Ground System Survivability Overview

TECHNOLOGY DRIVEN. WARFIGHTER FOCUSED.

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Ground System Survivability Overview

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The original document contains color images.
Excellence in Ground Systems Survivability Occupant Centric Vehicle Protection

Increasing Demands and Operational Flexibility Require Strategic Investments in Key Areas

Kill Avoidance
Penetration Avoidance
Hit Avoidance
Detection Avoidance

Cause Agent Breakdown (BI)
2002-2008

- Falls 1%
- Motor Vehicle Traffic 1%
- Firearms 20%
- Munitions and Explosives 77%

N= 7,092 patients

- Stand off
- Shaping
- Armor
- Crush zone
- Structure
- Restraints
- Seats
- Soldier

- Design from Occupant Out
- Hit Avoidance
- Penetrate Avoidance
- Kill Avoidance

Threat Lethality
Technical Complexity
Excellence in Ground Systems Survivability Occupant Centric Vehicle Protection

System Engineering Driving Technology Integration

Supporting the Current Force

Enabling the Future Fight

Requirements Development
Optimization Modeling
Concept Development & Test
Vehicle Integration & Design Studies (SWAP-C)
Integrated Product

Survivability
Burden
Transition

Requirements
Development

Optimization
Modeling

Concept Development & Test

Vehicle Integration & Design Studies (SWAP-C)
Integrated Product

Survivability
Integrity
Burden
Excellence in Ground Systems Survivability Occupant Centric Vehicle Protection
Driving Innovation across the Ground Community

- Novel, inventive vehicle design approaches
- Rapid acquisition (12-18 month timelines)
- Extensive use of M&S tools to optimize design
- Non-tradition defense project partners
- Embedded with ARCIC to drive requirements generation for future platform requirements

<table>
<thead>
<tr>
<th>Project Weight Class</th>
<th>Project Objectives</th>
<th>Project Partners</th>
<th>Project Schedule</th>
</tr>
</thead>
</table>
| **Heavy Combat** 100,000 - 140,000 lbs | • Soldier-Centric Vehicle Design  
• Modular, Reconfigurable Vehicle Systems  
• Targeting selected GCV Objective Requirements | RDECOM ACT VI Project     | • 18-24 months for Multiple Concept Development |
| **Medium Combat** 40,000 - 60,000 lbs | • S-MOD/MPC Threshold Survivability  
• Motor Sports Vehicle Design Process  
• M1 Equivalent Mobility | Professional Motorsports Industry | • 12-18 months from Concept to Build (tentative) |
| **Light Tactical** 14,000 - 16,000 lbs | • FED Program–OSD Funded  
• 30% Fuel Economy Improvement over M1151  
• Maintain Mobility of M1114  
• MRAP Threshold Survivability  
• <14,000 lbs Vehicle Weight  
• System Cost of $250,000 |  
• RICARDO  
• WTSI – Global Services  
• HARDWIRE – Composite Armor Systems | • 12 month Tech Discovery phase  
• 18-24 months from Concept to Build  
• 12 months from Design to Build |

RDECOM will rapidly develop platform designs and demonstrators driving innovation in the areas of ground platform survivability and mobility.
Risa Scherer
Team Leader - Blast Mitigation Team
Ground Systems Survivability
26 OCT 2010
Current Force Vehicles, although Survivable, have been designed from the outside in.

The Threat has Changed....our design philosophy has to change.

**Cause Agent Breakdown (BI) 2002-2008**

- Motor Vehicle Traffic: 1%
- Firearms: 20%
- Munitions and Explosives: 77%
- Falls: 1%
- Others: 1%

N=7,092 patients
New Design Philosophy

Occupant Centric Survivability

Encounter Avoidance
Detection Avoidance
Acquire Avoidance
Hit Avoidance
Penetrate Avoidance
Kill Avoidance

Design from Occupant Out

RDECOM
Designing from the Inside Out

Outside In

Inside Out

Occupant Protection Drives
Vehicle Design
- Provide superior customer support in the field of mine blast/IED and crash/rollover Occupant Protection technology Integration and Optimization and establish a state-of-the-art laboratory to analyze the effects of System-Level component interaction.
PRODUCT:
- Update/develop vehicle standards, models, and simulations for occupant protection against mines/IEDs
- Build and test two integrated Occupant-Centric Survivability Technology Demonstrators
  - Demonstrate an ideal occupant compartment on a concept demonstrator
  - Integrate ideal occupant protection technologies onto a current force vehicle
- Assessment and baseline of ground vehicles with respect to underbody blast/fragmentation
- Develop/mature & spinout TRL 6 occupant protection technologies, including: Underbody mine/IED armor solutions, energy management seats, active restraints, air bags, event data recorder, extremity fragmentation protection, M&S support for effects due to blast and fragmentation etc.

CUSTOMER:
- All ground combat platforms

TARGETED THREATS:
- All Underbody Mine/IED Threats
What Does Occupant Survivability Entail?

- Occupant Survivability is:
  - The combination of many factors, including: vehicle weight, geometry (stand-off, hull shape), occupant protection technologies (seating, location false floor), charge size, and charge location, and how these factors interact with the crew member.
- Most effective protection for the occupants against the blast impulse is to decouple the occupants from the system structure.
- Design principles:
  - Decouple the occupant from the system structure
  - Divert blast energy away from the vehicle
  - Limit acceleration of the vehicle
  - Prevent breach of the vehicle
  - Limit the acceleration of the occupants
  - Protect the occupants from lethal debris
- Occupant Survivability needs to be designed in from the beginning, not as an afterthought... design from the inside out.
RDECOM has one-of-a-kind “system level” underbody M&S capabilities that can be used for risk reduction for significant milestone decisions.

Capabilities can be used for requirements definition and trade studies.

Tools can be used to understand gaps between LFT&E events to increase confidence & decrease uncertainty in system capabilities & limitations.

Can be run in series with Concept Refinement and Technology Development activities and parallel to System Development and Demonstration activities.
Technology Evaluation Methodology

- Physical Testing
  - Drop tower
  - Live fire
  - Ergonomic evaluation

- M&S Analysis
  - Obtain Technology and/or vehicle models
  - Correlate the model to test event
  - Parametric studies
    - Technology characteristics (mounting, geometry, material properties etc.)
    - Threat size and location
    - How it will be integrated into the vehicle
  - Prediction of LFT&E event

- Injury Assessment
Recent Seat Development Programs:
- TWVS ATO Seat Selection
- ASV Seating Modernization
- MRAP Caiman RWS Seating
- MRAP Remote Weapons Station Integration
- MRAP RG31 Crew Seat Enhancement

Current Seat Development Programs:
- Cervigard Seat CRADA
  - Develop seat concept, FEA analysis, and sub-system level testing
- NDCEE CRADA
  - Develop EA seating concept, FEA analysis, and sub-system level testing
- ARC Testing
  - Desk top tool derived from testing seat parameters (materials, thicknesses, occupant sizes).
Objective: Provide PM MTV a recommendation for the crew seat to be installed in the FMTV Integrated Survivability Demonstrator (ISD) and FMTV Ballistic Demonstrator (BALDEM) and receive concurrence on the path forward.

The following seating candidates were evaluated using a combination of integration studies, cost analysis, modeling & simulation, and drop tower testing:
- BAE Belts-to-Cab Seat
- Martin Baker
- Allen Vanguard
- Armorworks Shockride
- Isringhausen
- GSS CCOOPPS Crush Box
- Seats Inc.
- Plasans/National Seating
- Simula/Armor Holding
- Mastercraft/Armor Holding

The final candidate significantly reduced probability of pelvic, spinal, and lower extremity injuries for the driver. The results were verified in an overmatch under-wheel (driver’s side) LFT&E event.
Objective: Provide PM ASV a recommended crush box height and cushion thickness for their seating modifications. There was 130mm of available package space, and an optimized solution was required to balance comfort and blast mitigation.

Modeling & Simulation
- The finite element seat model was correlated to a series of drop tower tests
- A series of parametric analyses were run using several variables for the crush box against the competing variable of cushion thickness.

The analysis showed that a height reduction to 40mm and reconfiguration of the crush-box would actually perform better than the initial direction provided by the PM (60mm).

PM ASV is currently in the process of fabricating and testing the prototypes of the final configuration.
**UNCLASSIFIED**

**MRAP Caiman RWS Seating**

- **Objective:** Provide an analysis for the reorientation of the Remote Weapons Station (RWS) seating location for the MRAP Caiman PM.

- **Modeling & Simulation:**
  - A correlated model of the Caiman was already available from previous analyses.
  - A design of the bracket for seat mounting was provided by the PM.
  - Evaluated a worst-case (95% male, full PPE) and best-case (5% female, standard PPE).
  - Plastic strain and effective stress on the mounting bracket were evaluated to ensure the material thresholds were not exceeded.

- The mounting bracket did not exceed the stress or strain thresholds for the materials selected.

- The solution was fielded with a minimum of physical testing and quicker turn-around-time.

- TARDEC also provided additional feedback relative to improvements in the Energy Absorbing (EA) mechanism and the integral footrest.
Several MRAP variants to be integrated with RWS; seats and footrests need to be rotated to face forward and maintain the same survivability performance

- Existing seat, existing mount points on vehicle and seat

TARDEC GSS and CASSI Analytics

- Decomposed existing seat
- Added new bracket developed in-house to mode
- Computationally reconstructed past MRAP tests in both the current and RWS-integrated configurations.

- Determined that new bracket design would most likely not fail and occupant impact protection was not significantly impacted

- Model is currently being refined – seat contractor CAD provided, impulses verified, occupant weights updated to represent test configuration
- Reduced the need to retest full vehicle
Objective: Evaluate two seat concepts (XBOX 1 and 2) that were developed to address severe spinal injuries being seen in theater.

TARDEC Engineering Approach:
- CAD and finite element models were generated from the paper concepts.
- Parametric M&S analyses were run to determine the optimum parameters for the designs.
- Prototype parts were fabricated from the optimized design.
- Drop tower testing of the prototypes were compared to the baseline seat, as well as a field of approximately 20 other seat concepts and COTS solutions, using the following equation:

\[
1000 \times \left( \frac{\text{Pelvis}_{AZ}}{A_{\text{critical}}} + \frac{\text{Spine}_{Fz}}{F_{\text{critical}}} \right) \times \frac{1}{\max \text{AZ}_{\text{input}}} \times T_{\text{max Pelvis}_{AZ}} \times 1000
\]

- A static and dynamic comfort evaluation of the top candidates was also performed by TARDEC.

The top three candidates were provided to PM MRAP for further consideration. Neither of the XBOX solutions were finalists.
Recent Underbody Development Programs:
- Tactical Wheeled Vehicle Survivability Underbody Kit Development

Current Underbody Development Programs:
- HEMTT Support
  - Develop
- Joint Light Tactical Vehicle (JLTV) Support
  - M&S support to predict / validate vendor underbody performance
- Combat Vehicle Armor Development (CVAD) ATO support
  - Provide a best practice guide on underbody design (standoff, geometry, material, etc.)
- Lockheed Martin & Fire Control
  - Test Lightweight Titanium Protected Crew Compartment
- Zero-G
  - Proof of Concept to decouple the crew floor and increase occupant survivability
- Generic Hull Testing
  - Releasable (to the general public) test data on hull testing and ATD resulting injuries
- HMMWV V-Hull
  - Virtually integrate and validate blast performance
UNCLASSIFIED

TWVS ATO Demonstrator Underbody Kit (U-Kit) Development

- Requirement for upgraded underbody protection on TWVS ATO Demonstrator
- Partnership with TARDEC GSS, ARL/WMRD, TARDEC CASSI, Letterkenny Army Depot
- Physical and computational analysis
  - Space claim under and inside vehicle
- U-kit was modeled
  - Existing cab, existing appurtenances
- ... And Tested
  - Prototypes were attached to representative hull/chassis, mine tested at ATC

• U-kit for TWVS ATO Demonstrator provides increased underbody protection
Recent Programs:
- Interior Appliqué for the TWVS Demonstrator

Current Programs:
- Air Bag / Restraint Technologies
  - TK Holding CRADA
    - Develop a suite of restraints and airbags to decrease occupant injury during a blast, IED, or crash event
- Vehicle Data Recorder
  - Integrate DTS Transient Shock Recorders into currently fielded vehicles, upgrade existing COTS systems, and data analysis infrastructure
- ATD Development
  - Perform cadaveric testing to characterize and develop a test dummy designed for the vertical loading seen in blast and IED events.
Interior Appliqué for TWVS ATO Demonstrator

- Leverage existing Phase II SBIR – Texas Research Institute, Austin
  - Expanded polypropylene w/ polyurea coating
  - Reduces blunt trauma injury to occupants

- Additional funding added to contract to develop prototype kits in support of TWVS ATO Demonstrator
  - Provide vehicle CAD to contractor
  - Determine high risk points for blunt trauma in vehicle
  - Utilize existing high heat testing at TARDEC to verify appliqué attachment

- Appliqué kit on TWVS ATO Demonstrator FY 10 full-scale testing

Material is unaffected by salt water!
Blast/IED Event Data Recorder System:

- Gaps exist in data collected in theater
  - Accurate post blast/crash data collection techniques and recording equipment do not currently exist
  - Without full understanding of the blast/crash events, countermeasures cannot be optimally designed and integrated

- Limiting Factors:
  - Accurate determination of the causative effects of injuries to the Warfighter
  - Understanding of injury mechanisms within operational context
  - Materiel/training solution development
  - Situational awareness of threat type and vehicle performance

- This directly supports:
  - Development of test procedures and resultant countermeasures to protect the Warfighter
  - Accident and combat event investigations
  - Gathering information for vehicle diagnostics and prognostics
  - Refine and improve Tactics Techniques and Procedures (TTP)

Critical data is unobtainable unless collected in real-time
Purpose: The OP SIL provides the mechanism to evaluate, optimize, integrate, and validate occupant centric survivability and safety systems to mitigate injury due to blast and crash events.

Products:
The test equipment simulates blast & crash events and evaluates the occupant and protection system response to these forces.
- MABS: Underbelly blast events at system level
- LIS: Front & side impact, side IED, and rollover
- VIT: Vertical forces and floor deformation
- HIP: Head protection systems

Payoff:
MABS
- State-of-the-art unique piece of test equipment
- Reduced number of LFT&E (~LFT&E $75,000 - $150,000; MABS ~$15,400)
LIS
- Multiple crash events evaluated on one test device
- System design optimization for multiple impacts
VIT
- Assess multiple occupants & lower extremity injury
- Configurable platform - vehicle specific layout
HIP
- Low cost, quick assessment of a head impact protection
- Assess interior padding solutions
Conclusion

- Occupant Survivability needs to be designed in from the beginning, not as an afterthought... design from the inside out
- Occupant Survivability is a complex issue that involves many technologies optimized for each unique system