Ground Systems Integration Domain (GSID) Materials for Ground Platforms

Ms. Lisa Prokurat Franks
Materials Engineer
Office of the Chief Scientist

20 SEP 2010

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Standard Form 298 (Rev. 8-98)
Prescribed by ANSI Std Z39-18
Overview

Tank Automotive Research, Development & Engineering Center

Dr. Grace Bochenek, Director
Mission

- Provides full life-cycle engineering support and is provider-of-first-choice for all DOD ground combat and combat support vehicle systems.

- Develops and integrates the right technology solutions to improve Current Force effectiveness and provide superior capabilities for the Future Force.

Ground Systems Integrator for the Department of Defense

Responsible for Research, Development and Engineering Support to 2,800 Army systems and many of the Army’s and DOD’s Top Joint Warfighter Development Programs
Reach back to over 8,500 Scientists and Engineers
Combat Vehicles
- Heavy Brigade Combat Team
- Strykers
- MRAPs
- Ground Combat Vehicles (Future)

Force Projection
- Fuel & Water Distribution
- Force Sustainment
- Construction Equipment
- Bridging
- Assured Mobility Systems

Tactical Vehicles
- HMMWVs
- Trailers
- Heavy, Medium and Light Tactical Vehicles

Robotics
- Technology Components
- Demonstrators
- Military Relevant Test & Experimentation
- Transition & Requirements Development

TARDEC Engineers Provide Cradle-To-Grave Engineering Support
TARDEC’s Warren, MI operations has a resource value of over $950M and occupies 12 facilities on the Detroit Garrison totaling over 840,000 square feet of laboratory space
Motivation

**DRIVERS**
- Lightweight/Mobile
- Threat Designable/Repairability
- Armor: Multifunctional Ballistic/Structural/Stealth

**NEED TO BALANCE**
The 3 Ps!

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Importance of Basic & Applied Research

**Basic Research**
- Brittle Materials:
  - Material properties
  - Processing/synthesis
  - Ceramic optimization
  - Failure mechanisms
  - Ceramic optimization
  - Dynamic behavior modeling
  - Laboratory characterization techniques
  - Determination of properties relevant to ballistic impact

- Mechanics of Composites:
  - Finite element codes
  - Strength of materials
  - Analysis of thick composites
  - Micro scale model

- Penetration Mechanics:
  - Constitutive material models
  - High-strain rate propagation
  - Metallurgy
  - Hydrocode development

**Applied Research**
- Armor Mechanics:
  - Defeat Mechanism
  - Encapsulation Techniques
  - Ceramic Optimization
  - Multi-hit
  - Structural Response
  - Ballistic Shock
  - Modeling
  - Trends analyses
  - Armor optimization
  - Initial trades studies/analyses

- Structural Design Tech:
  - Design trades
  - LW structural Response

**Adv Development**
- Armor module dev/fab
  - Robustness
  - Manufacturability
  - Attachment design
  - Shock transmission
  - Affordability
  - RAM

- Structure
  - Load optimization
  - Attachment design
  - Shock/vibration
  - Damage tolerance
  - Affordability
  - RAM

- Trades analyses
  - Performance
  - Weight
  - Cost

**Eng Development**
- Platform integration, producibility, and performance testing

Basic research critical to success, and must be a CONTINUING activity

INITIATION

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Materials for Ground Platforms

- Ideal situation: materials readily available and fully developed.
  - RHA
  - High hard steel
  - Aluminum
- Reality: Research projects are ongoing to further develop advanced lightweight armors.
  - Composites
  - Ceramics
  - Titanium
  - Magnesium
  - Composite and metal matrix

- Long Term Armor Strategy
  - A + B design
  - Requirements are classified
**Design Drivers – Cost/Weight/Volume**

- **Silicon Carbide Armor Tile Comparison at Equivalent Ballistic Protection**

<table>
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<th>Material</th>
<th>Weight (psf)</th>
<th>Cost ($/lb)</th>
<th>Thickness (in)</th>
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<td>SiC</td>
<td>20-23</td>
<td>$80</td>
<td>1.0-1.5</td>
</tr>
<tr>
<td>Titanium</td>
<td>20</td>
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<tr>
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<td>$30</td>
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  *(production cost)*

- **Titanium & Aluminum/Lithium Alloy Raw Material Cost**

  ~$12/lb vs. ~$4/lb for Conventional Aluminum
Structural Approaches

- **Space Frame**
  - Lightest “structure only” weight
  - Tailorable survivability
    - Ballistic armor tailored to mission requirements
    - Low burden integration of other enhancements.
  - Ease of repair
  - Improved transportability

- **Monocoque**
  - Lightest weight approach assuming a base level of ballistic protection
  - Efficient integrated structural armor solutions
  - Maximum interior volume
  - Lowest cost

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Combat Vehicles

Current

- Thick, heavy armor
- Structure as by-product of armor
- Inherently damage tolerant
- Arrive on ships
- Well understood materials and manufacturing practices
- Designed for force-on-force engagement
- Cumbersome logistics tail
- Basic situational awareness

Future

- Lightweight armor
- Structure plus armor (A + B)
- Relatively damage intolerant
- Air transportable (C-130)
- Advanced ceramic armors, use of polymer composites and associated mfg. practices
- Designed for noncontiguous, non-linear, reorganizing battlefield
- Common components, reduction of logistics footprint
- Network centric, highly interdependent
Issues to Lightweighting Combat Vehicles

- Development of survivable vehicle systems while keeping to air transport weight (aircraft dependent)
- Attachment methodologies for A + B armor concept, appurtenances
- Joining and fastening technologies (dissimilar materials), adhesives
- Balancing interior volume against the use of less efficient structural material solutions
- Signature management, electromagnetic shielding over potentially non-metallic surfaces
- Diagnostics & prognostics for structural health assessment
- Material costs and improving multi-hit performance
- Advanced structures offer part consolidation necessitating development of high yield mfg. processes
- Inspection and repair of advanced armor systems
- Improved modeling and simulation
Tactical Vehicles

Current

• Tired and aging fleet
• Corrosion prone
• Cabs typically unarmored. Armoring via add-on-armor kits
• Reduced vehicle payload, maneuverability, reliability, safety, maintainability, and life expectancy
  – Increased wear and tear on vehicle components, fuel consumption, and life cycle costs
• Multiple original equipment manufacturers, little commonality
  – Designed for traditional role of logistics support

Future

• Recapitalization with appliqué armor (A-kit/B-kit)
• Be more survivable in mine blast events
• Component commonality (hardware, transparent armor, B-kit panels)
• Gun turret and advanced countermeasures
• Crew installable B-kit, with minimal tools
• Enhanced crew survivability to meet threat
• Increased system reliability
• Taking on more of an assault role
Issues to lightweighting Tactical Vehicles

- Balancing material costs over a large vehicle fleet
- Integration of hybrid, advanced materials, and layered armor solutions
- A-frame with mounting points which allow for rapid addition/removal of B-kit, and spiral-in of emerging armor technologies
- Addressing seams and edges that result from modular armor
- Tile confinement for enhanced ceramic armor performance
- Improving armor multi-hit performance of advanced armors
- Opaque armors under 28 psf and transparent armors under 30 psf
- Keeping transparent armor thickness to a minimum
- Durability of advanced lightweight armors
- Health assessment of advance armors
- Improved modeling and simulation
Validated Design and Analysis Tools

- Quarter Section Testing
  - Flexure
  - Shear
  - In-plane

Develop analysis tools critical for structural design

Experimental Database for FEA

Database for Development and Validation of Laminate Modeling

Sub-element Testing Required

Cover Layer
Tile/Adh.
Base Plate

4"x4" Ceramic Tile
Top View of Tile/Adhesive/Composite Layer
Gap: Composite/Adhesive

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SUMMARY
Of Material Initiatives and Needs for Lightening Ground Platforms

- Significant challenges remain in areas of material development
- Need to look at not just basic materials but structural approaches
- Modeling and simulation is a critical enabler
Ground Systems Integration Domain (GSID)
Workshop on Materials for Ground Platforms

University Center - Macomb Community College
Clinton Township, MI

August 23-24, 2010
Ground Systems Integration Domain (GSID)
### Holistic Approach to Ground Combat Vehicle Platform Innovation

**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

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<tr>
<th>Platform Weight Class</th>
<th>Project Objectives</th>
<th>Project Partners</th>
<th>Project Schedule</th>
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</table>
| **Heavy Combat**      | • Soldier-Centric Vehicle Design  
                       | • Modular, Reconfigurable Vehicle Systems  
                       | • Targeting selected GCV Objective Requirements  | • ~36 months from Concept to Design (Includes tech development) |
| 100,000 - 140,000 lbs |                    | **RDECOM**      |                  |
| **Medium Combat**     | • S-MOD/MPC Threshold Survivability  
                       | • Motor Sports Vehicle Design Process  
                       | • M1 Equivalent Mobility  | • 12-18 months from Concept to Build (tentative) |
| 40,000 - 60,000 lbs   |                    | **Professional Motorsports Industry** |                  |
| **Light Tactical**    | • FED Program–OSD Funded  
                       | • 30% Fuel Economy improvement over M1151  
                       | • Maintain Mobility of M1114  | • 12 month Tech Discovery phase  
                       | • <14,000 lbs Vehicle Weight  
                       | • System Cost of $250,000  | • 18-24 months from Concept to Build |
| 14,000 - 16,000 lbs   |                    | **Ricardo WTSI Global Services** |                  |
|                       |                    | **Hardwire Composite Armor Systems** |                  |

RDECOM will rapidly develop platform designs and demonstrators driving innovation in the areas of ground platform survivability and mobility.
Primary Research Objectives (Occupant-Centric Survivability Focused):

1. 4500 lbs + trailer towing capacity; 4-6 man crew compartment
2. 14,000 lb curb vehicle weight
3. MRAP threshold survivability employing modular base armor
4. $250,000 base vehicle (@ 10K Qty)
5. 12 months

Secondary Research Objectives (Light Tactical Vehicle Key System Attributes):

1. Select JLTV requirements as secondary research objectives

Design & Integration of Key Technologies: Design & Integration of Key Technologies
Workshop Expectations

- Research Driven Opportunities
  - 6.1, 6.2 -> What should the GSID follow and support?
  - Awareness and participation in Material Science Programs

- Opportunities to integrate
  - Demonstrator programs (6.3)
  - Platform/Product/Part Driven Needs
    - PEO GCS, CS&CSS modernization programs
    - OEMs
    - DLA/Sustainment
    - Depots

- Barriers to adoption of new materials?
  - Environment, safety, cost, weight, size, MRL/TRL
• Most commonly from Army S&T (6.3 funded) TRL-6 to a Program of Record (6.4+)
• Know the Technology Readiness Level (TRL) of your technology

- Technologies going into a POR undergo Technology Readiness Assessments (TRA)
- What is the POR’s acquisition strategy – COTS or Developmental?
- PMs must have a requirement, validated by TRADOC, to acquire technology

• Get to know the target platform
  - Where is the program in its lifecycle?
    • Determines the amount of each of the funding types available to the PM
    • Determines the maturity of the technology (TRL) the PM can accept (for example: TRL-6 at MS-B)

• Understand the transition pathway – this is for you to have fully worked out
  - Does your technology have to be integrated in another manufacturer’s system?
  - Can you manufacture your technology in quantity?

• Cost matters!

Unclassified
Review of the ongoing activities in RDECOM, DARPA, academia, industry, partnering, and structured analysis to identify best opportunities—Funnel thru GSID

Safety: During production through Hostile Engagement

Primary: Power, survivability, communications, lethality

Environmentally safe and nonhazardous

Reflect heat, absorb solar energy to power batteries, shock absorbing (external and internal)

EMI friendly so we can add antennas and retain low signatures

Repeated heat/cold cycles.
Prioritized Capability Gaps

Protection against asymmetric threats
Power and Electronics *
Mobility – Maneuverability
Fuel Efficiency
- Hit Avoidance
- Occupant Protection
- Unmanned Operations
- Armor

- Energy Storage
- Reliability/Maintainability/Sustainability
- Assured Mobility

- Protection against Kinetic
- Force Projection
• New survivability materials must have good durability to last until needed
Synergetic effects of armor metallic (AL, STL, TI) laminated with ballistic
liners (Kevlar, E-glass, S-glass....)

• Reduced flammability: Don’t put polyethylene base composite inside the
vehicle such as Dyneema, Tenselon, Spectra

• Maintainability to allow field removal, replacement and/or repair: suitable
chromium replacement

• Compatibility to resist corrosion and/or fungus

• Affordability with no negative impact on SWaP-C - lightweight structures

• Materials for power electronics'
  – Suitable lead-free solder
  – Efficiency and increase operating temperature (i.e. SiC, magnetics)
  – Batteries to increase energy/power density (i.e. LiIon, energy dense
cathodes)

• Polymers for suspension and track

• Lubricants: Single lube forward compatible with VHM Sensors
PEO Material Property Needs

- Strength
- Lightweight
- Manufacturable
- Maintainable
- Corrosion and fungus resistant
- Environmentally friendly
- Low-cost
- Reduced flammability materials
- Long life
- End-of-life plan
• Replacement for Cr
• Lead free solder
• Replacement for Halon
• Polymers for suspension and track
• Improved metals, glass, cloth
• Energy storage materials
• Bridging technologies – bridge, boat, trucks, health monitoring
• Propulsion systems to burn JP8 without sacrificing sensors
• Packaging for water and fuel
• Single lube compatible with existing sensors
R&D Agencies Represented

- ARDEC
- ARL
- ARL WMRD
- ARO
- DARPA
- DOE-ORNL
- DOE-PNNL
- DOE-VTP
- NIST
- PEO CS&CSS
- PEO GCS
- TARDEC
- USACE-ERDC
Lightweight materials

- **Metals, alloys**
  - Advanced High Strength Steels – many varieties
  - Titanium – needs work to produce inexpensively
  - Magnesium
  - Structural amorphous metals

- **Non-Metals**
  - Composites of every variety
    - Carbon fiber
    - Graphene
    - Glasses
    - Ceramics
    - Polymeric fibers
  - Boron carbide
Materials of the Future

- Nanomaterials
  - Nano grain sizes
  - Carbon
  - Coatings
- Bio-inspired materials
- Structured architectures
- Self-healing
- Damage sensing elastomers
- High-strength fibers
- Armors that spread the energy
- Foams, lattice materials
- Chemical manipulation
- Unprecedented properties
- Multi-materials
• Army started UARCs why? nsf?
• Schuh: work non-aqueous deposition
• Biotechnology
• Assumption: normal structures are ltwt;
• Low energy cons?
• How does DARPA see GSID helping itself? Ti initiative: structural amorphous metals (SAMS)
• Where is basic material science incubating? Universities: National labs?
• Controlling microstructure?
• Establish property – architectural specs?
• What is the process to bring new ideas and materials to the PMs, PEOs, etc?
• How does the basic research translate to useable materials?
• 61., 6.2, 6.3 appear to be stove piped: how to fix?
Workshop Expectations

- Research Driven Opportunities
  - 6.1, 6.2 -> What should the GSID follow and support?
  - Awareness and participation in Material Science Programs

- Opportunities to integrate
  - Demonstrator programs (6.3)
  - Platform/Product/Part Driven Needs
    - PEO GCS, CS&CSS modernization programs
    - OEMs
    - DLA/Sustainment
    - Depots

- Barriers to adoption of new materials?
  - Environment, safety, cost, weight, size, MRL/TRL

- It is a Workshop
• Opportunities
  – 6.2, 6.3
  – PEO GCS, CS&CSS
  – OEM

• Why do we have the heaviest SLAT armor?
Needs

- Stronger, lighterweight
- High energy storage devices
- Better processing
  - Lower cost manufacture methods
  - New technology forming methods
  - Joining – welding
- Models and Simulations
  - Understand structures
  - Predict materials and properties
- Testing
  - NDE
  - Accelerated corrosion testing
  - Available standards
  - Standardized test methods
Greatest Need

- A guide to traverse the Valley of Death
  - Requirements understood by researchers
  - Complete technical specs for new materials transferred to PEOs
Review of Issues/Actions from Day 1

- Both PEO’s have commonality and SWAP-C needs
- Create GSID/PEO Integration Guide
- Avoiding the “Valley of Death” Guide
- Road mapping meetings?
- PEO TRA Support?
- Why is Value Engineering so Hard?
- Lightweight track ROI business case – share?
- Titanium path forward with DARPA
- P&E materials work skipped?
- Dan Morse – low temperature semiconductors
- Dr. Prater – materials by design
- Xtalic – quick win?
- Reversible damage sensing elastomer – Q-win?
- Tortorelli: CF8C – Plus steel – Cat – Q-win?
- What are transition issues to carbon fiber?
- Leveraging vehicle light weighting efforts