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NOTE: THIS DOCUMENT IS MAINTAINED BY THE TARDEC EXTERNAL BUSINESS OFFICE (EBO)

What we do: Identify, pursue and accelerate business opportunities that improve resource utilization for both the Army and external partners.

- Connect with others who innovate, develop, demonstrate and accelerate technology
- Communicate the Army's ground vehicle technical needs
- Create collaborative business agreements



<u>NOTE</u>: The information contained in this document was presented at 2016 TARDEC Industry Days. For 2017, TARDEC Industry Days is scheduled for 25 & 26 April, at Macomb Community College, Warren, MI. Check website for additional information for this, as well as for Ground Vehicle Systems Engineering & Technology Symposium (GVSETS), to be held in August of 2017.

Visit us at: www.army.mil/TARDEC

Your comments and suggestions are welcome through the **TARDEC Ground Vehicle Gateway** at: https://www.army.mil/e2/c/downloads/451947.pdf

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TARDEC's **30-Year Strategy** provides the overarching framework within which TARDEC will develop, integrate and sustain advanced manned and unmanned ground system (UGS) capabilities for the Current and Future Force. This document is the single resource that presents TARDEC's strategic context and future direction.

TARDEC's 30-Year Strategy has three **Value Streams** (VSs) that serve as the divisions of the end-to-end activities which, ultimately, deliver required products or services to Soldiers. The first value stream (VS1) entitled "Shape the Future Force," focuses on developing new concepts and capabilities to inform requirements for the Future Force. The second value stream (VS2) serves to "Support Systems Across the Acquisition Life Cycle" and focuses on providing the engineering and technology support required for ground systems as they are realized, upgraded or sustained. The third value stream (VS3) is entitled "Strengthen Foundational Competencies" and focuses on strategically improving TARDEC's core technical and non-technical competencies; the people, processes and tools which support all of TARDEC's stakeholders through deliverables in VS1 or VS2.

Lines of Effort (LOEs) are subordinate to each VS and enable their respective VS by focusing associated programs and strategic goals within each VS. LOE owners develop and manage objectives that target delivery-oriented outcomes and capability demonstrations. In turn, they ensure aligned programs achieve their objectives and contribute to the strategy's execution. This process focuses on what must be done, unifies efforts and supports task organization to achieve desired outcomes.

⇒ VALUE STREAM 1 (VS1): SHAPE THE FUTURE FORCE

The **VS1** focus is to shape the Future Force by informing the requirements processes that define the future direction of Army ground systems. This is accomplished by working closely with <u>TRADOC</u>, and developing new capabilities that are enabled by leap-ahead, innovative, modular, flexible, smart and adaptable technologies and architectures to demonstrate the art of the possible.

The five **VS1** Lines of Effort are:

- LOE 1.1: Autonomy-Enabled Systems
- LOE 1.2: Ground System Architecture
- LOE 1.3: Protected Mobility
- LOE 1.4: Power Density and Energy Efficiency
- LOE 1.5: Maneuver Support, Sustainment and Logistics Optimization

→ VALUE STREAM 2 (VS2): SUPPORT SYSTEMS ACROSS THE ACQUISITION LIFE CYCLE

The efforts undertaken in **VS2** extend the operational relevance and cost effectiveness of currently-fielded ground systems. To achieve these results, current systems must: 1) continually upgrade their capabilities to maintain technological superiority; and 2) possess the capacity to accommodate new capabilities as they are developed. In addition, the Army must have the means to understand and mitigate the costs of sustaining each platform. VS2's objective is to ensure TARDEC is the preferred source of affordable engineering service and support for the ground systems community.

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The three **VS2** Lines of Effort are:

- LOE 2.1: Technical Program Support
- LOE 2.2: Sustainment Engineering
- LOE 2.3: Tech Alignment & Transition

⇒ VALUE STREAM 3 (VS3): FOUNDATIONAL COMPETENCIES

The **VS3** focus is to strategically improve TARDEC's core technical and non-technical competencies through the people, processes, tools and facilities which support all TARDEC stakeholders through utilization in VS1 or VS2. VS3 uses an integrative approach of technical and mission-enhancing LOEs which allow TARDEC leaders to make decisions to strategically grow, sustain or divest in the VS3 resources that form the foundational competency. This undertaking aims to position TARDEC to provide superior products and services, such as military ground system engineering, experimentation, analysis, system integration, prototyping, manufacturing, assessment and sustainment engineering services to VS1, VS2 and other stakeholders in a reduced cycle time.

The fifteen technical Lines of Effort in **VS3** are:

- LOE 3.1 Force Projection Technology
- LOE 3.2 Ground System Physical Simulation and Test
- LOE 3.3 Ground System Survivability
- LOE 3.4 Ground Systems Autonomy Capability Development and Integration
- LOE 3.5 Ground Systems Software Engineering & Tactical Cyber Security
- LOE 3.6 Ground Systems Technical Planning & Management
- LOE 3.7 Ground System Development, Fabrication, Integration and Engineering
- LOE 3.8 Ground Vehicle Advanced Concepts Development
- LOE 3.9 Ground Vehicle Power and Mobility
- LOE 3.10 Platform Engineering
- LOE 3.11 Product Life Cycle Engineering (PLE)
- LOE 3.12 Quality
- LOE 3.13 Sustainment Engineering
- LOE 3.14 Ground Vehicle Performance Analysis and Assessment
- LOE 3.15 Vehicle Electronics and Architecture

The complete TARDEC 30-YEAR STRATEGY document can be accessed at: https://www.army.mil/e2/c/downloads/429599.pdf

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The following information was culled from the charts that were presented at TARDEC Industry Days on 26 April 2016

Ground System Survivability

Value Stream 1

- Advanced Ballistic Protection in support of Combat Vehicle Prototyping (CVP)
- Shaping future Active Protection System (APS) Requirements
- Develop hull structure & weight informed design process for CVP
- Fire Protection
- Advanced Laser Protection for the next Ground Combat Vehicle
- Advanced Blast Mitigation Protection
- C-IED/Mine Payload Development

Value Stream 2

- Demonstrating Modular APS on current ground systems
- Align & advance lightweight material S&T projects to needs of Programs of Record (MRAP, JLTV, Bradley, ABRAMS, Stryker, TV)
- Advanced Laser protection for Bradley
- Mechanical Countermine; Fire & Laser Protection;
- Foundational Blast Mitigation Protection for PM LTV and HTV, M-ATV and PM LAV
- Foundational Ballistic Protection
- Enhance effectiveness of POR Roller against AT threats

Value Stream 3

- Develop and grow expertise & capabilities in lightweight material design, analysis and testing for future
- Evolving data, process and tools to enable APS development
- Engineering services/support for fire protection
- Engineering services/support for Ballistic Protection
- Product Manager, Assured Mobility Systems (PdM AMS) Support to legacy Roller Programs

Current GSS Projects

1. CVP - SURVIVE Integrated Demonstrator- Purpose: Design, develop and demonstrate state-of-the-art ballistic/active protection, blast mitigation, and advanced material technologies to influence the next-generation of Infantry Fighting Vehicles.

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Products:

- Ballistic Protection (Armor) B-Kit and C Kit systems to defeat relevant kinetic and chemical energy threats.
- Hull, Frame, Body, Cab (Blast) Advanced active and passive soldier protection technologies; defined blast load subsystem interactions.
- Hull, Frame, Body, Cab (Structure) Advanced, manufacturable affordable vehicle structures.
- APS Concept Modular APS Framework and Architecture "Best of Breed" Soft-Kill & Hard-Kill APS
- Modeling High fidelity system-level vehicle models capable of modeling events with complex materials

Payoffs

- Improved overall vehicle survivability with net weight decrease
- >4X Underbelly Blast Performance
- 10-15% Survivability Weight Reduction
- Active Protection System (APS) concept for stressing chemical energy threats
- Modular, lightweight armors that defeat battlefield threats while maintaining system level performance metrics
- Improved Army vehicle development, integration, and analytical tools
- 2. Armor Program—Purpose is to Leverage current investments in combat vehicle armor to develop, mature and integrate lightweight base, add-on, and electrified armors, utilizing new materials and design approaches. Specific focus on reduction of integration burden while trying to achieve 10% weight reduction. Develop, mature, integrate and transition TRL 6 B-kit and C-kit systems to combat vehicle programs and OEMs.

Products:

- Lightweight B-Kit and C-Kit Armor packages to defeat both kinetic and chemical energy threats.
- Improved lightweight integration techniques to reduce integration weight and decrease install/uninstall time

Payoffs:

- Lightweight armors that will defeat current and future battlefield threats while maintaining system level performance metrics
- Improved mobility, fuel economy, and decreased logistics due to lighter weight armor systems
- Enhanced system level performance that may be tailored to complement other advanced survivability technologies (active blast, APS, etc.) and will function as stand-alone protection

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Challenges and Risks

- Traditional armor material combinations are too heavy to meet system weight goals
- Advanced materials and integration schemes have not been subjected to MIL-810 testing before
- Environmental/vibration effects to the advanced materials and integration schemes are unknown
- Currently working threat allocation between Active Protection and armor to ensure all threats and requirements are being addressed

Existing Contracts:

- Multi-year contract for development and fabrication of pilot scale automated armor manufacturing line - \$1.5M
- Pulse power supply component integration \$2.3M
- Ballistic Modeling & Simulation (M&S) code development \$1.0M
- Materials for prototype armor fabrication with various vendors \$2.9M
- Test and Evaluation Services \$1.9M

Opportunities (New/Competitive, and DME OTA Contracts)

- Armor Material Purchases \$16.6M
- ▲ Modeling and Simulation Development \$2.0M
- Test and Evaluation Services \$12.4M
- Manpower Support \$1.4M

Gaps and New Opportunities - Advanced Materials Development

- Improved ballistic performance against both direct fire and fragmentation threats
- ▲ Increased damage tolerant materials
- A Development of high strain rate material properties
- ▲ Improved impact and damage resistance
- ⚠ Improved Flame, Smoke, and Toxicity performance

Improved Manufacturing and Integration Processes

- A Significant cost reductions and improved manufacturing methods (e.g. polishing, grinding) of advanced ceramics
- Methods that address seams, corners and other vulnerable areas
- A Pultrusion experience for the automated fabrication of ceramic composite armor systems.

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Robust integration methods that provide weight reduction, reduce installation time (ease install and removal)

Transparent Armor

- A Significant cost reductions without performance loss
- A Decrease in haze; improved luminous transmission
- ▲ Improved interlayer material for wider temperature ranges
 - 3. Combat Vehicle Adaptive Armor (CVA²) Fundamental research to develop and demonstrate integrated adaptive armor systems comprised of mechanical and electrical mechanisms utilizing real time data and sensing technology in order to increase protection.

Products:

- TARDEC and ARL to collaborate throughout this multi-level effort in order to produce a suite of adaptive armor technologies.
- Demonstration of armor adaptability to relevant operational environments to achieve defeat of various threats of interest
- Armor system TRL 6 TDP
- Improved modeling and simulation tools for adaptive armor behavior
- Integration concepts including SWaP for current force platforms

Pavoff:

- Increased mass efficiency versus traditional armor systems (passive, non-energetic reactive, energetic reactive)
- Improved cost/performance versus traditional armor systems
- Improved holistic approach with concurrent experimentation, development and integration by TARDEC and ARL

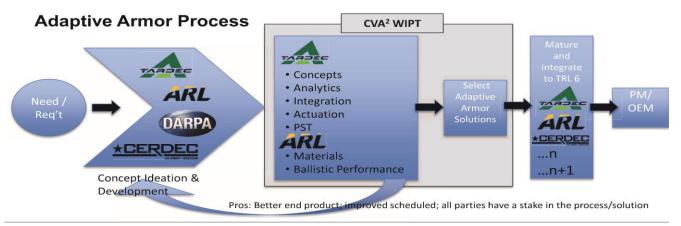
Standard Armor Process



Coupon Testing at ARL

Coupon mature to integrated TRL 6 W /Mil 810G Testing

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Existing Contract Actions FY16:

- Test and Evaluation Services \$50k
- Concept Analysis \$275k

Gaps and New Opportunities

- Concept Analysis \$3.0M
- A Component Design and Fabrication \$5.0M
- Test and Evaluation Services \$4.0M

Advanced Armor Development

- Development of real-time ability of armor systems to sense, adapt and protect against an array of known and unanticipated anti-armor devices.
- Novel approaches to adaptive armor design that combine multiple technology based armors, sensor technology and / or adjustable armor to defeat various threats including non-traditional and large threats.

▲ Improved Integration Techniques

- Robust integration methods that provide weight reduction, reduce installation time (ease install and removal)
- Incorporation of sensors and mechanisms (actuators, etc) that allow the armor to adapt and react to its environment
- Development of control systems that provide Modular Active Protection System (MAPS) compatibility
 - **4. Sensors, Protection from Lasers (STO-R) Program** Purpose and mission is to provide solutions protecting eyes and day-vision cameras from laser weapons, integrating and testing of the same and demonstrating to PM/OEM communities. Objectives include developing materials to limit the amount of light energy allowed to sensors, and to design optical systems allowing the integration of advanced laser protection materials.

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Existing Contracts:

- Concept Integration \$275k
- Laser Power-Limiting Materials \$50k

Gaps and New Opportunities

- Concept Integration \$425k
- ▲ Laser Power-Limiting Materials & Test Support \$2.0M
- High-Energy Laser Vulnerability Analysis & Concept Development \$2.0M

A Protection Concept Integration

- Integration of laser-protection concepts into existing ground combat vehicle sighting systems.
- Novel materials which provide a power-limiting approach when in the presence of laser energy.

▲ Far-Term Laser Vulnerabilities

- Perform vulnerability studies against far-term laser technologies.
- Develop proof-of-concept techniques which protect sensors from damage.
- **5. Blast Mitigation/Protection** Purpose is to mature blast mitigation technologies through product development, integration and validation. Fully understand blast load paths through vehicle platforms by decomposing the load paths through each technology and technology interface.

Products:

- Advanced active and passive soldier protection technologies
- Defined blast load technology interactions
- Standards and guidelines for all blast mitigating technologies
- High fidelity system-level vehicle models capable of modeling crash, rollover and blast events with complex materials such as composites

Payoffs:

- Minimized weight, enhanced soldier protection for ground vehicle systems through advanced technologies and integration strategies
- Improved Army analytical tools
- Documented Standard and Technology Design and Integration Guideline supporting the improvement of survivability, operability, and accommodation of future military vehicles

6. Exterior Blast Mitigation Technology

Purpose:

 Prevent catastrophic deformations in the vehicle hull that generate high floor loads resulting in occupant injuries

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- Reduce peak flooring accelerations
- Determine evaluation techniques
- Improve GV blast survivability while reducing cost and weight
- Control the transfer of momentum to the vehicle cab under various threat loads
- Determine system timeline for detecting/reacting to threat loads
- Provide an electric signal to various blast mitigation measures(technologies) in an effort to reduce injuries to the Soldier
- Reduce lower extremity injuries by controlling loads between vehicle cab and floor

Foundational Technologies	Advanced Technologies
1. Low Deformation Hull	1. Active Floors
2. Monolithic Hull	2. Active Blast Mitigation
3. Foundational Floors	

7. Interior Blast Mitigation Technologies

Purpose

- Develop integrated interior system (seats, restraints, airbags, cargo retention and protective trim) to maximize Warfighter survivability.
- Design the interior space from the occupant outward for a system capable of minimizing injuries against underbody threats.
- Leverage knowledge gained from previous programs, industry, and emerging technologies
- Inform the future requirements process through data accumulated during the maturation of these IBMT projects.
- Develop data to improve Modeling and Simulation of the effects of blast on interior occupants

Foundational Technologies	Advanced Technologies
1. Foundational Seat	1. Sensing/Active Seat
2. Foundational Restraints	2. Multi-Axis Seat
3. EA Protective Trim	3. Active Restraints and Airbags

Program Updates for FY16 - Projects completed

Exteriors – Integration of Active Blast Mitigation System (ABMS) Designed, fabricated, and evaluated a scaled concept of a ABMS decoupled integration which showed a significant reduction in structural accelerations.

Exteriors – Underbody Optimization Designed, analyzed, and tested component level underbody concepts to understand the increase/decrease on performance.

Exteriors – Adaptive Floors Initial investigation on flooring systems that protect a full range of occupants (5th, 50th, & 95th) over a wide range of threats while accommodating a more space constrained combat vehicle environment.

Interiors – **Modular Lightweight Seat** Designed a modular lightweight seating solution that was tested for blast, crash, and rollover performance.

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Hull, Frame, Body, Cab (HFBC) – Trade Study Event Trade study was conducted for the survivability technologies to identify the most balanced set of CVP SURVIVE-focused technical solutions among a set of proposed viable solutions. The viable solutions were ranked on performance, manufacturing, integration, and cost.

CAMEL Evaluations In order to test and validate the OCP requirements of improving occupant accommodation and survivability, a concept demonstrator, known as CAMEL, was developed. The CAMEL is a medium weight, clean sheet, ground-up system, designed around the 2015 Soldier population. The CAMEL Demonstrator recently completed the final Verification Blast Testing and User Evaluations, to prove occupant accommodation and performance capabilities to mitigating all occupant injuries at the 4x blast level.

Program Updates for FY17 - Projects Starting/Ongoing

Interiors – **Multi-axis Sensing Seat Concept** Project is to enhance energy absorbing seats to identify occupant size (weight), auto-adjust for the following features: energy absorbing mechanisms, head restraint, lumbar support, and restraint systems. This project is to support seat selection for combat vehicle to better accommodate and protect the Warfighter.

Interiors – **Restraint Testing** To physically and M&S test 2/3/4/5 point restraint systems using a drop tower, a servo sled, a rollover platform, ride motion simulator, and blast tests to gather data that depicts the amount of motion the occupant undergoes with each system and collect the injury data from the occupant using each system.

Exteriors – Active Blast Mitigation System (ABMS) Investigating Active Blast Mitigation System (ABMS) integration concepts to control momentum transfer to a vehicle cab and to learn how to integrate to a combat vehicle.

Exteriors – Adaptive Floors Developing flooring systems that protect a full range of occupants (5th, 50th, & 95th) over a wide range of threats while accommodating a more space constrained combat vehicle environment.

Exteriors – Advanced Manufacturing of Hulls Investigation of advanced manufacturing methods for casted hull design with optimization based on durability and blast analysis.

Existing Contracts (Awarded)

- Exterior Underbody/Hull Development, GVS OTA, \$1.4M (FY16)
- Exterior Floor Development, OTA, \$800K (FY16)
- Exterior Active Blast Mitigation System, OTA, \$900K (FY16)
- Interior Advanced Seat Development, OTA, \$725K (FY16)

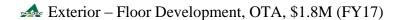
Opportunities (New Competitive and OTA Contracts)

A CVP - Blast Buck Fabrication, \$25M (FY17-19)

▲ Blast Mitigation – Blast Testing Contract, \$2.0M (FY17)

▲ Exterior – Underbody/Hull Development, OTA, \$3.5M (FY17)

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- Exterior Active Blast Mitigation System, OTA, \$1.8M (FY17)
- ▲ Interior Advanced Seat Development, OTA, \$3.0M (FY17)

Opportunities

- Blast/Rollover/Crash Mitigation Technologies
 - Low profile underbody protection solutions for blast events
 - Flooring solutions to mitigate lower extremity injuries and prevent binding of energy absorbing seat mechanism
 - Development of energy absorption and robust steering columns to protect the occupant and accommodate an airbag
- Fire, Smoke, and Toxicity (FST) Technology Testing Need fire resistant energy attenuating materials for improved vehicle interior head impact injury protection
- Impact Abatement for Secondary Effects of Blast
 - Mechanism and technology development to control or protect against extremity injuries caused by flail of the occupant(s)
 - Development of easy to use solutions for containing gear/cargo/ammo, so they do not become flying projectiles during a blast event and cause harm to the occupants
- Blast Retrofit Solutions Development and characterization of blast mats, floor tubs, energy absorbing resettable seats that accommodate 90% of population, hands-free restraint systems, energy absorbing flame retardant material to line vehicle interior to protect head and extremity injuries, decoupled underbody and flooring solutions
- Improved Manufacturing Processes for Hulls Cost effective means to produce high performing hulls to protect against blast threats
- Lightweight Materials for Hulls Development of lightweight metallic and composite materials or alternative innovative lightweight concepts that are cost effective
- Central Point Triggering Development of universal triggering system to trigger all active systems on the vehicle
- APrototype Fabrication, Repair, Maintenance, Test and Evaluation

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TARDEC Blast Mitigation Program (BMP) and the Michigan Chapter of the National Defense Industrial Association – (NDIA-MI) CRADA

- Forum for industry to collaborate in a non-competitive environment and exchange information with TARDEC
- Objective: Exchange information related to the Blast Mitigation Program Occupant-Centric Survivability standards and guidelines development

Topics Presented Include:

- Concept for Advanced Military Explosion-mitigating
- Land demonstrator (CAMEL) Overview and Tour (MAR 2016)
- Occupant Protection Laboratory Overview and Tour at Selfridge
- Air National Guard (SANG) base and "Drop Tower Seat Evaluation" (JAN 2016)
- "The Seated Soldier Study", "Seat Shape Modeling", "Interior Head Impact Protective Components and Materials" (OCT 2015)
- "Optimal Restraint System Routing Procedures for Restraint System Development" and "The Effects of Soldier Gear Encumbrance on Restraints in a Frontal Crash Environment" (AUG 2015)
- **8.** Advanced Countermine Program Develop capabilities to provide clearing and proofing across a broad spectrum of platforms from SMET; HMMWV/JLTV; MRAP and Tracked Platforms.
 - **HMMWV/JLTV:** TRL 6 (LTCMS) IEDs, AP/AT Mines, Wire Defeat Platforms in 15,000-2,5000lb. Category
 - Route Clearance: TRL 7-8 EHP (M 163) IEDs, AP/AT Mines, Wire Defeat Platforms in 35,000lb and up Category; Program of Record Roller and Wire Neutralization Systems.
 - **Tracked Vehicle:** TRL 5 Development in Progress. Focus on mobility and effectiveness.
 - Counter Mine and IED Payloads to meet a broad spectrum of platform capabilities: Platform dictates what is automotively possible, Roller system weight and standoff are determining factors in the relationship of the prime mover's mobility. The combination of the two dictate capability.
 - **Unmanned Clearance and Proofing:** TRL 7-8 IEDs, AP Mines, Wire Defeat Platforms in 1,500lb Category.

9. Light Tactical Counter Measure System (LTCMS)

- LTCMS supports the smaller and lighter vehicles (JLTV, HMMWV, and MATV) to provide Self Protection and IED standoff to enable inherent mobility capabilities (currently 46% lighter than EHP)
- Capitalizes upon the true modularity in design from the EHP WNS Equipment and the EHP Roller.
- Can develop an entirely new system with only 2% in additional part numbers from the EHP WNS equipment.

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- Can be "Roller" only or with "Wire Defeat" capability. "Neutralize command wire and buried IED components"
- Heavy Track Vehicle Roller Concepts
 - Basic concepts are in design for follow on testing in: Wheel Size and Type; Optimal Standoff; Roller System Articulation; Roller Needs to support mobility and effectiveness.
 - Envision a twin bank architecture with dual push arm configuration
 - Larger Wheel diameter covering the width of track (22-24 inches)

Program Updates for FY17

Mechanical Countermine Team developed Counter IED Payloads and demonstrated success on Squad Mission Equipment Transport (SMET) – Participating in Pacific Maneuvers Functional Assessment (PACMAN FA) July 2016.

The Core Competency effort has advanced into the architectural design process for a Heavy Track Vehicle Roller (HTVR).

Transitioned the completed design and Tech Data for Explosive Hazard Pre Detonation (EHP) Roller and Wire Neutralization System (XM 162 and XM 163) for production.

Began development of a Lighter Roller to provide Self Protection on Non Route Clearance use

Existing Contracts (Awarded)

- Utilize Multi-year contract with Michigan Tech for development and evaluation of mechanical countermine technologies. (\$350K)
- Combine customer funds with TARDEC dollars to incrementally develop sub-component systems for dismounted, tactical and combat vehicles. (\$1.48M)

Gaps and new Opportunities

Dismounted Maneuver –

Problem:-Dismounted Engineers at Company and below require unmanned capabilities enabling integrated multi-mission payload configurations able to operate non line of sight (NLOS) via a networked communications system in support of (ISO) CIED route reconnaissance/clearance, obstacle breaching, CBRN remote/stand- off detection, and small gap crossings.

Proposition:-Unmanned systems enable Engineers to execute tactical tasks beyond line of sight thus enabling mitigation of potential effects of explosive and/or CBRN hazards allowing for improved maneuverability and survivability operations

Combat Vehicle Protection - Combat maneuver forces lack high mobility, AT Defeat, self-protection.

Fire Protection Technology Integration Laboratory (FP TIL) - Establishing integration and test capabilities to evaluate performance of extinguishing components and agents, including: High-speed concentration analysis; ballistic fireball simulator; and Reconfigurable test enclosure.

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✓ Vehicular Fire Suppression Model – Further develop suppression model to predict AFES performance, including: Flame Propagation; Agent Dispersal; Fire Extinguishment; AFES Effectiveness.

Seeking R&D related to: Self Sealing and Fire Extinguishing Fuel Tanks; Material Flammability, Smoke, and Toxicity Standards.

Potential Efforts On: External Fire Protection Systems; Environmentally Friendly Agents; Li-ion Battery Vulnerability Reduction efforts.

Advanced Lightweighting

GOAL: An Expeditionary, Scalable & Ready Modern Army – Program purpose is to develop a weight informed vehicle design optimization process and architecture for the Army, to develop and execute strategies to enable a 10 -30% weight savings. Also to Utilize, develop, and evaluate tools, advanced materials, manufacturing, and assembly technologies to optimize component/subsystem/system weight while maintaining or improving performance

- **1.** Focus S&T investment to maximize the potential of emerging game-changing land power technologies to counter emerging threats.
- 2. Rapidly deploy, fight, and win whenever and wherever our national interests are threatened.
- **3.** 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).

Challenges – Component Design - To Develop and publish light-weighting metrics and requirements for research, development and acquisition programs.

- **1.** Continue investment to build Army core competency in design optimization for weight reduction using commercially-available design tools.
- 2. Promote use of prototype demonstration vehicles and experimental laboratory-demonstrations to drive technology advancement.

Challenges – Material Science and Manufacturing – Predominant hurdles in transitioning lightweight materials to combat vehicles do not lie in the materials science research; but rather in the M&S and manufacturing technologies required.

1. Leverage materials being developed within the automotive industry, Department of Energy Vehicle Technology Office (DOE VTO) and other government agencies.

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- **2.** Invest in specific material investments for continued long term research in advanced metal alloys, ceramics, composites, nano-materials, and environmentally acceptable materials.
- **3.** Invest in joining and advanced manufacturing technologies for emerging materials through ManTech and other manufacturing avenues where external (industry, OGA, academia) investments fall short.
- **4.** Continue as active voice in the National Network for Manufacturing Innovation (NNMI) hubs and provide the requirements of the Army to these consortia.

Program Updates for FY17

Holistic Advanced Lightweighting Optimization process development effort underway. Using Modified Automotive Advanced Quality Planning Process to identify high value light weighting targets and validate with weight optimization M&S techniques.1.

Golden Buckshot study complete, identifying high value components for lightweighting.

SBIR for advanced armor attachment methods

Weld wire development for 6XXX underway

Combat Vehicle Load Analysis document is in development; understanding individual vehicle component loads.

MIL-STD-3040 Welding of Armor Grade Steel (Out for Final coordination)

Model development to quantify Operational metrics and fully understand the impacts of primary system (MBT) weight growth on brigade costs.

Studying the inhibitors resulting in lack of lightweight technology Transition

Transition blast material technologies and hull design to the CVP team

Ballistic weld development and testing using DIC

Expanding weight reduction scope to include the entire vehicle not just the Survivability area

Existing Contracts (Awarded) - Include projects ongoing focused on the following technology objectives

- Holistic Advanced Lightweighting Opportunities (HALO) GVS OTA acquisition focused on internal LW process development, potential LW applications for CVP, and design and analysis of at least one LW application.
- Computer Aided Design for Fabrication of Advanced Materials (CADFAM) competitive acquisition for design and optimization of new or re-engineered components for fabrication using advanced material
- Adhesives OTA acquisition for development of very high strain rate loading performance of adhesively bonded joints
- Thermal Friction Stir Welding Studies
- Barriers to Lightweight Technology Integration
- Alcoa 6XXX Weld Wire development
- Lightweight Turret Structure Evaluation
- Advanced Joining Techniques (Bimetallic Casting, Upset Joining, Collision Welding, Brazing Foil, etc.)

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Technology Gaps:

- Lightweight advanced materials (e.g., metallic alloys, nano-composites, resin composites, etc.) that meet very high strain rate loading performance
- Lightweight joining techniques that meet very high strain rate loading performance such as blast and ballistic impact
 - Digital imaging correlation for ballistic shock testing of ballistic welds to measure the total response of the material and allow a better understanding and evaluation of failures
 - Characterizing and developing critical design parameters for several classes of adhesive materials
 - Dissimilar materials joining techniques
- Material characterization for dissimilar material combinations that are achievable through FSW is needed for proper modeling and simulation
- Research is need in dissimilar material joining to identify the possibilities for military applications
- Novel structural designs or tools that optimize designs that meet very high strain rate loading performance
- → Holistic vehicle light-weighting techniques.

Opportunities - (New Competitive and DME OTA Contracts):

- Titanium Road Arms/Wheel design and Optimization
- FeMnAl Structure
- Hydrogen Embrittlement Welding Studies
- Additive Manufacturing Studies for Welded Joints
- Surface Preparation and Joining for Composite Joints
- Material purchases
- Operational & cost analysis model modules for detailed weight metric generation
- Generic Vehicle loads analysis
- Barriers to Lightweight technology Integration for engines
- Lightweight Vehicle Architecture
- Multi-material Hull

Modular Active Protection Systems

Active Protection Systems - Hit avoidance vehicle defense systems which protect vehicles from inbound armor penetrators such as RPGs and ATGMs. APS typically comprises three (3) functions: Sense, Compute and Defeat

APS functions must be	APS Benefits must include
Autonomous	Increased area of protection

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Quick	Protection from advanced threats
Decisive	Weight avoidance from armor only solution
APS = High Complexity & Safety Burdens	APS + Armor = Weight Optimization

Operational Advantage of APS

Advanced threats require armor solutions that drive vehicles past a practical weight.

Impacting: Transportability & Mobility (e.g., width/rollover, suspension, propulsion, bridges)

Active Protection is the only known solution to provide the required survivability increment to address the desired threats a at minimal weight

Tangible benefits of an intelligent APS

Situational Awareness of shooter location and threat type

Rapid retaliation via automated weapon system cue with shooter coordinates

Ability to survive the engagement and complete the mission

Soft-Kill APS:

Employs CM (e.g. obscurants or electronic warfare devices) to interfere with the guidance mechanisms or the operator of susceptible threats causing it to miss the protected vehicle

Hard-Kill APS:

Employs CM (e.g. explosive fragments or blast pressure) to inhibit the lethal mechanisms of susceptible threats causing it to be ineffective against the protected vehicle

Purpose

Focus on the challenges of transitioning Active Protection Systems (APS) through the development of HW/SW that enables integration of tailored APS subsystem suites, with demonstrated Soft-kill (SK) and Hard-kill (HK) APS that are compliant with a modular approach to defeat Rocket Propelled Grenades, Recoilless Rifles and Anti-Tank Guided Missiles.

Products:

- Soft-Kill and Hard-Kill Modular APS Demonstrators
- Modular APS Controller (MAC) that is Configurable for Army Vehicle Fleet and Compliant with Army Safety Standards

Payoff:

• Establishes a common starting point, for all APS systems, for all vehicles, to facilitate transition across the fleet

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- Enables rapid innovation and the ability to adapt in an uncertain future where the enemy and environment is unknown and unknowable
- Creates "Best of Breed" component flexibility, growth capability and competition
- Provides integration of protection from advanced threats at an optimized weight
 Opportunities
 - Modular APS Framework (MAF) comprised of APS integration standards (Electrical, Physical, Data Interfaces) developed in collaboration with COI
 - APS Modeling & Simulation and System Integration Lab
 - ▲End-to-End analysis for transition risk reduction
 - AHardware-in-the-Loop System Integration Lab

Army Active Protection System (APS) - Strategy provides a phased Survivability Set technology approach, with the potential to grow and transition capability over time.

- Foundation of the strategy, Modular Active Protection System (MAPS), enables tailored capability, integration commonality on any platform, and an avenue for technology insertion and growth.
- Expedited APS informs APS strategy on integration issues, current limitations of NDI solutions, transition and fielding process, cost and reduce risk to follow on APS efforts.

Modular Active Protection Systems Details - Eliminate barriers associated with the US fielding of Active Protection Systems (APS) through a modular and safe design that establishes the foundation to transition tailored capability integrated on any platform, while demonstrating modular Soft-kill (SK) and Hard-kill (HK) to defeat Rocket Propelled Grenades, Recoilless Rifles and Anti- Tank Guided Missiles

Partners

TARDEC	 MAPS Framework and Controller Soft Kill Countermeasure APS Integration / Evaluation Modeling & Simulation Program Mgt and Sys Engineering
*CERDEC US ARMY- RDECOM	Soft Kill CM and Sensor Hard Kill Sensor Modeling and Simulation
[16] PG	Hard Kill CM Modular APS Controller Modeling & Simulation

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ARL	Design AnalysisRed TeamingModeling & Simulation	
AMRDEC	 Hard Kill CM, Development Sensor Development Modeling & Simulation	
Community of Interest (40+ Industry Vendors)	Safety Vehicle Integration Sensors, Countermeas	Information Assurance Communications / Protocols sures, Controller Sub Systems

MAPS Updates for FY 17

Kicked off the MAPS Industry Forum to engage industry and academia in the creation of the Modular APS Framework (MAF) on 29-30 April 2015 Year in Review December

Convened Source Selection Boards for all MAPS contracts to select subsystems that will be modified to become "MAF Compliant" for the Soft Kill and Layered Physical Demonstrators as well as the Virtual Demonstrators.

Successfully entered and conducted the System Functional Review on 30 June

Contract awards were made and followed by kickoff meetings for the following contracts:

- Modular APS Controller Hardware
- Modular APS Controller Software
- Prototype Controller Soft kill Demonstrator Software Development
- Soft kill Countermeasure
- Soft Kill Cueing Sensor
- Hard Kill Countermeasure phase 1
- Tracking Sensor phase 1

MAF Updates to the MAPS Industry Forum

- System Model 28 July
- Knowledge Point 1 30 Nov
- MAF Beta 26 Feb

Successfully conducted Tier 1 testing at Redstone on 21-25 to baseline Soft kill Countermeasure and Cueing Sensor performance before MAF compliant modifications are made

Existing Contracts

- Modular APS Controller
- MAC Software
- Prototype Controller Soft kill
 Demonstrator Software Development
- Soft kill Countermeasure for Soft Kill Demonstrator
- Soft Kill Cueing Sensor for Soft Kill Demonstrator
- Hard Kill Countermeasure phase 1 and 2
- Tracking Sensor phase 2

Gaps and Opportunities (New Competitive and DME OTA Contracts)

Revised October 2016

- ▲ Integration of Modular APS Controller into vehicle platforms
- Add new focus areas into MAPS Industry Forum
- ▲ Soft kill Countermeasure for Layered Demonstrator
- ▲ Soft Kill Cueing Sensor for Layered Demonstrator
- A CRADAs and TSAs enable efforts in the TARDEC Hit Avoidance Lab
- A Collaboration with Outside Labs
- ▲ Lessons Learned for Capability Evolution
- A Robust Compliance and Certification Community
- **A** Emulators Needed for Virtual Demonstrators
 - Hardware and Software
 - Primary mechanism will be "basket awards" from the subsystem OTA proposals

MAPS Community of Interest

- Directly and proactively affect MAF development
- Insight into MAF implementation methods
- Opportunity to create and shape the U.S. APS market
- Technical challenges identified throughout the forum proceedings may become opportunities for funded projects
 - Small projects short duration, limited funding
 - Could be funded by a variety of mechanisms
 - Great opportunity for cost sharing
- A MAF Compliance via Active Protection Integration Cell Lab

Current	Planned
Evaluate communications protocols	Virtual Demonstrators of MAF-Compliant APS
Develop node emulator prototypes	Systems and Subsystems
Integration of system components	Virtual Demonstrators of MAF-Compliant APS
Validation of MAF requirements	Systems and Subsystems

Ground Vehicle Power and Mobility

1. Advanced Combat Engine (ACE) Multi-Cylinder Engine (MCE)

Purpose: Design and develop novel modular, scalable and compact Combat Engines (750 – 1500 hp) to offset increasing combat vehicle weights (armor), increased electrical generation needs (onboard and exportable power), improved fuel economy (cost & range), enhanced mobility (survivability), and reduce cooling system burden (size, heat rejection) in a smaller package (reduce under armor volumes).

Revised October 2016

Product(s):

- High Power Density Low Heat Rejection Combat Engines achieving TRL 6 in FY19
- Engine Modeling and Simulation Data
- Engine Performance and Durability Data
- Controls Architecture & Algorithm and Design Specifications
- Unlimited & Government Purpose Rights for MCE

Payoff:

- This engine will provide an order of magnitude in energy efficiency while increasing power density, improving vehicle mobility, reducing fuel consumption and thermal loads.
- Leap-ahead technology in the engine to buy-back vehicle mobility and performance lost due to increasing weights and on-board power demands.
- Advancing technology readiness level of combat specific engine
- The ACE project fits in the area of Traditional R&D to transition an engine to CVP and align the development of the engine technology to schedules for CVP and future combat vehicle applications.

Program Updates FY 17

Advanced Combat Engine program was split into 2 Phases:

Phase 1: To design and build a Single-Cylinder Engine (SCE) 250 hp technology demonstrator as the building block to a family of combat engines. Both contractors have hardware. Engines are currently being built and tested.

Phase 2: To design and build a Multi-Cylinder Engine (MCE) up to 1000 hp based on the success of the SCE project to build a family of engine concept

Government System Functional Review (SFR) was held 21 March 2016. Preliminary Design review (PDR) scheduled for the end of September 2016.

Gaps and Future Opportunities

- Novel high-power density engine designs specific for military applications
- Turbine engine technologies for greater efficiency and durability
- A Commercial engine optimization specific to military applications for operation on military grade fuels
- Diesel combustion research leading to durable, compact air handling and fuel systems
- A Increasing engine thermal efficiency and reducing heat rejection with light weight, high strength materials and thermal barrier coating development
- Industry to leverage the engine development program data and results to evaluate the performance of lower heat rejection engines for the effective optimization and integration of powertrain systems for use in current and future military vehicles

Revised October 2016

2. Advanced Combat Transmission (ACT)

Purpose: Development of a high efficiency cross-drive transmission for a tracked vehicle, mated to a 1000hp high power dense engine while offering greater fuel economy (>10-15%), improved thermal efficiency (>15%), and lower heat rejection (<20%) for use in future combat vehicles and demonstrated in the CVP platform.

Product(s):

- Combat, Cross-Drive Transmission for tracked vehicles (45 Tons)
- TRL6 in FY19 for integration with a 1000hp Combat Engine and an electrical generator into the Advanced Powertrain Demonstrator (ADP).
- Transmission Modeling and Simulation Data
- Transmission Performance and Durability Data
- Controls Architecture & Algorithm and Design Specifications

Payoff:

- More efficient transmission will provide a 20% increase in vehicle range equating to savings in fuel usage.
- Increase in power from the engine to the sprocket to improve maneuver responsiveness/dash speed (agility and survivability/hit avoidance)
- Advancing TRL of combat specific transmission
- This program will contribute to TARDEC's Cultural Identity as a Center of Innovation in combat transmission development for current and future platforms.
- The ACT project fits in the area of Traditional R&D to transition a transmission to CVP and align the development of the engine technology to schedules for CVP and future combat vehicle applications.

Program Updates for FY 17

Contract was awarded to SAPA mid-December 2015

Government SFR held 21 March 2016. PDR scheduled for August FY16

Future Opportunities

Industry to leverage the multi-speed transmission development program data and results to evaluate the performance of more efficient transmissions for the effective optimization and integration of powertrain systems for use in current and future military vehicles

Technology Gaps

Multi-speed transmissions with greater ratio spread for tracked and wheeled vehicle applications with high efficient mechanical and torque converter designs

A High capacity launch clutch devices with unique clutch materials & pressure plate systems

Multi-speed and quick disconnect final drive for tracked vehicles

Revised October 2016

3. Advanced Thermal Management System (ATMS)\

Purpose: ATMS will leverage current investments in combat vehicle cooling technologies to develop, mature and integrate and efficient and effective cooling system for CVP. ATMS will also optimize cooling system reducing parasitic power in all modes of vehicle operation for more range and mobility, and maturing advanced technologies into integrated thermal solutions while enhancing performance, decreasing weight and minimizing costs.

Products:

- Improved Fuel efficiency for 10% increase in range
- Improved vehicle mobility
 - 8% increase in top speed
 - 5% increse in speed on grade
 - 5% increase in acceleration
- 10% less weight to help in meeting CVP requirements

Program Updates for FY 17

Contract awarded to AVL in September 2015

Government SFR held 21 March 2016. PDR scheduled for Q4 FY16

Technology Gaps

- A Leap ahead cooling technologies that contribute to increasing system fuel efficiency.
- ⚠ Cooling system modernization with advanced heat exchangers and fan systems with smart controls.
- Advanced LW cooling components that provide flexibility in form factor and reduce weight, volume and cost.

Future Opportunities

Industry to leverage the thermal management development program data and results to evaluate the propulsion cooling system for the effective optimization and integration of powertrain systems for use in current and future military vehicles

4. Integrated Starter Generator (ISG)

Purpose: To address onboard electrical power needs of Army combat vehicles (Stryker/CVP). Current vehicle alternators provide 10-20kW; inline generators to provide 160kW of high voltage electrical power. This will improve the buy-back power margin and allow for future capability growth for e-weapons and e-armor. The increased efficiency will save fuel, augment mobility and allow export power. Power electronics high temperature capability will improve from current 85C to 105C, with a power density improvement to 9kW/L, from 3kW/L.

Revised October 2016

Products:

- Verified 160 kW and 120 kW ISGs & controls for Combat Vehicles.
- High power generator and electrified auxiliary systems demonstration to include test methods, reports and analysis of high voltage OBVP and components, with the Advanced Powertrain Demonstrator
- Validated Model of OBVP components and systems.
- Specifications, ICDs, and evaluation of TRL.

Payoffs:

- 30% increase in electrical power over the CVP Baseline with minimum integration impact.
- Improved Operational Energy efficiency and mobility gains.
- Achieving Integration of safe high voltage OBVP (100-160kW) capability on Stryker and CVP Advanced Powertrain Demonstrator.
- Validated strategy for Intelligent Engine Start/Stop Electrified systems available without engine running.
- Core technology to enable future grid connectivity.
- 3X more power dense electronics at higher (105C) operational temperature enabling power pack integration.

Program Updates for FY17

Stryker Baseline SIL and Vehicle Testing Completed

Completed SRR and SFR

APOP SIL and Vehicle Testing planned FY16 completion

Completed initial design study for 105C 160 kW capable CVP ISG generator showing potential for holding original dimensions of 85C unit

Contingency inverter for CVP ISG is now primary with incremental path planned to get to 105C

ISG component contracts (generator & inverter) being executed for FY16

Existing Contracts

- FY16 APOP Stryker Vehicle Testing
- FY15 175kW 85 C Inverter at 8 kW/L
- FY16 160 kW Generator modifications for 105oC operation; L3COM FY16 Generator Controller Development contract; 175 kW, 105C, 9kW/L FY17 Surrogate SIL Development; L3COM/Various
- FY17 Generator modification based on results of component test
- FY17 Generator Controller modifications based on results from environmental testing FY18 - Generator and Generator Controller integration into Advanced Powertrain Demonstrator
- FY19 Test Support for Advanced Powertrain Demonstration

Revised October 2016

Technology Gaps

A Inverters and Generators capable of full rated power with 105C coolant

Power dense inverters (>8kW/L) that enable integration into existing vehicle platforms

Electrified auxiliary systems (fans, pumps, steering, air-compressors, HVAC, other)

Models with enough fidelity for auto-generation of control software - downloadable to controllers

New Opportunities – Industry may obtain access to government data on TARDEC test results and products for use in new systems, ECPs, etc.

5. Advanced Li-Ion Modular Batteries (Gen2 6T)

Purpose: Apply recent advances in Lithium-ion based anode, cathode, electrolyte and separator battery materials to electrode, cell, and pack designs to:

- Double the energy density for the Gen 1 6T Lithium-Ion Battery from 80Whr/kg to >160Whr/kg
- Increase power density for Gen1 6T Li-ion battery by 50%.

Products:

- Adv Li-ion battery materials for evaluation and demo.
- Gen 2 6T Lithium-Ion battery performance specifications and interface control documents

Payoff:

- Maximization of both power and energy density (Resulting in 3X silent watch duration).
- Reduced Weight: (2 PbA 6T batteries (160lbs) replaced by 1 Gen2 6T battery (40 lbs)) (120lbs saved per pair of batteries replaced)
- Reduced Volume (single Li-ion battery replaced two PbA batteries)
- Reduced Logistics & Sustainment Burden; Increased Cycle Life (3-5X improvement in cycle life duration)
- Decreased recharge time from ~10hr to 1hr (increase operational application and availability).

Program Updates for FY 17

Contract awarded to Navitas Systems (prime) through NAMC OTA for AMB program.

Finalized AMB requirements through systems engineering processes.

Conducting cell chemistry/design trade study.

Battery Management Systems (BMS) design optimization in progress.

Initial 6T Li-ion specification has been developed and released to current prototype 6T Li-ion suppliers - anticipate general release 1Q FY17. AMB program will leverage this specification.

Gen 1 6T Li-ion batteries from multiple suppliers currently under test and evaluation.

Revised October 2016

Existing Contracts

- OTA Navitas (FY15-19), AMB program for 2nd generation 6T battery development, delivery, and testing awarded September 2015.
- Phase II SBIR Enhancement Optodot Corporation (FY16-18), Effort to develop, mature and test advanced ceramic battery separators to improve safety.

Future Opportunities:

- A Potential material and cell technology insertion into the AMB program to accelerate meeting technical goals.
- Qualification of current Gen1 Li-ion battery technologies against the Li-ion 6T specifications.
- Qualified Gen1 and AMB (Gen2) battery products to be available for technology insertion into new systems as well as legacy systems. Test data will be available to PM's to evaluate use of these new battery technologies.

6. Advanced Powertrain Demonstrator (APD)

Purpose: The APD will mature powertrain technologies beyond GCV capabilities to provide a lighter, more fuel efficient powertrain. APD will demonstrate leap- ahead, scalable combat vehicle propulsion capability in an integrated powertrain demonstrator.

Products:

- Component and subsystem specifications
- TRL 6 Components to be integrated into the APD
 - Advanced Combat Engine: Common modular and scalable design providing low heat rejection
 - Advanced Combat Transmission: High efficiency
 - Integrated Starter Generator: On-board and export electrical power
 - Advanced Thermal Management System
 - Advanced Modular Lithium Ion Batteries 160kW ISG and power electronics

Payoff:

- 1.5x 2.0x improved installed sprocket power density
- 20 25% Increase subsystem fuel efficiency
- 10x increase of electrical power generation
- 20 -30% System weight reduction
- Improve mobility of platform to increase: vehicle range, speed on grade, and acceleration.

Program Updates for FY 17

General Dynamics Land Systems (GDLS) has been selected as the Advanced Powertrain Demonstrator (APD) integrator. (start of work – NOV 2015)

Revised October 2016

Successfully completed System Functional Review (SFR) 21 March 2016, working on after-action items

Existing Contract Actions

OTA project awarded to GDLS (Oct 2015)

Technology Gaps

Powertrain controls development for military applications requires a tremendous amount of engineering resource and testing infrastructure to support the required modeling, simulation, testing, verification, and correlation of each of the powertrain components and/or subsystems to assure an increase in energy efficiency across military ground vehicles

Tribology to evaluate finishes, coatings, lubricants for reduced friction for powertrain components

Future Opportunities: Industry may leverage the integration program data and results to evaluate the powertrain components for the effective optimization and integration of powertrain systems (improved power density) for use in current and future military vehicles

7. External Suspension Unit (ESU) Demonstrator

Purpose: Develop an External Suspension system to increase vehicle performance; provide vehicle designers with flexibility for complex hull shaping while buying back internal hull volume. The ESU will upgrade to alleviate effects of increasing GVW, such as degraded mobility and reduced ground clearance while providing for weight growth and optional height management with adaptive damping.

Products: Include performance and durability testing of an ESU to demonstrate a TRL 6, and the integration of ride height and adaptive dampening capabilities.

Pavoff:

- Suspension system which can accommodate for weight growth.
- Increased off-road mobility and vehicle performance through height management and adaptive damping.
 - Capable of up to 30% higher off-road speeds over severe terrain vs. passive systems.
 - Variable height control allows for transportation and blast mitigation.
- Enables "tuning" of the spring and damping characteristics; this provides for ride quality adjustability and optimization for weight and terrain.
- ~20 cu. ft. increase in exterior and interior hull volume over torsion bar system, allowing for more blast survivable underbody hull shaping.
- 20% reduction in system weight over current torsion bar system

Revised October 2016

Program Updates FY 17

21" arm with 23" of suspension travel, maximizes off-road capability.

Finalized requirements through systems engineering processes.

Detailed trade study selected an in-arm hydraulically damped configuration.

Presently undergoing a detailed FEA effort for weight optimization.

VEHDYN and DAD's models predict greater than 30 kph off-road on Perryman 3.

Long lead items ordered for in-house laboratory testing of different damping valve configurations.

Existing Contracts

- ESU Base effort: Horstman Design analyses to identify cost and performance trade-offs to optimally meet specified design requirements.
- ESU Option 1: Horstman Fabricating prototype components for preliminary laboratory testing to include spring and damper characterization, functionality, performance, and durability. Three complete prototype units will be manufactured for testing.
- ESU Option 2: Horstman Fabrication of a vehicle set of ESUs for TRL 6 on-vehicle system suspension test at YPG.

Future Opportunities – Industry may access suspension system designs, CAD and analytical data upon request.

Technology Gaps

Alternative means of height control capability (electrical VS hydraulic).

Cost reduction methods to reduce complexity of external suspension units.

8. Advanced Lightweight Track (ALwT) Demonstrator

Purpose: To reduce track weight through improved track system designs and optimization of materials, and increase track system durability through advanced elastomer materials. Goal to reduce maintenance and life cycle costs by developing an optimized running gear system.

Products:

- Advanced lightweight track system for a Combat Vehicle application with weight growth capability.
- On vehicle durability and performance testing to demonstrate TRL 6

Pavoff:

- Buyback of SWAP-C: Decreased track weight by 10%.
- Increased track system durability to 4,000 miles +.
- Flush back track design reduces vehicle rolling resistance, will improve overall fuel efficiency.
- Decrease vibration by 15%, improved ride quality, less warfighter fatigue.
- Bolt-less ground pad design will reduce track system maintenance.

Revised October 2016

Program Updates for FY 17

OTA Contract awarded to GDLS (prime) and Defense Service Tracks (formerly Diehl).

Finalized requirements through systems engineering processes.

Conducted weight reduction and durability improvement trade study.

Track and road wheel designs are underway

Road wheels are undergoing detailed optimization with advanced ABAQUS

Track system is undergoing detailed design.

Technology Gaps

Elastomer compounds which perform well in high heat and WRT chip, chunk, tear resistance.

A Road wheel manufacturing methods to reduce cost and increase reliability (i.e. advanced castings or 3D printing).

Future Opportunities – Include access to track system designs, CAD and data upon request.

9. Tactical Vehicle Electrification Kit (TVEK) -M22

Purpose: To develop and demonstrate an affordable truck auxiliary system electrification kit with positive Return of Investment (ROI) on one or more existing Tactical Wheeled Vehicle (TWV) platforms. To significantly improve vehicle operational energy, range, and system growth, and leverage DOE, Army, ONR, and Marines electrification investments.

Products:

- Validated Vehicle Electrification Kit w/Business Case for Transition
- Integrate LiON 6T batteries, e-steering, e-HVAC, e-engine cooling, e- pumps, shore power connection
- BOM to be made available to all OEMs (Military and Commercial)
- Implement intelligent start/stop strategy
- Demonstrate (T) 15%/(O) 25% fuel use reduction
- Common M&S model architecture and supervisory software
- Universal (platform agnostic) and affordable 85C inverter.
- Specifications and evaluation of TRL 7.

Payoff:

- Improved mobility performance and silent watch
- Capability to support future electrical needs for jamming, communications, eweapons, and e-armor
- Shore power connection for base power or vehicle auxiliary functions
- Reduced maintenance burden and elimination of hydraulic systems

Revised October 2016

- Achieving safe integration of high voltage power generation
- No impact to constrained space, weight, and cooling
- Affordable ROI auxiliary system electrification kit for tactical vehicles (1000 veh/yr)
- Project directly supports HEMTT, and LVSR.
- Project supports LoE: 2.1, 2.2, 2.3, and Key Outcome 4 (2.1.4; 1.4.1; 1.4.2)

Program Updates for FY 17

CAT15 engine fuel map test preparation begun (Test plan/instrumentation/data acquisition)

Completed System Needs Review (SNR) and Gate 1 review

RFI and RFP for 20kW and 75kW inverter controllers completed – pending award selection

Baseline electrical load analysis complete for HEMTT A4

Utilized AMSAA operational profile/duty cycle for heavy tactical convoys to calculate operational efficiency, operational costs, and return of investments (ROI)

Market surveys and outreach for other auxiliary system components

(HEMMT/LVSR) – steering, pumps, HVAC, cooling, DC/DC, PDU, and fans)

Existing Contract:

■ 20 & 75 kW 85C capable inverters – Contract pending award selection

Future Opportunities

- → FY16 Electrified Auxiliary subsystems solutions for HEMTT A4/LVSR
- Electrified auxiliary systems (steering, fans, pumps, compressors, HVAC, cooling systems, power export, front engine auxiliary drive, and batteries (6T LiOn) @ 28VDC & 600VDC
- Rotating equipment rated for coolant inlet temperature of 85C
- ▲FY17 Inverter modifications based on results from testing
- FY17 Electrified Auxiliary subsystem modifications based on testing results
- ▲FY18 Vehicle integration of auxiliary systems
- → FY18 FY19 Testing and demonstration Support for TVEK
- → BOM to be made available to all OEMs (Military and Commercial)

10. Compact Military Power

Purpose: To provide a SWaP-C optimized, high commonality power solutions for auxiliary power generation and small vehicle propulsion (< 75 kW)

Revised October 2016

Products:

- Heavy fueled engine technology for future vehicle applications (auxiliary power and prime mover)
- Affordable, low-risk auxiliary power solution for modernization efforts.
- Integration support for noise management, electrical, and engine subsystems.
- Specialized testing for small power systems.

Payoff:

- APUs directly support reduced operational energy of combat vehicles (reduced fuel/logistics burden; additional power; other capability developments)
- New small engine and APUs support the Army's integration of ultra-light vehicles, unmanned vehicles, modularity, etc. which results in a more expeditionary force.

Program Updates for FY 17

Compact Military Power includes auxiliary power generation and small vehicle propulsion. (Advanced Aux. Power presented in 2015 has been de-scoped from CVP)

Phase 1 SBIR for the variable energy ignition system in heavy fueled engine funded; kickoff Q2 FY16

Renewed group focus on modernization efforts on: Abrams SEPV3 APU optimization and noise reduction; M88 APU test support and evaluation for future applications.

Existing Contracts:

- Scalable Engine development contract awarded to SAIC; L3Com CPS is subcontractor.
 - Utilized traditional FAR contract through Omnibus contract mechanism
 - Two heavy fuel engine variants; effort continues to May 2016
- Development contract to Keweenaw Research Center/Michigan Technological University
 - Noise, vibration, harshness R&D for generic and specific applications
 - Small engine technology roadmap to assist future engine work

Future Opportunities – Industry may access government data and test results/product data for use in new systems, ECPs, etc.

Technology Gaps

Ultralight family of multi-fueled engines

- JP-8, DF2, and ULSD2 rated; at or better than 300 g/kW-hr
- Powers of ~5, 20, and 45 kW of interest, <~3 kg/kW

Components

- High pressure 6-12" diameter class fan
- High reliability fuel systems (pumps and injectors)

Revised October 2016

11. Fuel Cell Research, Engineering, and Logistics

Purpose: To provide future power generation capability through fuel cell technology evaluation, integration and logistics.

Products:

- Dual path approach
 - Leverage DOE Targets for automotive fuel cell technology performance
 - Demonstrate Military Specific fuel cell technologies in coordination with DOD partners
- Tactical hydrogen refueling capability utilizing logistically available fuels
- Energy dense solid hydrogen fuel storage analysis
- Premier source of research, engineering, integration, and testing of fuel cell based power generation systems

Payoff:

- Directly supports reduced operational energy of combat and tactical vehicles with added future capability
 - Continuous, silent power generation for exportable power, vehicle-to-grid power supply and/or auxiliary power
 - High reliability and minimal maintenance
- Robust knowledge and understanding of the current state-of- the-art in fuel cell technology areas
- Flexible solutions to suit widest array of vehicle needs, from small unmanned systems to main battle tanks

Technology Gaps / Future Opportunities

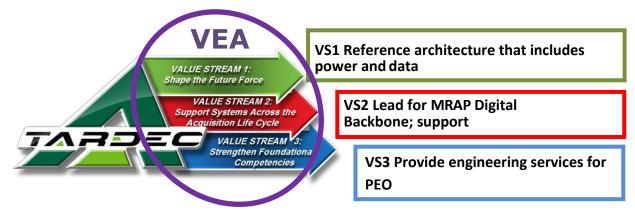
Low noise cathode air blower

- ▲ Low noise cathode air blower
 ▲ Power dense fuel cell stacks with built in controls
 ▲ Energy dense hydrogen storage
 ▲ Robust high temperature fuel cell stacks
 ▲ Access to data and experience of fuel cell integrations into military platforms to assist demonstrations that inform requirements or future vehicle upgrades
 ▲ Inline sulfur sensor for JP-8 fuel

Solid state and/or conformable hydrogen storage

Revised October 2016

Vehicle Electronics & Architecture



VEA Features:

- **FLEXIBLE** "Flexible" systems have many ways to accomplish a particular mission.
- **ADAPTABLE** "Adaptable" systems are able to rapidly change the way they accomplish their missions to optimize for the current environment.
- MODULAR "Modularity" in this context is a design that enables the tailorability of system components and mission packages.
- **SMART** "Smart" systems use automation to reduce the physical and cognitive burden on the soldier.

VEA Deliverables:

Autonomy Enabled Systems	Ground System Architecture
Main Battle System Platoon	Open System Architecture
Vehicle as a Member of the Squad	Non-Traditional Physical Architecture
AMAS Unmanned Convoy	System Level Design for High Voltage
Cab-less Trailers	
Power Density & Energy Efficiency	Protected Mobility
Vehicle Electrification	360° Situational Awareness
Power Dense, Common Modular Engine	Mobile Protected Firepower

VEA Deliverables - Combat Vehicle Prototype:

Power Architecture	Data Architecture
USG Open Software	USG Open Software
Interface Control Documents	Interface Control Documents
Converters, Inverters, Switches	Video Network
	Network Adapters
Vehicle Systems Control Software	System Design
USG Open Software	System Design Document
Interface Control Documents	Common Power and Network Design
Increase Fuel Efficiency	SE Documentation (SysML)

Revised October 2016

1. VEA Research SIL (VRS)

Purpose: The Army faces considerable challenges when integrating electronics on ground vehicles, compounded by the need to reduce cost and redundancy across multiple platforms. The VRS project will create a complete reference architecture to address the power, Vetronics, and C4ISR integration challenges facing the modernization of the ground vehicle domain. This architecture and the associated will support experimentation with future architectural concepts and implementations. This effort also includes the Power Management Technologies for the VRS project.

Product(s): Primary customer is PEO GCS. In addition to various design transitions throughout the project, the following will transition when the SIL is FMC (TRL 5).

- Vehicle Electronics & Architecture Research SIL
- HV and LV power electronics
- Vetronics, C4ISR integrated components
- Documented DoD AF Architecture Products
- DREN Interface to other RDEC SILs

Payoff: - Addresses significant SWAP challenges, and supports four out of the five TARDEC cultural identities by providing facilities, knowledge, and experience.

Program Updates for FY 17	
VRS has completed Critical Design Review (CDR)	
System Architecture Design Document (SADD) is completed	
Fully embraced Model Based System Design philosophy utilizing the PTC	
Integrity Modeler (formerly known as Artisan Studio) tool	

Existing Contract: DCS Work Directive - \$11.5M

Future Opportunities:

Test Service Agreement for use of the electromagnetic interference (EMI) chamber

A Test Service Agreement to test contractor developed high power components

→ Test Service Agreement to utilize the SIL

2. VEA Mobile Demonstrator (VMD) project overview

Purpose: Mature the open data and power architecture as well as the system designs to TRL 6 that were implemented as part of the VEA Research SIL at TRL 5 by integrating those subsystems onto a combat vehicle platform. Validate the power and data capabilities required for the future infantry or combat vehicle modernization efforts while increasing vehicle performance & decreasing SWAP over current implementations. Build the TARDEC bench on in- house vehicle integration of these systems

Revised October 2016

Product(s):

- Validated System designs, standards for Open Power & Data Architectures and Vehicle System Control Software, and component specification.
- TRL 6 hardware and Software
 - HV power system utilizing SiC
 - Vehicle Control Software w/power management
 - VICTORY/VECTOR C4ISR Implementation w/ CVP enhancements.

Payoff:

- Validates architecture implementation via a system design on a relevant platform (Stryker)
- Fuel savings of > 10% w/power management
- Provides mature standards and specifications to support future combat & infantry vehicle modernization programs
- Matures modular architecture hw/sw from TRL 5 to TRL 6
- Reduces risk for post-modernization technology integration & inform requirements for future efforts
- TARDEC will be better at vehicle integration w/ less reliance on outsourcing

Program Updates for FY 17

VMD has completed Stakeholder Needs Review (SNR)

Future Opportunities:

A Purchase of individual components in prototype quantities.

VICTORY Enabled Components Needed:

- 24 port Rugged Ethernet Switch (C1 Switch) with built-in Cross Domain Guard (transfer solution); allows one to transfer data from one domain to another.
- Vehicle Intercom (G2 Intercom, G3 Voice Radio, G4 Single Instance Audio Data Source, G5 Streaming Audio Data Source)
- A Firewall (D9 Network Firewall, D8 Intrusion Detection and Prevention)

Force Projection Technology

The Mission of the Force Projection Technology (FPT) group includes: Serving as the DoD responsible agent for all ground fuels and lubricants specifications, acting as DOD Lead Lab for Ground Water Supply and Wastewater Treatment, and as the National Depository Authority for the US Army on Military Load Classification. FPT supports all 3Value Streams.

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Value Stream 1

Improve protected mobility with new technology like advanced fuels and lubricants to enhance speeds and stability, as well as autonomous bridging.

Provide capabilities to increase speed and effectiveness in order to reduce logistics burdens such as employing improved bridging technology, fuels and lubricants, lines of communication, water treatment-generation- storage-distribution and petroleum. CD 2 Reduce the logistics burden for water and fuel requirements.

Value Stream 2

Impart technical expertise for operations and sustainment for phase of life-cycle including continuous support with fuels & lubricants, water, bridging and construction & material handling equipment

Value Stream 3

Develop and integrate advanced sea and ground capabilities into a cohesive force, and use energy-efficient technologies to support operations, maneuver support, sustainment and logistics optimization.

FPT S&P Roadmap

Technology Areas	FY 13	FY 14	FY 15	FY 16	FY 17	FY 18	FY 19
Fuel and Lubricants		Lubricant	imon Power		ulic Fluid		
Technology	Alternative Fuel Qualification& Advanced Fuel Research Extended Life Coolants Advanced Solid Film Lubricants						
	7	Water Qualit	ty Monitorin	g			
Petroleum and	Blac	k Water Tre	eatment & G	ray Water R	Reuse		
Water Systems				Small Wate	er Unit Puri	fier	
(PAWS)		Fue	el Quality M	onitoring &	Asset Visibi	lity	
Technolgy		High Press	sure Collapsi	ible Hose &	Life Storage	Materials	
						Advanced	Filtration
Bridging Technology		Bridge Hea	alth Monitor Multi-	ing Functional I	Bridge Tech	nology	

Revised October 2016

1. Fuel Efficient Gear Oils (FEGO)

Purpose: Develop new fuel efficient gear oils

Products:

- Federal Test Method & apparatus to measure axle efficiency (SAE J2360)
- New performance based specification (SAE J2360)

Payoff:

- 2-4% increase in fuel economy with no equipment modification
- Reduce wear, thus lessen logistics and maintenance burden
- Achieve OE ICD goals for fuel reduction

FEGO – Updates for FY17

Using the stationary axle efficiency test stand, completed efficiency mapping MTV axle over relevant speed and torque regimes. Will start and complete the mapping of LTV axle. This data will be used in developing final test methodology.

Completed SAE J1321 gear oil fuel economy assessments of the HET and HMMWV. Results will be used to ensure stationary axle test accurately reflects real vehicle data.

Added plan to include a vehicle assessment of gear oils suitable for limited slip differentials using TARDEC's Ground Systems Power and Energy Laboratory (GSPEL).

Started an economic analysis of FEGO to quantify overall net benefits.

Existing Contracts:

- Work directive Southwest Research Institute (SwRI), TARDEC Fuels & Lubricants Research Facility (TFLRF), \$781K
 - Establish a test methodology, using appropriate bench test, to assess limited slip differential capabilities of FEGO candidates
 - Assess extended performance (life) of FEGO candidates

Future Opportunities:

- Engagement with axle and gear manufacturers on test methodology through the Lubricant Review Institute (LRI) Gear Oil Review Committee
 - Work directive to TFLRF
 - Finalizing limited slip test procedure
 - Determine an optimal concentration of limited slip additive for military applications
 - Conduct FEGO candidate evaluations (e.g., efficiency, limited slip, extended life)Provide candidate products for evaluation
 - Provide qualified products for procurement by DLA under revised performance specification (SAE J2360)

Revised October 2016

2. Black Water Treatment & Gray Water Reuse

Purpose: Develop and integrate multiple technologies to produce compact, mobile, energy-efficient systems capable of rapid start-up that can treat black water to discharge standards and treat gray water to non-potable reuse standards

Products:

- A stand-alone black water treatment system
- A stand-alone gray water reuse system
- DOTMLPF analysis at Sustainability Logistics Basing (SLB) STO-D (formerly TeCD 4a), will inform requirements

Payoff:

- Reduces convoys and dollars required to provide potable water (for non-potable uses) potentially providing an order of magnitude cost savings for Army water logistics support.
- Reducing convoys saves Soldiers' lives
- Supports OE & Base Camp ICD and Force Provider CPD

BWTGWR - Updates for FY 17

Frontier black water treatment system demonstrated as part of the Network Integration Evaluation (NIE) 16.1 (SEP/OCT 15)

Extension of program into FY17 to conduct in-house testing and evaluation of alternative technologies.

NASA-Ames (gray water) and Cambrian Innovation (black water) systems completed and delivered for Government performance testing at the Sustainability Logistics-Basing, Science and Technology Objective Demonstration (formerly TeCD4a) of systems (JUN 16).

Existing Contracts:

- Cambrian Innovation, Inc., black water treatment system based on bioelectric & fuel cell technology, \$1M
- NASA-Ames Research Center, gray water treatment based on forward osmosis/reverse osmosis technology, \$750K

Future Opportunities:

- Cooperative Research and Development Agreement (CRADA) with EEC Global Operation, LLC to test its moving bed bioreactor wastewater treatment system at Carderock.
- Examination of membranes developed by PPG for enhanced gray water treatment
- APotential examination of technology improvements through VRA OTA
- **Transition to PdM PAWS or PdM FSS program of record in FY19

Revised October 2016

3. Water Quality Monitoring

Purpose: To enable rapid contaminant detection and process verification for mobile water treatment and supply systems.

Products:

- Prototype Inline automated monitor measuring water quality parameters (low cost, common, adaptable)
- Prototype toxin and pathogen detection devices
- Demonstration of Smart Sensor capability
 - Automates recording & expedited reporting
 - Alarms for Quality and Malfunctions

Payoff:

- Reduces Army convoys:
 - Solves Capability Gap for long-term tactical water purification skilled man power for equipment complexity
 - Improves efficiency of water production
- Protects Soldier Health through improved process monitoring

WQM - Updates for FY 17

Phase 1 SBIR with Giner: Proved feasibility of electro-chemical methods to measure organic carbon (chemical oxygen demand, or COD).

Phase 1 SBIR with Luna: Proved feasibility of microbial encapsulation to measure biological oxygen demand (BOD) and use of phages to detect E. Coli.

Reviewing Rapid Innovation Fund proposals for technologies to verify integrity & performance of non-reverse osmosis membranes, e.g. nano and micro filters, in the field. Technologies include advanced particle counting and flow cytometry.

Existing Contracts:

- SBIR, Two Phase II Awards of \$1.0M to Giner and Luna for Real-time inline wastewater (black and gray) monitoring
- ARO Grant, UCLA, \$514K Cyst assay using cell-phone camera

Future Opportunities - FY 16:

Provide COTS sensors for pH, turbidity, conductivity, temperature, chlorine, dissolved oxygen, chemical oxygen demand, and total organic carbon for Army integration

4. Small Unit Water Purifier (SUWP)

Purpose: Develop a system that produces 30 gallons per hour.

Products:

Lightweight, energy efficient high pressure pump incorporating energy recovery

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- Advanced, simple, robust pretreatment that produces membrane quality feed water
- New system design integrating advanced components and state of the art reverse osmosis
- Draft detailed specification and drawing package

Payoff:

- Fills the Petroleum and Water CBA Gap # 22: develop a man-portable water system
- Reduces the distribution footprint and waste associated with bottled water.
- Reduces soldier risk, one USMC study reported one casualty per every 50 fuel and water convoys in Afghanistan.
- Technologies will be transitioned to PM PAWS.

SUWP- Updates for FY 17

Began in-house design and fabrication of a baseline demonstrator using COTS components.

TARDEC working with CASCOM on the development of a requirement document for a program of record.

DoD Small Business Innovation Research (SBIR) FY2016 Topic A16-081 Advanced Reverse Osmosis Elements was released.

Existing Contracts

- Two Phase I SBIR awards for FY2015 Topic A15-089 Advanced, Robust, and Simple Pretreatment to Reverse Osmosis:
 - Filtration Solutions, Inc.
 - Pacific Research Group

Opportunities: Procurement and evaluation of COTS and emerging:

Pretreatment

RO membranes

Lightweight components

Power sources

Intake systems

Disinfection technologies

A Pumps and energy recovery devices

5. Fuel Quality Surveillance (FQS)

Purpose:

- Develop technologies to enable fuels quality surveillance in minutes.
- Investigate: Light obscuration, high speed imaging, light scattering, and ultrasound for contaminant detector; and Near Infrared Spectrometry for the portable fuel property monitor.

Products:

- Prototype sensors with corresponding algorithms based on TARDEC's library of fuels for each fuel sensor technology
- Develop Acceptable fuel property limits

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Payoff:

- Instrumentation will be incorporated into the Army Petroleum Expeditionary Analysis Kit
- Gives a fast moving Army the ability to test captured fuel in minutes.
- Increases number of properties that can be checked at the point of issue.
- In-line and real time fuels monitoring for several PM-PAWS systems.

Fuel Quality Surveillance (FQS)Updates for FY17

MIL-DTL-83133J for JP-8 was published 16 DEC 2015 and now includes particle counting for monitoring incidental contamination. The same spec limits are included in MIL-STD-3004D Change 1, which is the latest revision.

Awarded \$368K contract modification to Artium Technologies for development of inline water and particulate contamination detector

Existing Contracts

- Artium Technologies: inline-fuel-contaminant analyzer development, \$661K for base effort – Design and development of inline analyzer
- Real-Time Analyzers: (24 months), \$1M Develop a portable Fuel Property Monitor (FPM), capable of identifying and predicting critical specification properties of procured fuels and fuels in storage

Future Opportunities:

- Inline-fuel-contaminate detector Option 1: (12 months), \$367K Research light scattering methods to reduce power consumption
- Inline-fuel-contaminate detector Option 2: (12 months), \$0.5M Develop two (2) portable 2 in-line full flow prototype fuel contaminant analyzer systems
- Inline-fuel-contaminate detector Option 2: (12 months), \$0.5M Develop algorithms and laboratory software to rapidly compute data
 - 6. Multi-Functional Bridging Technology (MFBT) Phase 1

Purpose:

Develop a single bridge system which can be reconfigured for use in all Bridging missions; enable User to adapt to any condition encountered at a gap site.

Products:

- Evaluation of applicability of composites, advanced materials for bridging applications
- High strength, lightweight, scalable bridge components

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Payoff:

 Single, common bridging solution consisting of compact, generic, agile gap crossing equipment adaptable to multiple bridging missions, gap lengths, load levels

Multi-Functional Bridging Technology (MFBT) Updates for FY 17

Project now slated to run through FY19.

Current focus is assault capability for Stryker:

- 1. Launch / retrieve approach determined, initial design of launch/ retrieve mechanism ongoing.
- 2. Changes concurrently being made to the bridge design to ensure compatibility with launch/ retrieve mechanism.

Advanced Material Evaluation ongoing, with initial application of these materials being targeted for the bridge components. Applications to the launch/ retrieve mechanism will be assessed at a later date.

Existing Contracts

 Assembly and test support for durability testing of the existing Advanced Modular Composite Bridge prototype (assess durability of composite joints) – awarded to Seeman Composites as part of a contract to further develop a Composite Assault Bridge

Future Opportunities:

- A Contract(s) to supply composite materials for further material assessment, est.\$600k
- A Contract to manufacture full scale bridge module, est. \$1.0M

Technology Gaps:

- → High pressure (740 psi) collapsible hose + coupling assembly
- Real time measurement of all water quality parameters in EPA drinking water standards, particularly pH, turbidity, dissolved oxygen, total dissolved solids, temperature, oxidation reduction potential and free available chlorine
- For reverse osmosis systems, simple, robust raw water pre-treatment that will produce a feed water of equivalent quality as membrane systems
- For composite materials in bridging structures, understand repair-ability & long-term effects of the environment, multi-material joining of dissimilar materials
- Affordable composite material manufacturing techniques
- ATechnology to enable rapid load engagement for MHE

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- Highly energy-efficient, specialized lubricants and surfaces that enable service-free components (e.g., synergy between the lubricant and surfaces)
- → Pigment technology for solid film lubricants
- Accurate volumetric fluid measurement for collapsible fabric storage tanks
- ▲ Long-life, lightweight materials for collapsible fabric storage tanks
- New bio-inspired approaches to wastewater treatment to reduce system volume and energy requirements, and provide more robust operation
- Polymeric additive that is soluble in fuel to suppress mist fires and enable fire resistant fuel.
- Means to capture the mechanical energy imposed on modular bridging components and convert to electrical power to operate structural health equipment
- FQS Source sought for ruggedized particle counter calibrated to ISO-11171
- ▲MFBT Dissimilar Material Joining
 - Primary focus on joining of aluminum to composite, secondary focus on aluminum to steel
 - Formal solicitation pending; dependent Advanced Material Evaluation and subsequent material selection results

Ground Vehicle Robotics (GVR)

GVR Objectives:

- Manned-unmanned teaming for mounted and dismounted units
- Coordinated unmanned air and unmanned ground systems operations\
- Improved 360 degree vision
- Development of optionally-manned and unmanned vehicles
- Applied robotics for installation and base operations

Near Term Capabilities 2020	Mid Term Capabilities 2030	Far Term Capabilities 2040
Leader Follower Convoy Technology Employment	Improve the autonomy of unmanned systems	Enable manned and unmanned teaming in both air and ground maneuver through scalable sensors,

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Lighten the Soldier load	Enable unmanned Cargo delivery	scalable teaming, Soldier- robot communication, and shared understanding
Enhance stand-off from threats and improve situational awareness	Act as a "teammates" rather than tools	through advancements in machine learning.
	Micro autonomous air/ground systems will enhance Platoon, Squad, and Soldier SA	

1. Autonomous Ground Resupply

Purpose:

Develop and demonstrate an improved and optimized distribution system that integrates new and emerging technologies across the full spectrum of operational and tactical supply movement operations

Products:

- Convoy Operations:
 - Autonomy-enabling kits for tactical wheeled vehicles and material handling equipment
 - o Advanced vehicle behaviors for convoy operations
 - M&S-enabled analytical tools for predicting the performance of AGR in a variety of terrain and weather conditions
- Supply Point Operations:
- Complete electronic supply point configuration, storage, and movement control systems that utilizes emerging technologies to optimize receipt/ store/ issue processes for Class V items
- Tagging and tracking of all supplies in austere environments
- Enablers:
 - Common interfaces and architecture
 - Hardware-in-the-loop (HIL) simulator for evaluating cargo and vehicle configurations and implementations of autonomous ground resupply on realistic routes
 - Improved T&E procedures for robotic systems utilizing M&S tools

Payoff:

- Increased sustainment operations effectiveness and efficiency
- Optimized, streamlined Class V supply point operations
- Real-time inventory visibility (quantity and location)
- Efficient automated Class V resupply that enables on-demand access and accountability of Class V supplies

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Decreased development time from concept to prototype through

Existing Contracts:

- Lockheed Martin (\$2.1M—FY16) Integrated Systems Developer
- Oshkosh (\$1.4M—FY16) By-wire Kit Developer
- Robotic Research (\$1.4M—FY16) Autonomy Kit Developer
- DCS Corporation / SwRI (\$3.1 M—FY16) Warfighter Machine Interface & Autonomy Kit Behaviors
- NREC (\$700K—FY16) Autonomy Kit Behaviors

Opportunities and Gaps:

- A High Speed, Off- road Robotic Mobility
- A Common Interfaces and Architecture
- → Joint Developed Robotics Software Library (Apps)

Gaps That Industry Can Help Fill:

- A Robotic Behaviors (High Speed, Off Road, Driver Intent, etc.)
- ⚠ Robotic Operating System Military (ROS-M)
- Modeling and Simulation and Hardware in-the-Loop Validation
- A Common Interfaces and Architecture (Interoperability Profiles (IOP))
- → Joint Developed Robotics Software Library (Apps Based)
- Autonomous Testing Methodologies and Procedures
- ▲ Negative Obstacles (Open and Occluded)
- → Bodies of Water Detection and Fording Determination
- Environmentally Tolerant Hardware (Sensors, Switches, CPUs, etc.)
- Self-calibrating Sensors
- → High Vertical Resolution LIDAR
- Cyber and Physical Security
- ABalanced Communication Solutions (Bandwidth, Range, Resilient)

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2. Ground Degraded Visual Environment (gDVE)

Purpose:

To increase local situational awareness (LSA) in all conditions and environments, to include degraded visual environments (e.g. dust, smoke) for ground vehicle systems using scalable LSA sensing & immersive intelligence.

Products:

- Scalable low cost LSA sensors that effectively operate in degraded visual environments (e.g. dust, smoke).
- Sophisticated digital video architecture and sensor processing with in-vehicle displays to bring timely and useful information to indirect vision driver.
- Advanced vehicle crew stations with scalable Warfighter- Machine Interface (WMI), augmented reality and crew aids.
- Hostile Fire Localization (HFL) and collision avoidance through the use of affordable RADAR & electro-optic sensors.

Payoff:

- Operation in degraded visual environments to maintain OPTEMPO and decrease occupant injury.
- Leveraging aviation capabilities to provide a complete sensor to Soldier system that is scalable to the mission & vehicle family.
- Increased situational awareness to enable indirect vision driving maneuverability; driving aids to reduce accidents; & threat detection to improve survivability.

Existing Contract: - DCS Corporation \$2.4M

Opportunities and Areas of Investment/Interest:

Low latency digital video architecture

Human-machine interface

▲ Display human factors

▲Low cost EO/IR sensors

Methodologies and procedures for safely testing vehicles in degraded visual environments.

3. Applied Robotics for Installations & Base Operations (ARIBO)

Purpose: ARIBO is a strategic initiative to accelerate the adoption and use of intelligent ground vehicle systems for military and commercial applications. It uses a systems approach that links technology with real-world operational use cases for use experimentation in semi-controlled environments.

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Products:

- Collaborative network of government and commercial partners
- Standardized data collection tools and methodologies
- Optionally-manned systems consisting of base platform and modular, IoPcompliant architecture leveraging and feeding TARDEC Robotic Kernel and Autonomous Ground Resupply (AGR) projects

Payoff:

- Increased reliability of robotic technologies
- Increased socialization and living experimentation of robotic technology
- Standardized data for informed policy decisions and transportation system design
- Sustainable business model (re-invested operational savings)
- Inter-agency partnership, collaboration, and decision making
- Living laboratories for smart/intelligent systems development and shaping formal requirements
- Disruptive approach to innovation and technology transition addresses immediate needs and enables future program development and fielding

Office of Chief Scientist (OCS)

The Office of the Chief Scientist is responsible for overseeing the basic scientific research at TARDEC, and setting the direction and priority for future efforts. The Office helps to develop scientific personnel and to mentor existing and potential researchers to maintain a core competency of scientific expertise. The Office also coordinates TARDEC's R&D efforts with those of other government laboratories, academia and industrial partners to ensure a balanced ground vehicle research portfolio. The end goal is to have TARDEC be a technology leader in the years to come, with a steady stream of new science always being incubated and nurtured at the Center.

TARDEC OCS – Top 3 Initiatives:

- **1. Next-Generation NATO Reference Mobility Model (NRMM)** Leading technology efforts across NATO to predict mobility world-wide for military ground vehicles, focusing on:
 - Off-road mobility (vehicle, vehicle-terrain and terrain)
 - 6 thrust areas (GIS Terrain & Mobility Map, Simple Terramechanics; Complex Terramechanics, Intelligent Vehicles, Stochastics, Verification and Validation)
 - 48 members from 15 nations, several industry partners (BAE, LM, ESRI) and academic partners (MIT, Wisconsin, CO State, U. AL)

Search on: AVT-RTG-248 for .pdf booklet

2. Modeling &S Framework for Autonomy-Enabled Systems - Focusing on:

- Model-based Development of Mobility vs. Latency vs. Autonomy Relation
- Three different tech areas (Platform Mobility, Communications, Autonomy)

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- Sensor and Perception Algorithms
- Analysis and Mitigation of Delays/latencies
- Physics-based dynamics solvers with different levels of fidelity
- **3. Automotive Research Center (ARC);** Focusing on open-literature basic research:
 - Dynamics and Control of Vehicles
 - Human-Centered Modeling and Simulation
 - High-Performance Structures and Materials
 - Advanced and Hybrid Powertrains
 - Vehicle System Integration, Optimization and Robustness

In partnership with: *University of Michigan, Wayne State University, Oakland University, Clemson University, Virginia Tech, and the University of Iowa*

Areas of Advanced Research Need

1. Intelligent Vehicle Mobility - Development of Mobility, Latency & Autonomy inter-relationship Shared Control (Tele-operated →Fully auto), Man-machine teaming Human Cognitive Modeling, Extreme Mobility, Compute Power for High-Fidelity Solution, Cybersecurity Intelligent navigation, interaction w/others, World Model

Strategic Thrust Area Relationship with: Autonomy-Enabled Systems

2. End-To-End Mobility Solver - Physics-Based Approach to Off-road Mobility/Terra-mechanics, Multi-scale Vehicle/Soil Modeling, Next Gen NRMM, Deformable Vehicle Dynamics.

Strategic Thrust Area Relationship with: *Autonomy-Enabled Systems, Protected Mobility*

3. Systems-Level Underbody Blast – Develop Rapid (Fast running), Stable Algorithms for Blast Biofidelic Test /M&S dummies (Acceleration and Blunt injuries)

Strategic Thrust Area Relationship with: Autonomy-Enabled Systems, Protected Mobility

- 4. Light-weighting New/Smart Materials, Nanotech, Corrosion, Multi-material joining Light Weight Track, Armor, Low-Friction Tires, reconfigurable materials. Strategic Thrust Area Relationship with: Ground System Architecture, Protected Mobility, Power Density and Energy Efficiency, Advanced M&S and Systems Engineering Tools and Methodologies (Foundational Competencies)
- **5.** Physics-Based Data to Full Systems Trade Space Tools (ESP, MDO, RBDO, SWaP-C, Gaming/Battlefield Simulations/Crowdsourcing (ESP) Modularity Modeling: Benefits/Burdens, Big Data Mining.

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Strategic Thrust Area Relationship with: *Ground System Architecture, Power Density and Energy Efficiency, Advanced M&S and Systems Engineering Tools and Methodologies (Foundational Competencies)*

6. Next Generation Propulsion Systems - High Power Density, Multi-fuel Engines, Spray Combustion Efficient Cross-Drive Transmissions, Next Gen battery materials Low-heat Rejection Engines, Solid H2, CFD Simulations. **Strategic Thrust Area Relationship with:** *Power Density, Protected Mobility*

Existing Contracts:

- M&S Research ARC (Automotive Research Center) ~\$2.5M
- Academic Research Centers CVRC (MSU), SIMBRS (Miss State), FAJRI (Oakland)
 ~\$8.5M
- Contractor support (Technical Writers, Researchers) ~\$0.45M
- Innovation/Other Projects (Oakland, MIT, JPL, Georgia Tech, Univ of Illinois) ~\$0.45M
- FY15 SBIR/STTR contracts managed by TARDEC (\$25.6M)
- Rapid Innovation Fund (RIF) managed by TARDEC (FY14 \$3.1M, to TORC Robotics, Cascade Inc., FBS Inc., FY13 \$1.86M to Univ of Wisconsin-Madison)

Opportunities and Areas of Investment/Interest:

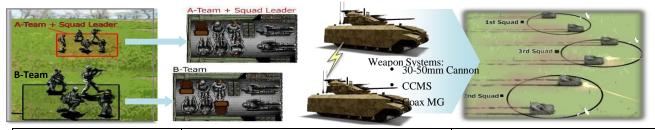
- Focused Advanced Technology Demonstration seed projects up to \$0.5M (FY16)
- Innovation Projects and other Seed projects (TARDEC associates partnered with Industry) up to \$0.5M (FY16)
- ▲SBIR/STTR Projects for Phase 1 and Phase 2, \$20-30M
- ▲ 17.1 SBIR Topics will be posted 9 Dec 2016 8 Jan 2017
- 4-6 internships (FY17 summer) of 9-12 weeks working in TARDEC labs with experienced mentors on all TARDEC technical research areas. *Announced Jan 2017*
- Access to past research products, and participate in setting new research direction as Industry Quad Principal in ARC partnerships http://arc.engin.umich.edu
 Features:
 - Ability to get critical fundamental research needs addressed by Army Research Laboratory (ARL) and Army Research Office (ARO) in their Research Formulation meetings
 - Industry Access to DoD High Performance Computing (HPC) resources for collaboration projects with TARDEC
 - Industry and TARDEC Joint proposal submissions, e.g. to: DARPA (GXV-T, Multi X Demonstrator, Griffin, Blast Demonstrators), DOE (e.g., NNMI hubs, US-China Clean Energy Research Center CERC), American Lightweight

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Materials Manufacturing Innovation Institute (ALMMII), ARPA-E, ONR, MANTECH

Emerging Capabilities Office (ECO)

Squad Centric Mounted Maneuver (SCMM) - SCMM presents an alternative developmental concept approach to current (Bradley) and recent Infantry Fighting Vehicle (IFV) design.



Dismounted Squad Conducts Fire & Maneuver by Fire Team Networked Fire Team Vehicles Comaintain Squad Integrity; Enabled through Enhanced Situational Awareness Fire Team Vehicles Preserve Squad Integrity within each Platoon Section; Sections able to Operate Collectively or Independently

- Two coherent Fire Team vehicles co-maintain squad integrity through networked Situational Awareness
- Future IFV capabilities (mobility, protection, lethality) in a smaller size vehicle (reduced under armor volume

SCMM Subsystems & Technology Overview: (Phase I Using Modified Bradley Surrogates)

- **•** Effective Distributed Operation (Enhanced Situational Awareness)
 - Squad Tablets & Virtual Ramp Window Display Situational Awareness Data TRL 6 (Jun 2015 Demo)
 - Virtual Sand Table ("Madden Draw") Supports Dynamic Mission Planning TRL 6 (Jun 2015 Demo)
 - Platoon Voice & Data Network
 - V2V Communications
 - V2S Communications (Nett Warrior) TRL 6 (Jun 2015 Demo)

Closed Hatch Driving

- Helmet Mounted Display (HMD)- Dynamic Head Tracking creates intuitive "transparent" armor
- Indirect Driver Vision
 - 120° Stereo Fwd Cameras (Depth Perception)
 - 2x Flank/Track Cameras (Close Quarters Movement)
 - Rear Camera
 - Map

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Closed Hatch Target Detection TRL 6 @ 2018 Demo

- Integrated UAS
- On-Demand Area Surv. & Route Recon
- Target Designation
- Radar: Ground Vehicle & Dismount Target Movement Indicator ≥ 5.5km
- 360° Local SA + Intuitive HMD Display
- Shared/ Networked Target Detection & MIL- STD-2525 Symbology
- Active Self-Noise Cancelling & Ambient Acoustic Sensing (not HFD)
 - Shouting, Gunshot, Other Tracked Vehicles, Horn, etc.

Reduced Crew Task Load

- Driving Automation Leveraging Ongoing AMAS Tech Developments
 - Drive by Wire
 - Driver Warning & Assist
 - Supervised Waypoint Following TRL 6 @ 2018 Demo

Phase 1 Objectives	Areas of Interest
Distributed Ops (Enhanced SA)	Real-time virtual collaboration toolsHigh bandwidth communicationEncryption
Closed Hatch Driving	 Other indirect sensors (e.g., proximity warning) Intuitive displays/HMDs Driver aids, assistance & autonomy
Closed Hatch Target Detection	 360deg Local Situational Awareness Sensors Infantry/vehicle Ground Movement Target Indicator Radar Integrated Unmanned Aerial Systems (UAS) Ambient Acoustic Sensing
Reduced Crew Task Load	 User interface technologies (yokes, joysticks, HMDs, etc.) Automated target detection, classification
Unmanned / Remote Turret	 Open Architecture Design Turret/Weapon Station Adaptable Controls Phase 1B: Med Caliber Turret Upgrade

Mobile Protected Firepower Prototype (MPF)

The Problem

Infantry Brigade Combat Teams (IBCTs) require a protected, long range, precision direct fire capability to defeat enemy prepared positions, bunkers and armor threats in order to ensure

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freedom of movement and action during offensive operations or defeat attacking enemy during defensive operations

Mobile Protected Firepower Prototype will provide IBCTs; Rapid action on the objective, Increased Mobility, Increased Lethality, Increased Force Protection and Increased Survivability. MPF may be delivered via Low Velocity Airdrop (LVAD) or Roll On/Roll Off (RORO).

Mobile Protected Firepower Prototype Plan

Based upon a consortium-led, Soldier-driven design/evaluation process, TARDEC will build and deliver two operational prototypes of the same design in FY19. (Downselect from four concepts)

TARDEC and the Army will gain the benefit of Soldier, Industry, and Designer input to obtain the most feasible, acceptable, and suitable design solutions and use them to inform requirements and enter the acquisition process at Milestone (MS) B.

Phase 0: Public/Private Partnership for MPF Concept Definition

MPF "Mobile" Soldier Innovation Workshops - Capability Development (SIW-CD)

- Soldier Driven Design Process to influence Requirements and design
- Combined Government/Industry Design teams travel to engage with IBCT units
- Focused User Feedback through SIW-CD process (Designers/Warfighters/Engineers)
- Individual soldier specified and derived MPF requirements
- Industry (both traditional and non-traditional) design teams take Soldier influenced MPF design to full system concept
- Prior to Industry efforts, current Gov't MPF M&S jumpstarts CDD refinement and informs senior leaders

Outcomes:

User/Industry/S&T specified and derived requirements informing baseline MPF system concept for S&T Prototyping effort

Virtual operational assessment of MPF system to inform physical experimentation for Force 2025 Maneuvers

MPF VIRTUAL RODEO - Soldier Innovation Workshop - Virtual Assessment (SIW-VA)

- Leverage virtual environment to evaluate enhanced government and industry provided system concepts through user gaming experiments and mass data analytics
- Soldier selectable MPF configurations used in realistic virtual experimentation environment to determine most effective configuration
- Most effective solution becomes baseline for phase 1 prototyping effort
- Virtual platform performance assessment

(survivability, mobility, fuel consumption etc...)

- Technology Readiness Assessment
- Projected Platform Cost (AUMC/APUC)

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Outcome: Sr. Leaders review results and provide approval to go to System Prototype (Phase 1)

Phase 1: Public/Private Partnership for MPF Prototype Development

Phase 1				
Year 1	Year 2		Year 3	
\$74M	\$86M		\$15M	
Prototype Design				
			Prototype Build	
Industry Engagement Test / Eval				

Features:

- Public/Private partnered MPF prototype development team
- Continuous industry access to TARDEC Open Design Studio to enable an open collaboration forum for industry participants throughout the prototyping process
- Utilize TARDEC Advanced Collaborative Environment (ACE) to provide online access to industry to all design, system engineering, and modeling documentation
- Continuous Soldier Feedback from virtual operational analysis to inform F2025 Maneuvers Campaign of Learning

Outcomes:

- Informed MPF requirements and performance capabilities
- Reduced Risk to follow on Program of Record
- Hardware for Soldiers to evaluate and update MPF Operational Concepts
- Repeatable Govt/Industry/User prototyping process for future system definition and acquisition
- Government owned prototype & Intellectual Property to enable Rapid Acquisition
- Establish a Common Industry Baseline for MPF with defined cost and performance vehicle requirements to open competition

Purpose:

- Delivers 2 prototype systems for User assessment and Technical evaluation
- All required documentation (or waivers non-statutory requirements)
- Risk Assessment
- Provides Technical Design (architectures)
- Refinement of CDD

Benefits:

- Delivers required artifacts to enter MS B
- Government Owned Prototype and Intellectual Property
- Reduces traditional Acquisition timeline by almost 50%
- Demonstrates Government capability to Prototype
- Builds/Strengthens Government/Industry cooperation and collaboration
- Increased exposure of non-traditional partners directly to the Govt.
- Allows utilization of the VRA OT

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MPF Communities of Interest / Best Practices

- Maintain ongoing and open dialogue across the community
- Avenue for FOUO artifacts to be shared with the forum and community
- Facilitate Industry recommendations for developing Programs
- Community understanding of how and where the Requirements are evolving for next Army Acquisitions
- Establish a Common Industry Baseline for future Programs of Record w/ defined cost & performance requirements
- Regular engagements (face to face, conference calls, artifacts)
- Conduct at For Official Use Only level
- COI facilitation team needs close, direct interaction w/ the Govt. team
- Need to engage Industry in the development of work products

MPF Current Program Status

High level Objectives	Areas of Interest
Transportability	LVADROROC-17
Mobility	Track, wheeled, bothPower Train
Lethality	Destroy target setSituational awarenessCDD Compliance
Force Protection	Crew survivabilityAutomated target detection/ neutralizationCDD compliance
Survivability	Vehicle protectionCDD compliance

Physical Simulation & Test (PS&T)

Value Stream 1

VS1 - Autonomy-Enabled Systems: Crewstation development and testing in support of workload reduction.

VS1 - Protected Mobility: Mobility and Survivability focused T&E support in both physical and simulated environments

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Value Stream 2

- **VS2** Technical Program Support: T&E matrix support and physical and simulated testing
- VS2 Sustainment Engineering: Reverse engineering testing support
- VS2 Tech Alignment & Transition: ECP T&E support in both physical and simulated environments

Value Stream 3

- VS3 Ground Vehicle Simulation and Test
- **VS3** Ground Systems Autonomy Capability Development and Integration:

Autonomous Systems Evaluation & Qualification Standards Development

- **VS3** Ground System Development, Fabrication, Integration and Engineering: T&E support in both physical and simulated environments
- **VS3** Ground Vehicle Advanced Concepts Development: T&E support in simulated environments
- **VS3 -** Ground Vehicle Performance Analysis and Assessment: Physical simulation data to support high fidelity models

PS&T Alignment to Digital & Physical Thread





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Physical Simulation Capabilities
Vehicle N - Post Testing, with Environmental Chamber
Turret Testing Systems
Heavy Vibration Testing (3DoF) / Light Vibration (6DoF), with Environmental Chamber
Component Testing
3D Laser Scanning Terrain Profiler
Tire / Runflat & Road Wheel Testing
System Characterization Capabilities
Vehicle Mass & Suspension Properties
Damper Properties (Shock / Strut / Suspension)
Man-in-the-Loop Simulation Capabilities
Crew Station / Ride Motion Simulator / Seat Assessment
Physiological Measures (EEG & Eye Track)
Impulse Response
Serious Mental Illness (SMI) Evaluation
Virtual Environment Capabilities
Sensor Modeling
World Modeling
Infrared / Nightvision
Vehicle Modeling

Test & Evaluation Support

Purpose:

Manage, develop, and support integrated life cycle Test and Evaluation (T&E) services. Provide strategy to innovatively test for performance and reliability of ground systems, and mitigate risks associated with the deployment of ground systems while ensuring timely focus on reliability and maintainability requirements.

- TRL Maturation
- Requirements Testability
- TEMP Development
- Subsystem Integration / Developmental / Operational Test Management
- Engineering Change Validation
- T&E Efficiencies

Crewstation Capability Lead

Purpose:

Develop the overall TARDEC Crewstation Capability that will address task automation, crew size reduction, and the interfaces associated with performing these functions. This is a Cross Functional Team (CFT) with representatives from ACT, VEA, GVR, TP, and PS&T.

Products:

- Crewmember task decomposition.
- Advanced crew station architecture.
- Experiments to assess crew effectiveness.
- Experiments to assess crew-squad interaction.

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Payoff:

- Proof of concept for various crew configurations.
- Mature crew station architecture.

Physical Simulation & Test - Updates for FY 17

Developed monthly e-newsletter, PS&T Connect, that highlights current and future lab activities as well as our capabilities

Working in conjunction with Squad Centric Mounted Maneuver (SCMM) program to develop 2-Man Crewstation concept with the ability to operate during closed hatch operations.

Developed "PST severity" tool which provides rapid data analysis for common types of pre-process data.

Identification of the Autonomous Systems Evaluation & Qualification Standards Development (ASE&QSD) Lead to coordinate, understand, develop and validate standards for the Test and Evaluation (T&E) of autonomous ground platforms.

Existing Contracts

- Simulation Support and Integration: DCS Corporation.
- Test & Evaluation Services: SURVICE Inc.
- Test Surge IDIQ: Link Engineering Co.
- Rolling Resistance Force and Moment Measurement: Camber Ridge
- Simulator Maintenance IDIQ: MTS Systems

Opportunities

- Ground Vehicle Systems Other Transactions Agreement (GVS OTA) Topic(s)
- A Current topic is "Modeling, Simulation and Stimulation Tools for Autonomy-enabled Systems" – FY16
- Additional topic(s) being considered for next cycle FY17
- ▲ New Simulation Support and Integration Contract FY17
- ⚠ New Test & Evaluation Services Contract FY17

Technology Gaps

**TARDEC Virtual Experiment Capability (TVEC) Support We may need expertise with respect to multiple M&S aspects including model and scenario development, experiment design and execution, software/hardware integration, and M&S tool development and integration.

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A Crewstation Capability Development (Focus is on SCMM)

We may need expertise with respect to task analysis/decomposition and human factors engineering.

A Test and Evaluation Engineering Support

We may need expertise with respect to multiple T&E aspects including requirements creation and validation, budget planning and execution, test program schedule.

TARDEC Software Engineering Center (SEC)

The TARDEC Software Engineering Center (SEC) is responsible for embedded software that resides on Army platforms. NOT responsible for enterprise network IT applications/software.

Vision

To be the first choice software lifecycle engineering and management expertise for ground systems and support equipment – today and tomorrow.

Mission

Provide full software lifecycle management; to engineer, develop and integrate precise software solutions; to improve Current Force effectiveness; and to provide superior software capabilities for the Future Force.

People	Process
Advanced Degree Engineers	Continuous Process Improvement
Professional Certified Engineers	CMMI Level 4 Certified
Acquisition Career Field Certifications	Organizational Set of Standard Processes

SEC Key Functions / Capabilities Software Development

- Software Assurance
- Software Acquisition Support to PM's
- Software Integration & Test
- Continuous Process Improvement
- Lifecycle Software Support

Current Projects

- MRAP Integrated Bridge(IB) SW
- Post Production Software Support (PPSS)
- Software Acquisition Support to PEO's/PM's

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TARDEC Software Engineering Center (SEC) - Updates for FY 17

Continued Growth in all areas of Software Engineering where SEC has the lead for software or providing significant support.

VS#1: MAPS, Robotics, SCMM VS#2

VS#2: MRAP IB, Abrams, Bradley,

Stryker, LTV

SEC Assessed at Capability Maturity Model Integrated (CMMI) Maturity Level (ML) 4 in October 2014. Currently working towards a CMMI (ML) 5 assessment in October 2017.

Moved our SEC Information Systems Security Engineering (Cyber) employees to a newly formed group in TARDEC Ground Systems Cyber Engineering

Continue to grow our SEC organization:

Brought onboard 17 new "software engineers" in CY2015.

Added 8 new "software engineers" so far in CY2016

Value Stream #1 Contractor Engineering Services will be obtained primarily through our existing engineering services support contract.

Value Stream #2 Contractor Engineering Services will be obtained primarily through our existing engineering services support contract. PM/Acquisition Software oversight sometimes cannot be filled by a contractor. ie: PM/Government oversight roles

Product Lifecycle Engineering

Value Stream 1

VS1 Develop Material and HVAC technology requirements for the Combat Vehicle Prototyping (CVP) program

Value Stream 2

VS2 PLE plays numerous roles in Technical Program Support, Sustainment Engineering, and Tech Alignment and Transition. Areas of specialization include: Industrial Base Engineering Support, Reverse Engineering, Environmental Engineering, Materials and Corrosion, Tires and Wheels, Vehicle HVAC, 28 Volt Charging Systems and Electrical Components.

Value Stream 3

VS3 Provide test and evaluation capabilities in the Ground Systems Power & Energy Laboratory Lab (GSPEL) and in the Metallurgy Lab to internal TARDEC programs, PM customers, and OEMs.

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Product Lifecycle Engineering Technology Areas

Materials & Corrosion

- Design to prevent corrosion and Corrosion Prevention Control Plans
- Evaluate, test, and develop solutions for corrosion/materials issues
- Corrosion prevention and control for the field fleet.
- Analyze material failures to determine root cause

Environmental

- Prepare environmental documents (NEPA and PESHE)
- Eliminate/reduce hazardous materials
- Execute environmental policy and regulations

Climate Control & Electrical

 Development, testing, and upgrades for climate control systems, electrical components, and charging systems

Tire Engineering

- Resolve field obsolescence issues
- Tire source approval
- Engineering support to DLA, TACOM

Industrial Base/ DMSMS

Provide LCMC with Industrial Base/ DMSMS Guidance and related engineering support

Reverse Engineering

Provide LCMC with Reverse Engineering Technical Support and Guidance

CAD & Model Based Engineering Team:

- Review, validate, develop best practices and approve 3D models
- Provide technical SOW contract language
- Convert Developmental technical data packages (TDP) to Production technical data packages
- Convert 2D raster drawings into 3D models

Configuration Management Team:

- Manage the data configuration of DOD ground combat and combat support systems through a discipline approach throughout the products full lifecycle
- Develop CM SOW contract language, CM policies and procedures

Standardization Team:

 Implement DoD Standardization Program policy and promote standardization of materiel, facilities, and engineering practices to improve military operational readiness, reduce total ownership costs, and reduce acquisition cycle time.

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Secondary Item Data Management Team:

- Provide technical procurement data support to TACOM LCMC and Defense Logistics Agency (DLA)
- Primary developer and manager of systems capabilities of the product data management process for TARDEC, Rock Island, Edgewood
- Chemical Biological Center and Natick

1. Electrically Adaptable HVAC System (EAHS)

Purpose:

Meet or exceed cabin cooling specifications (which are not currently being met) with an Environmental Control System (ECS) that is more efficient and potentially smaller than current systems and designed for use across platforms.

Product:

- 2.5 and 5-Ton Electrically driven Military Vehicle Air Conditioning (MVAC) prototypes capable of operating on multiple voltages with performance specification documentation for Bradley procurement. (TRL6)
- MVAC prototype system, operating on multiple voltages with performance specification documentation for Abrams (TRL6)
- Cabin cooling baseline data to validate vehicle models.

Payoff:

• Higher cooling capacity, 30% to 60% higher energy efficiency and improved reliability within the same space claim as existing systems.

Existing Contract

Electrically Adaptable HVAC System (EAHS): \$6.5M – Family of electrically driven variable HVAC systems for US Military vehicles. System could be built to provide cooling capacity for all current and future ground vehicles using a modular family of components.

Future Efforts:

■ EAHS Abrams environmental control system: \$2.8M Modification of existing contract to provide Abrams specific module. Due to unique power and space requirements with limited power and most cooling needed in turret a vehicle specific module will be developed.

2. Corrosion / Coatings & Adhesive Projects

- **Integrated Corrosion System** Focuses on optimizing the complete Army ground vehicle paint system for corrosion, durability and service life.
- Multi-Substrate Paint Adhesion Improvements- Optimizing military paint systems to adhere to a variety of substrates such as composite panels adhesively

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- bonded to a steel or aluminum structures. The focus is developing properties to be used in flexible paint systems and adhesion to diverse bonding materials.
- Consolidation of Adhesives and Sealants- Focuses on streamlining the Army's
 industrial adhesives and sealants to reduce logistical complexity and cost and
 reduce the impact on the environment associated with the use of these products,
 without impact to technical performance to include material
 compatibility/degradation.

Future Projects:

- Flame Spray Powder Primer- Focus is to evaluate the potential for flame- spray powder application to remanufactured depot materiel. Expand the ability to use powder technology for DOD assets beyond applications suitable for oven cure, because only 5 to 10 percent of applications are suitable for oven cure.
- Multi-materials Joining- Focus is to formulate and test joining solutions specific for multi-material subsystems. This will include using an array of new materialspecific corrosion prevention coatings.
- Water Condensing Coatings- Evaluate existing coatings to improve the
 efficiency of condensation. The technology can then be applied to the water from
 air system to reduce the energy required to produce water.
- Enhanced CARC Topcoat- Optimize CARC topcoat to maximize cleanability (resist soiling and associated moisture entrapment) and mold resistance while improving environmental and emissions compliance.
- Powder Coating Application Robustness- Optimize powder application parameters/performance: particle size, film thickness, voltage, gun and tip type and bake to enable faster adoption of powder technology.
- Reversible Adhesive System- Focus is thermoplastic adhesive reinforced with graphene nanoplatelets (GnP) and ferromagnetic nanoparticles (FMnP) will be used to evaluate the reversible bonding behavior for a combination of steel, aluminum, and glass-fiber reinforced composite substrates.
- Long-term Storage for Tires- Investigate coatings and tire rubber technologies to mitigate the observed effects of long-term storage.

Product Lifecycle Engineering - Updates for FY 17

FY15- Competitively awarded, Existing OSD Cooperative Agreement (CA) under the Commercial Technologies for Maintenance Activities (CTMA) Program, with National Center for Manufacturing Sciences (NCMS): \$1.75M

FY16- Competitively awarded, Existing OSD CA under CTMA Program with NCMS: \$6.0M

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Center for Systems Integration

Mission: To develop, fabricate and integrate advanced solutions into current and future ground systems

CSI Roles:

S&T funded projects and demonstrators; Prototype build/development

PM funded development and integration efforts

TARDEC's capability to develop and integrate emerging capability demonstrations.

Business Model:

Customer reimbursable organization: PEOs (Ground Combat Systems, Combat Service & Combat Service Support, Land Systems), REF, SOCOM, RDECOM.

CSI collaborates with RDECs for specialized capabilities, industry for surge capability and depots for production.

Contracts are primarily 4464 for materials and services

123 Government and 28 Contractor Personnel

Core Competencies:

Ground Systems Installation and Integration, Prototyping, Systems Engineering, Reverse Engineering, Drawings, Technical Manuals, Watercraft Systems Integration, Bridge Design

Key Capabilities:

- Project Management
- Creo/CAD 3D Modeling
- Finite Element Analysis (FEA)
- Mechanical & Electronic Eng. Design
- Technical Data Package Development
- 112,000 sq. ft. Facility

- 16 Integration Bays
- Robotic Welding
- Laser Cutting
- Water Jets with chamfering capability
- Multi-Axis CNC Turning/Milling
- Circuit Board Design & Mfg.
- Direct Metal Deposition Machine

Past / Recent Products and Innovations:

- Capability Set-13/14/15/16
- Collapsible RPG Defeat Kit
- Line of Communication Bridge
- Caiman EFP Kit Integration
- Robotic Deployment System
- HMMWV & MRAP Egress Trainers = ET-REMADE
- Overhead Wire Mitigation Kits
- Add-On Armor Kits

- Squad Centric Mounted Maneuver
- Fuel & Water Distribution &

Treatment Equipment

- Army Watercraft Upgrades
- ROBODEX
- LAV-R A2 Upgrade
- HUSK HET A1 Armor Cab

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TARDEC's Support of the Army Watercraft Mission

TARDEC will collaborate with the Program Manager, Transportation System teams to plan, develop, and integrate all Command, Control, Communications, Computers, Intelligence, Surveillance and Reconnaissance (C4ISR) for the existing fleet.

Next Steps:

- Transition knowledge from the Navy's SPAWAR Command
- Integrate input from other Army R&D organizations
- Establish C4ISR system commonalities
- Utilize contractor support where appropriate

Existing Contracts:

- Awarded "Blue Collar" Contract to Advanced Technology Systems, LLC for welders, machinists, material handler, heavy vehicle mechanics and electronics technicians on 26 November 2014. In option year 2.
- Awarded Technical Writer, Illustrator Contract to Addon Services, LLC on 24 September 2014. In option year 2.
- Awarded "White Collar" Contract to ASRC Federal Field Services, LLC for mechanical and electrical design engineers, drafter/CAD operators and project data management services on 14 August 2015.

Gaps and Opportunities

- Ground Vehicle Prototype Development:
 - Starting in FY17 and extending for several years
- A Hull and Turret materials and welding support
- A Harness design and fabrication
- Army Watercraft Systems:
 - Starting in FY17
 - C4ISR component purchases and installation support (OCONUS)
 - Sustainment maintenance on vessels

Analytics - Ground Vehicle Performance Analysis and Assessment

Description of Tech Area/Efforts

- CAEBAT: TARDEC and Advanced Vehicle Powertrain Technology Alliance (AVPTA)
- Collaboration with AVPTA
- Developing and leverage M&S tools to assess emerging electric drive vehicle Li-ion battery technologies for thermal, life, reliability, safety, and performance

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Four main pillars of efforts to advance DPT capabilities:

- 1. Tools and capabilities.
- 2. Tech data storage and management.
- 3. Processes.
- 4. Tool Integration.

Multi Material Joining: TARDEC and AVPTA partners

- Characterized different armor materials and weld filler materials for material properties
- Utilized material properties in modeling and simulation of ballistic impact
- Validated welded H-plate under high speed impact loading (ballistic impact) finite element models with physical ballistics impact test measurement

ISABEL (Integrated Software for the Analysis of Blast Effects Library)

- Blast Institute (Blast Protection for Platforms & Personnel Institute (BP3I) program)
- Collaboration with ARL and DoD HPC Modernization Office
- Development of software toolset ISABEL
- Predicts blast protection for platforms and personnel within an enterprise level toolset capable of exploiting HPC assets

CREATE-GV - Mobility performance predictions generated from HPC based M&S

- 3D high fidelity simulations
- Vehicle Dynamics
- Powertrain M&S
- Track/Tire Soil Interface M&S

Digital Physical Thread (DPT)

Utilizing the right tool at the right time through the complete product development cycle

Purposefully managing the data created

Enabling rapid development and evaluation of both future vehicle concepts and current fleet upgrades

Agile and Interconnected Micro-grid

- Teaming with Army Research Lab and Michigan Technological University
- Adapt ongoing micro-grid work to a four vehicle stationary grid systems developed by PTMS
- Perform energy analysis to understand the benefit of optimal grid control.

Analytics Physics Based CAE Capabilities

Vehicle Dynamics Performance Analysis

Mobility – Dynamics & Durability

•Ride & Shock quality

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•Lateral Stability

•Durability Assessment

•Structural Integrity Analysis

•Composite Material Analysis

•Soft Soil Performance

•Speed on Grade

•Step Climb

•Drawbar Pull

•Fuel Economy

•Range

•Cooling

Quantify on/off road mobility

Automotive Performance. - Power-Train

Dash Speed

Survivability - Energetic Effects & Crew Safety

- •Structural material/design analysis for improved energy management and survivability
- •Occupant protection and restraint system analysis in crash and blast

Thermal & Signature

Fire Suppression

- •Under hood cooling & Airflow
- •HVAC
- Acoustics / Signature

Computational Methods & Sys Behavior

Multi-Disciplinary design Optimization

System Behavior M&S

Data Mining

Analysis Capabilities development

Existing Contracts:

- GPU Vehicle/Soil Interaction M&S Physics-Based Modeling/Simulation/Visualization on an Advanced Computing Infrastructure for Ground Vehicle Mobility Assessment (U of Wisc.)
- ANCF FEA MBD M&S Integration of computational geometry, finite element, and multibody system algorithms for the development of new computational methodology for high-fidelity vehicle systems modeling and simulation – Non linear flexible bodies in MBD (Computational Dynamics Inc. SBIR)
- Intelligent Terrain-Aware Navigation and Mobility of Unmanned Ground Vehicles Operating Under Varying Degrees of Autonomy (Robotic Research LLC. STTR)
 - Advanced terramechanics modeling
 - Compensate for communication delays
 - Incorporates driver aids
 - Develops path planning and obstacle avoidance schemes for high speed mobility
- SBIR, developing prototype thermal properties measurement device to address thermal characterization of existing/mounted systems. (Thermo Analytics Incorporated)
- SBIR, Tactical Behavior Mining of a Soldier-Based Gaming Environment. Developing capability to visualize multiple replays and apply big-data techniques to discover individual and group tactics employed in TVEC. (SoarTech and Decisive Analytics)
- SBIR, Mountain Braking Brake Fade Advanced Warning System & Mountain Descent Test Procedure. SBIR contracts with Nevada Automotive Test Center (NATC), and Link Engineering Co. to develop road and laboratory tests to safely quantify brake temperatures for severe mountain environments.
- Other Ongoing contracts SoarTech, ASA Corp., Computational Dynamics Inc. SimBRS, ALION, ALTAIR, ESI, LSTC, ETA, TASS, Humanetics, Beta CAE, CD-Adapco, Gamma Tech., MSC, Dassault Systems, RecurDyn, LMS, PHM, MathWorks, PTC, Mechanical Simulation Corp., nCode, ANSYS, TAI, Datapoint Lab

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Analytics - Ground Vehicle Performance Analysis and Assessment - Updates for

Virtual Proving Ground for robotic/autonomy platforms M&S, Ongoing with PS&T

Computational System Behavior, ERS tradespace, and CREATE-GV ongoing

Operational Assessment/Effectiveness M&S, JOEI efforts ongoing

Reduce logistic burden (fuel and water usage) M&S. JOEI efforts ongoing

Light-weighting and multi-disciplinary optimization M&S,

o In-house developments ongoing using existing software suites.

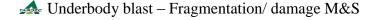
Trade-space, META or Reduced Order tool development/enhancement M&S

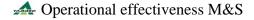
o DARPA Adaptive Vehicle Make (AVM) Blast tool being employed in-house.

Technology Gaps:



Off-road mobility – Soils M&S





Robotic Vehicle M&S (Tele-Ops - Shared-control – Full autonomy, & Safety Certification)

Cyber Engineering

Mission

Lead ground systems and Army watercraft cybersecurity efforts for TARDEC and its partners throughout the development and acquisition lifecycles by engineering security solutions, managing assessment and authorization activities, and conducting penetration testing. [Manage risk and make sound investment decisions]

Tech Area/Efforts

- Cybersecurity Engineering Objectives:
 - Manage cybersecurity risk and as an integral part of ground system and Army watercraft portfolio
 - Ensure assessment & authorization (A&A) of all tactical information systems
 - Deliver trustworthy cybersecurity solutions that satisfy program requirements within the established risk tolerance while enabling mission and user needs
 - Deliver any cybersecurity solution, regardless of its scope, size, complexity, or the stage of the acquisition or development lifecycle in which the solution is being sought
 - Advance the field of ground systems cybersecurity engineering

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- Penetration Testing Objectives:
 - Model the activities of real-world attackers
 - Validate suspected vulnerabilities in targeted systems
 - Demonstrate exploits under controlled circumstances
- Science & Technology Objectives:
 - Platform Cyber Resiliency
 - Platform Trusted Systems

Ground Systems Cyber Engineering - Updates for FY 17

Cyber Gaps from 2015 Industry Day

- "Real Cyber not IA or IT."
- "Missing Cyber Defense and Security. And perhaps cyber offensive?"
- "Cyber vulnerabilities to various systems."

TARDEC restructured to meet Cyber Engineering requirements

- December 2015 Established TARDEC's Ground Systems Cyber Engineering (GSCE)
- Staffing Ten personnel on board, eleven personnel in the process
- Warfighting Mission Area Ground systems and Army watercraft
- March 2016 Designated Joint Cyber & Vehicle Electronic Architecture (VEA) Laboratory
- April 2016 FEDITC Task Order to provide Strategic Cyber Planning Support

- END -