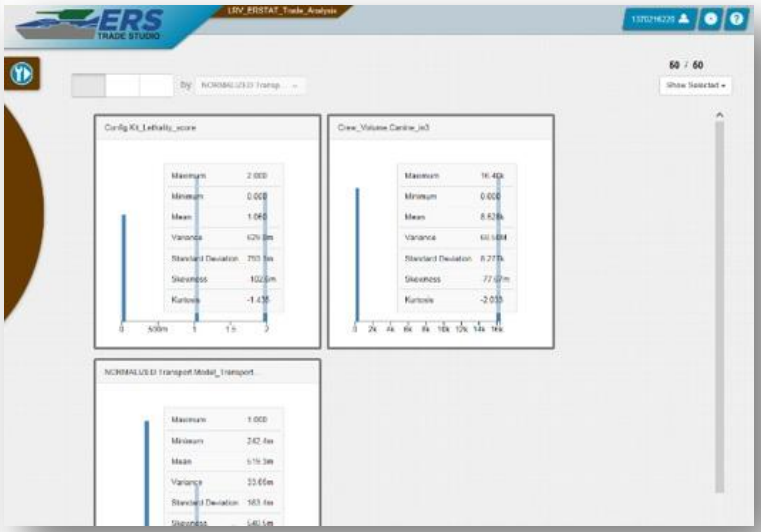
Silhouette Area -With Configuration Kit :



ERS TradeAnalyzer

- Performance metrics can be weighted equally or prioritized
- Objective/constraint violations can be allowed or penalized





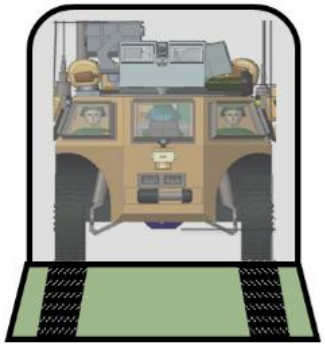
Transportability Scoring

- Transportability performance for each design was scored according to transport mode
- Scores from transportability and other performance metrics were weighted to rank designs

Score = 1.5

1 **RORO (Internal)**

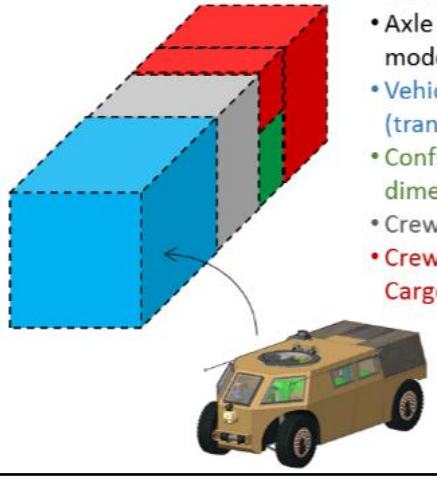
RORO Checks:
- Total Weight
- Axle Weight
- Vehicle Dimensions



Score = 0.5

2 **Transport Mode (Internal)**

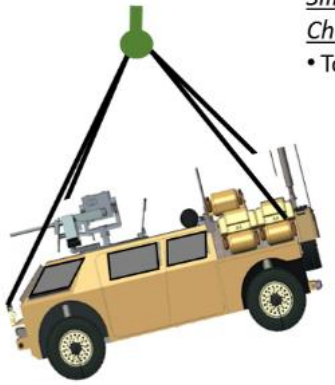
Transport Mode Checks:
- Total Weight
- Axle Weight (transport mode)
- Vehicle Dimensions (transport mode)
- Configuration Kit dimensions
- Crew dimensions
- Crew and Mission Cargo volume



Score = 1.0

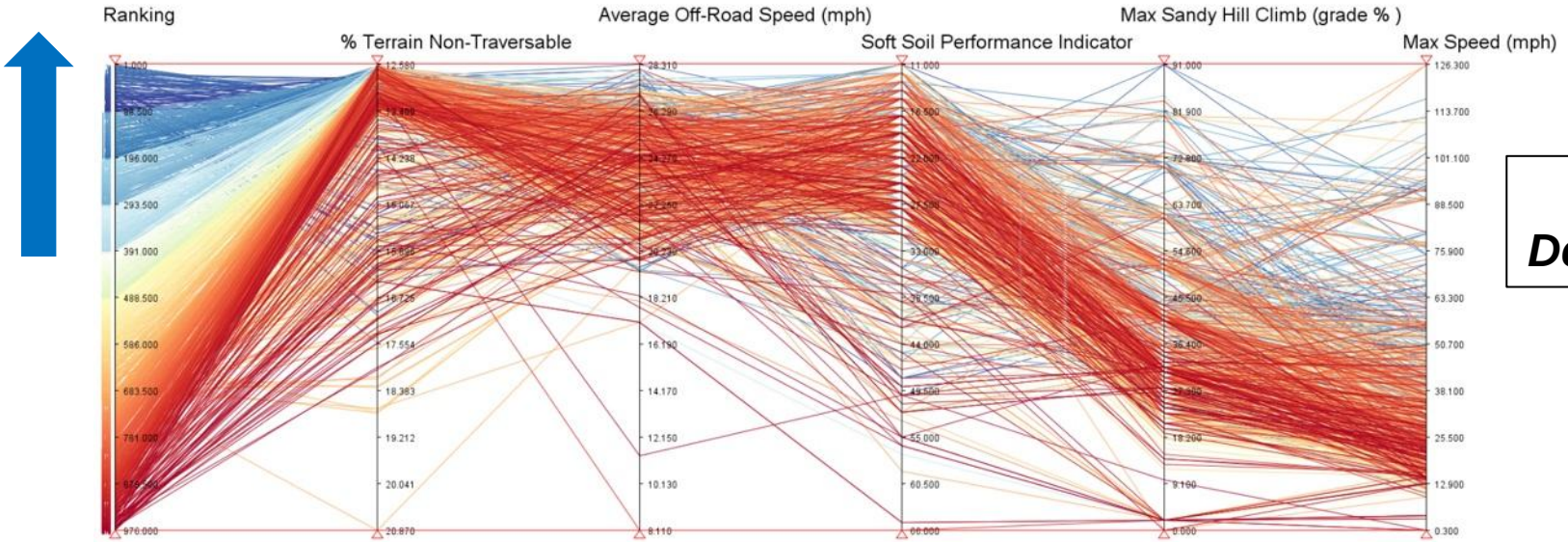
3 **External Sling Loaded**

Sling Loaded Checks:
- Total Weight



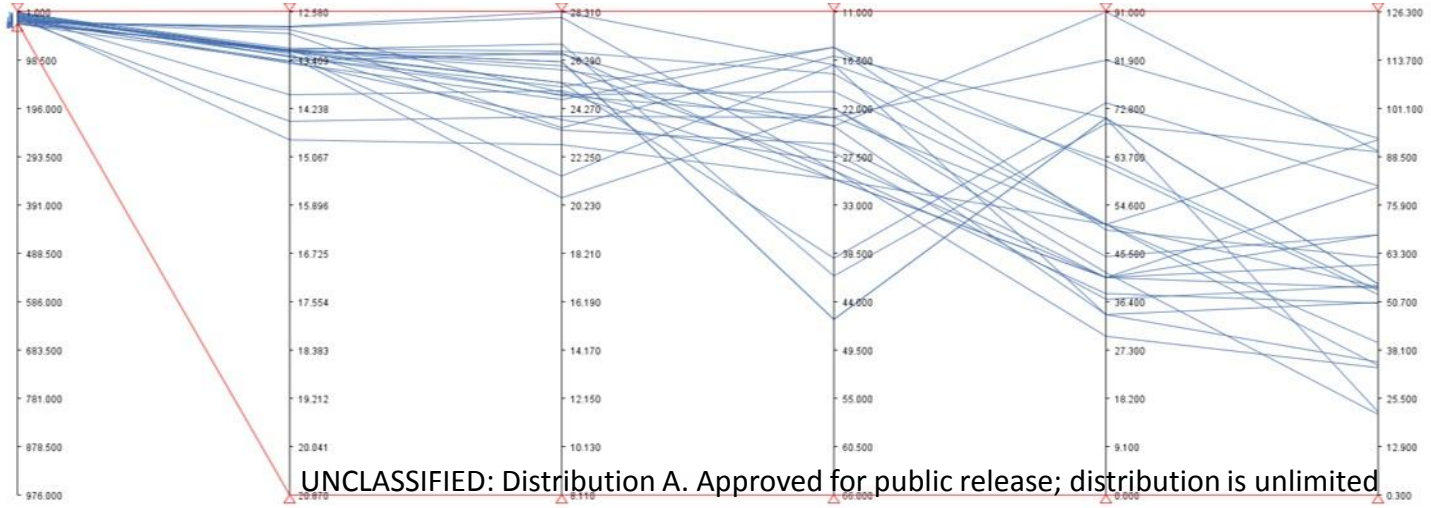
Trade Space Ranking Results: Mobility Metrics

Higher is better *for all metrics (axes have been inverted in some cases)*



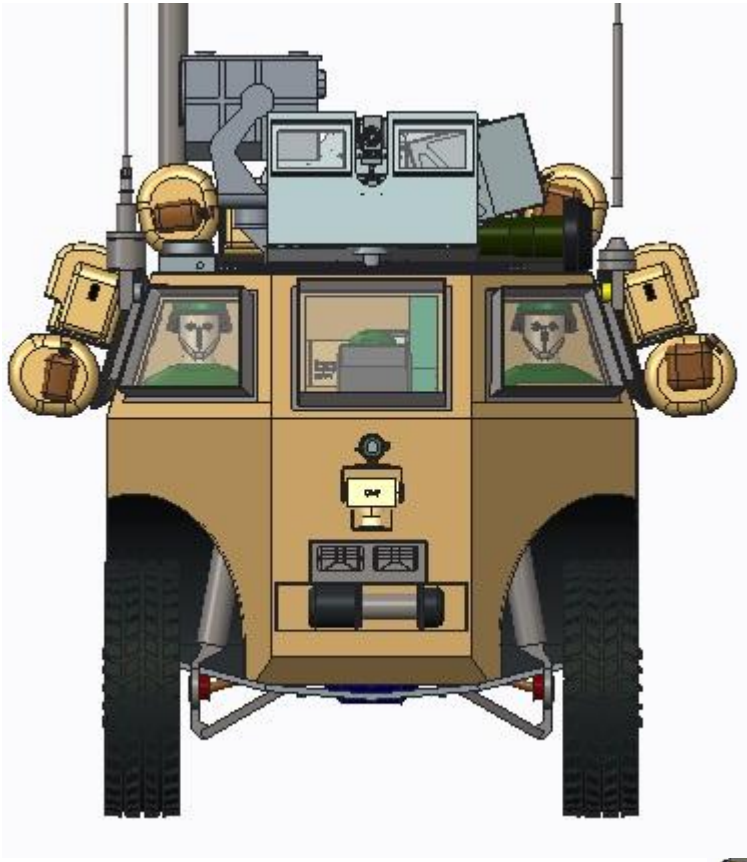
976 Designs

Design Ranking | **Off-Road Terrain Traverse** | **Off-Road Speed** | **Soft Soil Performance** | **Sandy Hill Climb** | **On-Road Speed**



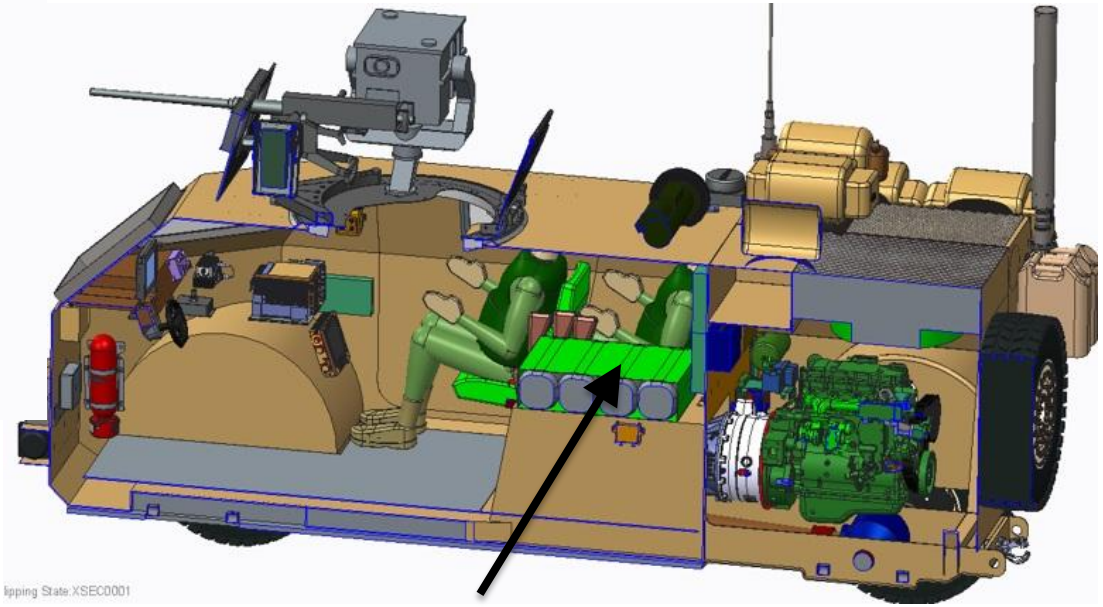
25 Highest-Ranked Designs

Common features for highest-ranked designs



- CH-47 sling-load transportability
- V-belly, floating floor, higher standoff
- Interior space for crew of 6 + canine
- Full reconnaissance & surveillance kit

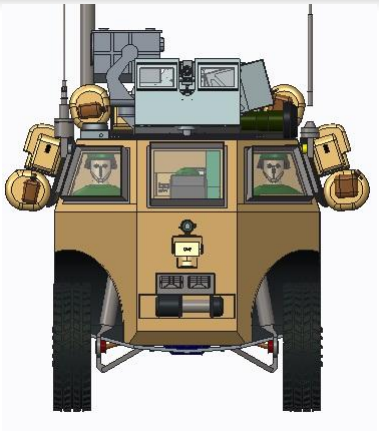
Floating Floor & V-Belly Armor

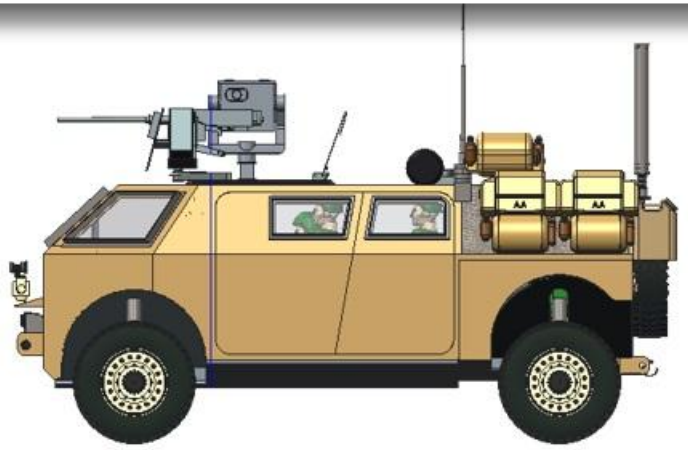


Canine Area

Conclusions

Trade space exploration *with an iterative, collaborative process led to a new set of highest-ranked designs =* ***new concept***





Though still in early development phase, these tools have some key attributes…

- Designed and built for **trade space exploration**
- Feature tight **integration with HPC** resources
- Provide an **adaptable platform** for building/running models, combining/storing/sharing results, collaborating on projects

Acknowledgments: ERS, CREATE-GV, ECO

US Army TARDEC

- Denise Rizzo
- Dan Melanz
- Mark Feury
- Joe Raymond
- Jeremy Mange
- Dan Kedziorek
- Tom Skorupa
- MAJ Roy
- COL Vanyo
- …

US Army ERDC

- Alex Baylot
- Owen Eslinger
- Willie Brown
- Daniel Chaussé
- Jody Priddy
- Chris Goodin
- …

Thank you!