Revolutionary Research . . . Relevant Results

Preparing for the future….
Never forgetting the past!

Office of Naval Research Code 30
Thrust Area Willful Intents
FY12 - FY13

Autonomy TIA - Willful Intent

Current Capability:

- Remote control single purpose, dedicated platform; Line-of-Sight operations; all processing, manipulation and decisions made by operator

FY	Desired Capability	S&T Challenge	S&T Solution
Near Term FY12-FY17	• Transition from UGS teleoperation to autonomous logistics connector UGS with follow-me/come-to/go-to and independent path planning functionality with doctrinally correct behavior • Navigate trafficable on/off-road terrain • Enhanced human-robot interface that builds warfighter trust through more natural interactions and ability to effectively explain its decisions • Effective operations day and night and in GPS-denied environments	• Relative localization accuracy to within 1% of distance traveled (10m error over 1km) • Extracting high fidelity information from low cost sensor suites ($10-20K) – Positive obstacle detection at 50m at 40mph, negative OD at 15m at 20mph • High computational burden associated with current perception systems (particularly vision-based) • Current visual sensors have limited dynamic range which limits the range of lighting conditions in which they are useful • Ability to adapt to rapidly changing conditions and missions • Ability to detect and accurately reference external landmarks to determine an absolute position in the absence of GPS	• Integrate visual odometry into the dead-reckoning/low-cost IMU pose estimation solution • Spectral and textural terrain classifiers for passive vision sensors. Fusing multi-modal sensor data at the lowest level. Use of new low-cost multi-return lidar. • Distributing processing and use of specialized computational architectures (GPU, FPGA, OMPA) • Dynamically controlled and optimized illumination arrays • Use of cognitive architectures to add reasoning to the system • Correlation of off-board (aerial imagery, terrain elevation data, celestial) a priori data to on-board sensor data
Mid Term FY17-FY22	• Transition from autonomous logistic connector UGS to close operations with dismounts • Autonomous “Wingman” capable of human-like performance • In stride support of USMC rifle squads to include tactical decision making while in enemy contact • Set-it and forget-it enhanced mission planning tools • Advanced perception of individual humans, urban environments/rules, and effective operations under difficult weather conditions • UAS/UGS coordination in support of logistics connector and wingman missions	• Relative localization accuracy to within 0.1% of distance traveled (1m error over 1km) • Developing algorithms that produce a wider range of robust and tactically appropriate behaviors • Interfaces for warfighter interaction with autonomous systems that allow natural interaction and ability to work in close quarters • Understanding meaning and semantics from COTs cameras and low-cost lidars • Perception that is robust in poor weather and environments with dust and other obscurants	• Integrate lidar-based odometry with visual odometry with the dead-reckoning/low-cost IUM pose estimation solution • Machine-based coding techniques • Gesture and natural language interfaces using cognitive architecture for context • Context-based reasoning and feature-based classifiers • Use of raw data from automotive radar
Far Term FY22-FY27	• Transition to fully autonomous multiple-role platform with independent and cooperative decision making • Self-sustaining, integrated man/machine system-of-systems • Enhanced mission planning tools	• Inability for UGS to team naturally with Warfighters and instill trust in autonomy • Inability to weigh and integrate various perceptual input from multiple agents to form common situation awareness • Inability for a UGS to reason about what is known and unknown (meta-level reasoning) and to create its own independent goals within limits of ROEs and mission	• Peer-to-peer mixed initiative planning • Artificial intelligence for doctrinally complex independent missions • Meta-level cognitive reasoning algorithms

Endstate:

- Adaptable, robust, warfighter-focused, autonomy and intelligent behavior models that reduce warfighter workload and increase warfighter trust.

Mobility TIA – Willful Intent

Current Capability:

- Limited/degraded mobility, payload, and ride quality performance of vehicle platforms due to up-armoring
- Reduced safety and increased rollover incidents due to platform instability while operating on challenging terrain
- Vehicles designed with little or no consideration to fuel efficiency
- On-Board Vehicle Power (OBVP) requirements exceed limits of vehicle belt driven alternators
- No ABS, Stability Control, or other chassis control technology currently incorporated in Marine Corps vehicles

FY	Desired Capability	S&T Challenge	S&T Solution
Near Term **FY12-FY16**	• Reduce Fuel Consumption (by 25 %) • Increase Power Density • Increase Vehicle Agility	• Control Injection timing , spray atomization, penetration, charge shape to maximize engine power and fuel efficiency. • Wider gear ratio and ranges with reduced gear and friction losses to increase transmission efficiencies. • Reduce loads and increase accessory drive efficiency (at least 20%) • Improve Driveline efficiency (at least 10%) • Develop high efficiency (at least 10%) cooling systems for higher output engines. • Increase the installed powertrain density (engine transmission and cooling). • Interactive vehicle controls to improve vehicle mobility capabilities.	• Fast acting/low hysteresis high power injector solenoids with novel nozzle plate configuration (hole diameter, shape, spacing and angle) and control strategies. • Obtain real time combustion information to control cylinder pressure rise with control algorithms to detect mass fraction burn rates and minimum best timing MBT (Combustion Quality SBIR). • COTS Engine JP8 fuel optimization. • High efficiency 32 speed (forward and reverse) binary logic transmissions and control strategies for greater transmission efficiency (92%) with greater torque carrying capacity. • Variator for existing hydrostatic transmissions to increase efficiency and performance. • Decrease parasitic losses due to pump and torque converter inefficiency , and reduce friction losses (materials, finishes, coatings and lubricants). • High efficiency PTO planetary gear drive and controls (SBIR). • Electrification of accessory drives (SBIR). • High power density final drive to increase horsepower and torque carrying capacity, reduce friction through materials, finishes, coatings and lubrication, reduce weight and installed volumes (SBIR). • Micro channel radiator using light weight materials with high heat transfer coefficients. • Higher operating temperature radiators • Low heat rejection engines & transmissions with lower cooling burden. • High efficiency multi speed fan drives. • Efficient Powertrain Technology to integrate latest COTS engine and transmissions. • Next generation high power density low heat rejection (single module) combat engine research (3.0 hp/ft3 to 6.0 hp/ft3). • Reduce lag and increase range and efficiency of turbo machinery using novel drive systems (SBIR). • Integrated chassis control algorithms to coordinate the actions of the vehicle dynamic control systems.

Mobility TIA – Willful Intent Continued

FY	Desired Capability	S&T Challenge	S&T Solution
Mid Term **FY16-FY19**	• Increase fuel efficiency by 40% • Demonstrate multiple active chassis control systems on a single platform with increased off-road stability and payload capability • Provide 40kW power on the move, and silent watch capability • Develop and demonstrate integrated electric power and propulsion system • Demonstrate the use of multifuel capability / and thermal reduction	• Develop combustion quality sensor and control algorithms to allow for military fuel compatibility. • Decrease accessory power consumption through development of high efficiency drive mechanisms. • Hybridization (series/parallel) • Battery development • High power electronics • Develop high efficiency cooling systems for higher output engines • Waste heat recovery • Development of high temperature materials and coatings to allow higher engine operating temperatures and improved thermal efficiency • Efficient electrical power generation • Development of new high efficiency transmissions with wider gear ratio and spread with control algorithms. • Development of designs and technologies with which to lower heat rejection.	• Advance suspension actuation, torque vectoring, and chassis control technologies, increased tire/terrain traction • Efficient Powertrain integration (engine & transmission) • Independent Laboratory In House Research (ILIR) Combustion and JP* research • Next Generation Combat engine development • High Operating Temperature High Engine Density (HOTHED) development • Advanced Binary Logic Transmission (SAPA and KERTRAIN) development. • University and private industry combustion optimization studies. • Increase electrical power to 40kw
Far Term **FY19-FY23**	• Increase fuel efficiency by 50% of current tactical vehicles • Reduce occupant absorbed power and shock inputs to the platform structure • Provide fuel efficiency by minimizing energy losses at the tire-terrain impact zone. • Increase tactical vehicle speed over all terrain • Provide power for active protection and other projected energy applications	• Development of designs and technologies with which to improve thermal efficiency. • Development of new engine technologies with optimized combustion chamber design. • Investigation and development of new fuel delivery systems for next generation of military engine technologies. • Development of next generation electronic engine controls. • Investigation and development of novel high power density engine designs. • Development of designs and technologies with which to lower heat rejection. • Waste Heat Recovery • Development of designs and technologies with which to efficiently transfer heat ,lower cooling system burden and improve efficiency. • Powertrain space claim • Vehicle weight	• Embedded sensors to measure terrain, suspension forces and response, including wheel spin rate and drive torque, vertical strain, rate and position, twist strain, rate and position, and tire pressure • University and private industry tribology studies • High temperature low friction materials development • Light weight aluminum metal matrix composite material development and engine component application. • University and private industry combustion optimization studies • HOTHED engine development • Increase electrical power to 60kw

Endstate:

- Maximize mobility, stability, payload capability, fuel efficiency, safety, and export power capability of Marine Corps vehicles through incorporation of power generation, conversion, and advanced suspension and chassis control technologies. Investment will increase operational tempo and significantly reduce the MAGTF footprint.

Survivability TIA – Willful Intent

Current Capability:

- Defeat heavy machine gun threats with light armor technologies at mass efficiencies (Em) of 2.5 relative to Rolled Homogenous Armor (RHA) steel
- Defeat of predominant Rocket Propelled Grenade (RPG) fuse type at the threshold requirements using passive & pulsed power technologies
- Protect occupants against centerline underbody events with a probability of less than 10% Abbreviated Injury Scale (AIS) level 2 against XX threat and is platform dependent

	FY	Desired Capability	S&T Challenge	S&T Solution
Detection Avoidance	**Near Term FY12-FY16**	• Low burden multispectral Signature Management (SM) appliqué for application to ground systems able to blend with local backgrounds	• Variable intensity lighting system for all daylight conditions dusk-to-dawn. • Visible patterning system to match color, texture & high contrast background • Thermal patterning system to match backgrounds day and night	• Variable lighting system to eliminate shadows for back-lit systems from dusk-to-dawn • Visible system able to match texture, color & contrast of local background @< 50 mW/m^2 • Thermal Management system with $\Delta T \leq 0.5^{o}C$ from ambient temperature
Detection Avoidance	**Mid Term FY16-FY19**	• SM system that matches background when viewed from quartering angles	• Multispectral SM system that displays proper background when viewed from normal & off normal angles. • Control system to manipulate display to match backgrounds for off-normal viewing.	• Display technology that provides normal and +/- 45° angle patterns simultaneously • Control software to blend display patterns for all angles.
Detection Avoidance	**Far Term FY19-FY23**	• Fully 360 degree SM system integrated into operational ground systems for on-the-move	• Multispectral SM system with independently controlled surfaces to match backgrounds while on-the-move	• Control software and display system to continuously match backgrounds when viewed from all angles while on-the-move
Active/Reactive Protection	**Near Term FY12-FY16**	• Defeat of all unitary warhead RPG threats using Low lethality Active Protection System (APS) or Electromagnetic Armor (EMA) countermeasures	• Lightweight, low burden, non lethal, technology able to defeat all RPG fuse types with high percentage of success	• Lightweight countermeasure of <10 lbs/square foot (psf) • Non-lethal defined as no injury at >10 ft from vehicle • Low power (<100KJ) appliqué systems • System success rate $\geq$ 75%
Active/Reactive Protection	**Mid Term FY16-FY19**	• Low lethality system to defeat all unitary and tandem RPG threats and select ATGMs	• Defeat of all unitary and tandem RPG threats and select ATGMs with a common system architecture able to delineate threat type and countermeasure sequencing	• Lightweight countermeasure of <10 psf • Non-lethal defined as no injury >20ft from vehicle • Low power (<100 KJ)
Active/Reactive Protection	**Far Term FY19-FY23**	• Defeat of all RPG and ATGM threats and select KE threats	• Multiple countermeasure / single fire control system to defeat RPG (~300 m/s), ATGM (~300 m/s), and KE (~1.6 Km/s)	• A threat sensitive system that will employ the counter measure required to defeat that threat

Endstate:

- Maximize platform and crew survivability across the battlefield environment with investments in detection avoidance, lightweight armor, active protection systems, pulsed power protection systems, and shock mitigating seats while addressing payload, performance, and cost. Investment will significantly increase protection and save lives at dramatically reduced weight and cost.

Survivability TIA – Willful Intent Continued

Current Capability:

- Defeat heavy machine gun threats with light armor technologies at mass efficiencies (Em) of 2.5 relative to Rolled Homogenous Armor (RHA) steel
- Defeat of predominant Rocket Propelled Grenade (RPG) fuse type at the threshold requirements using passive & pulsed power technologies
- Protect occupants against centerline underbody events with a probability of less than 10% Abbreviated Injury Scale (AIS) level 2 against XX threat and is platform dependent

	FY	Desired Capability	S&T Challenge	S&T Solution
Lightweight Armor Materials	**Near Term FY12-FY16**	• Light armor Em $\geq$ 3.0 at 30% less cost compared to today's technology	• Isolate and evaluate the effect of material properties to determine effect on armor performance (e.g., ceramic hardness, yield and fracture toughness; and composite yield, elongation, and stiffness)	• Develop and validate ceramic/composite armor performance, properties-based design equations for Armor Piercing and Fragment threats.
	Mid Term FY16-FY19	• Light armor Em > 3.5 at 30% less cost compared to today's technology	• Expand and validate armor performance design equations to novel/new light armor systems • Develop a methodology to determine material and system fabrication costs	• Expand armor performance design equations to include novel/new ceramic/composite light armor solutions to meet Em • Develop material processing techniques to meet the Em goals at reduced costs
	Far Term FY19-FY23	• Structural light armor Em > 5.0 at 30% less cost compared to today's technology	• Lightweight cost effective structural armor systems to meet the Em and cost goals	• Develop structural design equations for light armor systems that include ballistic, shock, and blast loadings and meet the light armor Em and cost goals
Crew Protection	**Near Term FY12-FY16**	• End-to-end M&S capability for vehicle mine blast events • Occupant protection against any axis of acceleration • Medically based measurable injury criteria for vehicle occupants that supports requirements, acquisition, and T&E communities	• Fully coupled end-to-end model verified, validated & accredited (VVA) to Live Fire Test (LFT) data • Isolate injury criteria from LFT and field data to design advanced crew protection systems and the test equipment to evaluate them • Identify gaps in injury criteria from the field and develop new criteria to fill gap	• Verify & validate applicable models that can be coupled into a robust end-to-end M&S tool • Ability to simulate/test any axis of acceleration to evaluate an occupant protection system • Valid set of injury criteria based on data from the field that can be correlated to Anthropomorphic Test Data readings and fills the gaps for Military application
	Mid Term FY16-FY19	• Mine/IED mitigation technologies for all IED types • Occupant protection systems to mitigate accelerations during mine/IED events with a probability < 10% AIS level 2 vs. XX threat (platform dependent)	• Develop passive & active systems to mitigate mine/IED structural damage from shock/acceleration/fragments • Develop design parameter set for "smart/active" protection systems that detect accelerations, restrain occupant and reduce acceleration to survivable levels	• Lightweight, low cost, passive and active integrated mine/IED shock, acceleration and fragmentation mitigation • Smart protection systems to protect vehicle occupants from any given acceleration angle
	Far Term FY19-FY23	• Occupant protection system to mitigate accelerations due to underbody events with a probability < 10% AIS level 2 against YY threat (platform independent)	• Technologies that conform to an occupant to provide the maximum protection for Mine/IED events	• Occupant protection systems that actively adjust to individual for maximum protection

Endstate:

- Maximize platform and crew survivability across the battlefield environment with investments in detection avoidance, lightweight armor, active protection systems, pulsed power protection systems, and shock mitigating seats while addressing payload, performance, and cost. Investment will significantly increase protection and save lives at dramatically reduced weight and cost.