SURVIVABILITY AND MOBILITY

The Marine Corps' future operating environment will be increasingly complex and marked by the proliferation of conventional and unconventional threats. The solutions to these threats need to be affordable, scalable, and preferably take a system-of-systems approach. In addition to these novel solutions, maintaining and improving legacy vehicles' capabilities is critical to the Marine Corps' overall objectives. As an expeditionary force that is concentrating its efforts on re-honing its amphibious skills, the Marine Corps must ensure that its current and future tactical vehicle fleet is light, fast, easily transportable, and survivable.

The Marine Corps' Program Executive Office (PEO) Land Systems (LS) continues to collaborate closely with the Marine Corps System Command (MSCS), Marine Corps Warfighting Lab (MCWL), Marine Corps Combat Development Command, Office of Naval Research (ONR), Research Development and Engineering Center (RDECOM), Tank Automotive Research, Development, and Engineering Center (TARDEC), among other agencies in efforts to address the competing challenges of Survivability and Mobility.

The Survivability and Mobility Focus Areas introduce technologies that will enhance mobility and survivability for both the Marines and the vehicles. Survivability and Mobility are addressed together as a combined S&T Focus Area due to their symbiotic relationship.

4.2.1 Survivability consists of:

- 4.2.1.1 Fuel Containment/Fire Suppression
- 4.2.1.2 Safety

4.2.2 Mobility consists of:

- 4.2.2.1 Crew Visibility
- 4.2.2.2 Corrosion
- 4.2.2.3 Autonomy
- 4.2.2.4 Weight Reduction

4.2.1 Survivability

The Challenge

The design, development, production and maintenance of survivable PEO LS vehicles are complex engineering problems because the system-of-systems architecture of the vehicles themselves. Improving and maintaining legacy vehicles remains a substantial challenge within the PEO LS, especially in an environment where affordability is as important as capability. The solutions to these complex engineering problems not only must be cost effective, but it is required that the vehicle must provide the mobility for the Marines to successfully complete the mission.

Potential Solutions

FNC Efforts

GBAD-OTM High Energy Laser Demonstrator
This FNC will demonstrate the capability of a rugged expeditionary high energy laser demonstrator cued by a radar capable of detecting low radar cross section threats and performing hard kills of unmanned aerial system (UAS) to prevent reconnaissance, surveillance, targeting and acquisition of expeditionary forces.

DARPA Efforts

Ground X-Vehicle Technologies
The effort will investigate ground vehicle technologies that enable crew/vehicle survivability through means other than traditional heavy passive armor solutions. This will be accomplished through research and development of novel ground combat and tactical vehicle technology solutions that demonstrate significantly advanced platform expeditionary mobility and survivability.

ONR Efforts

Active Protection Technology
This project will investigate novel countermeasures to defeat RPG/ATGMs inflight.

Advanced Topcoat Systems for Ground Vehicles
The goal of the program is to develop, test, demonstrate and validate an advanced topcoat technology that will replace the legacy polyurethane-based chemical agent resistant coating (CARC) topcoats used on Marine Corps ground vehicles.

Amphibious Autonomy
These risk reduction efforts will serve to provide assurances of a baseline of autonomous amphibious capability development through supplementary research and development activities that leverage existing Government-owned solutions and expertise in perception, world modeling, and route planning. Lessons learned and capabilities developed will be made available to industry performers selected under the BAA allowing them to jump-start their own activities or backfill risk areas.

Autonomy and Unmanned Vehicle Technologies to Support Amphibious Operations
The primary objective of the amphibious vehicle technology area is to develop technologies for a small, low-cost amphibious vehicle culminating in a full-scale development of up to 20 vehicles. ONR seeks to minimize the size and cost of the vehicles to allow for experimentation with a very large number of vehicles. The project will address the amphibious vehicle technology.

Biological Design Features that Retard Visual Detection and Recognition
This will explore and quantify the design features of animal concealment patterns to defeat human perception with a particular focus on edge design techniques and motion concealment.

Eye tracking with human subjects will explore the effectiveness of different concealment patterns (background matching, mottle, and disruptive coloration) and edge designs.

Study cephalopods in complex and diverse visual habitats focusing primarily on Rapid Adaptive Coloration (RAC)

Cybersecure Platforms
There is a need to understand the existing cybersecurity posture of the U.S. Marine Corps (USMC) ground vehicle fleet and a desire to mitigate any vulnerabilities and exploits that may exist. The goal of the overall program is to identify any failure modes and attack vectors that currently exist in USMC ground vehicle control systems and to provide technological solutions to diminish any discovered threats.

Detection Avoidance material and M&S Development
Investigate materials and develop improved M&S for advanced camouflage application

Detection Avoidance Technologies
Reduce vehicle signature. Continuing to develop advanced technologies in this area. Details classified.

Directed Energy Weapons Mitigation
Investigate DEW threats and develop countermeasure technologies.

Disruptive Coloration

This proposal focuses on the design features of animal concealment patterns that have proved effective in avoiding detection or retarding recognition by animal predators with diverse and sophisticated visual systems. Emphasis will be on determining the detailed designs of edges of animals such as cuttlefish (marine mollusks of the Class Cephalopoda), which have refined body patterns that enable them to conceal themselves in a wide array of natural backgrounds such as seagrass beds, kelp forests and coral reefs that have great diversity of light, structure and scale.

GOLEM

The intent is to demonstrate a platform-based protection system that can neutralize RPG/ATGM threats and has inherent light armor protection. This effort will support sensor development, fire control system research and software programming, and system assessment for the Golem Protection System to support USMC vehicle needs.

Flawless glass+P2

To further develop the methodology to produce flawless commercial glass as part of a transparent armor (TA) system. Reducing surface flaws in commercially available glass can increase performance of the TA systems thereby allowing for a reduced weight and cost armor system.

Functionally Gradient Armor materials (Additive Mfg)

Using additive manufacturing, fabricate light armor ceramic composite systems with novel geometries and seams.

Hybrid Layered Metal/Composite (H-LMC)

Explore the response of aluminum-composite structures to underbody blast events.

Injection Molding and Additive Layer Manufacturing of B4C

Utilize flowable and highly loaded B4C suspensions with minimum viscosity, maximum loading and tailored rheology using a mix of Polyethylenimine, B4C, HCl, and Water as the basis of B4C ceramic armor tiles.

Establish methods of injection molding and 3D printing of B4C greenbodies with subsequent pressureless sintering to produce high density ceramic armor plates.

Injection Molding and Additive Layer Manufacturing of Boron Carbide for Ballistic Testing

Boron carbide (B4C) possesses a low density and high hardness making it ideal in certain armor applications. However, to achieve these favorable properties, B4C must be sintered to full density. Historically, B4C has been sintered using an externally applied pressure, via hot pressing or hot isostatic pressing, due to the challenges associated with densification. Hot pressing approaches limit the geometries of the final pieces to simple shapes such as pellets, plates, disks, and rods and are considered time consuming and costly.

Internet of Things-enabled Condition-based Monitoring, Diagnosis, and Prognostics for Navy Equipment

Mission readiness and longevity of Navy fleet heavily depends on how its equipment is well maintained. Currently, maintenance still accounts for a major portion of the ownership costs for DoD. Fundamentally, the limitations lie in (i) the lack of effective understanding of the system health status in real time; and (ii) the inability to accurately model the degradation and predict the failure time of each in-field unit. predicted catastrophic failure occurs.

This proposal aims to bridge the knowledge gaps from the rich data to smart condition-based monitoring, diagnosis and prognostics for navy equipment driven by the IoT technology.

Lightweight Armor Applications/Integration

Investigate applications of CNTs in high strain

rate using lessons learned from 6.2 program for application in hard-armor systems.

Littoral Automated Threat Reconnaissance

The objective of this effort is to produce a low-cost, multi-modal Littoral Automated Threat Recon (LATR) system in order to enhance Counter Tactical Surveillance and Targeting (CTST) capabilities. The LATR system will enable automated detection and classification of humans, threats/weapons (especially Rocked Propelled Grenade (RPG)), and surface swimmers in real time from fixed or moving platforms, with a focus on riverine operations.

Nanostructured Carbide Armor Composites

Use a polymeric method to produce nanostructured ceramics that exhibit high performance as next-generation vehicle armor systems

Nanostructured Ceramics

This project aims to utilize the NRL developed polymeric method for the production of nanostructured ceramics in the preparation of test articles for the next-generation armor systems for USMC tactical and amphibious vehicles.

The primary objective of this work is to deliver to the USMC vehicle program offices nanostructured ceramics technology for armor applications that will meet threat requirements with decreased system weight and/or cost

Next Generation Lightweight Armor

Investigate methods for inexpensive formation of ceramics (SiC); Develop mesostructure mechanical property relationships for carbon nanotubes (CNT) to guide material development; Improve processing methods for ultrahigh strength and stiffness CNT yarn and tape.

Pre-Shot Sniper Detection

The overall goal of the project lead by FirstGuard Technologies is to deliver a field demonstration prototype Ka-band radar with embedded Cavity Induced Modulation (CIM) to detect sniper rifles in cluttered environments prior to the weapons being fired.

Scaling Studies in Ballistics

Using knowledge from previous ONR programs, investigate Lightweight materials for armor applications for USMC platforms (ACV, JLTV Objective, etc.)

Survivability Analysis

Survivability Technologies for USMC Vehicles will entail passive light armor development and ballistic testing and Active Protection System (APS) Technologies. A material(s) and technologies search will be conducted by NSWCCD for novel manufacturing techniques and materials for use in lightweight armor and active protection systems.

Tactical Coordinated Behaviors

The Multi-role Autonomous Ground Vehicle (MAGV) program was sponsored by ONR Code 30 to develop an autonomy kit that could be installed on an expeditionary ground vehicle to support partial or fully autonomous missions, including route reconnaissance and clearance, remote over watch, and logistics connector.

Tandem Threat Defeat and select ATGM

Continue with technology development to defeat Tandem CE threats and ATGM.

Technologies for Lightweight, Low Profile Active Protection System (APS)

Investigate technologies to advance the state of the science active protection system applicable to vehicles and watercraft for defeat of air delivered chemical energy threats with minimal fratricide.

Transparent Armor Integration

Develop and demonstrate advanced transparent armor systems in a field environment using lessons learned from Flawless glass, SBIR and polymeric material TA.

Transparent Armor SBIR
Reduce transparent armor for relevant threat by over 30%. Develop ballistic model useful for other programs. Transition technology.

Unmanned Swarming Amphibious Assault Craft
The USAAC program will develop autonomy and vehicle technologies for a swarm of amphibious vehicles to support a contested amphibious landing.

RIF Efforts

Long Range Obscurant System
Raytheon's long-range obscurant system is designed to disrupt the line-of-sight between an incoming ATGM and the launcher or the missile and the target, effectively eliminating tracking and/or guidance capability of the missile. This two-year program (FY18/19) will build and test Controlled Flight Test Vehicles (CTV) to deliver obscurant at ranges required for defeat of incoming ATGM guidance, to include fly-outs to demo CM guidance, control, and obscurant payload delivery within the extreme environments and time constraints of the APS mission.

High Pressure Vacuum Relamination of Transparent Armor
AutoCell Brief (Apr 2017) title: Transparent Armor Delamination

Objective: Develop a relamination capability for transparent armor for all USMC vehicles. Solution is applicable to all vehicles that have transparent armor.

TARDEC Efforts

Advanced Armor
Leverage current investments in combat vehicle armor to develop, mature and integrate lightweight base, add-on, and electrified armors. Mature and test Pulse Power system to enable electrified armors. Mature advanced armors into integrated armor solutions while maintaining performance, decreasing weight, and maintaining cost.

Advanced Combat Engine (includes BA4)
Design and develop a novel 1500 hp Military Engine to meet mobility needs for combat vehicles. To meet the Army's need for enhanced protection and fuel efficiency, high power engines (800 – 1500 hp) are needed to offset increasing combat vehicle weights (armor), increased electrical generation needs (onboard and exportable power), improved fuel economy (cost & range), enhanced mobility (survivability), and reduced cooling system burden (size, heat rejection) in a smaller package (reduce under armor volumes).

Advanced Countermine/IED Payloads Competency
Army Elements lack the ability to conduct mounted and dismounted movement and maneuver on and off road, in all terrain conditions where the threat of AT mine and IED engagements exist. This effort will capitalize on small incrementally funded activities combined with customer focused efforts to achieve technical capabilities that can ultimately be packaged into a single system adaptable to truck, tracked and robotic platforms.

Advanced Passive/Active Blast Mitigation (HFBC) (includes BA4)
Mature blast mitigation technologies through product development, integration and validation. Meet the ≥4X underbody blast requirements by integrating interior and exterior blast mitigation technologies on combat vehicle representative blast bucks. Fully understand blast load paths through vehicle platforms by decomposing the load paths through each technology and technology interface.

Cybersecurity
This will focus on the protection of manned and unmanned ground vehicle and Army watercraft platforms from cyber security threats and Cyber-Attacks. This is critical to address the continuous expanding vulnerability of Army platforms to cyber threats due to their increasing dependence on

computers, networks, data, digitization, and communication

Combat Vehicle Adaptive Armor
Develop and demonstrate integrated adaptive armor systems comprised of mechanical and electrical subcomponents on a representative combat vehicle platform

CVP PMO
The CVP Mission is to execute a five-year Ground Vehicle technology development program that delivers a portfolio of leap ahead technologies at TRL 6 by FY19 to the Army and can be integrated and demonstrated on a prototype platform by FY21. The CVP Vision is to develop ground vehicle leap-ahead technologies that ensure the Warfighter maintains its overwhelming ground combat superiority against any enemy worldwide.

Fire Protection Competency
Provide legacy and future vehicle programs with improved damage mitigation techniques to protect against current and emerging fire threats.

Future Sensor Protection Research (TBD)
Purpose: Prevent destruction of combat vehicle optical systems from High Energy Laser (HEL) weapons.

Ground Degraded Visual Environment (gDVE)
Increase local situational awareness (LSA) in all conditions and environments, to include degraded visual environments, for ground vehicle systems. Utilize scalable LSA sensing & immersive intelligence to improve occupant and vehicle survivability and provide augmented transparent battlefield vision.

Ground Vehicle Coating System Production Process Improvement
New for 2017 no funding info provided

Mechanical Countermine Competency
Army Elements lack the ability to conduct mounted and dismounted movement and maneuver on and off road, in all terrain conditions where the threat of AT mine and IED engagements exist. This effort will capitalize on small incrementally funded activities combined with customer focused efforts to achieve technical capabilities that can ultimately be packaged into a single system adaptable to truck, tracked and robotic platforms.

Modular Active Protection (includes BA4)
To demonstrate Soft-kill (SK) and Hard-kill (HK) Active Protection Systems (APS), that are compliant with a modular approach, to defeat Rocket Propelled Grenades, Recoilless Rifles and Anti-Tank Guided Missiles.

SCN Phase 2
This project will analyze roadblocks (perceived & actual) to efficient R&D prototyping and development within current production centric network accreditations

Design, implement, and validate network accreditation that: lower latency from concept to execution, maximizes user flexibility/ efficiency, encourages collaboration, manages risk at level commensurate with R&D activities, minimizes sustainment costs

Sensor Protection from Lasers (Combined w/ Future)
To improve and adapt sensor protection technologies to a variety of platforms as well as develop new materials/devices/strategies for countering advanced laser threats. Reduction of optical cross-section, minimization of jamming and dazzling, and overall increase in damage thresholds.

4.2.1.1 Fuel Containment/ Fire Suppression

The Challenge

Fuel Containment and Fire Suppression technologies remain important to the PEO LS Science and Technology representatives. Addressing fires caused by accelerants and IEDs, accidental fires caused by leaks or

malfunctions, or battle damage fires all present the same core challenges: to increase the survivability of the vehicle and its occupants.

Potential Solutions

ONR Efforts

Aqueous Based AFES
In a vehicle disabled by IEDs, protect incapacitated occupants from secondary long-duration external fires. The cab is flooded with a breathable foam produced by compressed air and an aqueous agent. The challenge is dispensing foam in a continuous fashion to suppress internal re-flash and protect occupants from burn injury for five minutes until rescue arrives. This effort will develop aqueous breathable foam system to protect ground vehicle crew from thermal burn injuries and develop criteria for burn injury due to skin exposure to heat in humid environment.

TARDEC Efforts

Fire Protection Competency
Provide legacy and future vehicle programs with improved damage mitigation techniques to protect against current and emerging fire threats

4.2.1.2 Safety

The Challenge

Safety preserves personnel and equipment, but safety considerations cannot contradict the mission of the Marine Corps' operational objectives. Safety considerations include vehicle stability, safety equipment that include restraint harnesses, fire suppression, clear fields of view, training, policy, procedures, and lines of communication with the warfighters.

Potential Solutions

Joint Live Fire Efforts

Improved Local Accelerative Loading Measurement Techniques
The Accelerative Loading Measurement Techniques effort is aimed at improving our ability to accurately measure the shock loading experienced in underbody blast events. To this end, continued concept gauge R&D, further refinement of a gauge performance characterization protocol and characterization of current live-fire instrumentation will all be completed under the effort, resulting in determination of those gauges best suited for capturing acceleration in the blast environments well as a user's guide to educate testers on pros/cons of different measurement devices in specific usage conditions.

Underbody Vulnerability Map
This Underbody Vulnerability Map effort complements the PM, USMC- JLTV Program Office blast modeling and simulation effort by providing a vulnerability assessment methodology (for both structural failure and risk to occupant injury). The methodology for developing and reporting vehicle blast performance in a vulnerability map scenario may be utilized by other vehicle programs to inform future design trades as well as future testing and vehicle employment.

ONR Efforts

Multi-DOF Rollover-Impact-Blast Effects Simulator
Develop the capability of simulating crew response to an underbody blast in a laboratory setting without the use of explosives and capturing complex local structural motion by novel fixturing developed through modeling and simulation.

4.2.2 Mobility

The Challenge

The Marine Corps is organized on the concept of Expeditionary Maneuver Warfare and relies on tactical flexibility and agility to project strength against critical targets. The mobility of its fighting force is therefore of utmost importance. The challenge is to find an affordable balance of payload, protection, and performance that maximizes the effectiveness of USMC vehicles.

Potential Solutions

ONR Efforts

ACV High Water Speed Parameter Setting Study
Determine the bounds of physics for the three ACV High Water Speed lanes.

Amphibious Swarming Vessel
Analyze potential mission sets and payload modules. Determine system parameters and desired performance capabilities.

Anhedral Foils (Halobates II)
The overarching objective is to demonstrate the feasibility of using composite anhedral cantilevered hydrofoils with wingtip electric motors to propel very heavy combat vehicles at up to 30 knots in the sea with a fraction of the power previously envisioned.

Armored Reconnaissance Vehicle (ARV)
Plan, initiate, execute, and manage a robust S&T program to research revolutionary technologies and demonstrate the realm of the possible for the next generation Armored Reconnaissance Vehicle

Configurable Terrain/Tire Interface
Develop a novel tire material that can adapt its 'footprint' or stiffness to different terrain conditions via stiffness change of a thermoplastic styrene based polymer around glass transition and phase change of low temperature Bi-alloys encapsulated in an elastomer matrix.

Dynamic Vehicle Center-of-Gravity and Gross Weight Estimation Using Readily Available Sensors
Poseidon Systems, in collaboration with Rochester Institute of Technology will develop and demonstrate a novel system for estimating vehicle gross weight and center-of-gravity (W&CG). The proposed system uses a set of low cost sensing elements in combination with physics-based kinematic relationships to determine W&CG of a vehicle platform. No vehicle-specific design information are utilized in the system allowing for deployment across a wide variety of platforms. The solution is minimally intrusive, low cost, and easy to deploy. Existing vehicle data buses are used to provide results for display to the vehicle operator.

Electrohydraulic Exoskeletons with Haptic Sensation Powered/Cooled by "Robot Blood"
Research novel energy storage approach where the electrolyte is distributed throughout the exoskeleton components in a human-like circulatory fashion

Extreme Power Internal Combustion (EPIC) Engine
Conduct feasibility studies, combustion M&S, and kinematic analyses of a Navy patented novel rotary internal combustion engine concept that affords high power and torque in a small, lightweight, and fuel-efficient package.

Fundamentals of Radiative Transfer Modeling of Complex Sediments with Variable Saturation Levels
A physics-based approach to retrieving geotechnical parameters from spectra to reduce the amount of empiricism that currently exist in the derivation of surficial sediment strength from hyperspectral imagery. This could lead to the development of fundamental radiative transfer theory-based tools that include models that relate the basic scattering and reflection properties of terrestrial materials as a function of material type, grain-size distribution, moisture content, plasticity limits, porosity, mineralogy, and other factors describing the complex and diverse nature of terrestrial materials.

Hydrofoil Assessment
The objective of this study is to establish the feasibility of developing a foilborne high water speed amphibious vehicle through the following:

(1) Utilize physics-based analytical methods and tools along with existing empirical data to assess the theoretical hydrodynamic resistance and powering performance of a foilborne high water speed amphibious vehicle.

(2) Determine the practicality of various hydrofoil configurations with a goal to minimize the propulsion required. While integration of the foils, in terms of retraction or handling during land operations will not be designed, subject matter expertise will be used to bound the realm of the possible with operationally relevant solutions.

Mobility Technology Analysis

The objective is to provide technical analysis support to ground and amphibious platform science and technology in the areas of mobility, cyber, and power & energy. Support cyber protection analysis for ground platforms, assist in technical design of new rotary engine concept, and develop performance specification for swarming amphibious craft.

Predictive/Adaptive Mobility (PAM)

Predict upcoming environment and terrain characteristics via on-board databases and remote sensors (UAVs, Stalleites, lead platforms, etc) and Intelligently adapt, in near-real time, Platform Mobility Dynamics Systems so as to optimize, Mobility, Agility, Safety, and provide just-in-time trafficability.

Trafficability and Mobility Analysis from Remote Sensing (TMARS)

Use remote sensing focused on terrain and soil characteristics to generate the mobility corridors from the Modified Combined Obstacle Overlay to improve maneuver planning in the littorals. Demonstrate relevance of UAS and satellite imagery to evaluating soil characteristics, extending database and models to cover broader operational environments, and correlating trafficability products to characteristics of vehicle classes.

Variable Stiffness Materials for Smart Tire Application

Develop a novel tire material that can adapt its 'footprint' or stiffness to different terrain conditions via stiffness change of a thermoplastic styrene based polymer around glass transition and phase change of low temperature Bi-alloys encapsulated in an elastomer matrix.

Vehicle Agnostic Modularity (VAM) - Virtual Framework - Phase II – III

Development of a multi-criteria/multi-objective optimization methodology for use within a dynamic simulation code to estimate system and subsystem benefits as well as the ability to predict effects of module-level design changes on system-level operational capabilities. Application of the developed methodology to assess the efficacy, benefits, and burdens of novel Modularity concepts within a realistic operational environment.

Unmanned Swarming Amphibious Assault Craft (USAAC) CONOPS and Performance Spec. Development

Analyze potential mission sets and payload modules. Determine system parameters and desired performance capabilities.

Unmanned Swarming Amphibious Assault Craft (USAAC) Conceptual Design and Technology Research

Concepts generation and whole system trade analyses.

USAAC/Quadski Autonomy Development

The objective of this study is for SSC PAC and NSWCCD to develop a baseline set of capabilities for use as an advanced technology demonstrator. NSWC CD will measure key capabilities, document vehicle attribute strengths and weaknesses, and to advise and educate USAAC project participants. NSWCCD personnel offer unique capabilities to the USAAC development team. NSWCCD will determine the safe operation of the vehicles based on operational testing and develop

materials for a classroom and infield review of the vehicles for autonomy performers. SSC PAC will develop a drive by wire kit for the Gibbs Quadski and install on each of the 10 procured vehicles. SSC PAC will also conduct exploratory autonomy investigation using stereovision and LIDAR based on previous ONR autonomy related efforts.

ONR/SBIR Efforts

Dynamic Vehicle Center-of-Gravity and Gross Weight Estimation Using Readily Available Sensors

Poseidon Systems, in collaboration with Rochester Institute of Technology will develop and demonstrate a novel system for estimating vehicle gross weight and center-of-gravity (W&CG). The proposed system uses a set of low cost sensing elements in combination with physics-based kinematic relationships to determine W&CG of a vehicle platform.

Low Complexity Suspension System for Amphibious Vehicles

An externally mounted suspension system with retraction capability is proposed that includes the use of compressible fluid to serve as both the spring and damping media to reduce shock loads, increase damping, reduce heat buildup, and improve reliability of system components.

Variable Vehicle Cone Index (VCI)

The objective is to develop sensor technology to provide a central tire inflation system (CTIS) with a real time view of the tire contact patch to dynamically optimization of vehicle cone index (VCI) for the MTVR

SBIR Efforts

Adaptive Hull Structures

The single biggest technical challenge in developing an amphibious vehicle with the required speed and range is this: the hull shape required for an effective land-mobile armored fighting vehicle produces too much hydrodynamic drag and too little buoyancy to achieve the speed and endurance required to support an over-the-horizon amphibious assault. However, innovative adaptive hull devices comprised of lightweight, relatively simple inflatable structures can overcome these shortcomings while avoiding the mechanical complexity that plagued the canceled EFV program.

High-Speed Amphibious Assault Vehicle Hull

To facilitate assault operations, the Marines need an amphibious vehicle that can quickly move troops and equipment between ships and the shore. However, due to an increased level of sophistication in the anti-ship weapons available to potential adversaries, Navy ships must remain far from shore during assault operations (i.e., many tens of miles). This creates a need for assault vehicles that can achieve high speed in the water. Current displacement hull-based assault vehicles do not provide the desired high-speed capability. The need that is addressed in this proposal is the development of an adaptive hull structure for amphibious assault vehicles that can achieve high speed. We have developed an innovative planning hull concept that also incorporates an adaptive propulsion system that meets the requirements for low-speed operation in shallow water and high-speed operation in deep water when in the planning mode. In Phase I of the project, the Creare team will develop its innovative hull concept by conducting computational fluid analysis and finite element analysis to validate the design concepts.

RIF Efforts

Buoyancy And Speed Enhancement - Inflatable Kit (BASE-IK), Navatek Ltd.

The project objective is to design and demonstrate a buoyancy kit for ACV 1.1 vehicle and to conduct at-sea tests to confirm performance improvement.

TARDEC Efforts

Active Suspension/Lightweight Track

TARDEC is developing an Advanced Running Gear as a system, consisting of an advanced External Suspension Unit (ESU) and Advanced

Lightweight Track (ALwT) system that will maximize weight reduction, improve vehicle durability and mobility and augment system survivability. The products will support PM CVP with additional support to the Bradley Family of Vehicles. Track and suspension technologies are historically developed as individual components leading to sub-optimal system performance. The Advanced Running Gear must be developed as an optimized system to achieve optimal performance and durability at minimal weight.

Advanced Lightweight Track (ALwT)
This effort aims to achieve low track system weight and high track system durability through new, novel designs and advanced elastomer materials.

Advanced Running Gear
Purpose: Develop external suspension and high capacity lightweight track system that will improve the vehicle mobility and survivability. The products will support PM CVP with potential to support other heavy tracked vehicle customers.

External Suspension Unit (ESU) System
The External Suspension Unit (ESU) System will provide flexibility for complex hull shaping to support survivability. Permit access to precious internal hull volume. Achieve superior off-road performance and reduced interior vibration through greater ground clearance, semi-active damping, and height management.

4.2.2.1 Crew Visibility

On the battlefield, any number of factors, both natural and manmade, can obscure the crew's ability to see. Despite the obstruction – darkness, smoke, or weather – the crew must maintain the ability to navigate, identify vehicles, maneuver, and sustain situational awareness. On the future battlefield, the enemy will have increased access to night vision devices, infrared surveillance, and other tools to pierce the fog of war; it will be crucial to maximize crew visibility to combat most potential obstructions.

The Challenge

Paramount importance is given to crew survivability but the cost, weight, and optical limits of transparent armor can burden vehicles with hindered visibility. Optimizing visibility without sacrificing the safety of the crew or imposing a heavy penalty on size, weight, power, and cost presents a significant technological challenge.

4.2.2.2 Corrosion

For the Marines who preserve and maintain thousands of pieces of ground equipment in often harsh saltwater environments, fighting corrosion is uniquely challenging. To face it, the Marine Corps has established an extensive corrosion-prevention program for all tactical ground equipment. The intent is to reduce maintenance requirements and costs through developing corrosion prevention and control products, materials, technologies, and processes.

The Challenge

The Marine Corps will identify and implement anti-corrosion technologies to extend the service-life of its existing fleet as well as reduce required maintenance, and prolong the operational viability of legacy systems.

4.2.2.3 Autonomy

Autonomy is a combat multiplier that has the potential to save live by reducing the Marine's exposure to high-risk tasks. Increasingly, unmanned ground vehicles (UGV) have been developed to work in concert with manned systems; the UGV augments the capability of the Marine and diverts manpower that would otherwise be required for logistics missions toward more tactical roles.

The preeminent value of the UGV is the standoff capability they afford to the Marine.

For that reason, they have found their niche in route clearance and counter-IED operations, dealing with such threats without putting anyone in the line of fire. In addition, autonomous vehicles can free up manpower from logistics missions, allowing human resources to be taken advantage of more efficiently.

The Challenge

The greatest struggle in the development of UGVs is balancing autonomy with vehicle performance. Current UGV's are not truly autonomous and need a remote human operator to maneuver quickly and navigate difficult terrain. Advancement in artificial intelligence, scene analysis, and similar developments will increasingly lighten the burden placed on the operator. The UGV of the future will be a 'man-in-the-loop' system where a human provides oversight to a vehicle that otherwise acts independently, or completely 'man-out-of-the-loop' system where the vehicle can act in complete absence of human input. This autonomous vehicle will need to capture many of the other S&T Focus areas, such as Mobility, making this challenge even more complex.

Potential Solutions

ONR Efforts

Air/Underwater Micro Drone

Develop the first unmanned aerial/submersible micro drone with swarm capabilities. Large number of these micro drones could be carried in small package and deployed from air/water/ground vehicles such as a four-wheeler jetski to overwhelm/neutralized targets by homing in RF or magnetic signals searching for mines or other threats.

Causal and Counterfactual Reasoning in an Attention-Driven Cognitive System

The proposed work seeks to substantially extend an existing computational model of perceptually-grounded human causal judgment to cases that involve simultaneous causes, causal over determination, pre-emption, and reasoning about chains of causal events. The outcome of our efforts will comprise the first cognitive process model capable of doing so and explicitly capable of making human performance predictions.

Cognition for UGV/Warfighter Teaming

The project will develop a cognitive framework to enable intelligent interaction between humans and unmanned autonomous systems. Its approach relies on developing algorithms to extend situational comprehension from real time sensor data without the need to translate objects and features into semantically identifiable symbols.

Collaborative Heterogeneous Autonomous Systems

The purpose of this work is to develop and demonstrate collaborative robotic behaviors involving multiple autonomous vehicle types including mixed teams of ground and air platforms.

Complex Scene Analysis

The approach will focus on merging bottom-up and top-down processes to move beyond pixel-level analysis and provide deep understanding of objects and relationships within a scene. The intent is to exploit vision-based systems to achieve enhanced automated perceptual understanding in a dynamic, complex environment, providing a sufficient level of comprehension to enable advanced autonomous navigation and develop tactically relevant behaviors.

Contextual Modeling and Spatiotemporal Reasoning for Autonomous Systems (CMSRAS)

In the context of a study on human-robot interaction, performer proposes a new cognitive theory that uses mental models to represent the communicated content and their integration. Approach will identify different types of models, which can then be used by a robot to decide how to respond (e.g., confirm an instruction, request a clarification) and,

when an unambiguous model is obtained, what tasks it should perform. Study supports context of a surveillance mission where the operator and robot perform as a team, and the robot is governed by a goal reasoning decision process. The environment will be dynamic and multiagent, presenting several challenges for decision making.

Coordinated Tactical Behaviors

This effort will develop, implement, and demonstrate multi-vehicle autonomy enabling multiple unmanned ground vehicles to perform collaborative behaviors in support of various expeditionary military mission (force resupply, convoy protection route reconnaissance).

Data Diver

The Data Diver collects depth measurements by resting at the surface of the water, recording its GPS coordinates and running its motors in reverse until it is pulled under and down. Once the vehicle detects that it cannot make further progress, because it has hit the bottom, it records the pressure value at that time and converts it to a depth. After the Data Diver has recorded the depth value, it stops running its motors and, due to its positive buoyancy, floats back to the surface. Back at the surface the vehicle uses its radio to broadcast the coordinates where it dove as well as the depth value it recorded.

Expeditionary Wingman Navigation

The Wingman concept envisions mobile autonomous systems that are fully integrated with small-unit Marine ground forces. Wingman will provide added operational capability, load bearing, and security for multiple mission profiles, environments, and conditions. The objective of this project is to develop and demonstrate advanced navigation and path-planning algorithms that will allow a robotic wingman to maintain position and pace with a dismounted squad while autonomously traversing complex terrain and obstacles.

Intelligent Autonomy Architectures

The intent of this project is to develop, mature, and advance an architectural framework for integrating technology components and subsystems of unmanned autonomous ground vehicles. It will facilitate the use of open, modular hardware and software development while fostering science and technology innovation, multi-developer participation, and interoperability.

ITV Autonomy Conversion - Autonomy Integration

Autonomy will facilitate transition, integration, and maturation of autonomous capabilities for a full system demonstration and LMUA of Autonomous Logistic Connecter Mission in FY16/FY17.

MARS: Deliberative Planning, Reactive Control, Low-level Control

The Johns Hopkins University Applied Physics Laboratory (JHU/APL) shall provide engineering and testing in support of the "Maneuver/ Deliberative Planner," "Reactive Control," and "Low-Level Control" technologies areas for the Forlorn Hope Program's Technology Area 1: Autonomy and Manned-Unmanned Teaming.

MARS: Localization and Spatial Orientation Sub-System Development

To enable autonomous amphibious mission operations, Charles River Analytics proposes to integrate multiple localization, sensing, and processing capabilities into a Localization and Perception module to support Autonomous Amphibious Robot Optimized Navigation (AARON). The AARON Localization and Perception module, which fits into the USAAC system architecture will provide state-of-the-art processing techniques to support effective localization in open water, through the sea-surf-shore interfaces, and inland in varied operating conditions, including day, night, fog, smoke, and precipitation. AARON will perform localization (both with and without GPS) onboard each vehicle using a variety of sensors

fused within a Robot Operating System (ROS) framework.

MARS: Perception and World Model Sub-System Development

The objective of this project is to engineer a system that models the environment via sensory input and provides mapping information, which aids in the autonomy of an amphibious vehicle. The final deliverable for this project is the World Model software stack that can be distributed across multiple unmanned amphibious vehicle fleets.

MARS: Sensor and Perception Sub-System Development

Leveraging substantial prior and ongoing development in land and maritime autonomy, and advancement of open, modular, and extensible appliqué autonomy solutions, the Neya Systems led team proposes to develop and demonstrate Swarming Multi-Modal Amphibious Robotic System (SMARS).With partners drawn from industry this effort will develop and deliver Perception and Wave Modeling modules as part of the sensing and computing hardware and autonomy software to transform an amphibious platform into an unmanned asset capable of performing diverse missions in concert with other manned and unmanned assets.

MARS: Systems Integration and Testing

SSC PAC is continuing development of the amphibious autonomy capability utilizing the Gibbs Quadski surrogate platforms. SSC PAC has demonstrated the baseline ground autonomy functioning properly on the quadski and has demonstrated basic on-water vehicle maneuver capability with the same architecture. A preliminary perception and inertial sensor data collection has been performed in the surfzone with 2-3' surf and that data is being analyzed. SSC PAC has drafted an initial strawman autonomy architecture for the USAAC/MARS program as a starting point when the contractors come on board.

Natural Interaction between UGV and Squad

The goal of this project is to develop and demonstrate technologies that will enable Marines to communicate with autonomous machines, and vice versa, using the same familiar methods commonly used to communicate with each other. Focus areas include: two-way voice communication, two-way visual sign usage, understanding of intent, implementation of rehearsed coordinated action, and machine interpretation of text, tactical graphics, maps, and overlays.

Natural Perception and Cognition

The objective of this project is to explore artificial means of replicating the cognitive and perceptual performance of biological systems in unmanned autonomous systems. The approach targets sensing and perceptual processing for knowledge acquisition and understanding.

Night Operations with Electro-Optical Perception System

The intent of the program is to enable autonomous Night Operations by developing and quantitatively demonstrating a low cost electro-optical perception system to perform stereo camera-based navigation during night operations and a localization solution (sensors + algorithms) with less than 1% error (2D) over 1hr in GPS-denied environments at 20mph.

Panoptes: Seek and We Shall Find

Design and implement a portable vision system for autonomous vehicles. This system is designed to take input from stereo cameras and 360° cameras and provide pixel-wise segmentation of the entire scene into one of multiple object classes. This system will also provide path-planning for autonomous vehicles to follow the road, avoid obstacles, and detect objects of interest in the scene.

Perception Under Adverse Conditions

This project will focus on developing and demonstrating advanced perception capabilities that will enable the continued operation of

autonomous systems when optical sensor performance is degraded by photonic absorption or scattering due to rain, snow, fog, smoke, dust, or visual obscurants.

Proteus: Adaptive Camouflage in Organoids

The overall goal of this ONR effort is to generate a material that can change its color and shape (in response to specific stimuli, but with a significant degree of autonomy), is self-healing, and is addressable. The effort also includes components dedicated to interrogating natural examples of such functionality, to understand the algorithms by which living organisms perceive, model, and control their own properties in a changing environment.

Q.E.D.: Demonstrate Value via Force-on-Force Simulation

The objective of this effort is to develop an adversarial tactical simulation test bed to identify concepts-of-employment for newly conceived autonomous systems, as well as the associated Science and Technology gaps.

Robust Traversability in Complex Terrains

Demonstrate that a path planner that uses high-fidelity terrain, kinodynamic vehicle models, and nonholonomic trajectories will enable navigation to be 20% faster and with 25% less interventions through complex (3.5 RMS, Gxx(n)=9.2x10-1(n)-2.1) In cluttered environments (50% obstacle density with an average gap/vehicle width ratio of 1.3 for autonomous unmanned ground vehicles.

Scene Comprehension and Representation

This project builds on previous efforts to further develop and ultimately demonstrate advanced cognitive robotic perceptual capabilities. The objective is to create the ability for a machine to process streaming sensor data into actionable information and knowledge. The approach encompasses advances in scene comprehension, symbolic representation, attention allocation, anticipation, probabilistic expectation, contextual reasoning, learning, and adaptation.

Sensor Fusion for Robust Perception

Demonstrate a low-cost perception system ($10k-$20k) for an autonomous ITV-sized vehicle that can provide 20cm X/Y spatial resolution at ranges to 40 meters; surface normal data, classify environmental material with an accuracy > 75%; perform nighttime perception with a perception distance > 63% of daylight requirement.

Squad Level Tactical Behaviors

Autonomous robotic vehicles interacting with human teammates as part of an integrated squad will require the ability to perform tactical movements and behaviors that support the team's overall mission while enhancing its effectiveness. The objective of this project is to develop and demonstrate a functional set of tactically relevant responses and behaviors that will enable a robotic team member to perform mission-related tasks in concert with humans and in accordance with the squad's TTPs.

Supervision Denied Deep Learning

Autonomous vehicles need visual understanding of their environment for navigation and exploration. Military vehicles will encounter rural environments with unpaved roads and surprise obstacles. It is critical that the vehicle be aware of traversable obstacles, can follow unpaved roads, and monitor road conditions to prevent vehicle damage.

Deep neural networks excel at learning from large amounts of data, but generalize poorly to new datasets or environments. Even a slight departure from a network's training domain can cause it to make spurious predictions and significantly hurt its performance (Tzeng et al., 2017). We develop simultaneous pixel and feature level adaptive learning models which transfer information from the prevalent and annotated urban road scenes to the rural scenes encountered in military operations.

Terrain and Object Perception

This effort will develop perception algorithms for recognition and representation of

operationally relevant objects and features in the environment. The approach will utilize multi-modal sensing, both passive and active, to enable discernment of specific features from within a complex dynamic environment, including: terrain and landscape features, roads/pathways, people, vehicles, structures, and other features to allow improved autonomous navigation, actions, intelligent decision-making, and behavioral learning.

Warfighter/UGV Team Intent Reasoning and Adaptation

This effort is motivated by the need for autonomous systems to make inferences and apply reasoning based on the dynamic information being continuously received from sensors observing the environment and specifically Warfighters with which the system is interacting. The project objective focuses the utilization of advanced perception capabilities to support reasoning about friendly and adversarial activities and intent in dynamic situations with evolving context.

Wave Prediction from a marsupial platform

Develop model of wave measurement effects on small vessels in the surf zone and hardware package to conduct wave measurements from small vessel requiring small footprint and low sensor height of eye while simultaneously enabling wave observations in extended region around vessel and minimizing sensor cost.

Wingman JCTD

The purpose is to develop an effective Lethal Unmanned Ground Vehicle System controlled by a Command and Control vehicle in close proximity and assess against a Scout Gunnery Table VI. The technical objective is to define and decrease the gap between autonomous vehicle control and required level of human interaction.

Payoff:

- Increased stand-off/Enhance the reach of the Warfighter.
- Demonstrates operational benefits and risks of an autonomy-enabled direct fire platoon concept and mixed company formation.
- Assessment capabilities for future Remote weapon systems.
- Mitigates current gaps in robotic technology by utilizing soldier-in-the-loop situational awareness.

Wingman Platform and Mission Packages

The purpose of this project is to design and develop an autonomous test bed vehicle platform for use in testing, maturing, and demonstrating new autonomy-enabling technologies and payloads related to the wingman robotic squad member concept.

World Modeling and Tactical Path Planning

The program will Investigate the potential to extract higher level knowledge elements from World Model datasets using segmentation and clustering techniques to identify distinct regions, paths, and objects for use in advanced navigation and reasoning solutions

Unmanned Swarming Amphibious Assault Craft (USAAC) CONOPS and Performance Spec. Development

This project will determine system parameters and desired performance capabilities for potential mission sets and payload modules.

Unmanned Swarming Amphibious Assault Craft (USAAC) Conceptual Design and Technology Research

This effort will generate concepts and perform whole-system trade analyses.

RDECOM & TARDEC Efforts

Autonomous Ground Resupply

The program will develop and demonstrate an optimized distribution system to integrate new and emerging technologies across all operational and tactical supply movement operations.

Autonomous Robotics for Installation and Base Operations
The purpose of the program is to accelerate adoption of intelligent ground vehicle systems for military and commercial applications by linking technology with real-world operations in semi-controlled environments.

R2V2 - Tethered UAV
The purpose is to fulfill Army G3 capability gaps for development of an integrated ground and air platform capable of unmanned maneuver and unattended persistent surveillance and collection operations in order to mitigate enemy threats.

Payoff:

- A vehicle that increases Soldier survivability and increase battlefield situational awareness
- TARDEC leads future robotic development for the Army in support of the operating force
- Assists with determination of manned-unmanned teaming behaviors and operational tactics, techniques, and procedures for robotic integration in the army force structure

TORVICE
Purpose: US Army project with Australia DST-G to develop and test the control and protection of a robotic vehicle over intercontinental communications while in a contested environment by building into TARDEC's Robotic Technology Kernel (RTK) novel autonomous behaviors, electronic warfare (EW) resilience, and integration of real-time aircraft ISR imagery for situational awareness.

Outcome: The result is a matured autonomy kit that extends the reach of the Warfighter by improving robot robustness under challenging conditions and a template for deploying robots under EW. Furthermore, all realized capabilities become part of TARDEC's RTK, which feeds current and future Army robotics efforts, resulting in significant time and cost savings.

United States - United Kingdom Coalition Autonomous Resupply
Purpose: Accelerate, demonstrate and evaluate the [cost/mission] effective use of autonomous systems for coalition [UK/US] based Holistic Assured Autonomous Resupply (HAAR) to positively change the future conduct of military logistics

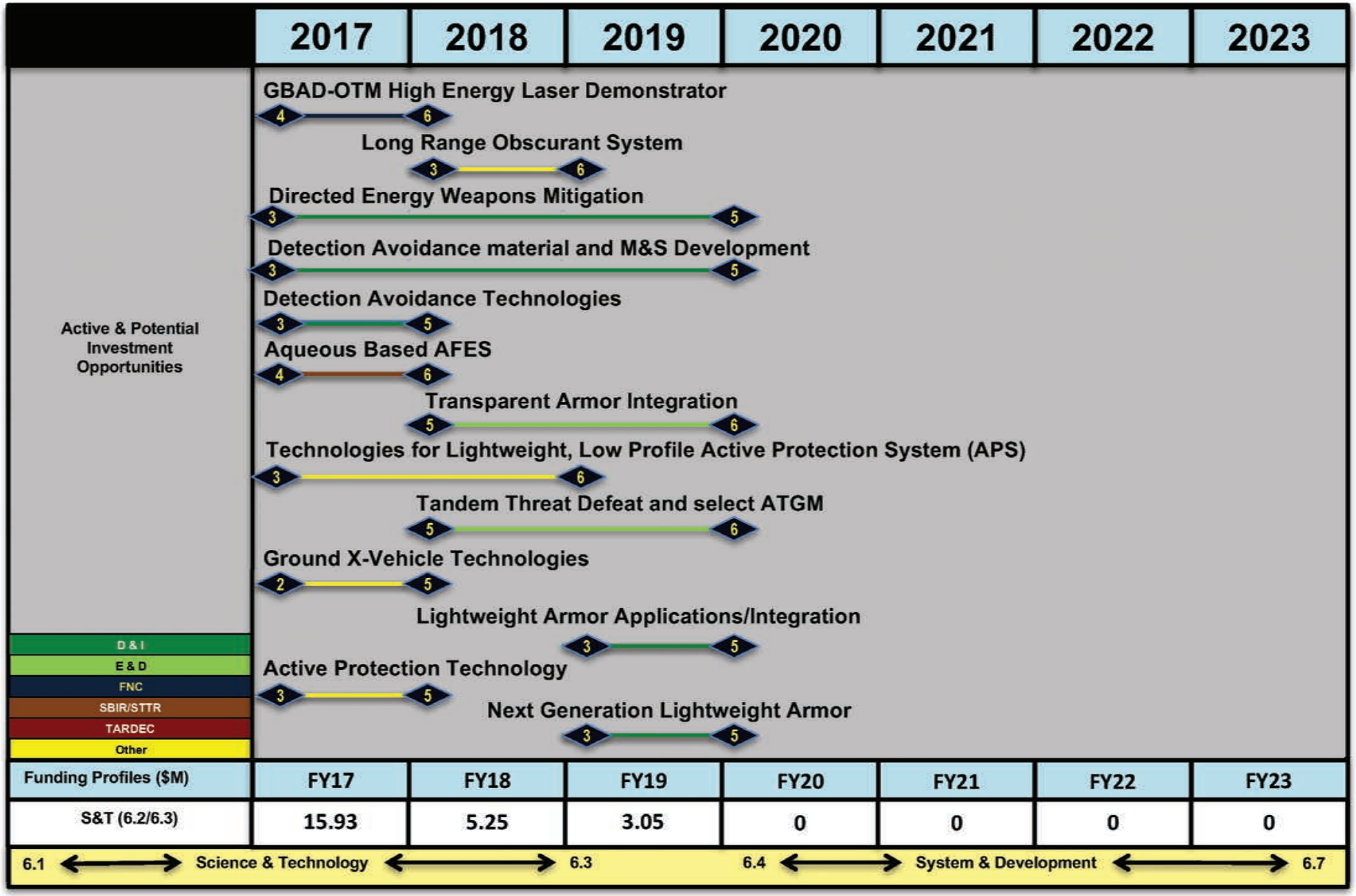
4.2.2.4 Weight Reduction

Weight reduction extends the reach of the Marine Corps vehicle fleet by improving fuel efficiency, increasing the ability to navigate harsh terrain, and enhancing maneuver from sea. Light-weighting results in a more agile and flexible fighting force.

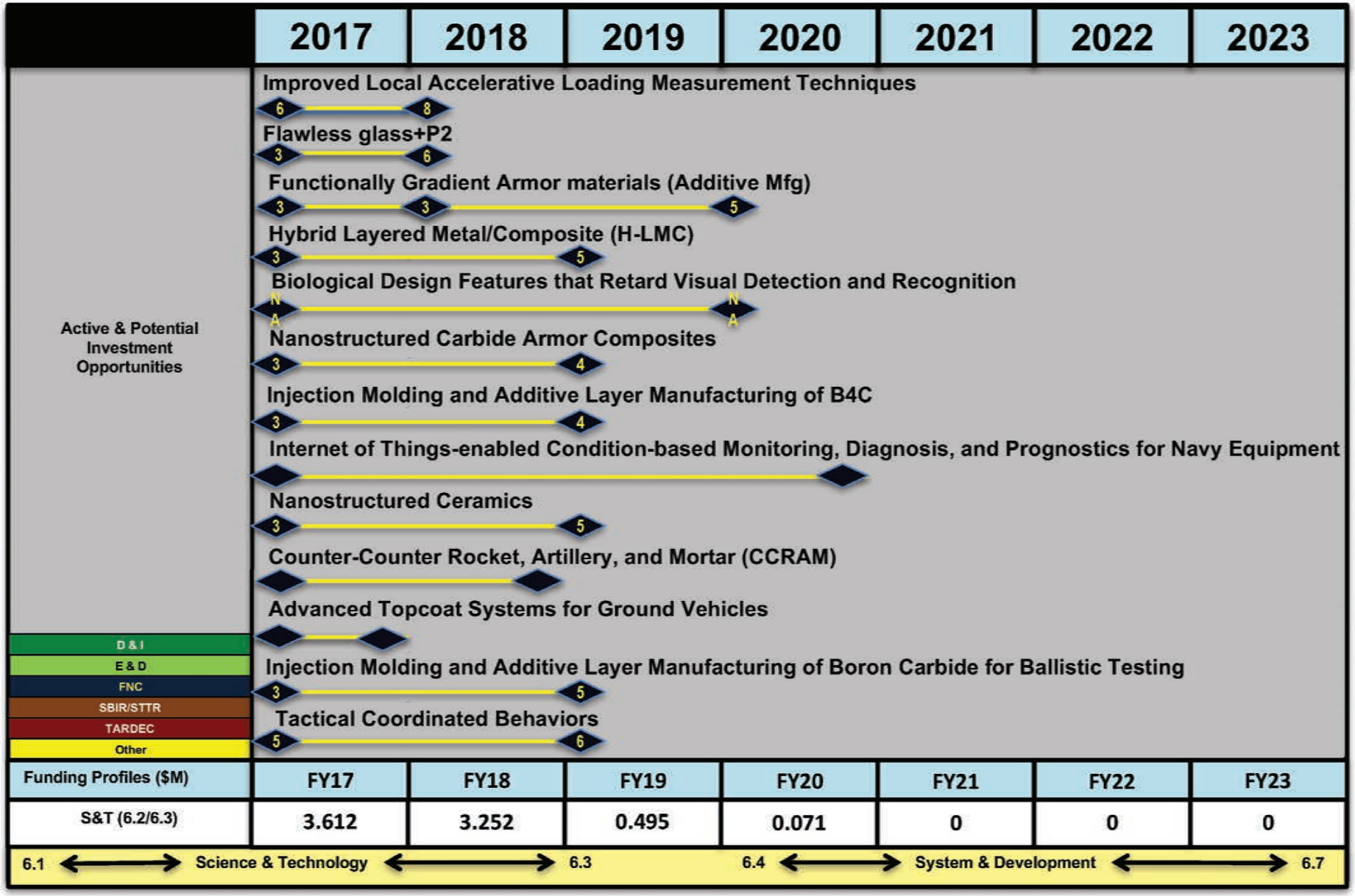
The Challenge

Marine Corps vehicles are designed to optimize efficiency, therefore there are a limited number of areas where weight can be reduced without losing critical functionality. Weight reduction measures must be affordable and cannot compromise the reliability of the vehicle or the survivability of its crew.

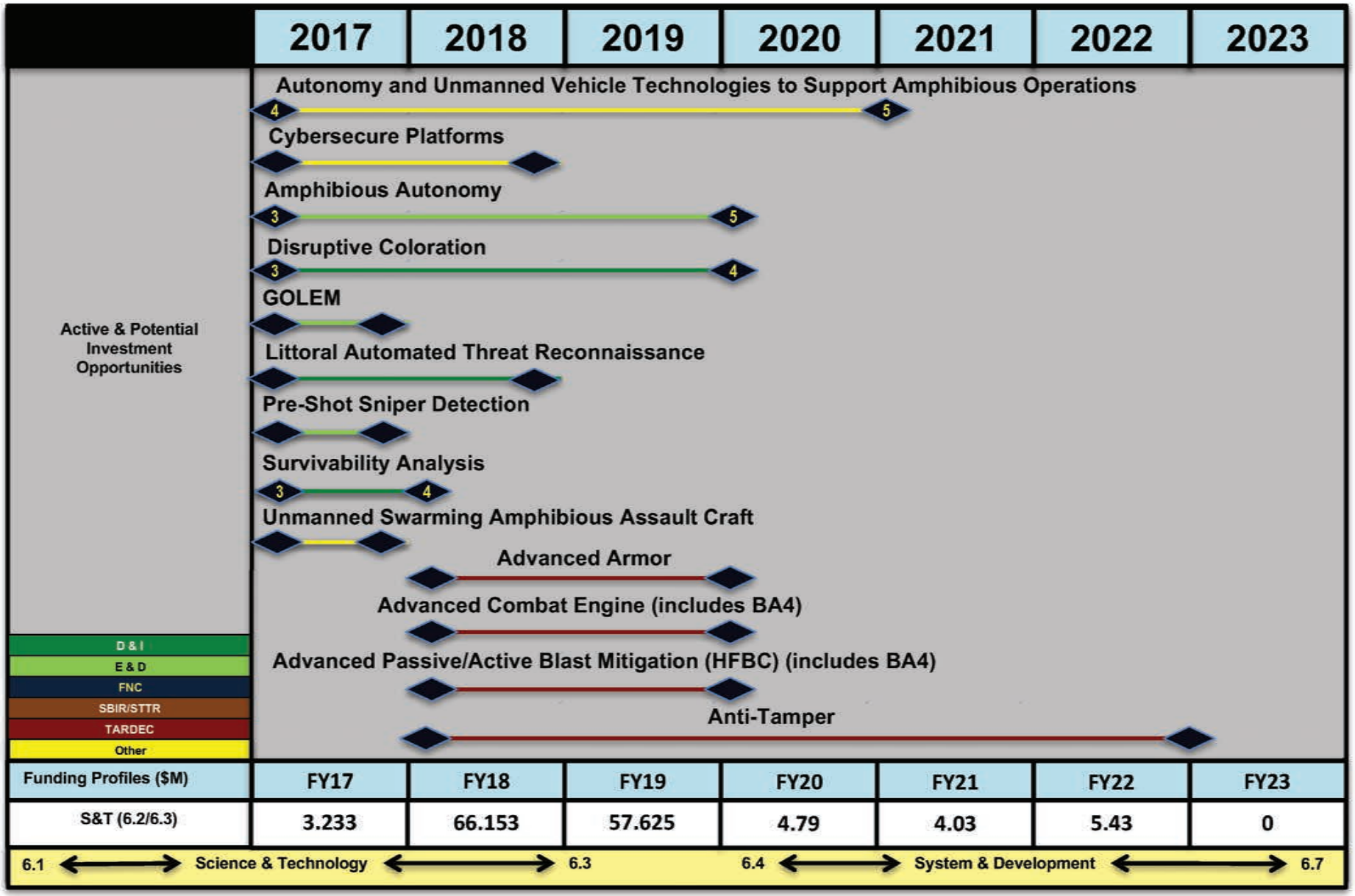
Survivability



Survivability



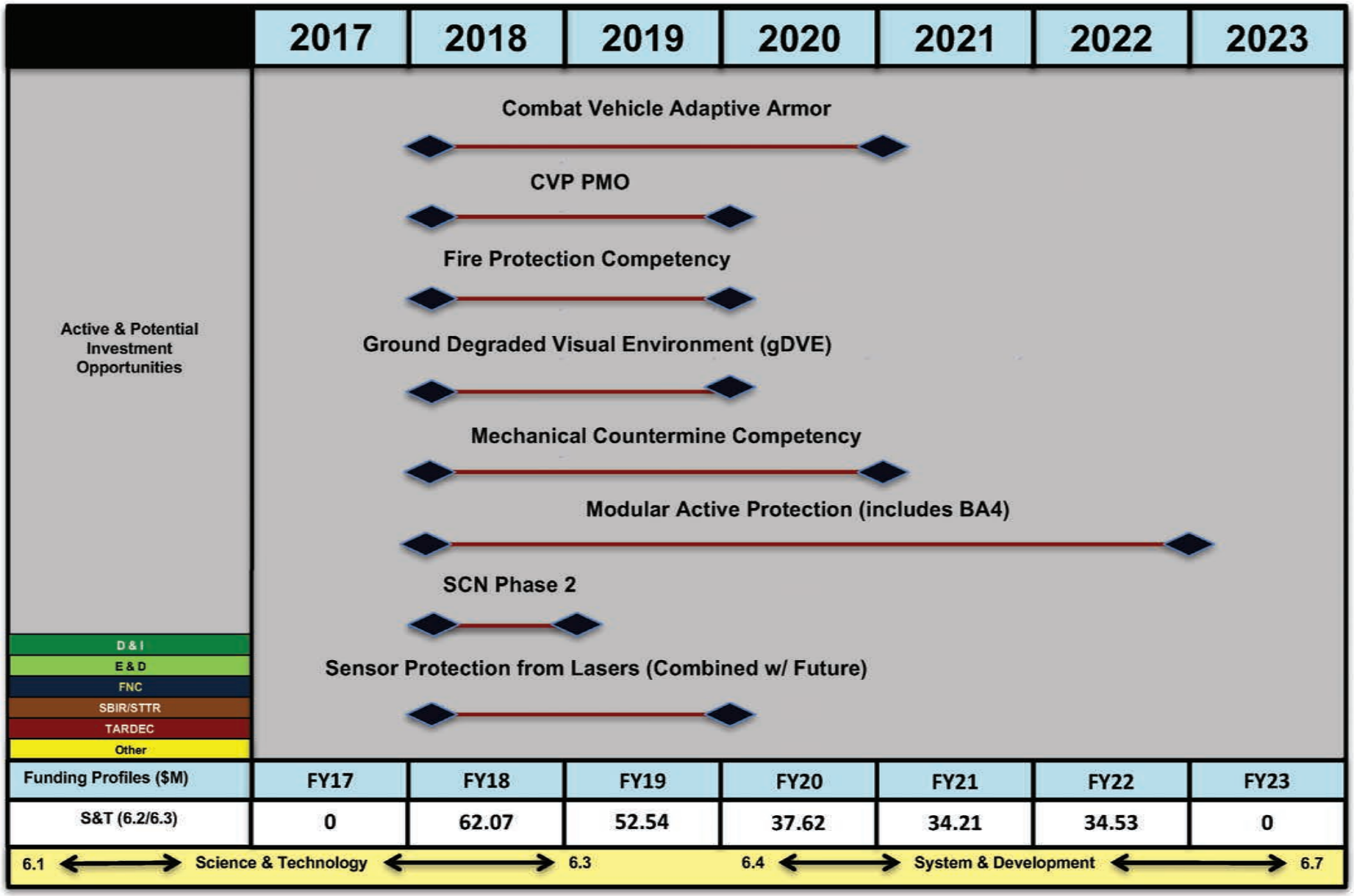
Survivability



Funding Profiles ($M)	FY17	FY18	FY19	FY20	FY21	FY22	FY23
S&T (6.2/6.3)	3.233	66.153	57.625	4.79	4.03	5.43	0

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

Survivability



Funding Profiles ($M)	FY17	FY18	FY19	FY20	FY21	FY22	FY23
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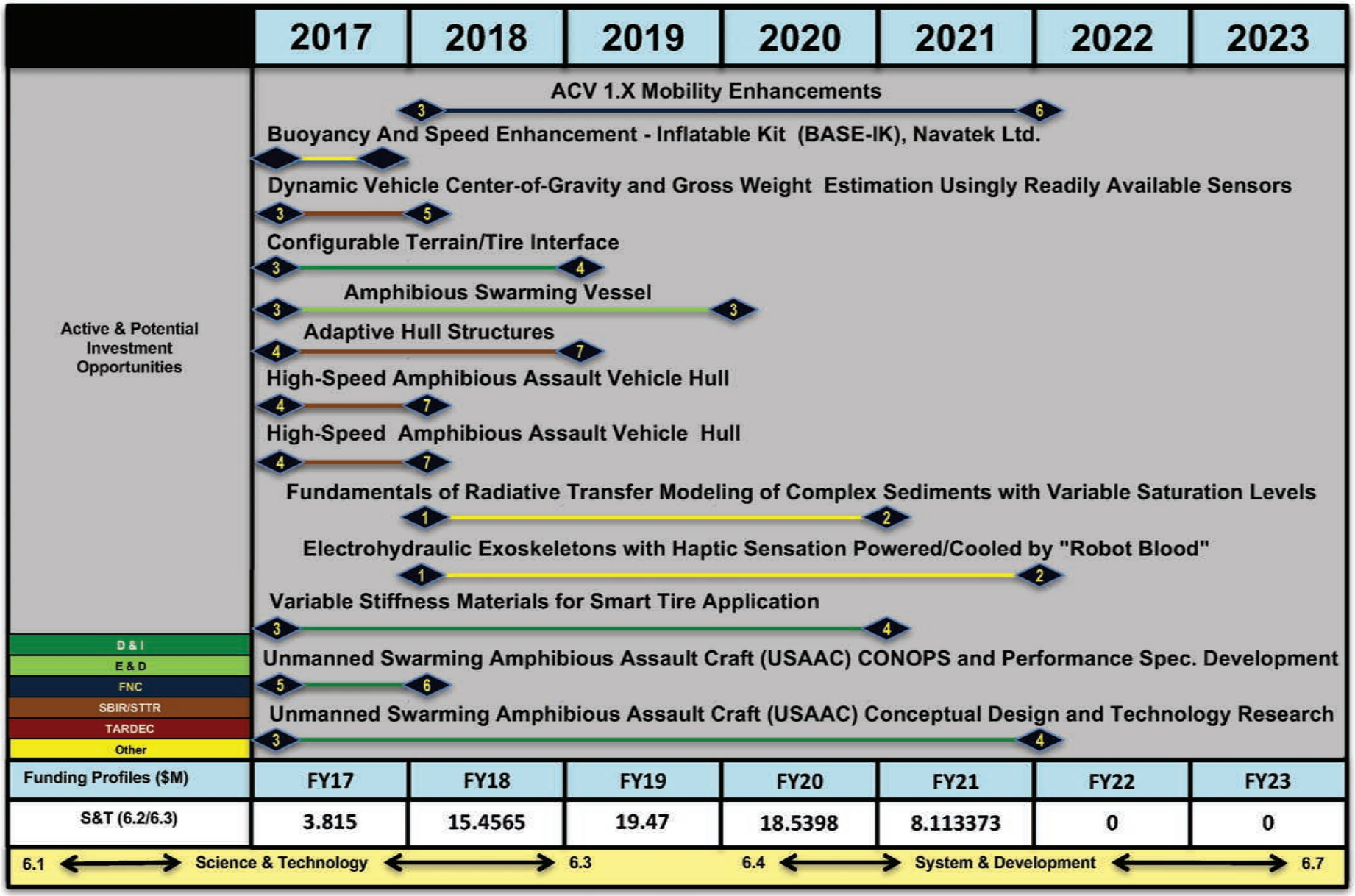
6.1 ⟷ Science & Technology ⟷ 6.3 6.4 ⟷ System & Development ⟷ 6.7

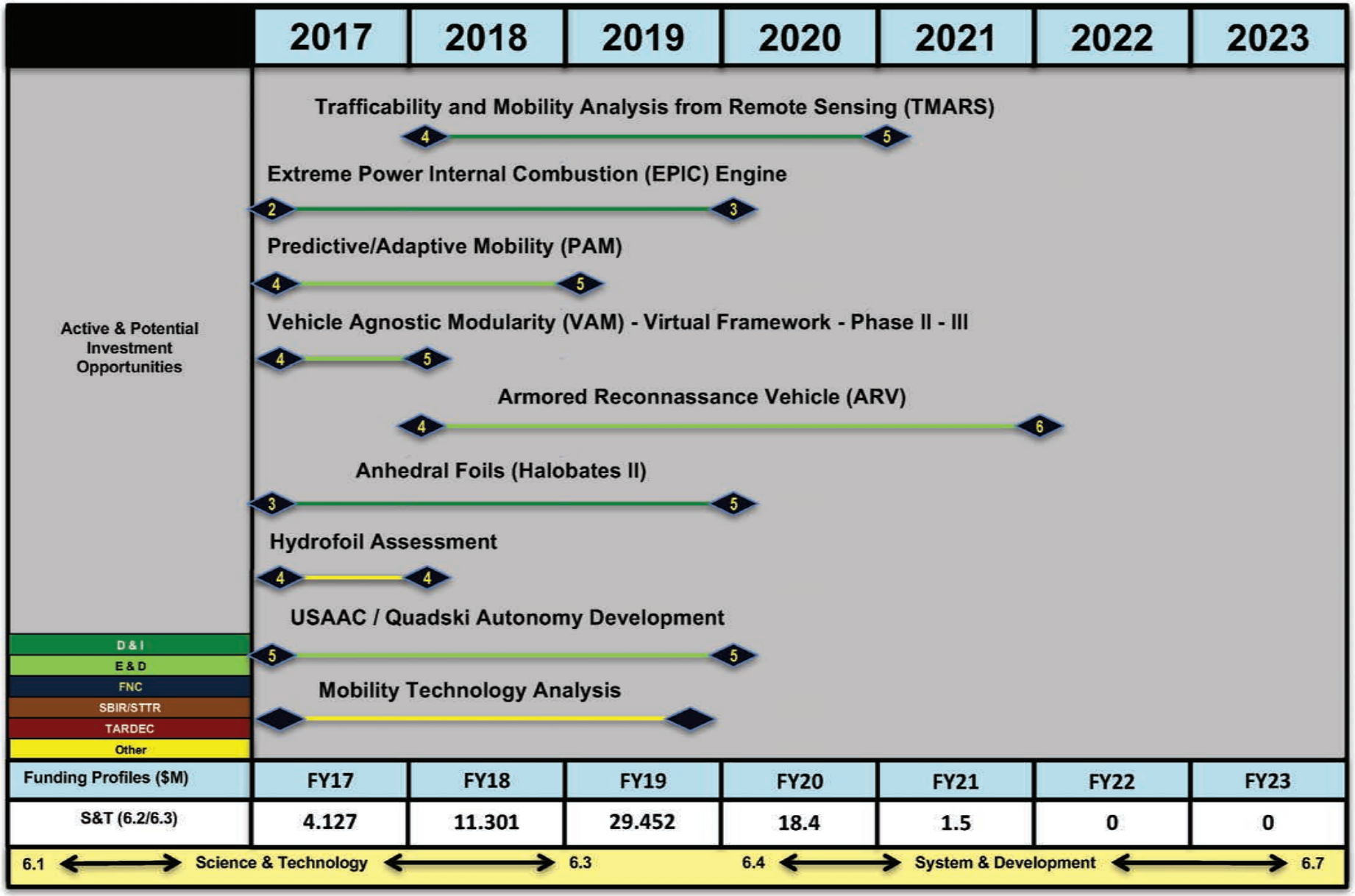
Mobility



Funding Profiles ($M)	FY17	FY18	FY19	FY20	FY21	FY22	FY23
S&T (6.2/6.3)	3.815	15.4565	19.47	18.5398	8.113373	0	0

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

Mobility



Funding Profiles ($M)	FY17	FY18	FY19	FY20	FY21	FY22	FY23
S&T (6.2/6.3)	4.127	11.301	29.452	18.4	1.5	0	0

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