U.S. ARMY TANK AUTOMOTIVE RESEARCH, DEVELOPMENT AND ENGINEERING CENTER

Weight Analysis Of A Combat Vehicle

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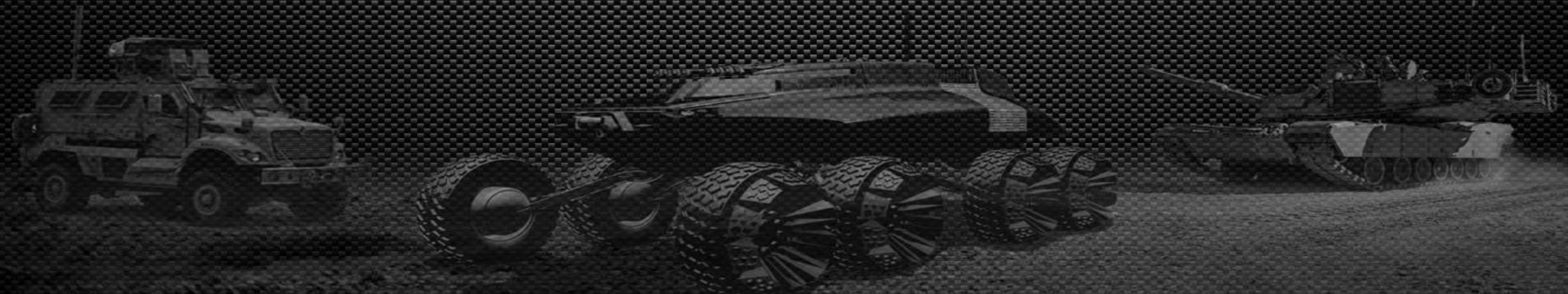


MISSION:

Develop, integrate and sustain the right technology solutions for all manned and unmanned Department of Defense(DOD) ground systems and combat support systems to improve Current Force effectiveness and provide superior capabilities for the Future Force.

VISION:

The first choice of technology and engineering expertise for ground vehicle systems and support equipment – today and tomorrow.

We help our Warfighters succeed and come home alive

Future Goals

<u>We Need An Expeditionary, Scalable & Ready Modern Army (From CSA Priorities, SEP 13)</u>

- Focus S&T investment to maximize the potential of emerging game-changing land power technologies to counter emerging threats.
- Rapidly deploy, fight, and win whenever and wherever our national interests are threatened.
- Train and equip the Total Army to rapidly deploy, fight, sustain itself, and win against complex state and non-state threats in austere environments and rugged terrain (The expeditionary mindset).

But what does the future force look like?

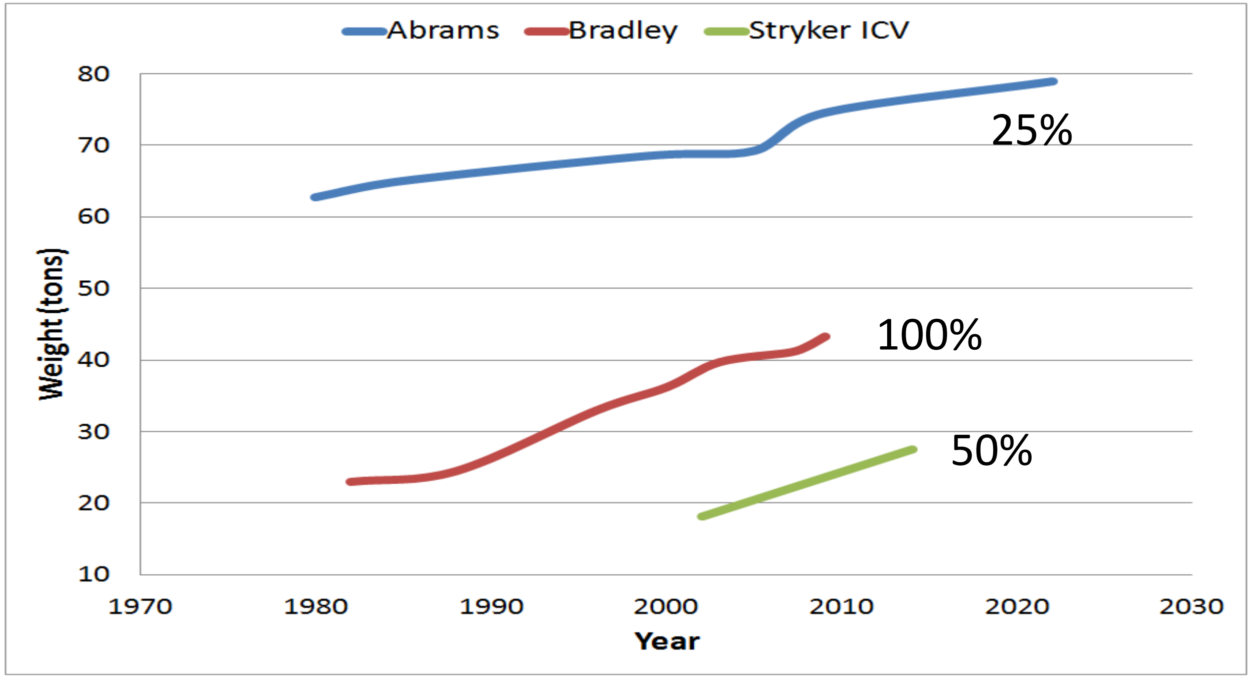
<u>Weight reduction is a key enabler for an expeditionary force</u>

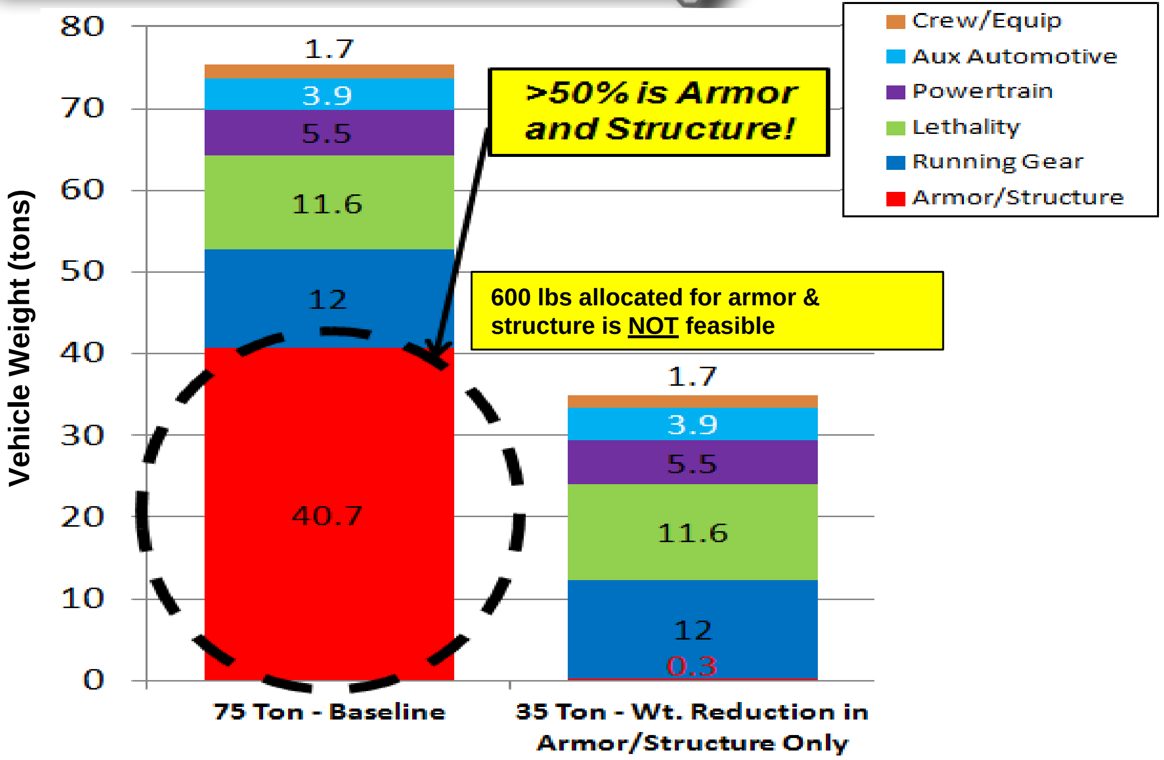
Deploy globally and rapidly; seize & maintain initiative without sacrificing protection

Challenge: Reducing Weight w/Increasing Threats

Vehicle weights have risen in response to new and increasing threats and increasing vehicle protection areas

Increasing Threats and Coverage

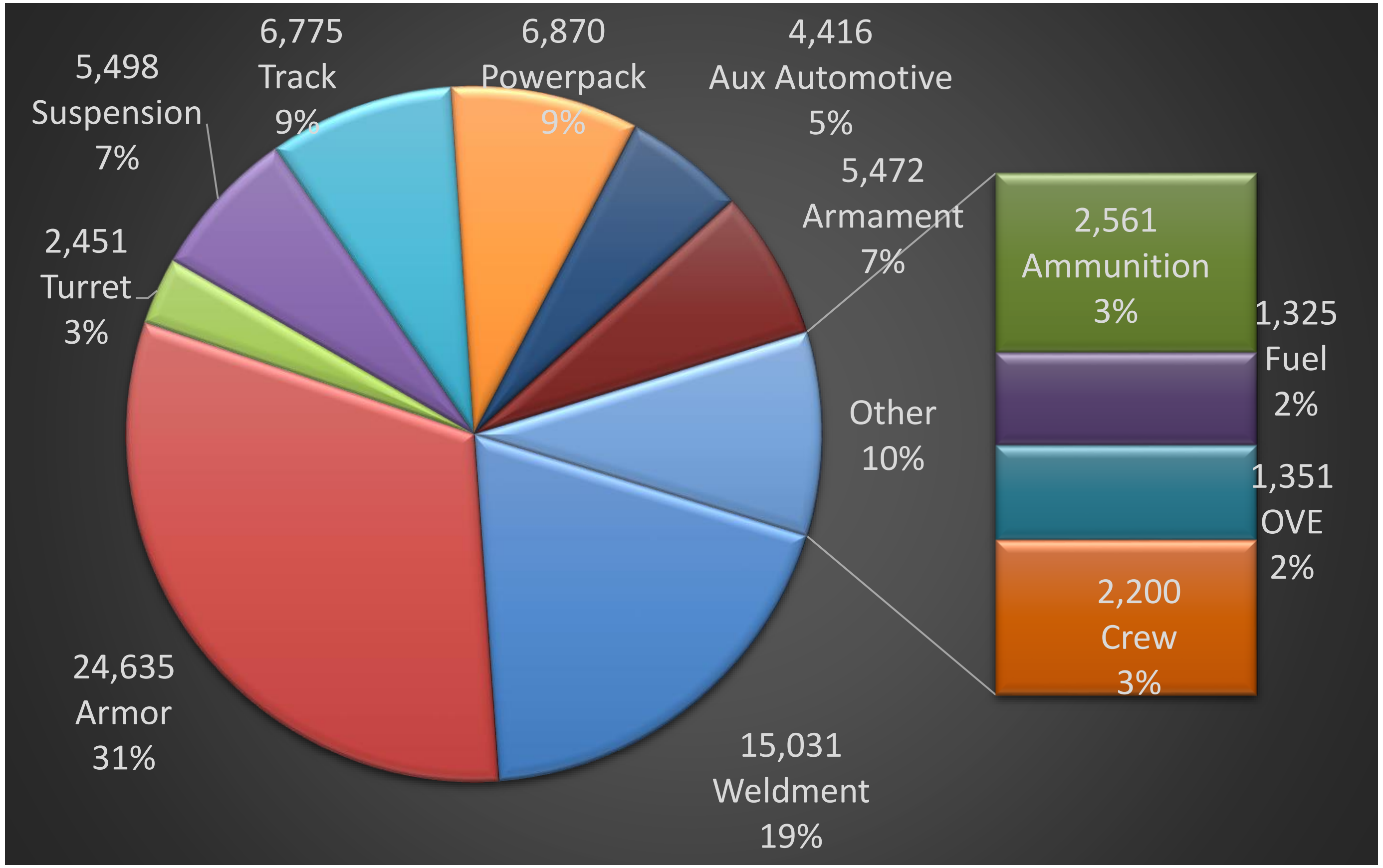




M2A3 Infantry Fighting Vehicle (IFV)

BRADLEY FIGHTING VEHICLE	
In Service	1981 - present
Length	21.5'
Width	12'
Height	9.8'
Weight	36-40 tons
Crew+Dismounts	3 + 6/2
Variants	M2/M3
Armament	M242 25mm Bushmaster Chain Gun
Top Speed	36 mph

- Closes with the enemy using fire and movement to defeat or capture him or to repel his assault by fire, close combat, or counterattack.
- Crew of 3, plus 6 Dismounted Infantry



Lightweighting Process

- Taxonomy
- Data (BOM, CAD)
- Sub-system / part requirements (performance)

Baseline Vehicle / Technology Analysis → **Idea Generation**

Requirements/Needs Analysis

- Requirements-Weight relationships
- Evaluation Factors
- Operational Metrics

Idea Generation

All:
- Tech ideas (including those with tech gaps)
- Idea linking (mutually exclusive, mergable, etc.)

Adv. Concepts/CSI/LWS:
- Packaging
- Option evaluation
- Recommendations (bundled tech ideas)

Concept Optimization

Technology Groups:
- Specific tech models
- Cost modeling
- Manufacturing modeling

Analytics
- Modeling and Simulation.
- Adoption barrier analysis
- Concept evaluations
- Recommendations

Simulation TRL 4/5

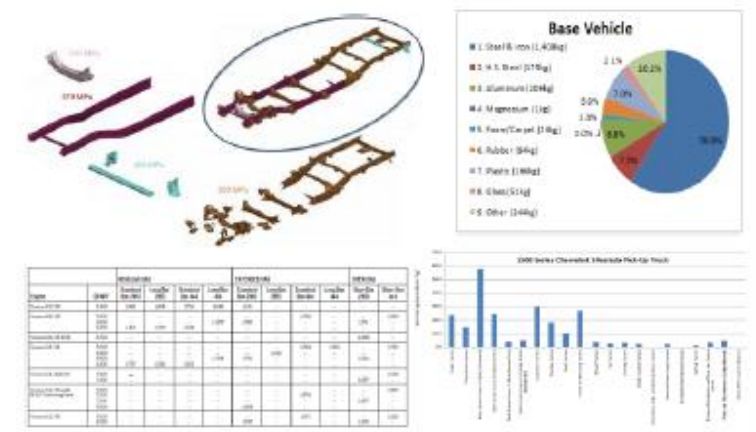
Technology Validation

- "overcoming adoption barriers"
- "focused"
- Model validation
- Detailed design
- Hardware development
- Cost reduction

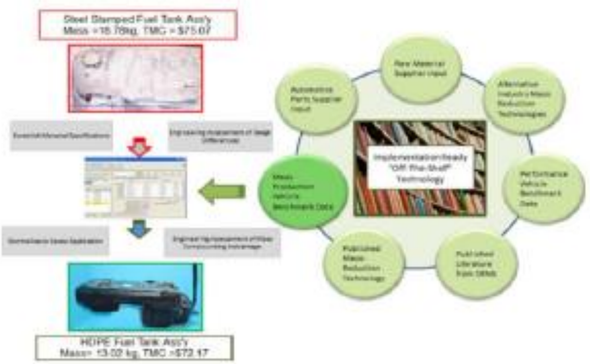
Technology development
Physical TRL 5/6

HALO Idea Generation

1.1 Baseline Technology Evaluation

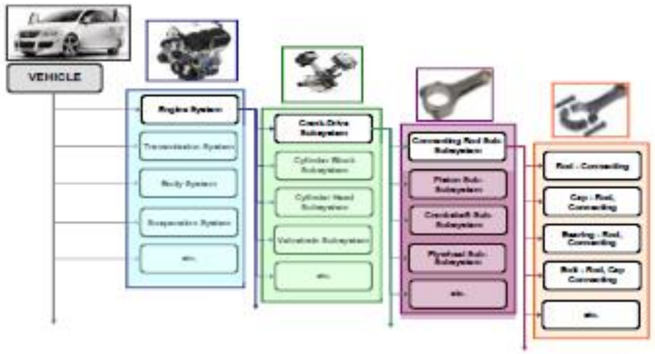


1.2 Idea Generation

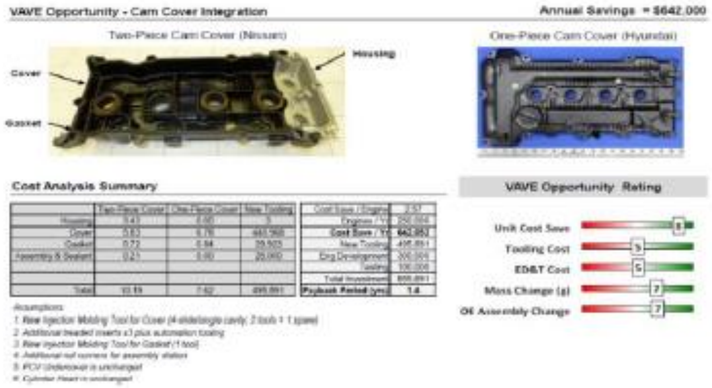


1.3 Idea Scoring

1.4 Idea Down Selection



1.5 Report Out



M2A3 Baseline Technology Evaluation

- BOM contains 2618 line items:
  - No individual component requirements (loads, stiffness, etc.)
  - Material specification:
    - 550 parts had material specified with varying levels of detail: “Steel”, “Steel 1018-1030”, “Alum 5083-H321”
    - 50 parts had density
    - 300 parts had no mass
    - 2000 parts had no material.
  - No cost information
  - Limited / no CAD files
  - Some of the line item information had to be obtained from multiple databases

- Requirements
  - Have high level vehicle requirements
  - Do not have individual component requirements
  - Dilemma: assume current component was designed to meet requirement.
  - Dilemma: existing vehicle is severely packaging constrained
  - Constraint: cannot change hull dimensions

- Limits the kind of analysis can be performed
  - Use a simple BOM (148 components)
  - Relies heavily on SME input
  - Sacrifice precision

- Study Goal:
  - Identify near term technologies (TRL 5+) that can help reduce weight of Bradley
  - Estimate weight savings
  - Put plan together for developing those technologies

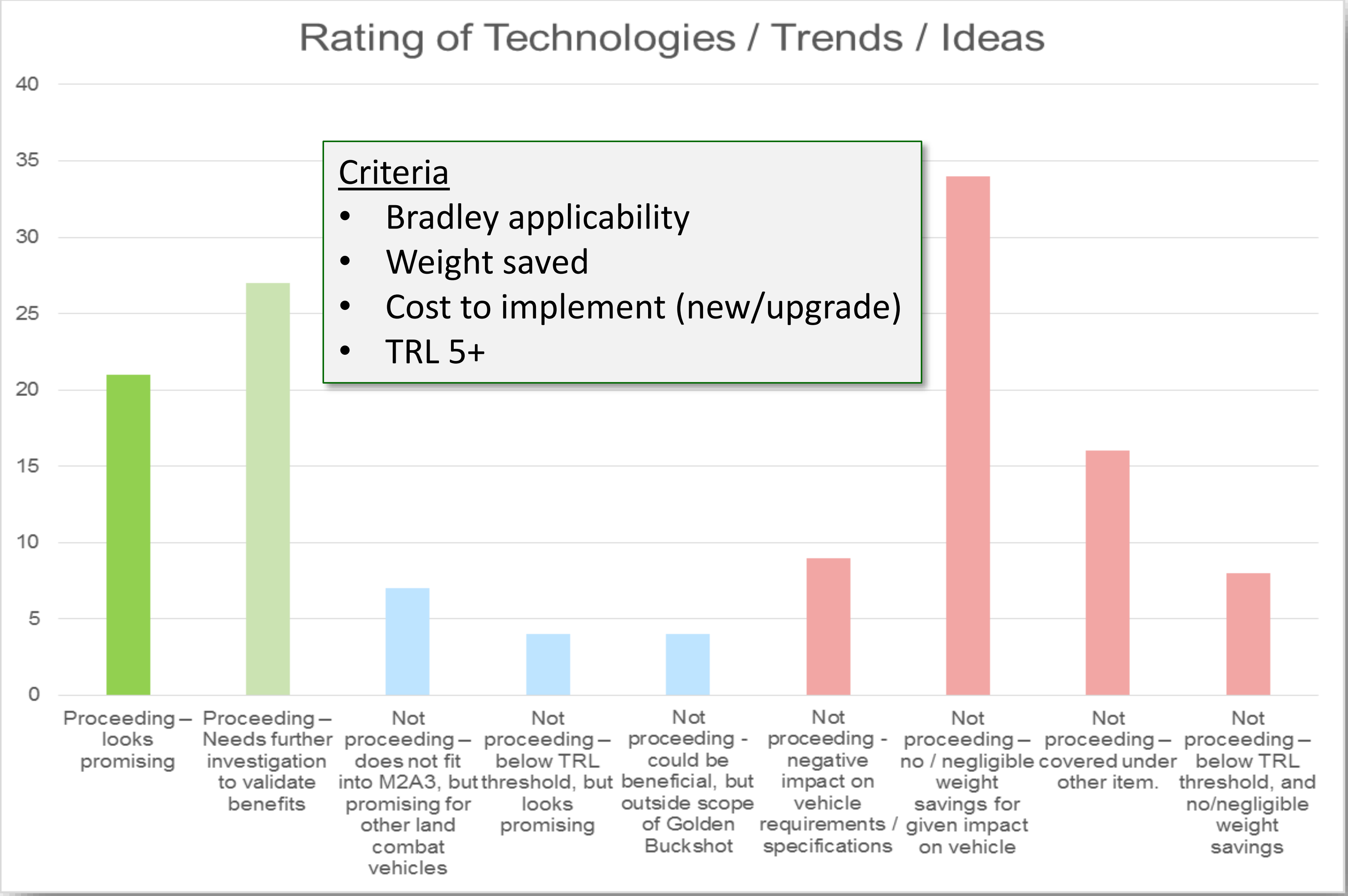
Idea Generation (Technologies)

- Incorporated technologies from multiple sources:
  - Ricardo under contract
  - LCVSTC team
  - Literature Review
- Open SME brainstorming. No idea a bad idea, no idea too small to consider
- 200+ ideas generated
  - Materials
  - Component specific material substitution
  - Manufacturing processes
  - Alternative component technologies
  - System architectures
  - Component elimination
  - Etc.

Example Technologies (no particular order)

Idea	Technology Name	Technology Description	Initial Comments	Initial SME Rating
011	Lightweight (non-blast) seats	Utilize lightweight structural architectures and materials such as aluminum, mesh, carbon fiber, Kevlar	M2A3 w_IED seat frames + cushions are about 20# each. Driver seat is 50#. Squad seats are 210 lbs total (for 7 occupants); so each seating location is ~30#, including bracketry . Not sure what the baseline seat frames are constructed from. Seat bracketry is mix of steel and aluminum. Could potentially save around 12# per seat location, but there might be incompatibilities due to current A2 bench configurations. TARDEC developing next gen blast seat that might be able to save up to 50%. While there may be representative seats available, Bradley-specific seats likely require structural / material optimization. Also space claim may be an issue.	Proceeding – looks promising
012	Lightweight Mechanical/Electronic pedals	Replace baseline mechanical controls system/components with electronic components. This will enable brake by wire, drive by wire.	Requires integration with engine controls. The BOM says the whole throttle mechanical pedal / linkage assembly is only ~3 lbs, which seems light. Assume replacement with an electronic pedal is a wash based on this. Current brake install is ~xx lbs. Could probably save 75% by going to electronic brakes.	Proceeding – Needs further investigation to validate benefits
013	LED lighting	Replace incandescent lighting with LEDs	LED lighting is in service. Marginal mass reduction and cost increase. Biggest benefit is efficiency and durability improvement. Easy plug-and-play, but would think that Bradley has already moved to these.	No further research required, check w/ bradley
014	Suspension architecture - alternative spring / damping	Investigate alternate suspension architectures; coil over / strut / air over oil / MR fluid/ Christie/ hydropneumatic	Assume we're sticking with a trailing arm suspension since almost all modern tanks use it. Can look at coil over, strut, hydropneumatic (rotary and linear) all of which exist. External suspension units generally are two wide and require new hull (barrier).	Proceeding – Needs further investigation to validate benefits
015	Lightweight track	TARDEC FCS track, band track, hyvo chain	TARDEC developing longer life track that is 10% lighter, and relatively easy to transition. Diehl has a lightweight track (DLT 464C) for Puma which saves 20-30% over conventional steel tracks. Diehl rubber band track 325B. Baseline track mass is ~5600 lbs. 20-30% savings > 1000 lbs	Proceeding – looks promising
016	Torsion bar & Road wheel optimization	alternate materials	Looking at alternative materials, topology, and joining methods for lightweight torsion bar suspension. Must consider dirt buildup. 15-20% weight reduction potential	Proceeding – looks promising
017	Battery/Electric storage - Li-Ion	Advanced battery technology including Li-Ion battery and adv. lead acid	TARDEC working on Li-Ion 6T battery (75% weight reduction over lead acid). Working on lowering cost.	Proceeding – looks promising
018	Alternative communication protocols,	Such as fiber optic cables (Replace copper signal cables with fiber optic cables)	Fiber optic cables are immune to EMI, but require transceivers and receivers for electrical signal conversion; applied to entertainment/communications in automotive; Mercedes S-class saved 50kg; use for backlighting	Proceeding – looks promising
019	Integrated Starter Generator (ISG)	remove starter and alternator from engine and replace with ISG instead	Based on the low power generation requirement (~8.4 kW; 28v @ 300a), ISG is not a good application for this vehicle since ISGs are generally 10-15kW+.	Not proceeding – no / negligible weight savings for given impact on vehicle

Idea Scoring



Example Scoring

Rank	Technology	Component / System Application	TRL	Mass Saved (kg)	Cost* ($)	Cost* per Mass Saved ($/kg)
1	Mass efficient filter media / housing	Air induction / filter system	7	38	$ 1,200	$ 32
2	Aluminum	Roadwheels, idler wheels, misc covers, misc brackets	8	253	$ 13,000	$ 51
3	Band track	Track	8	1,063	$ 80,000	$ 75
4	Modern, Low-speed diesel engine	Powertrain & Cooling	8	300	$ 55,000	$ 183
5	Dual-pin optimized track	Track	8	393	$ 75,000	$ 191
6	Modern, High-speed diesel engine	Powertrain & Cooling	7	508	$ 105,000	$ 207
7	Li-Ion	Batteries (6T)	7	66	$ 35,000	$ 530
8	Carbon-Fiber Composite	Torsion bars, prop shaft, misc covers, misc brackets	4	317	$ 185,000	$ 584
9	Titanium	Torsion bars, sprocket carrier/drive, muffler, prop shaft, misc covers, misc brackets	6	742	$ 545,000	$ 735
10	Rotary Damped Suspension	Suspension System	8	120	$ 115,000	$ 958
11	Aluminum wiring	Harnesses, cables	5	63	$ 80,000	$ 1,270
12	Single-pin optimized track	Track System	8	71	$ 100,000	$ 1,408
13	InArm Suspension	Suspension System	4	100	$ 150,000	$ 1,500
14	Drop-in camera-based replacement	Periscope system	7	16	$ 45,000	$ 2,813
15	Bespoke camera/display system	Periscope system	7	30	$ 114,000	$ 3,800

- Data is indicative / relative, not absolute.
- Cost data was modified from a Distribution D Contractor Report. While indicative, it is not accurate as shown.
- Some Technologies are mutually exclusive.

Report Out

TECHNOLOGY	COMPONENT	WEIGHT SAVINGS
MEDE provides 20% wt reduction for RHA weldment (assumes new material is the same thickness as the RHA it replaces); no change in special armor weight.	Underbody, hatches, exhaust grills	796
Affordable Protection from Objective Threats=TTR Composte armor technology provides 25% wt reduction over metallic laminates. Cast encapsulates provide 10% wt reduction.	hull, b-kit, external stowage	2,467
Optimized Design of Aluminum Roadwheels w/7xxx series Al provides 15% wt reductionTitanium Roadarms provide 35% wt reduction;	roadwheels / idlerarms	1,065
GB: Modern Low Speed Diesel Engine (TRL 9) can save 24%; Modern High Speed Diesel Engine (TRL 7) can save 40%. GVPM does not believe it will work for variety of reasons. Abrams uses Turbine engine so recommendation may not apply	engine	1,112
Durable Composites provides 20% wt reduction over metallic solutions (16)	fenders, interior hatches, stowage, sprocket carrier,misc mounting, battery box, seats, turret basket	337
UHMWPE provides 10% wt reduction	C-kit	1,225
Ti or coposite Torsion bars provide 20-50% weight reduction (.3*1891=567) and would be easier transition than external suspension. External suspension has other advantages	suspension	285
Lightweight track-CVP, 10% savings	track	587
Advanced Li-ion Modular Batteries (Gen II) provides 120 lbs saved per pair of Pb-A batteries (75% reduction)	battery	144
Mass efficient filter media / housing for the air induction filter system (TRL 7) saves 48% (GB); may not apply to abrams	air intake	70
Multi-function Video Display (MVD) provides 90% wt reduction	periscopes	36
Aluminum Alloy Development proves 20% wt reduction over current Al alloys	bulkheads, rear ramp	190
aluminum wiring harness (TRL=5) saves 48% (63kg; 138 lb) @ 1.3k	wiring harness	137
VEA tech eliminates some boxes?	electical boxes	30
Glass Development provides 10% wt reduction over current designs	glass appendage	13

COMPONENT	weight save	cumulative	cum %
C kit (various)	1,187	1,187	14%
Engine w/oil	1,112	2,299	27%
Roadarms/wheels (Ti/Al)	945	3,171	37%
Welded Hull (APOT)	872	4,018	47%
B kit (APOT)	847	4,963	58%
LW Track	587	5,550	65%
Turret Armor (APOT)	471	6,021	71%
Underbody (MEDE)	399	6,420	76%
Torsion bars (Ti)	285	6,705	79%
Hatches (MEDE, Adv. Al)	232	6,937	82%
Rear Ramp (adv. Al)	173	7,110	84%
Intake/Exhaust Grills (MEDE)	165	7,275	86%
Ext. Stowage (Composites, APOT)	165	7,440	88%
Turret Structure (APOT)	164	7,604	90%

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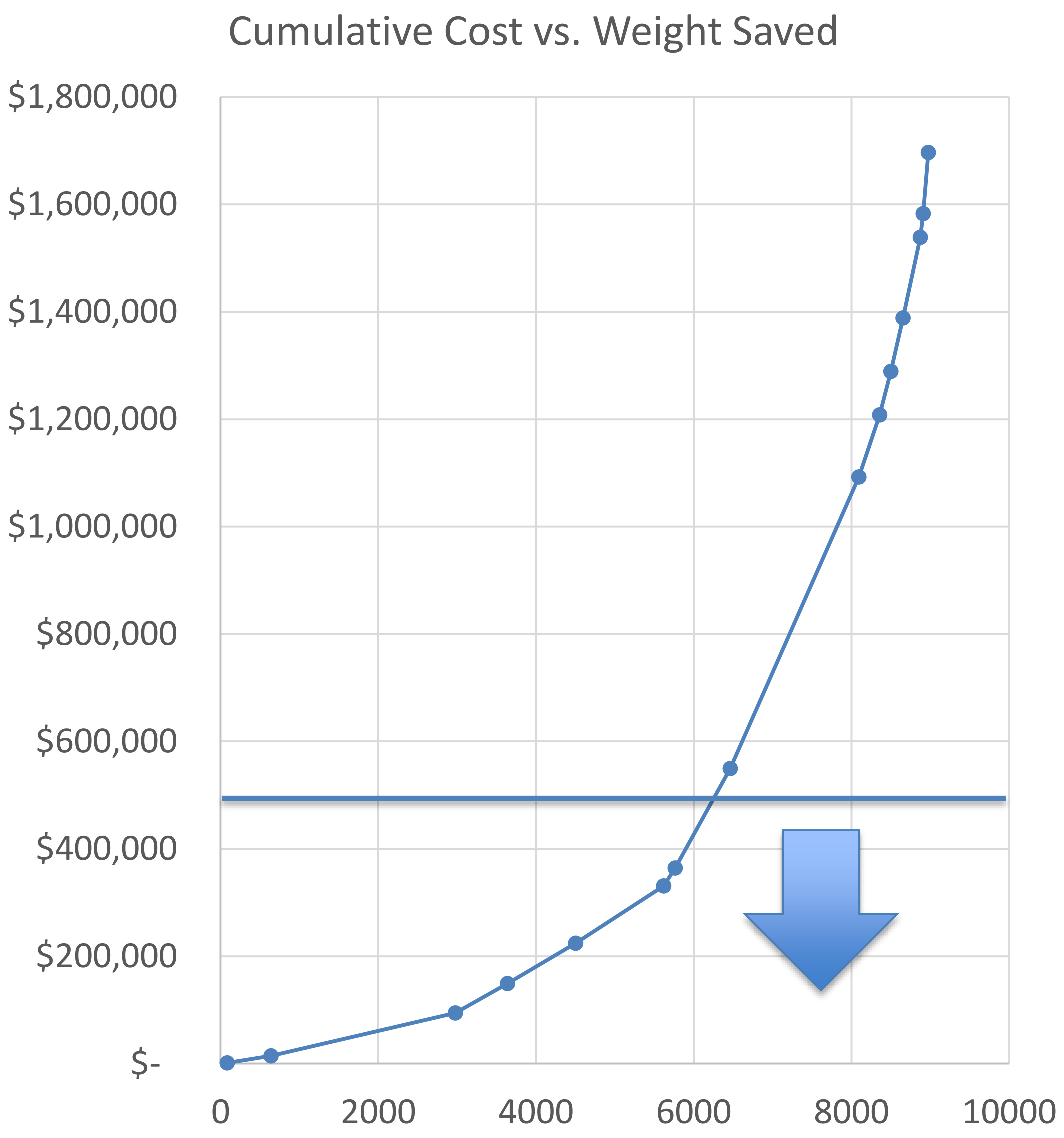
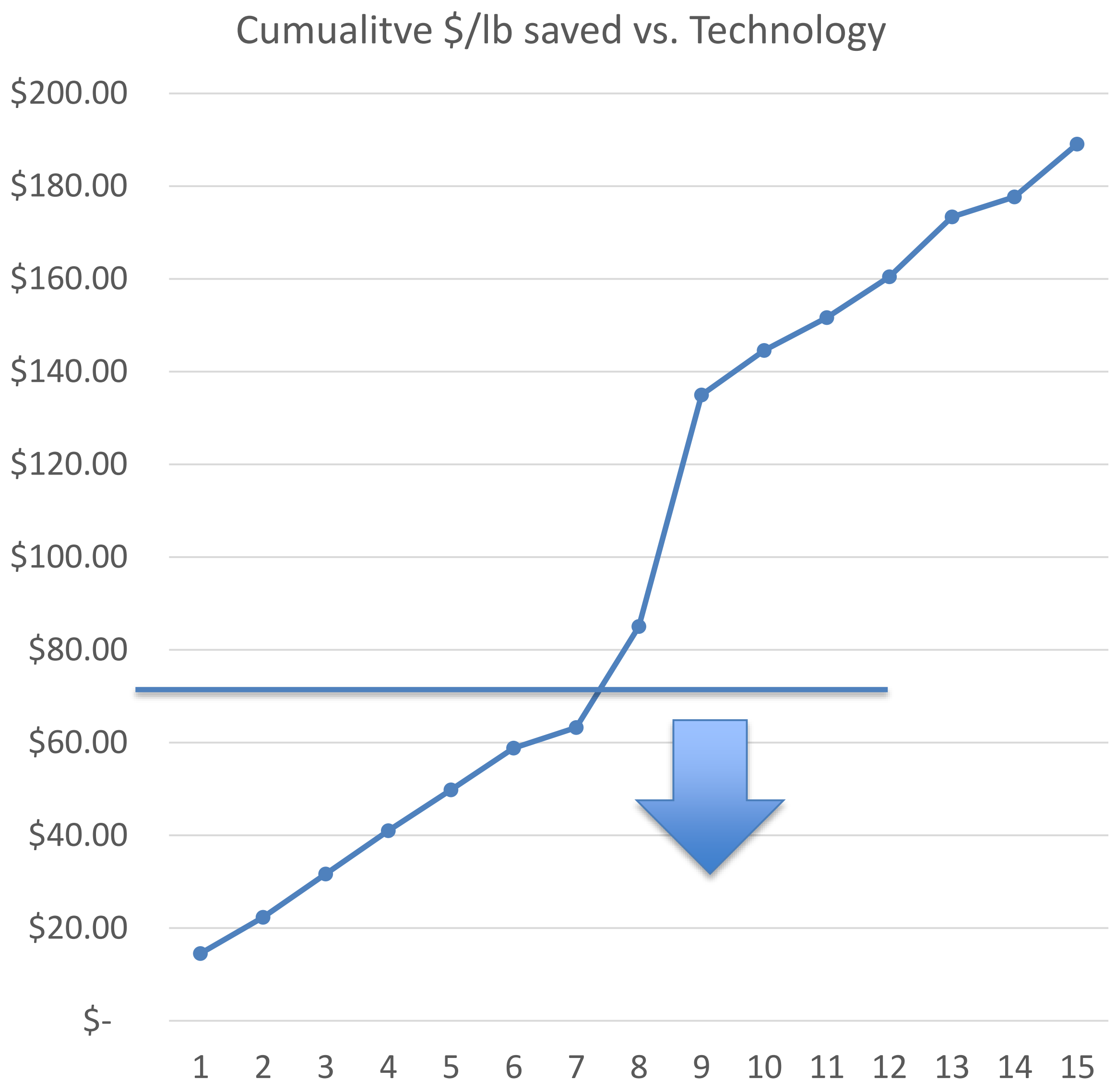
- No claim of accuracy

Report Out



Cumulative Cost vs. Weight Saved
$1,800,000
$1,600,000
$1,400,000
$1,200,000
$1,000,000
$800,000
$600,000
$400,000
$200,000
$-
0
2000
4000
6000
8000
10000



Cumualitve $/lb saved vs. Technology
$200.00
$180.00
$160.00
$140.00
$120.00
$100.00
$80.00
$60.00
$40.00
$20.00
$-
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15

Summary & Conclusions

- Vehicles keep getting heavier despite increasing desire to be expeditionary
- Need to take a holistic approach to weight reduction
  - Working diligently on instilling state of the industry engineering discipline
  - Cannot only focus on armor
- Lightweight analysis of military vehicles involves detailed and difficult work
  - Army does not design and manufacture vehicles
  - Army does not own TDP
  - Do not have detailed design history for any component
  - Cannot assume existing component design is weight optimal.
  - Getting cost estimates is difficult.
- Need SME input
- Any technology that is TRL 9 commercially is automatically TRL 5 in military.
- Work together with industry partners to identify technologies, estimate costs, and apply to specific military vehicle requirements

Thank you
Questions?