U.S. ARMY TANK AUTOMOTIVE RESEARCH, DEVELOPMENT AND ENGINEERING CENTER

Robotics and Autonomous Systems (RAS)

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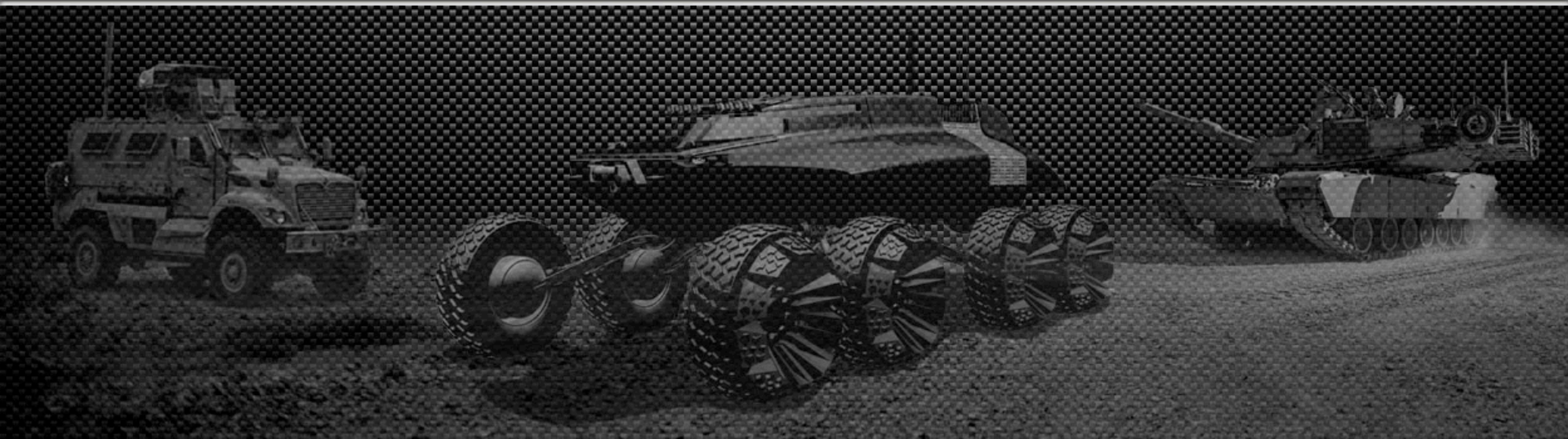
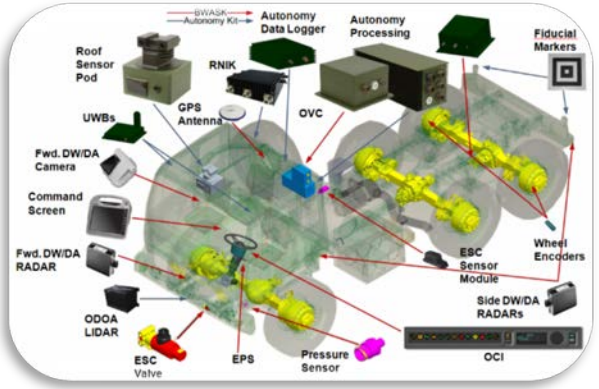
TARDEC Ground Vehicle Robotics



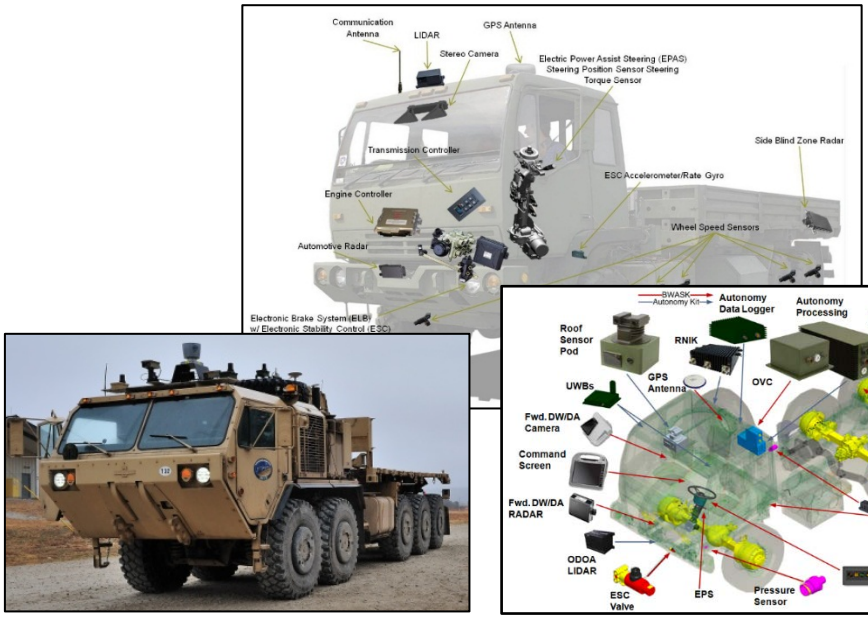
Outline

- Ground Vehicle Robotics & TARDEC
- Commercial vs. Military
- Connection to RAS Strategy
- Strategic Direction
- Enablers
- Current Efforts
- Discussion

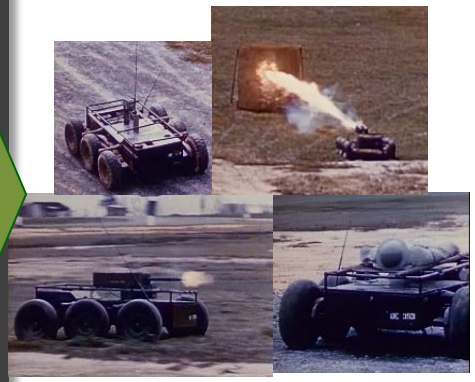


Ground Vehicle Robotics (GVR) Mission

Provide **Transition-Ready**, Cost-Effective, and Innovative **Robotics and Control System Solutions** for Manned, **Optionally-Manned, and Unmanned** Ground Vehicles driven by **War Fighter Requirements** through Advanced **Technology Research, Development, Experimentation** and **System Integration**



"Little David"
Circa 1950s



The Birthplace of Army Ground Robotics

RDECOM's Support to TRADOC and ACQUISITION

TRADOC / ARCIC

SHAPING FUTURE REQUIREMENTS
(Far Term)

- **Develop And Demonstrate Advanced Warfighting Capabilities**
- **Validate Operational Concepts with Analytical Engineering Capabilities**

PROVIDE NEW REQUIRED CAPABILITIES FOR CURRENT AND EMERGING SYSTEMS

***SUPPORT THE CURRENT* FLEET**
(Near Term)

- **Develop Technology Solutions**
- **Provide Engineering Support**

ACQUISITION & SUSTAINMENT

PEO GCS

PEO CS&CSS

MARCORSYSCOM

PEO Land Systems

ILSC

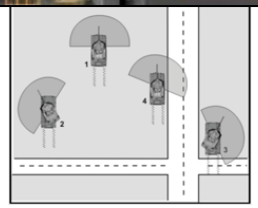
INDUSTRY

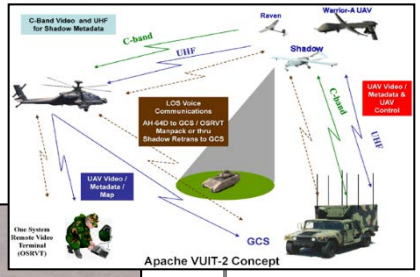
ADVANCED CAPABILITIES TO THE WARFIGHTER

Reduce the Burden
- Robotic follower
- Optionally-manned vehicles
- Logistics re-supply
- Mundane tasks

Mitigate Risk
- Capabilities for C-IED
- Capabilities for CBRNE
- Active Safety Technologies
- Pilot Decision Aides

Manned - Unmanned Teaming





Prevent Surprise
- Unmanned Wingman
- All-terrain Surveillance
- 360 Situational Awareness

Extend the Reach
- Single-user multi-robotic control
- UAV/UGV collaboration & control
- Extended range unmanned operations

"Operationalize" unmanned systems through Experimentation and CONOP Development

Challenges for Fielding Unmanned Vehicles

Cultural

- Trust and confidence issues related to autonomous behaviors
- Concern added UAS/UGV capability equates to force structure reduction
- Potential return on a robotic investment not realized

Moral

- Responsibilities associated with the unmanned application of force

Social

- Incurious nature (lack of curiosity in a machine)
- Lack of comfort for people to operate in close proximity to machines

Policy

- Who is responsible and liable for an autonomous asset?
- DOTMLPF-P

Technical

- Machine Intelligence, Perception, and Reasoning
- Human/Unmanned System Interaction & Collaboration
- Scalable Teaming of Autonomous Unmanned Systems
- Test & Evaluation and Verification & Validation

Need to Leverage Commercial Sector

Commercial Versus Military Comparison

	Commercial	Military
Understanding the Environment	■ Structured Environment ■ Potential for Vehicle-to-Vehicle and Vehicle-to-Infrastructure assistance ■ Benign, Permissive	■ Unstructured Environment ■ Minimal Command & Control Infrastructure ■ Adversarial & GPS Denied ■ Off-Road: Incl Jungle/Bldgs /SubT/MegC
Human/ Unmanned System Interaction & Collaboration	■ Consumer acceptance/trust ■ Affordability ■ Structured Environment ■ Accepted operator interface	■ Soldier trust ■ Affordability ■ Dynamic, Unstructured Environment ■ Current interfaces degrade normal conduct of operations
Scalable Teaming	■ Primarily individual vehicle systems or adjudication of multiple systems operating independently	■ Small unit teams including heterogeneous systems
Flexibl… Ad… Syst… Learn	…y and uniformity of …environment …nt for learning	■ Unknown and dynamic conditions creates necessity for learning

Testing and Experimentation Protocols Liability 101

Cheap rugged sensors, on-road visual solutions, Obstacle Detect, Warning, & Avoidance

Commercial: large numbers, structured env…
Military: smaller numbers, dynamic & high OP… …risk

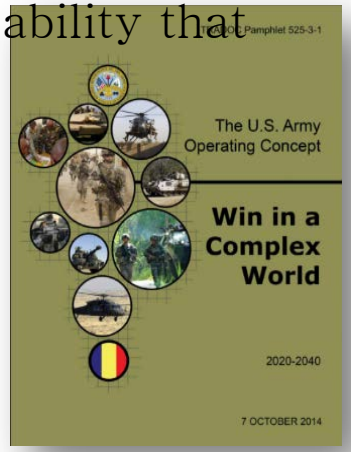
Why a Robotics and Autonomous Systems Strategy?

- TRADOC's 2014 Robotics Research Study confirmed the utility of Robotics and Autonomous Systems (RAS) systems based on 14 years of war; RAS platforms provide vital human stand-off from dull, dirty, and dangerous tasks

- Most RAS procured through contingency funding… to become an enduring capability, the Army must transition to programs of record

- The **Army Operating Concept** lists RAS as an enduring capability that will:

  - ✓ *Reduce risk to Soldiers and units*
  - ✓ *Provide opportunities for increased efficiencies*
  - ✓ *Provide differential advantages over U.S. adversaries*

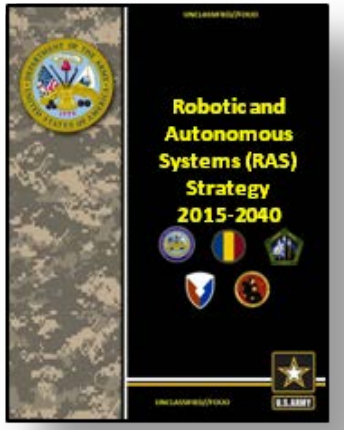


The Army is developing a strategy to deliver RAS capabilities, rather than an itemized list of things to purchase – taking a similar approach with the Combat Vehicle Modernization Strategy.

The Robotics and Autonomous Systems Strategy

Purpose:

- **Aligns** and prioritizes robotics and autonomous systems requirements across all formations
- **Describes** operational employment of RAS in Force 2025 and Beyond
- **Integrates** RAS as an increase in capability and a key to the Army's ***differential advantage*** **over adversaries**



Vision:

RAS capabilities for ***expeditionary maneuver*** with forces that can:

- See and fight across extended distances
- Share situational awareness and promote operational understanding across all echelons
- Operate widely dispersed while maintaining mutual support
- Gain and maintain contact with the enemy to set favorable battlefield conditions
- Sustain high tempo operations at the end of extended and contested lines of communication
- Establish and maintain security across wide areas and pose enemy forces with multiple dilemmas ***while reducing risk to Soldiers and units***

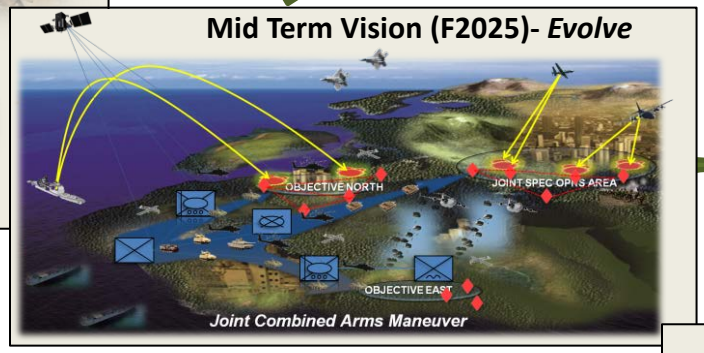
RAS must enable Army formations to retain overmatch, support expeditionary and joint combined arms maneuver, and enable Army forces to win in unified land operations

Framing the RAS Strategy in Three Phases

As the Army develops its Robotics and Autonomous Systems (RAS) Strategy seeks integration across multiple Warfighting Functions, the vision will show ***realistic capabilities*** in the **near term**, ***feasible capabilities*** in the **mid term,** and ***visionary capabilities*** for the **far term.** Each successive phase is linked and builds from the achievements of the previous phase.

Near Term Capabilities :

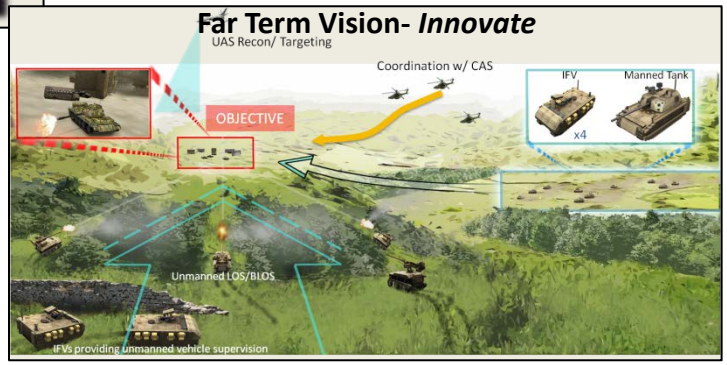
- *Leader Follower Convoy Technology Employment*
- *Lighten the Soldier load*
- *Enhance stand-off from threats and improve situational awareness*



Mid Term Capabilities :

- *Technologies improve the **autonomy** of unmanned systems*
- *Technologies will enable unmanned cargo delivery*
- *Robots act as a "team mates" rather than tools*
- *Micro autonomous air and ground systems will also enhance Platoon, Squad, and Soldier situational awareness.*

Source for All Listed Capabilities: **TRADOC Pam 525-3-1, *Army Operating Concept*, Appendix C-2.**



Far Term Capabilities :

*Technologies will **enable manned and unmanned teaming in both air and ground maneuver** through investments in scalable sensors, scalable teaming, **Soldier-robot communication**, and shared understanding through advancements in machine learning.*

Strategic Capability Progression

"Maturation, Integration, and Demonstration"

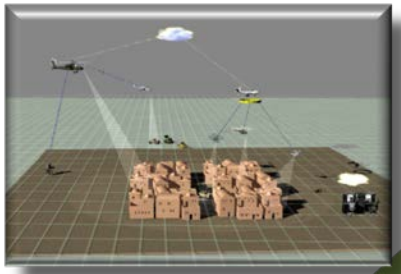
2015

Active Safety Driver Assist Appliqué Kits (2015)

2020

Extend the Reach of the Warfighter (2020)

Unmanned Air Systems Autonomy (2020)



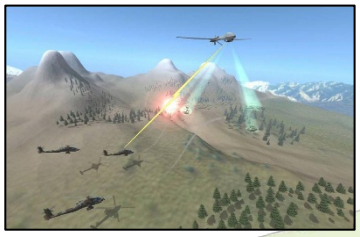
2030

Synergistic Unmanned-Manned Intelligent Teaming (SUMIT) (2020-2025)

Autonomous Convoy Operations (2020-2025)

2040

Dynamic Force & Mission Autonomy (2030-2040+)

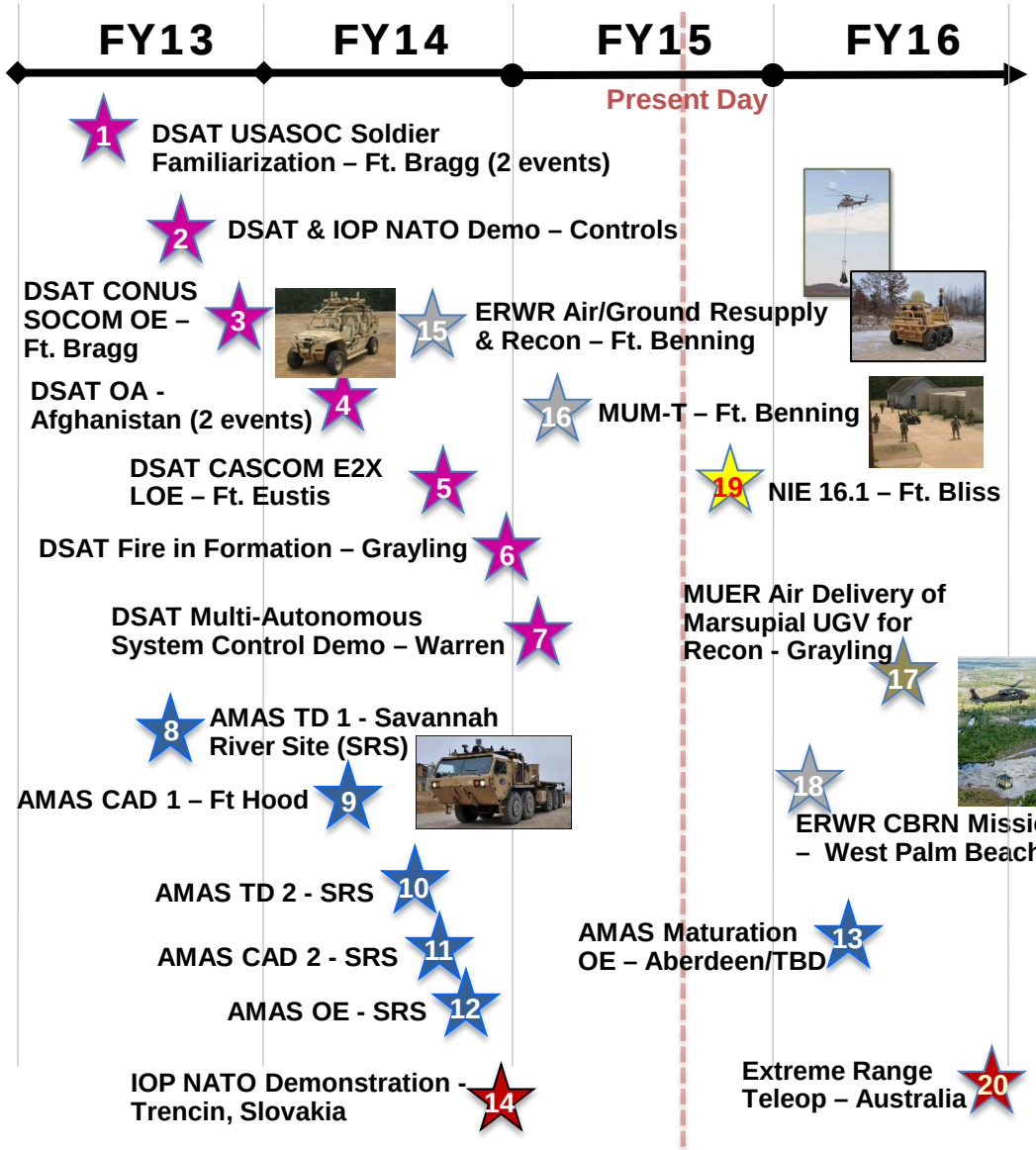


Combined Arms Maneuver (2030-2035)

Visualizing 2040: Autonomous Resupply

Increase throughput & tempo with autonomous systems

Sampling of Autonomy-Enabled System Capability Demonstrations



Capability Demonstration Purpose

(1) Familiarization of soldiers with DSAT technology for USASOC Soldiers.

(2) Demonstrate use of a common controller to interface multiple vehicles for verification of IOP validity.

(3) Demonstration of vehicle capabilities to SOCOM soldiers.

(4) Operational Assessment of DSAT capabilities in Afghanistan.

(5) Autonomous tactical resupply demonstration.

(6) Table VI scout/gunnery qualification demonstration with M240 armed (blanks, man-in-loop) autonomy-enabled system.

(7) Multi-vehicle control from a single operator control unit, extending the range via mesh networking.

(8) Engineering test on by-wire active safety kit.

(9) ARCIC requested demonstration for identifying the realm of possibilities for unmanned systems.

(10) Engineering test on autonomy kits.

(11) Demonstration of higher truck speeds.

(12) Provide vehicles to Soldiers & Marines for 8 weeks to use system in combat scenarios to determine if there is a military user assessment by COCOMS (CENTCOM and TRANSCOM).

(13) Soldier testing for driver warning/driver assist for M115.

(14) UGV Interoperability Profile demonstration at the NATO EOD CoE Demonstration and Trials Event.

(15) Demonstrate the added capability resultant from merging unmanned air and unmanned ground systems with long-distance control capabilities.

(16) Synchronized employment of Soldiers, manned and unmanned air and ground vehicles, robotics, and sensors to achieve enhanced situational understanding, greater lethality, and improved survivability.

(17) Perform an extended duration RSTA mission with an autonomous marsupial vehicle and small UGV's.

(18) Demonstrate the ability to perform a high-risk mission at long distances without placing the Warfighter in harms way.

(19) Technical integrator for TRADOC with MUM-T

(20) Demonstrate ability to conduct extreme range tele-op

Teaming Technology Development

Manned/Unmanned Teaming

- Scalable/Joint Open & Modular Framework
- Scalable Autonomous Capability
- Human Machine Teaming Technology
- Enhanced Geospatial Information
- Autonomous M&S Capability

Autonomous Ground Resupply & Autonomy/HMI/M&S Integration

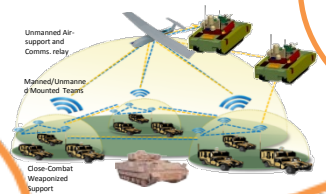
- Enhanced Robotic Convoy Technology
- Tactical Resupply
- Autonomous Material Handling Equipment
- Off-Road Autonomy
- Open & Modular Frameworks

UGV/UAS Teaming for logistic BCT

- Large UAS/UGV Collaboration
- Enhance Long Distance SA
- Improved Testing Procedures

Mounted Armed Wingman

- Mounted Tactical Behaviors
- Robotic Weaponization
- Networked Engagement



Robotic Weaponization

- Unmanned Vehicle & Wireless Weapon Integration and Testing
- UGV Launched directed weapons
- Requirement Informing Experiments


Assured PNT & Network Mission Command

- An assured PNT system that is scalable and configurable for autonomous platforms
- Tools, protocols and architecture for networked autonomous systems


Dismounted Squad UGV Maneuvers

- Dismounted Tactical Behaviors
- Network and Mission Command
- Human Dimension

Robotic Research & CTA's

- Perception, Learning & Reasoning
- Human-machine interaction
- Interaction with the physical environment
- Dexterous manipulation & unique mobility
- Micro Mechanics, Electronics and Processing

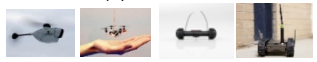
Expand influence through soldier-machine collaboration

Soldier use of Micro UGV/UAS

- Soldier Borne ISR
- Squad Organic Sensors
- Soldier Cognitive Science

Dismounted Soldier Deployed

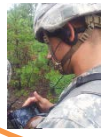
Integration with Soldier System Platform (Nett Warrior)



Micro Autonomous Robotics Advancements and Integration

Human Dimension

- Tactical Edge User Interface Concepts & Device Integration
- Cognitive Research and multi-modal displays/inputs
- Soldier and Squad In-The-Loop Interactive Assessments



Technology Dependencies and Relationships

Enabling Capabilities

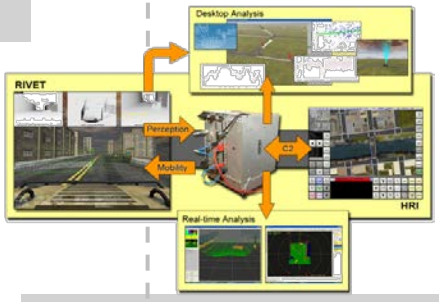
Pedestrian/Vehicle Detection, Classification, & Tracking

Dynamics of Distributed Role Allocation in Teams

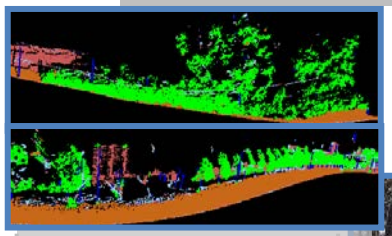
Autonomous Moving Object/Complex Terrain

Collaborating Socially, Organizationally & Culturally

Autonomous Complex Dexterous Manipulation



Modeling & Simulation



Terrain Classification Technologies

Faster movement and terrain feature mapping through real-time adaptive learning

Plan *Real-time Data* *Dynamic Re-Planning*

Interactively Understanding Situations, Contexts, and Activities

Secure, Robust, High Speed, Low Latency Network enabling collaboration and compliant weapon systems autonomy

Example Enabling Capabilities

Plan ***Real-time Data*** ***Dynamic Re-planning***

Interactively Understanding Situations, Contexts, and Activities

Example Enabling Capabilities

Plan ***Real-time Data*** ***Dynamic Re-planning***

Interactively Understanding Situat… Contexts, and Activities

… Can assist soldiers as well

Example Enabling Capabilities

Pedestrian/Vehicle Detection, Classification, & Tracking

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Faster movement and terrain feature mapping through real-time adaptive learning

Secure, Robust, High Speed, Low Latency Network enabling collaboration and compliant weapon systems autonomy

Autonomous Mobility Appliqué System (AMAS)

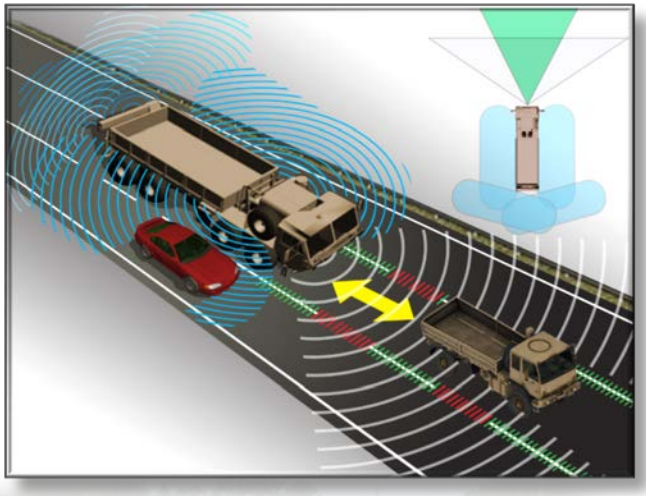
Purpose:

Provide tactical vehicles with an optionally manned capability to increase safety. AMAS develop, integrate, and demonstrate:

1. A vehicle-specific By-Wire/Active Safety kit to control the physical actuation of a vehicle.
2. A common, appliqué Autonomy kit that contains the primary intelligence and autonomous decision making. The Autonomy kit will function and inter-operate regardless of vehicle type.

Products:

- By-Wire Active Safety Kit: vehicle specific devices to retrofit current fleet
- Common Interfaces and Architecture
- Autonomous Testing Methodologies and Procedures



Payoff:

- Increased Operational Efficiency and Effectiveness
- Improved Situational Awareness
- Increased Driver Safety (reduce accidents/rollover avoidance)
- Improved Operations in no/limited visibility conditions

Dismounted Soldier Autonomy Tools (DSAT)

Purpose:

- Develop a suite of autonomy tools to enable dismounted soldiers to operate unmanned vehicles. Develop an open and extensible kernel for ground vehicle autonomy with Interoperability

Product(s):

- Operational and Performance Capabilities Summary
  - Fused Perception and World Model systems for advanced obstacle detection and avoidance
  - Optionally-manned Vehicles
    - Polaris MRZR
    - Jeep Rubicon
    - HMMWV
  - Multiple Modes of Operation
  - Advanced Communication
    - UWB low bandwidth C2
    - Rajant Radio higher bandwidth C2
  - Payload Integration
    - RSTA Sensors (CRADA)
    - “NATO Pallet” Payloads

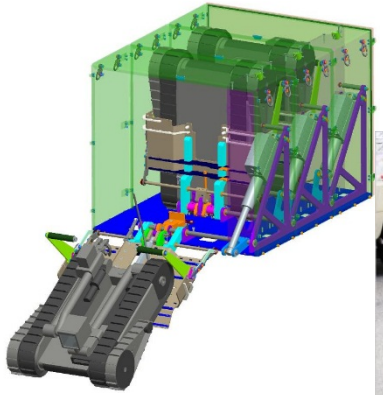
Payoff:

- S&T Toolset for incremental development
- Feeder program for Autonomous Ground Resupply and Manned/Unmanned Teaming

Expeditionary: Extending Warfighter Reach

Multi-UGV Extended Range

- Operational experiment to examine the feasibility of long distance operation of multiple unmanned vehicles deployed from an unmanned marsupial vehicle.
- Expand technical development in:
  - Soldier-robot interfaces
  - Multi-platform, long distance C2
  - Power, energy, and mobility requirements for long duration missions



Grayling II

- Utilize a UAV to deploy a UGV at remote locations without a soldier on the ground
- CBRN payload integration & mission execution
- Air Assault mission scenario

Discussion/Questions