Section 5.2 Focus Area

SURVIVABILITY AND MOBILITY

"We must provide adequate protection for our tactical mobility systems. Our goal is to provide a mix of survivable tactical vehicles that are compatible with expeditionary and amphibious deployment means."
Marine Corps Vision and Strategy 2025

Survivability

United States Marines, as soldiers of the sea, normally operate and deploy from a shipborne environment, which significantly increases the complexity of combat operations. In order to support ground operations that are launched from the sea and accomplish the mission, the Marine Corps' tactical vehicle fleet must be easily transportable with survivability as a critical design characteristic. Maintaining legacy vehicles will be a challenge in an environment where affordability is as important as capability. The fact is, the Marine Corps will be maintaining its current fleet for many years to come and will be required to find innovative ways to modernize the fleet and increase vehicle and occupant survivability.

Mobility

The mission of the Marine Corps includes fighting oppressive regimes, evacuating refugees, and providing humanitarian aid to both natural and manmade disasters, anywhere in the world. Responding swiftly, with little warning, requires a fully orchestrated, agile, fast, and highly mobile fighting force. Untethered from roads, Marine Corps mobility entails operating with speed and swiftness from ocean beaches, desert sands, jungle swampland, or urban rubble.

The Challenge

The Survivability and Mobility focus area consists of technologies that enhance mobility and increase the survivability of both the Marine and the vehicle. Survivability and mobility are addressed as a combined S&T focus area because often what affects one of these elements directly affects the other. Providing increased protection to the warfighter while maintaining or increasing mobility requires rigorous engineering that incorporates the latest technology applied in a "systems engineering approach." Within this focus area, certain topic areas that warrant specific attention will fall under the domain of either survivability or mobility as sub-topics.

5.2.1 Survivability consists of:

- 5.2.1.1 Fuel Containment/Fire Suppression
- 5.2.1.2 Safety

5.2.2 Mobility consists of:

- 5.2.2.1 Crew Visibility
- 5.2.2.2 Corrosion
- 5.2.2.3 Autonomy
- 5.2.2.4 Weight Reduction

5.2.1 Survivability

PEO LS is working to enhance warfighter and vehicle survivability by collaborating with MCSC, MCWL, DC, CD&I, ONR, RDECOM, TARDEC, and other agencies. The objective is to develop affordable, state-of-the-art survivability technologies such as lightweight armor, blast absorbing seating, and Rocket Propelled Grenade (RPG) countermeasures.

The Challenge

The design, development, and production of survivable vehicles that adequately protect our warfighters is a highly complex system of systems engineering problem. Additionally, the vehicle must provide the required mobility in order for the Marine Corps to successfully conduct expeditionary/amphibious operations.

Potential Solutions

ONR Efforts

Advanced Camouflage Detection Avoidance
Minimizing the ability of our adversaries to detect our systems overall will improve platform and Marine survivability. Technologies are needed to provide advanced camouflage design that can be easily integrated onto ground platforms.

Energy Absorbing Structures for Blast Mitigation
This project, which includes development and testing of energy absorbing structures (e.g., crush tubes, cellular structures, and hydraulic/pneumatic absorbers) mounted between the blast hull and the crew compartment of a tactical vehicle (5- to 15-ton), is intended to mitigate crew injuries (<10% AIS Level 2) during an underbody mine/IED attack.

High Strength-High Ductility Nano Composites
The hypothesis of this project is that having nano-scale reinforcements, in combination with a dispersion strengthened ceramic (B4C, SiC) matrix in a coarse grained region, will produce a multi-scale nano-composite aluminum that has tailorable plasticity with high strength and high ductility.

Multi-Degree Of Freedom (MDOF) Rollover-Impact-Blast Effects Simulator
The goal of this ONR/Army Research Laboratory (ARL) project is to design and build a MDOF motion simulator to test local and global vertical acceleration and rotation by simulating off-center of gravity underbody blasts and rollover effects. This simulator will enable ONR and ARL to develop and validate crew protection concepts under representative loading conditions.

Additional ONR S&T projects that are of interest to PEO LS include:

- Antitank Guided Missile (ATGM)/ RPG Neutralization
- Carbon Nanotube Processing and Fiber Alignment
- Expeditionary Light Armor Seedling Development (see write-up in section 5.2.2.4)
- High Strength-High Ductility Nano-Composites Lightweight Armor Materials (see write-up in section 5.2.2.4)
- Outyear Active Protection Technology
- Outyear Blast Mitigation
- Outyear Crew Protection Technology
- Outyear Detection Avoidance
- Outyear Lightweight Armor
- Multi-Modal Pre-Shot Sniper Detection
- Phase Change Shock Absorption behind Armor Materials

RDECOM & TARDEC Efforts

U.S. Army, Occupant Centric Platform (OCP)
The Occupant Centric Platform project is intended

An MRAP undergoes testing at Aberdeen Test Center, Maryland.

to design vehicles around the occupant. It seeks to identify, develop, and integrate technologies that will protect occupants of ground vehicle systems from underbody threats, crashes, and rollovers while maintaining or improving the mobility of the vehicle system and reducing the weight required to provide that protection. OCP seeks to accomplish these goals by addressing:

- Gaps in occupant protection standards;
- Tools and techniques to research blasts;
- Crash and rollover mitigation capabilities;
- Ground vehicle interior technologies for protection of occupants; and
- Ground vehicle exterior technologies to mitigate the effects of underbody blast events.

Addressing these elements successfully will enable the OCP project to provide affordable and manufacturable survivability solutions for ground vehicle platforms to protect soldiers against known and anticipated threats. The project's overall purpose is to develop and document a design approach that will lead to the design and demonstration of an occupant-centric ground vehicle with improved vehicle survivability and force protection, and that will prevent or decrease injuries to soldiers and Marines due to underbody IED and mine blast events and the resulting crashes and rollovers.

The OCP Technology Enabled Capability Demonstration (TECD) is in the process of developing an occupant-centric approach that first addresses the safety of operators and crews in the design or reengineering of ground vehicles, an

initiative that 12 years of conflict in Southwest Asia have proven to be essential. The project's near-term objectives (FY17) are to establish baselines; develop occupant protection standards; mature interior and exterior occupant protection technologies; increase lab testing capability; and improve confidence in M&S predictions. A longer term goal is to reduce overall platform weight by 25% and reduce casualties and Wounded In Action (WIA) by 50% across each mission role with scalable protection levels that will defeat a wide range of threats, enhance mobility, and maintain freedom of action during full spectrum operations.

System Integration Laboratory (SIL)
The Integrated Survivability System Integration Laboratory (ISSIL) developed at TARDEC is a tool that enables and enhances the integration of soldier survivability technology suites. TARDEC utilizes the ISSIL to bridge the gap between concept and capability of survivability initiatives. The ISSIL is a critical tool for enabling the integration of mechanical, electrical, data, and networking components as well as for validating the system integration through soldier/Marine usability trials.

Architecture, Maturation, Evaluation of Defense Aid Suites (ARMED), Advance Combat Vehicle Armor Development (ACVAD)
Part of the TARDEC ARMED program, ACVAD will develop next generation armor materials and threat-specific armor recipes that will demonstrate ballistic performance after being packaged and mounted on a vehicle or representative structure and being exposed to relevant environments.

ARMED, Integrated Defensive Aid Suites (IDAS)
Part of the TARDEC ARMED program, IDAS will provide a Common Architecture (CA) for hit avoidance systems (hard-kill and soft-kill) for use in future DoD anti-RPG and ATGM initiatives. These systems will include defeat capabilities that increase the survivability of Army/Marine Corps ground tactical and combat vehicles.

Military Engineering Technology
This program element (PE) investigates, evaluates, and advances technologies, techniques and tools that can be used to:

- Conduct mobility, counter-mobility, survivability and force protection experiments.
- Research focuses on special requirements for battlefield visualization, tactical decision aids, weather intelligence products, and capabilities to exploit space assets.
- Depict and represent physical and human environments for use in military operations.
- Characterize geospatial, atmospheric and weather conditions and impacts on systems and military missions.
- Enable secure, sustainable, energy efficient facilities.

Multimaterial Joining
This kinetic energy armor integration project explores advanced joining processes, weld wires, and procedures for joining dissimilar aluminums, composites, and for developing novel simulation models for welding aluminum and Automatic Heat Stress Systems (AHSS). The development of new MIL-STDs for joining of dissimilar aluminums and for AHSSs for hybrid and friction stir welding processes will result in lighter weight vehicles, increased fuel economy, increased reliability, greater payloads, greater survivability and lower costs.

Tactical Vehicle Armor Development
As part of the TARDEC ARMED program, the goal of Tactical Vehicle Armor Development is to develop lightweight opaque armors for the defeat of direct fire and IED threats; to support ManTech efforts to reduce the cost of materials and fabrication for advanced armor systems; to fabricate prototype and subsystem level armor packages; and to provide subject matter expert support to PM offices.

Warfighter Injury Assessment Manikin (WIAMan)
The goal of WIAMan is to develop an improved blast test manikin incorporating medical research that provides an increased capability to measure and predict skeletal injuries of ground vehicle occupants during underbody blast events.

SBIR Efforts

Post IED Hull Inspection Tool
The Post IED Hull Inspection Tool(s) will be designed to help maintainers assess structural damage and make more informed decisions regarding the health of the hull after a blast event.

5.2.1.1 Fuel Containment/Fire Suppression

Although the DoD has historically addressed the fire threat to Tactical Ground Vehicles (TGV) with minimal or no fire suppression/extinguishing equipment, the campaigns in Afghanistan and Iraq have highlighted the importance of fuel containment and fire suppression. TGV fires pose a significant threat to our Marines, vehicle platforms, and critical cargo.

The Challenge

Given space/weight limitations as well as cost constraints and the levels of survivability required, providing suitable fuel containment, fire detection, and extinguishing capabilities presents a serious challenge to vehicle programs. Potential solutions include the use of a "Clean Agent" that safely and effectively suppresses fire, prevents explosion, and provides for rapid evacuation of the crew. PEO LS is specifically exploring an aqueous-based Automatic Fire Extinguishing System (AFES), which will include research into identifying the crew casualty injury criteria required for design and development of an aqueous-based AFES. After crew casualty injury criteria are identified, development and testing of a prototype aqueous-based system is planned.

Potential Solutions

PEO LS Efforts

Lightweight HybridSil Nanocomposites for Ballistic, Blast and Flame Protection to MTVR Fuel Tanks and Engine Components
The goal of this Phase II Small Business Technology Transfer is to develop protective coatings for fuel tanks that are durable and easily applied.

Modular Lightweight External Fuel Tank System (SBIR)
The objective is to design and develop a lightweight, modular fuel tank that can withstand hydrodynamic ramming forces and provide protection against the ballistic impact of 14.5 mm armor-piercing projectile using a multi-layer laminate design, with significant reduction in weight compared to existing systems.

ONR Efforts

Fuel Tank Protection System for Tactical Wheeled Vehicles (SwampWorks)
The PEO LS S&T Directorate has teamed with the MCSC SIAT Directorate, ONR SwampWorks, NSWC Philadelphia Division, and ARL to address Fuel Tank Protection Systems for Tactical Vehicles. This effort seeks to develop a new class of integrated fuel tank protection for combat vehicles, which will encompass a coating technology that: 1) self-seals upon small arms ballistic impacts; 2) self-protects against pool-fire threats; and 3) provides fire suppression for IED and Explosively Formed Penetrator (EFP) events. This effort will also develop a Joint military specification and qualify potential permanently self-sealing coatings for Tactical Ground Vehicles that will be applied to current and future vehicle fuel tanks. Integration of fire suppression and self-sealing technologies into a singular design will reduce overall costs, streamline procurement efforts, and result in a significantly improved fuel tank with enhanced protection to the benefit of our warfighters.

The photos above reveal before and after results of pool fire testings at Aberdeen Test Center.
Left: Prepared Test Vessel; Middle: Tank in pool fire during testing; Right: Fuel tank with full volume of fuel post fire

RDECOM & TARDEC Efforts

Advanced Fire Protection Research and Development

This project, which will provide fire protection solutions for the combat vehicle modernization and retrofit programs, entails basic research as well as development of system specifications for survivable fuel tanks and materials that will increase soldier and system survivability while providing vehicle design flexibility.

Common Automatic Fire Extinguishing System

The goal of this project is to develop a reliable, maintainable, and safe common tactical vehicle AFES that will reduce the probability of crew incapacitation and vehicle kills from fire threats and reduce logistics and maintenance costs.

Fire Protection System Integration Laboratory

This laboratory will provide in-house integration and evaluation of fire protection system technologies, including an M&S capability that will allow prediction of fire extinguishing system performance and comparison of multiple configurations. Other lab capabilities include:

- Analysis of agent distribution within test vehicles.
- Test fire performance of different vehicle configurations in a reconfigurable box.
- Simulation of ballistic threats with variable fuel spray test setup.
- Analysis of occupant safety for noise, impact force, and toxicity levels.
- Conduct of fire performance simulations.
- Reduction in integration and test costs.
- Enhanced ability to transfer fire protection technologies to vehicle PMs.

SBIR Efforts

Aqueous-Based AFES

This SBIR effort will research and identify crew casualty/injury criteria for aqueous-based systems and identify the process required to develop, verify, and gain final approval of criteria. The project will research and identify concepts for an aqueous-based AFES and identify potential chemical compositions, environmental and health risks, injury protection capabilities, and delivery systems. The project will also research and identify requirements for test instrumentation and techniques applicable to measuring crew casualty/injury levels for aqueous-based systems.

5.2.1.2 Safety

Operational objectives for safety are in accordance with an organization's mission, vision, goals, and capabilities. Risk is inherent to the activities of the Marine Corps, but it must be managed by controlling and mitigating its effects regardless of operational complexity. Operationally, safety should be at the forefront of the planning process,

and programmatically it should be a part of the acquisition process.

> *"Safety is central to the idea of readiness and must not be an afterthought of our actions in combat, in training and while on liberty."*
> **Commandant's Safety Policy,**
> **General James F. Amos, Commandant**
> **USMC 28 March 2011**

The Challenge

Safety is required to preserve personnel and equipment but safety considerations cannot contradict the mission of the Marines Corps' command and operational objectives. Safety considerations include vehicle stability; safety equipment, including restraint harnesses; fire suppression; clear fields of view; training; policy; procedures; and lines of communication with warfighters.

Potential Solutions

ONR Efforts

Flawless Glass Armor

The performance of glass-based transparent laminates may be improved by increasing the glass strength using materials processing routes that will reduce the population of surface flaws. The objective of this ONR/ARL venture is to develop transparent armor technologies that meet required multi-hit performance requirements at reduced areal densities (20-30%). Because this effort has focused on materials development, characterization has been limited to quasi-static testing and single shot performance. This project will transition the materials development to industry and develop multi-hit armors that meet ground vehicle ballistic requirements at the reduced areal density objectives.

M 777 Howitzer crew conducts a fire mission

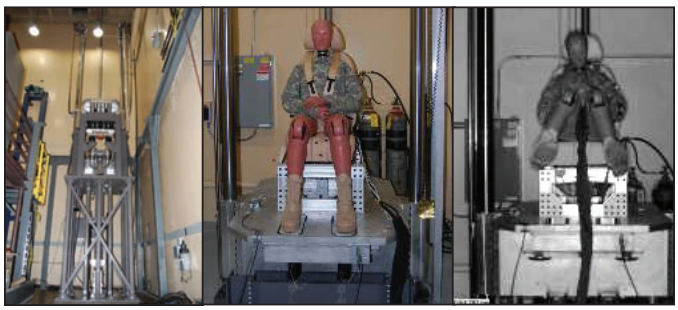
Integrated Mobility Dynamics Controls
This project is intended to provide the HMMWV dynamic stability improvements of 30% in yaw and 20% in roll, for a vehicle with increased ground clearance, at speeds exceeding 25 mph on cross country terrain. These improvements will be achieved by controlling the sprung mass motion about the roll, pitch, and yaw axes through a supervisory controller.

RDECOM & TARDEC Efforts

Active Safety Applique
This Occupant Centric Platform project seeks to develop an active system that involves the steering, braking, transmission, and engine functions of the vehicle. The goal is to reduce soldier injuries and deaths due to combat vehicle crashes and poor situational awareness. This project will reduce the physical and mental burdens on soldiers and Marines and enable vehicle operators to focus on other mission tasks, including threat detection.

SBIR Efforts

Active Laser Protection System
This goal of this SBIR effort is to develop innovative technology approaches to protect the eyes of vehicle crew members from frequency-agile lasers. Battlefield lasers are moving from fixed frequency lasers to frequency-agile lasers that have enough power to blind vehicle crew members, which will prevent them from visually evaluating the battlespace as well as prevent the driver from operating the vehicle.



The ONR Crew Seating Blast Effects Simulator (CSBES) is used to simulate vehicle blast effect accelerations to validate crew-seat protection concept models and devices.

Modular Anthropomorphic Test Device (ATD)
The Modular Anthropomorphic Test Device project is researching the important components of the ATD: the frangible bones, the tibia instrumentation, and the soft tissue surrogate. Project participants are modeling the two types of bones separately using an anatomically correct canal that can be filled with fluid and that can indicate breakage.

5.2.2 Mobility

The Challenge

Expeditionary Maneuver Warfare, the concept that guides how the Marine Corps organizes, deploys, and employs its forces, emphasizes strategic agility and tactical flexibility with the capability to project power against critical points. Mobility is central in providing that agility and flexibility.

Finding the affordable balance between payload, protection, and performance (mobility) is the challenge.

Potential Solutions

ONR Efforts

Advanced Propulsion with Onboard Vehicle Power
This project will develop, characterize, and test the enabling technologies to increase OBVP from 10-20 kW on current systems to 100-160 kW.

"Mobility advancements are a multi-dimensional issue; first is the ability to move within the environment utilizing organic advancements; second is the ability to find advantage over the enemy though speed."
Marine Corps Operating Concepts (MOC) Third Edition June 2012

Advanced Transmission Technology

This project will develop and demonstrate a 32-speed binary logic transmission with increased transmission efficiency (greater than 90%) and reduced power loss (35% down to 10%) for 20- to 40-ton tracked military vehicles.

Failure Analysis Study (AAV Dynamic Component)

This ONR project will evaluate the dynamic components of the AAV in order to improve component reliability and overall vehicle reliability, availability, and maintainability.

Integrated Mobility Dynamics Controls (IMDC)

The goal of the IMDC program is to develop stability improvements (of 30% in yaw and 20% in roll)for a vehicle with increased ground clearance, at speeds exceeding 25 mph on cross country terrain. These improvements will be achieved by controlling the sprung mass motion about the roll, pitch, and yaw axes through a supervisory controller having full coordination authority over the responses of a semi-active suspension system, through a variable slip differential and through a brake-based stability system.

VAM (formerly Modular Vehicle Platform)

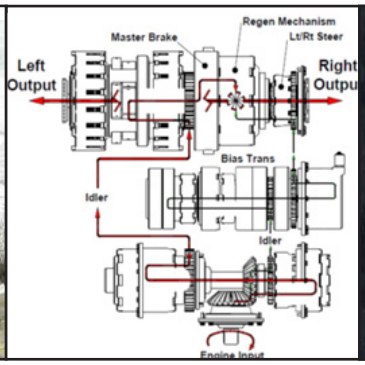
The goal of this project is to demonstrate mobile modular combat capabilities (e.g., weapons, command and control, trauma bay) that are housed in modular containers. The enhanced combat capabilities of VAM will provide Commanders tactical flexibility and adaptability on the battlefield.

Marines load the ITV into the MV-22 Osprey.

"Marines will maneuver from the seabase in a family of high-speed connectors that includes amphibious vehicles, tilt-rotor and rotary bladed aircraft, and high-speed surface craft. Once ashore, Marines will have freedom of maneuver either dismounted or utilizing a family of highly mobile and survivable combat vehicles."

2012 U.S. Marine Corps Strategic Plan

MTVR boarding an amphibious vessel.



The Advanced Transmission Technology is intended to bring new life into the AAV.

Strategic enhancements will include a reduced MAGTF footprint and total ownership cost savings that will result from increased parts commonality, decreased manning/training requirements, and more flexible and efficient power management. Capability enhancements that result from this project will have applications across several tactical platforms.

RDECOM & TARDEC Efforts

Advanced Running Gear Research

The Advanced Running Gear Research is focused on mobility technologies and control strategies that will advance the state of the art in military vehicle mobility, safety, and survivability. This project is aimed at increasing mobility by developing a Performance Lightweight Track System and an advanced suspension. Specific projects include work to resolve MRAP rollover issues and the involvement of vehicle suspension with vehicle underbody blasts, and to develop less weight sensitive suspension technologies by developing a more fuel efficient track system.

CBM Technologies

The goal of this project is to develop, integrate and demonstrate condition-based maintenance algorithms, data acquisition storage, and transfer capabilities.

Continuous High Output Engine Research

The goal of this project is to continue R&D activity on high speed engines and implement design change improvements identified during exploratory development phases to increase specific output. The best engine candidates will be identified for more advanced development of next generation diesel engines.

Elastomer Improvement Program

The purpose of this project is to develop improved thermoset components that improve track system durability and reliability and reduce life cycle costs. The goal is to improve track system life by 50%.

Modular Vehicle Demonstrator (MVD)

The MVD will determine the feasibility of developing a reconfigurable vehicle platform. This project will focus on rapid reconfiguration of a ground vehicle platform (MRAP MaxxPro Base), with the goals of retaining vehicle survivability, minimizing platform cost, minimizing platform weight, reducing fleet life cycle cost, and enabling optional manning of the vehicle. The reconfigurable platform will be able to handle a wide range of mission-specific roles by interchanging "podded" sections, which will decrease the need for multiple platforms.

Next Generation Combat Engine Research

The purpose of this project is to conduct R&D on a novel engine design to meet the mobility needs of combat vehicles. This engine will provide an order of magnitude in energy efficiency to improve existing military ground vehicles while increasing power density, improving vehicle mobility, and reducing fuel consumption and thermal loads. Leap-ahead technology in the engine will buy back vehicle mobility and performance lost due to increasing weights and onboard power demands. The anticipated power output is 200-300 horsepower.

Additional RDECOM & TARDEC S&T projects that are of interest to PEO LS include:

- Advanced Lubricants
- Advanced Suspension Development (Ride and Handling)
- Advanced Transmission Technology
- Advanced Vehicle Control Methods
- Alternative Fuels and Petroleum, Oils and Lubricants
- Automated Armor Manufacturing (part of TARDEC ARMED)
- Distributed Soldier Load Through SMART Vehicle Control
- High Performance Track Development

- Hybrid Vehicle Testing and Reliability
- Next Generation Combat Engine Multi Cylinder Engine Development
- Next Generation Combat Engine Prototype Engine Development

SBIR Efforts

On-Board Weight and Center of Gravity Measurement System for Tactical Vehicles
The objective of this SBIR effort is to develop an innovative, cost-effective, and reliable onboard weight and center of gravity measurement system for tactical vehicles.

Variable Vehicle Cone Index (VCI)
The objective of this project is to develop a system that will enable on-the-move monitoring of road conditions and that will automatically adjust to optimal tire pressure. Running at optimal tire pressure will improve tire life, improve fuel efficiency, and increase mobility on varying terrains.

5.2.2.1 Crew Visibility

A tactical vehicle crew member requires clear vision for achieving situational awareness and a better cognitive understanding of the impending battle space. Enhancing the visibility of the battlespace from the tactical vehicle will increase the crew's situational awareness and will facilitate effective decision making.

The Challenge

The requirements for survivability sometimes hinder the crew's ability to view the battlespace. The cost, weight, and limits associated with manufacturing transparent armor mean that today's armored tactical vehicles are burdened with limited visibility of the battlespace. Increasing this visibility for Marine Corps vehicles without imposing a heavy penalty on Size, Weight, Power and Cost (SWaP C) presents a significant technology challenge.

Potential Solutions

RDECOM & TARDEC Efforts

Advanced Directed Energy for Protection for Camera and Eyes
This Occupant Centric Platform project is an ARL/TARDEC initiative that includes:

- **Vision Protection from Lasers**. The eyes of crew members and optical viewing systems are both vulnerable to damage from frequency-agile laser weapons and to detection via retro-reflection. The purpose of this project is to enable future combat vehicles to avoid detection and to protect and maintain crew member vision during exposure to anti-sensor laser weapons.
- **Vision Protection Design Integration to GCV or Stryker**. This project, part of OCP, will transfer laser protection techniques developed for the Abrams M1A2 fire control to the GCV, Stryker, and future vehicles.

Transparent Armor
The purpose of this project is to research and develop technologies and processes to improve the performance and environmental stability of transparent armor laminates and to develop products and test procedures to improve rock-strike and delamination resistance. The project will also further refine Automotive Tank Purchase Description 2352 to improve the overall quality of transparent armor purchased using this specification without additional cost to the Government.

SBIR Effort

Active Laser Protection System
The goal of this Phase II SBIR effort is to develop innovative technology approaches to protect the eyes of vehicle crew members from frequency-agile

lasers.

5.2.2.2 Corrosion

Corrosion is the deterioration of a metal due to a reaction of the metal with its environment. The Marine Corps operates in a highly corrosive saltwater environment, with high humidity, sand, coral, and mud and road debris accelerating the process of corrosion.

The Challenge

With tightening national defense budgets and the resulting reduction in new equipment procurements, the Marine Corps' $460 million annual cost associated with corrosion is untenable. Enhanced anti-corrosion technologies will extend service life, reduce required maintenance and prolong the operational viability of legacy systems. The Marine Corps will thus be required to make do with much of its current gear and its existing vehicle fleet. Service Life Extension Programs (SLEP) and enhanced maintenance and anti-corrosion technologies will be required to extend the life of the Marine Corps' equipment, keeping them operationally viable and ready.

Potential Solutions

ONR Efforts

Polyfibroblast Self-Healing Paint

ONR partnered with John Hopkins University Applied Physics Lab (JHU/APL) in this three-year effort to develop a self-healing paint that delays the onset of corrosion and extends the life of a particular system. Self-healing paint instantly repairs scratches below a maximum width and protects the material below the paint from corrosion. The current approach is to paint surfaces with a protective coating. However, the currently available protective coating has limited abrasion resistance and can be easily compromised and thus expose the corrosion-susceptible material below. There are a number of self-healing paints available on the market, but none offer the performance and reliability of the polyfibroblast self-healing paint that JHU/APL has developed.

MCSC Efforts

Corrosion Prevention and Control (CPAC)

The goal of this MCSC effort is to establish an effective CPAC program to extend the useful life of all Marine Corps tactical ground and ground support equipment, and to reduce maintenance requirements and associated costs through the identification, implementation, and, if necessary, development of corrosion prevention and control products, materials, technologies, and processes. The use of these technologies and processes will repair existing corrosion damage and prevent, or at least significantly retard, future corrosion damage on all Marine Corps tactical ground and ground support equipment.

Recognized by the Office of the Secretary of Defense for its successful corrosion prevention and repair efforts, the Marine Corps CPAC program has

Corrosion Service Team (CST) members perform corrosion maintenance on site.

become a model Service program. This program continues to deliver best-value return on investment across all phases of Marine Corps' equipment life cycles. Since its inception in 2004, the CPAC Program Management Office has maintained a viable, comprehensive program that is credited with saving the Marine Corps over $20 million annually. With the expansion of the program and the use of advanced technology, savings are anticipated to continue to accrue.

5.2.2.3 Autonomy

As autonomy is a combat multiplier that will save lives, Unmanned Ground Vehicles (UGV) have been playing an increasingly important role in combat operations, and the need for new capabilities has been increasing steadily. The Marine Corps and Department of the Defense have been intensifying efforts to develop unmanned ground systems that can work together with manned systems to augment Marine Corps capabilities and save lives.

The Challenge

Current unmanned vehicle technology requires a Marine to operate the vehicle remotely. Vehicles that do not require a human operator tend to move slowly and have difficulty traversing terrain that has even minimal obstacles. For UGVs to be truly useful to the military, they must be able to conduct resupply missions without requiring human drivers. It is essential that future UGVs not require troops for protection and that they be able to cross rugged terrain quickly and easily without requiring human assistance.

Potential Solutions

ONR Efforts

Anticipation in Cognitive Models for HRI
Computational cognitive ACT-R/E models will be built based on how people think and reason. ACT-R/E is a hybrid symbolic/sub-symbolic architecture which will be used for building cognitive models.

Cognitive Architecture that Engenders Trust through Intelligible Natural Language for Ubiquitous Human-Machine Collaboration
This project will investigate components that can enable effective interaction between a robot and warfighters in support of the wingman concept, using a neuro-inspired cognitive architecture that tightly integrates natural language understanding and visual processing to reduce ambiguity. If it is

> *"Unmanned systems are proving to have a significant impact on warfare worldwide. The true value of these systems is not to provide a direct human replacement, but rather to extend and complement human capability in a number of ways."*
> **Science Board Task Force Report: The Role of Autonomy in DoD Systems, July 2012**

successful, this project will result in more effective interaction (lower cognitive load and increased trust) between the autonomous system and the operator.

Coherent and Accurate Status Update (CASU)
The objective of this effort is to adapt existing robotic cognitive architecture models of damage control and patrol to enable meta-information access. When asked for a status update, the model will provide a coherent and accurate status update (CASU) based on several assumptions/hypotheses:

- **Match Assumption**: The type of information explained must match the type of status update (what, why, how, where).
- **Representational Assumption**: Qualitative descriptions are preferred; quantitative information should be avoided.
- **Detail Assumption**: High levels of detail should be avoided unless specifically requested.

High Level Reasoner/Robotic Controller Integration
A hybrid architecture using a high-level reasoner integrated with a low-level robotic controller that can be used to achieve a performance gain of over 50% using only a low-level robotic controller.

Internally Transportable Vehicle (ITV) Autonomy Conversion - Autonomy Integration
The objective of this effort is to facilitate transition, integration, and maturation of autonomous capabilities for a full system demonstration and Limited Military Utility Assessment of the Autonomous Logistic Connecter Mission in FY16. This capability will enhance tactical mobility and maneuver, increase mission capability (time/space), and improve force protection for high risk missions.

Night Ops with Electro-Optical Perception System
The goal of this effort is to enable autonomous 24 -hour operations by developing and quantitatively demonstrating a covert illumination system that can be used to perform stereo camera-based navigation with illumination of 30m range and 200W average electrical power and navigation of <1% error (2D) over one hour in GPS-denied environments.

Novel UGS Behaviors using Genetic Programming
This effort evaluates academia, industry, and government efforts toward autonomous vehicle software development and automated behavior generation, identifying best-in-class performers and teaming opportunities.

Perception Computing Techniques for Wingman UGS
The objective of this effort is to develop a roadmap to a stable autonomous wingman platform in order to support the development and input requirements for wingman-specific research topics. Researchers require inputs on sensor suite and software and hardware requirements so that technologies will achieve convergent evolution to enable effective platform development.

Robust Traversability in Complex Terrains
This project is a path planner that uses high-fidelity terrain, kinodynamic vehicle models, and nonholonomic trajectories that will enable navigation to be 20% faster and with 25% fewer interventions. Several planners will be created, including a planner that utilizes equivalence classes to reduce the number of potential trajectories to primary unique trajectories; and a maneuver planner that employs sequential composition to select the maneuver sequence that is best suited to a particular scenario, environment, or vehicle state. An adaptive trajectory simulation engine will be created that is dependent on component simulation models with varying fidelities, and an intelligence layer will be created that reasons about differences in fidelity and the computational efficiency of various model constructions.

Sensor Fusion for Robust Perception
Unmanned Ground Systems must be able to negotiate rugged off-road terrain in real time without human

intervention. Achieving this capability will reduce the necessity for warfighter presence and enable new mission opportunities. The objective of Sensor Fusion for Robust Perception is to demonstrate a low-cost perception system ($10k-$20k) for an autonomous ITV-sized vehicle that can:

- Detect obstacles during daylight positive conditions from 50m at 40mph.
- Detect obstacles during daylight negative conditions from 15m at 20mph.
- Classify terrain with an accuracy >70%.
- Perform nighttime perception.

Trust in Adaptive Autonomous Systems

Operator-centric intelligent decision systems can offload decision-making to adaptive agents with high assurance of effective mission performance in complex military environments. ONR will investigate high-trust human-robot interaction by experimenting with an interface/control architecture that integrates three key functionalities: a human cognitive model, an adaptive agent to assist human cognition, and a high-assurance supervisor.

Virtual Environment for Cognitive Algorithm Development (VECAD)

The objective of this effort is to develop an open architecture simulation virtual environment for developmental testing and evaluation of behaviors for unmanned systems; and to improve the quality of operationally relevant advanced autonomous behaviors, including advanced mobility behaviors and "cognitive architecture"-based reasoning systems, while reducing cost, risk and time for development and deployment.

World Modeling for Tactical Path Planning

The goal of this effort is to enhance the capabilities of a UGV's World Model so real-time sensor data can be extracted to higher level knowledge elements and be integrated with real-time and persistent multi-modal sensor data. Achieving this capability will enable increased system performance and reliability in more challenging environments for an advanced path planner and cognitive behavior operating on this World Model.

Additional ONR Autonomy S&T projects that are of interest to PEO LS include:

- Applied Robust Traversability in Complex Terrains
- Applied Spatial Phase Imaging for UGV Perception
- Autonomous Wingman Resupply Vehicle
- Autonomy Component Integration
- Wingman Next Generation Autonomy Algorithm Development

RDECOM & TARDEC Efforts

Autonomous Mobility Appliqué System (AMAS) Joint Capability Technology Demonstrator (JCTD)

The intent of this JCTD is to implement a convoy solution using a variety of tactical wheeled vehicles with supplemental "driver-assist" safety features so as to provide today's military vehicles with an optionally manned capability to increase safety and provide the warfighter with additional flexibility. AMAS will be adaptable and deployable in a variety of missions and conditions. It will be integrated onto military vehicles by developing, integrating, and demonstrating: 1) a vehicle kit to control the physical actuation of a vehicle called the By-Wire/Active Safety kit, which is unique to each type of vehicle platform based on differing hardware requirements; and 2) a common appliqué autonomy kit that will contain the primary intelligence and autonomous decision making. The autonomy kit will be common across all vehicle platforms and will be designed to function and interoperate regardless of the type of vehicle platform on which it is installed.

Autonomous Robotics for Installation & Base Operations (ARIBO)

ARIBO is a series of living laboratories that produce "co-evolutionary" technical and social-behavioral value, that is, a cyclical stream of data collection, reliability analysis, and technical improvement. Users learn and adapt their behavior as they become increasingly familiar with autonomous systems and more comfortable using and interacting with them. Concurrently, the technology will be refined and improved to accommodate user behavior and emergent operational needs.

Dismounted Soldier Autonomy Tools (DSAT) (part of the Occupant Centric Platform initiative)

The goal of this effort is to supply early adapters with a suite of autonomy tools to enable the dismounted soldier to control engineering vehicles from a position that is out of harm's way. This effort will build on DSAT capabilities and provide robust non-intrusive follow capabilities to dismounted infantry for mechanized offloading of equipment.

Multi-UGV Extended Range Experiment

The strategy of this operational experiment is to conduct an operational experiment to examine the feasibility of long distance command and control (C2) of multiple unmanned vehicles deployed from a V-22 capable unmanned marsupial vehicle. This experiment will expand technical development in the area of multi-platform C2 while providing an operational context for user communities such as DTRA/20th Support Command, SOCOM, TRADOC, and USMC. It will also address technical development areas related to soldier-robot interfaces; C2 mode transitions between operators and platforms; power, energy, and mobility requirements for long duration missions; and the feasibility of designing a V-22 capable package. This experiment addresses operational needs for Chemical, Biological, Radiological, Nuclear and Enhanced Conventional Weapons, anti-area denial, and strategic reconnaissance. This effort will also provide insights into tactical small unit employment.

STTR Efforts

Visible Electro-Optical (EO) System and Laser Imaging Detection and Ranging (LIDAR) Fusion for Low Cost Perception by Autonomous Ground Vehicles

The objective of this effort is to develop a low-cost perception/classification system for Joint exploitation of LIDAR and passive multi-spectral data obtained across the visible spectrum, employing self-calibrating algorithms for use in autonomous ground vehicles.

5.2.2.4 Weight Reduction

The Commandant's directive to "Lighten the MAGTF" led to initiating the Weight Reduction focus area. Lightening the MAGTF will increase the ability to traverse harsh terrain, increase fuel economy, and enhance maneuver from the sea, and provide the combat multiplier of speed.

The Challenge

Successful weight reduction efforts will generate benefits including expanded range, superior mobility, increased energy efficiency, and greater speed. The challenge is to implement weight reduction measures that are affordable and that will not degrade survivability nor reduce reliability.

> *"We need to significantly lighten the MAGTF, which will require considerable paradigm shift across the Marine Corps and will have a significant impact on research and development, programmatic budgeting, acquisitions, doctrine development, and employment of future systems."*
>
> **Marine Corps Operating Concepts (MOC) Third Edition June 2012**

Potential Solutions

ONR Efforts

Expeditionary Light Armor Seedling Development
The hypothesis of this effort is that by expanding existing ballistic performance design equations development of properties-based equations for state-of-the-art and emerging ceramic composite armor systems will be possible. Possible equation parameters could include ceramic hardness; yield and fracture toughness; and composite yield, elongation, and stiffness.

High Strength-High Ductility Nano Composites
This initiative will investigate the feasibility of combining submicron-scale ceramic reinforcements (B4C) with a dispersion strengthened (or precipitation strengthened) matrix in a coarse grained region; and will determine if this combination will produce a multi-scale nano-composite aluminum that has tailorable plasticity with high strength and high ductility.

Additional ONR projects of interest to PEO LS are:

- Efficient Powertrain Technologies Integration (Partnered with TARDEC)
- Fuel Efficient MTVR (project includes weight savings attributes; see section 5.1, Power and Energy focus area, for details)

RDECOM & TARDEC Efforts

TARDEC ARMED
This program has many subsets with weight saving benefits. More details can be found in section 5.2 under RDECOM and TARDEC Efforts.

Light Weight Vehicle Structure
Lighter vehicles are an enabling factor for faster transport, higher mobility, increased fuel efficiency, and a reduced ground footprint of supporting forces. At the same time high levels of protection must be offered by the vehicle to its occupants against explosive threats. The goal of this project is to demonstrate affordable, multi-material designs for structures that reduce vehicle weight. Weight reduction and high levels of survivability are mutually competing objectives.

> *"We will be light enough to leverage the flexibility and capacity of amphibious ships, yet heavy enough to accomplish the mission when we get there."*
> **The Posture of the United States Marine Corps, 2011 Report to Congress, General James F. Amos, Commandant USMC**

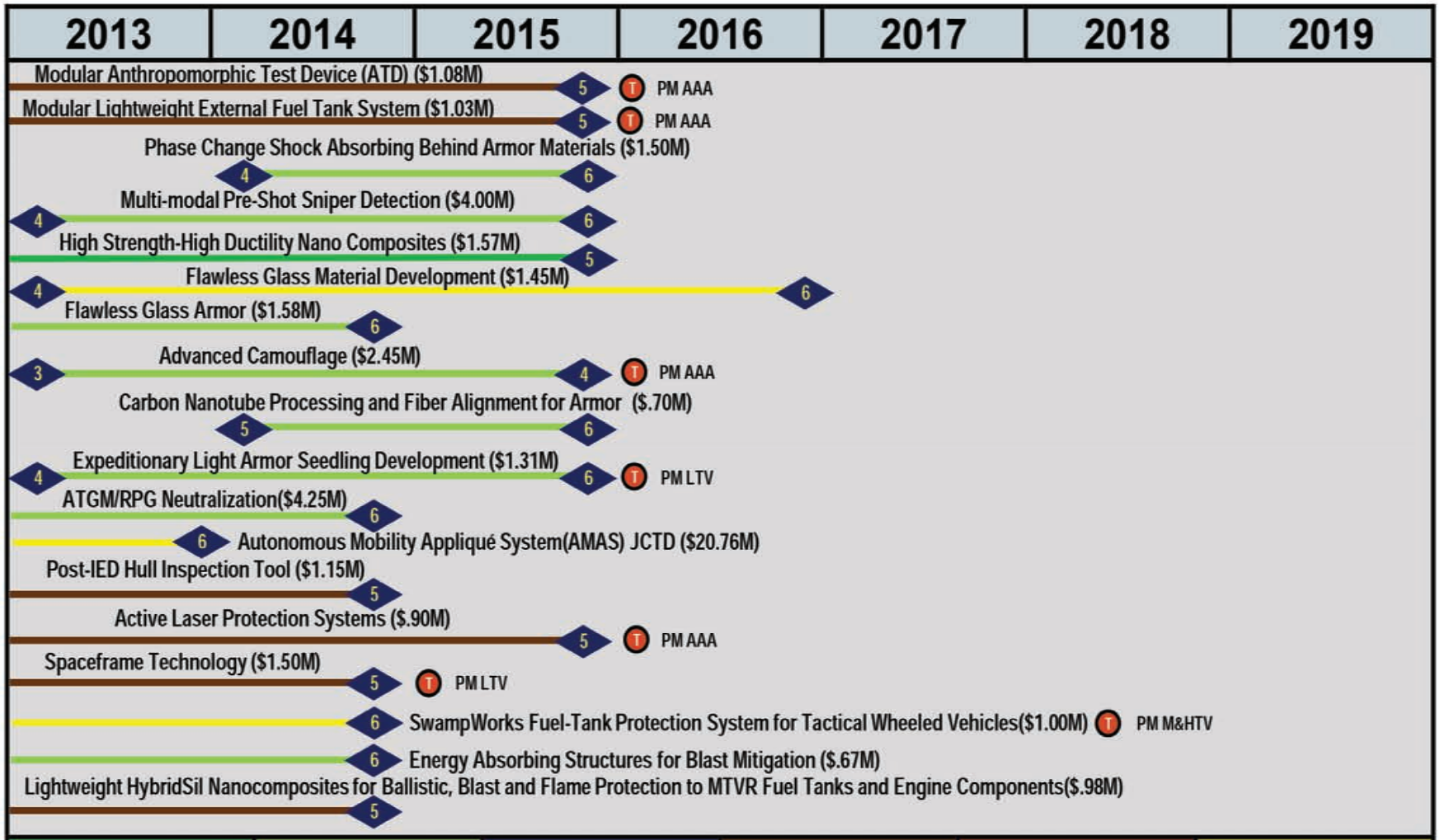
SBIR Efforts

Modular Lightweight External Fuel Tank System
The objective is to design and develop a lightweight, modular fuel tank that can withstand hydrodynamic ramming forces and that can provide protection against a ballistic impact from a 14.5 mm armor-piercing projectile using a multi-layer laminate design that achieves a significant reduction in weight compared to existing systems. A lightweight, modular fuel tank would reduce the power and fuel requirements for an amphibious vehicle while mitigating fire issues and increasing freeboard.

MTVR Composite Trailer
This project uses composites to lighten trailer weight and increase payloads, resulting in fewer trucks on the road and reduced fuel consumption.

The Survivability & Mobility focus area charts on the following pages highlight critical efforts monitored and supported by the PEO LS S&T Director.

Survivability

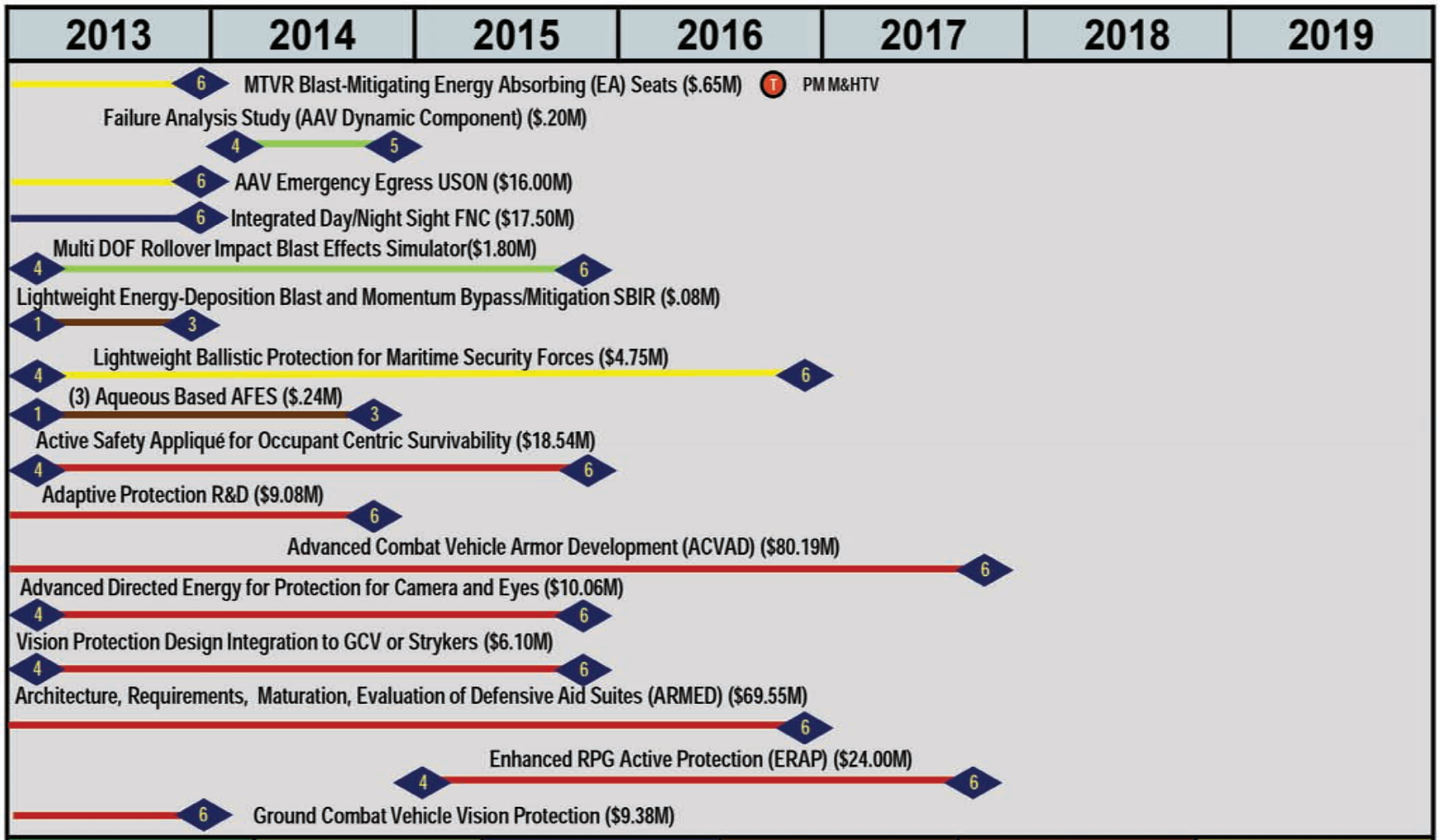


D&I	E&D	FNC	SBIR/STTR	TARDEC	Other

Funding Profiles ($M)	FY13	FY14	FY15	FY16	FY17	FY18	FY19
S&T (6.2 / 6.3)	21.00	11.14	9.11	0.25			

6.1 ← → Science & Technology ← → 6.3 6.4 ← → System Development ← → 6.7

Survivability

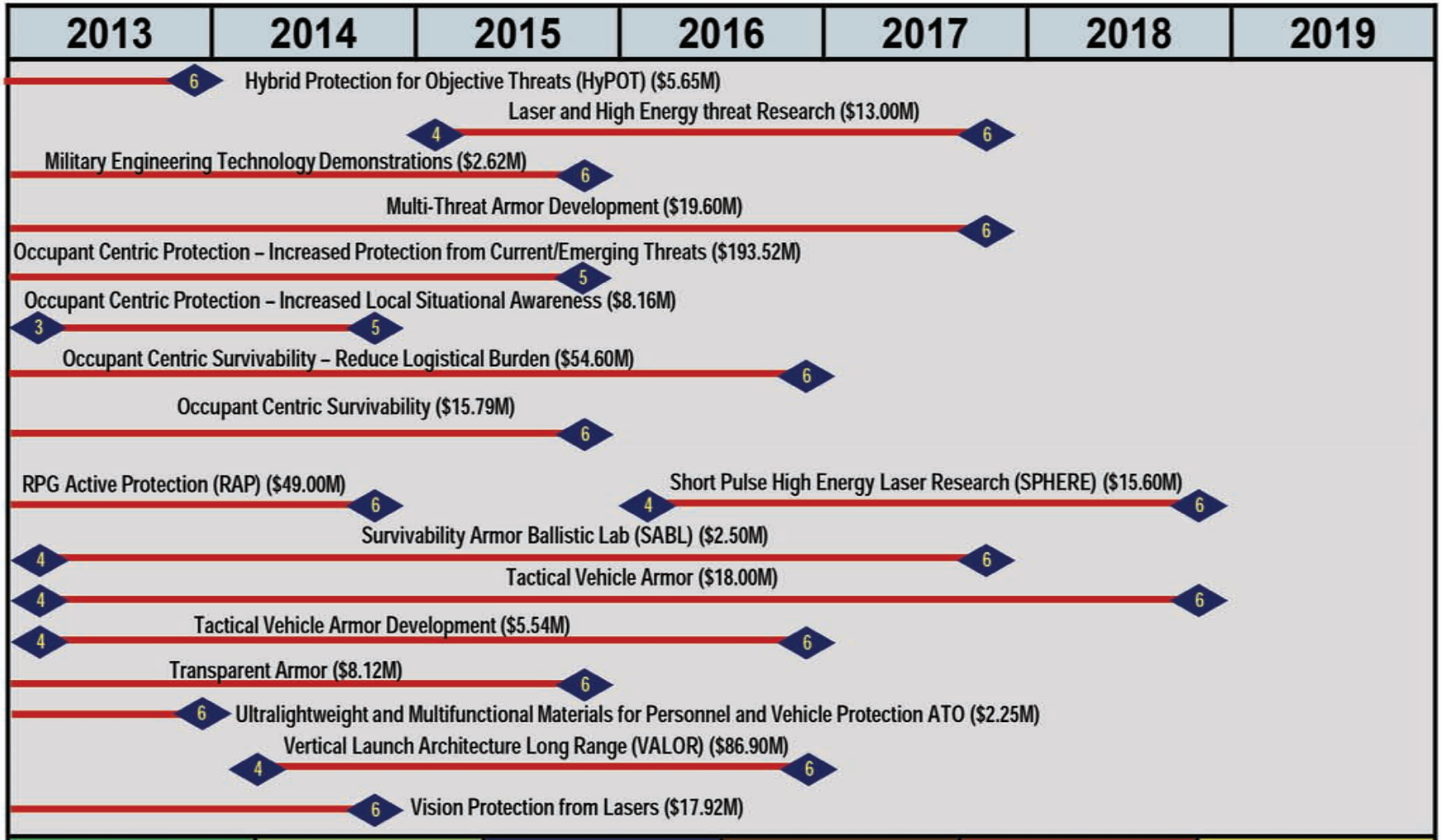


D&I	E&D	FNC	SBIR/STTR	TARDEC	Other

Funding Profiles ($M)	FY13	FY14	FY15	FY16	FY17	FY18	FY19
S&T (6.2 / 6.3)	46.59	32.43	61.85	52.20	16.00	46.59	

6.1 ← → Science & Technology ← → 6.3 6.4 ← → System Development ← → 6.7

Survivability

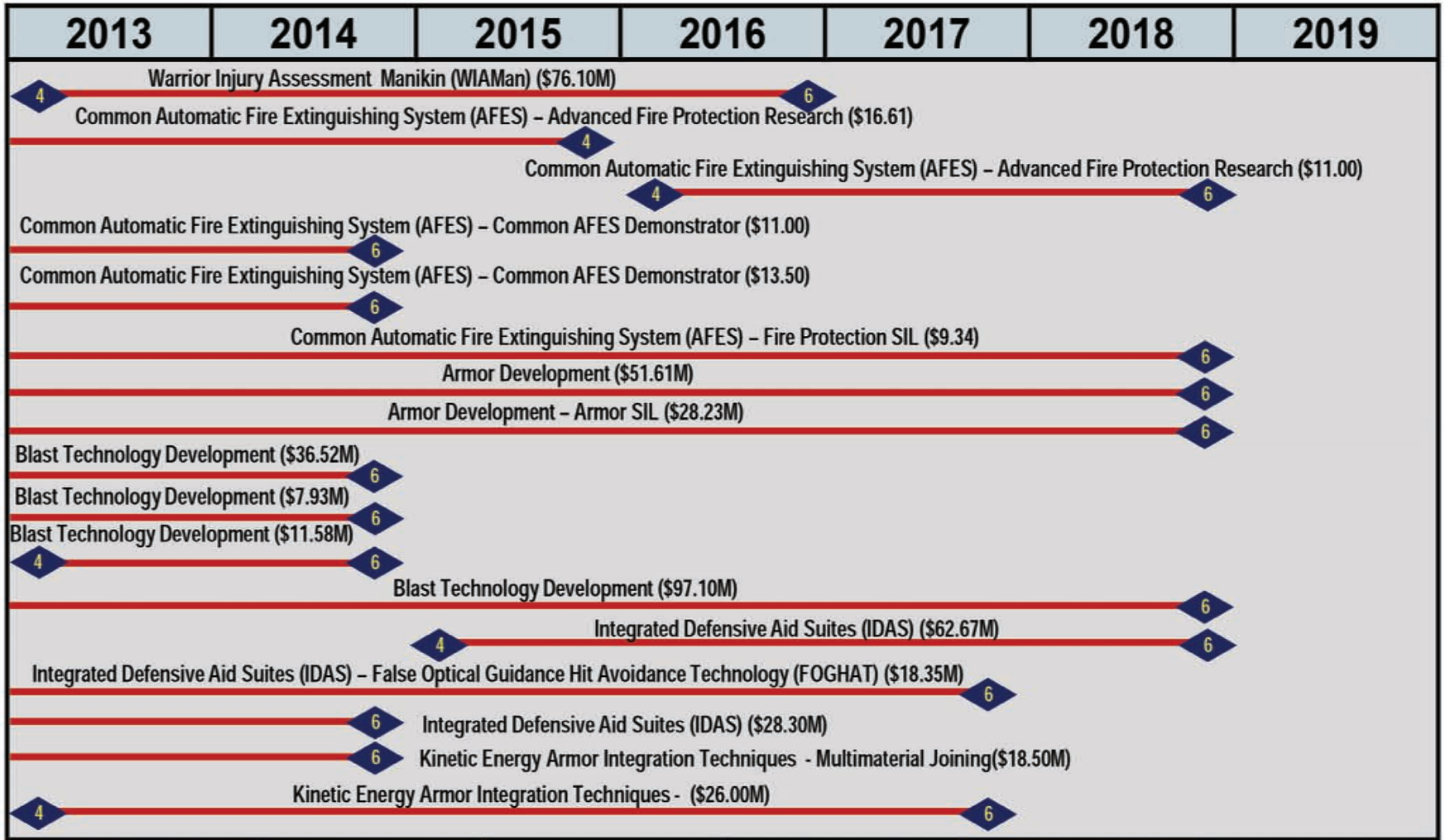


D&I	E&D	FNC	SBIR/STTR	TARDEC	Other

Funding Profiles ($M)	FY13	FY14	FY15	FY16	FY17	FY18	FY19
S&T (6.2 / 6.3)	111.92	94.54	93.88	59.20	19.60	16.00	

6.1 ⟷ Science & Technology ⟷ 6.3 6.4 ⟷ System Development ⟷ 6.7

Survivability

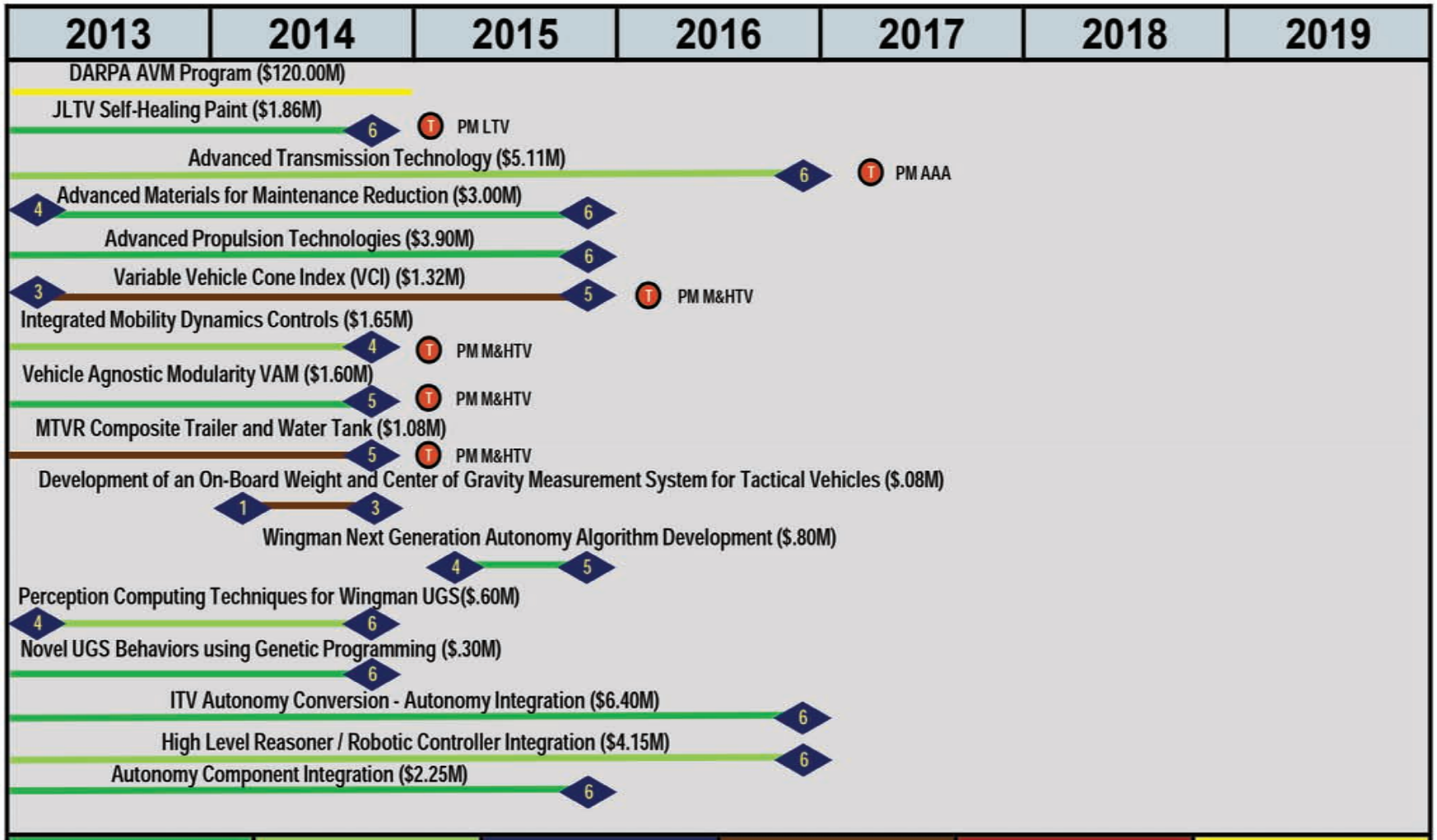


D&I	E&D	FNC	SBIR/STTR	TARDEC	Other

Funding Profiles ($M)	FY13	FY14	FY15	FY16	FY17	FY18	FY19
S&T (6.2 / 6.3)	102.87	88.67	63.38	66.98	66.27	54.76	

6.1 ⟷ Science & Technology ⟷ 6.3 6.4 ⟷ System Development ⟷ 6.7

Mobility

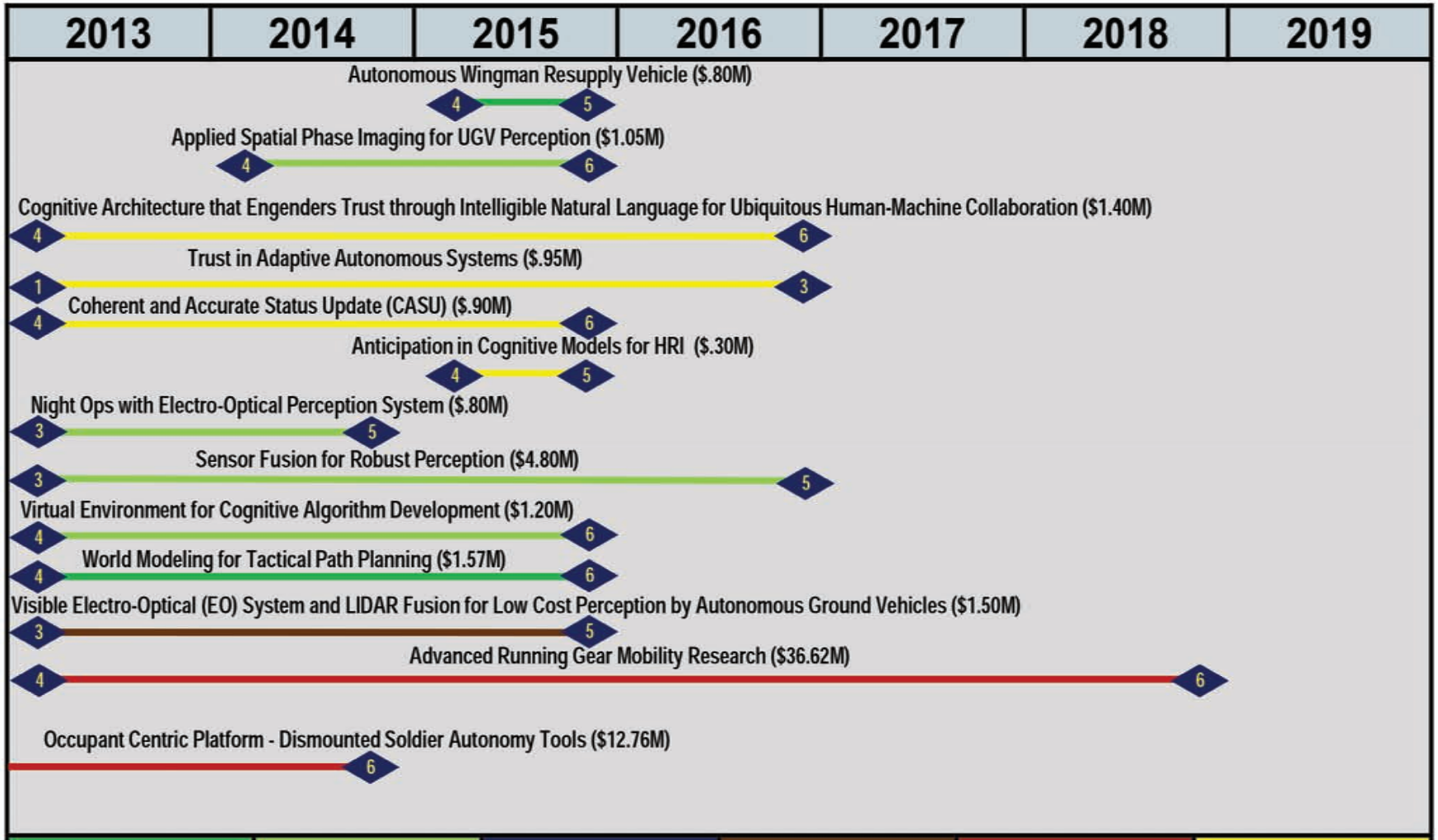


D&I	E&D	FNC	SBIR/STTR	TARDEC	Other

Funding Profiles ($M)	FY13	FY14	FY15	FY16	FY17	FY18	FY19
S&T (6.2 / 6.3)	69.12	68.94	8.25	3.10			

6.1 ⟷ Science & Technology ⟷ 6.3 6.4 ⟷ System Development ⟷ 6.7

Mobility

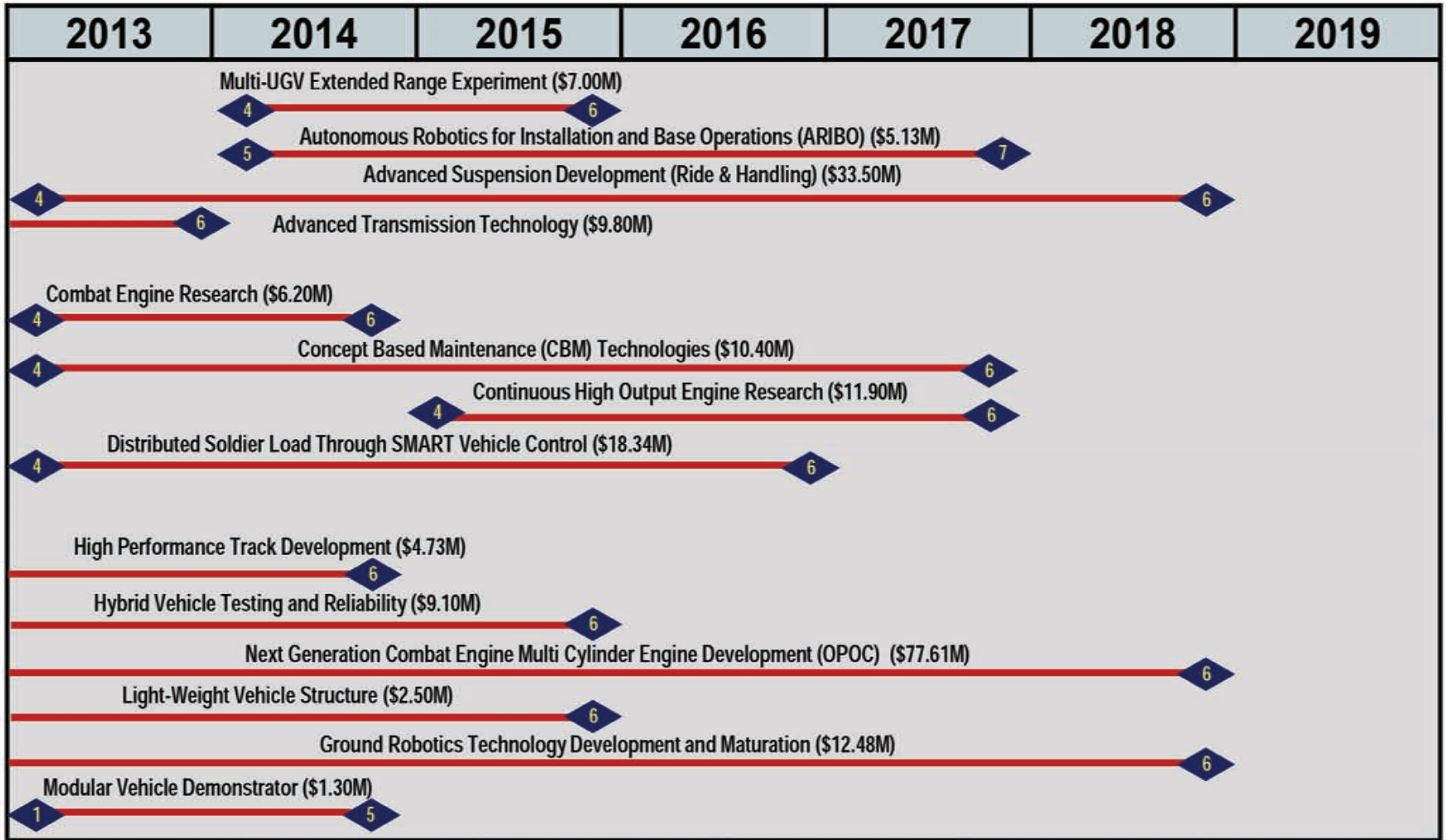


D&I	E&D	FNC	SBIR/STTR	TARDEC	Other

Funding Profiles ($M)	FY13	FY14	FY15	FY16	FY17	FY18	FY19
S&T (6.2 / 6.3)	13.74	13.19	9.12	6.83	5.60	8.42	

6.1 ⟷ Science & Technology ⟷ 6.3 6.4 ⟷ System Development ⟷ 6.7

Mobility

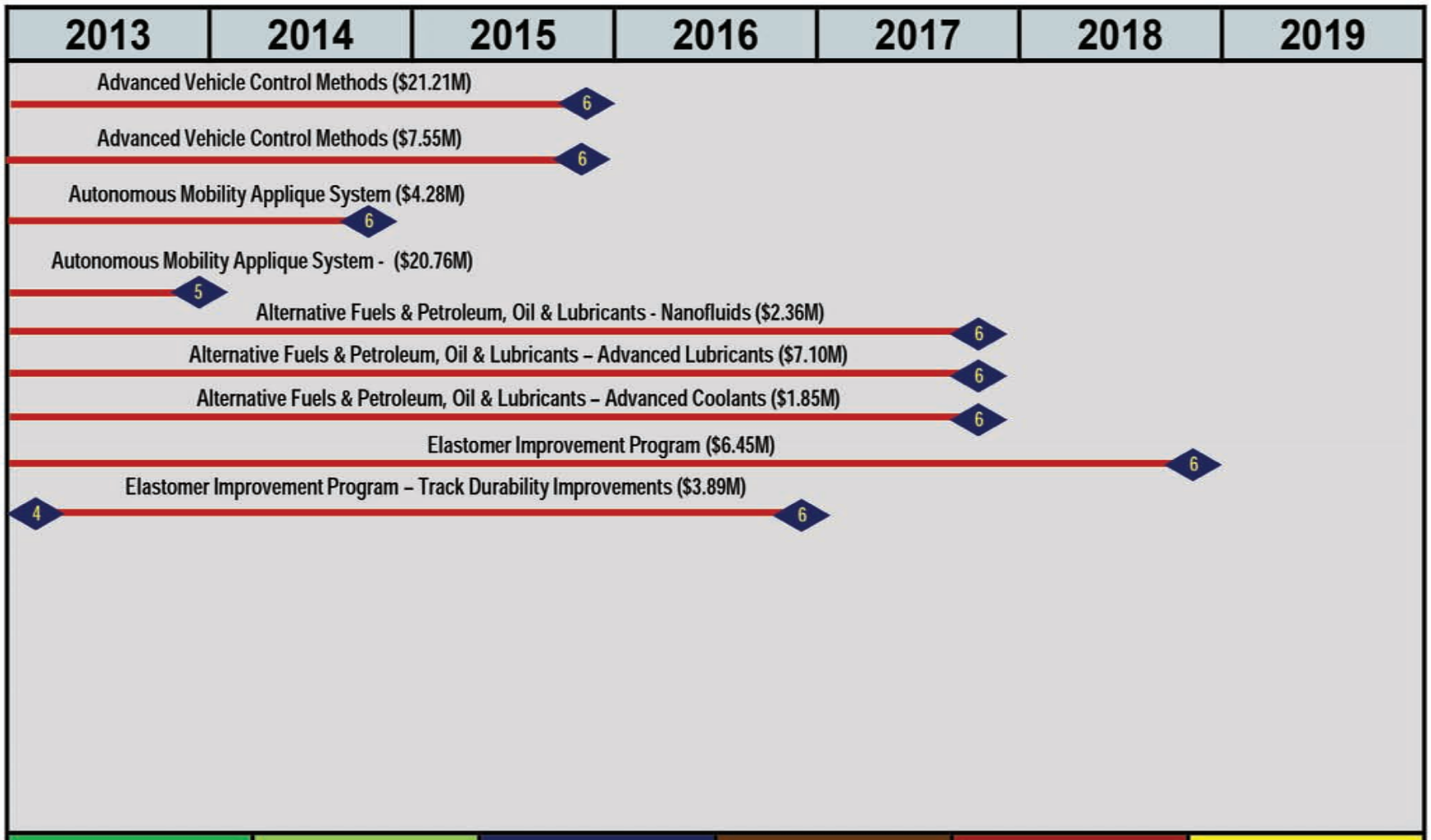


D&I	E&D	FNC	SBIR/STTR	TARDEC	Other

Funding Profiles ($M)	FY13	FY14	FY15	FY16	FY17	FY18	FY19
S&T (6.2 / 6.3)	32.50	33.12	43.82	35.02	31.62	23.67	

6.1 ← → Science & Technology ← → 6.3 6.4 ← → System Development ← → 6.7

Mobility



D&I	E&D	FNC	SBIR/STTR	TARDEC	Other

Funding Profiles ($M)	FY13	FY14	FY15	FY16	FY17	FY18	FY19
S&T (6.2 / 6.3)	24.95	11.98	10.00	3.98	2.97	1.00	

6.1 ← → Science & Technology ← → 6.3 6.4 ← → System Development ← → 6.7