Army’s S&T Investment in Ground Vehicle Robotics

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TARDEC Ground Vehicle Robotics

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Key Programs Building a Foundation for MUMT

**Logistic Resupply**

**Autonomous Ground Resupply**

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

**Expedient Leader Follower**

Rapidly delivery and issue 70 leader follower enabled PLSs to Soldiers for a one year Operational Technical Demonstration (OTD) starting 4QFY19.

**Robotic Combat Vehicles**

**Combat Vehicle Robotics**

Develop/integrate technologies that enable scalable integration of multi-domain robotic and autonomous system capabilities teemed within Army formations supporting all combat warfighting functions.

**Future Manned / Unmanned Teaming Formations**

**Small Robotics for Urban / Subterranean**

Development of capabilities to support urban and underground operations such as unmanned complex tunnel investigation, CBRNE missions and reconnaissance.

Built on Open Autonomy Architecture (AGVRA)
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Government managed Robotics Architecture enables incremental software capability upgrades

- Military library of autonomous behaviors in open, non-proprietary, modular format (ROS-M)
- Interface definition enables integration of payloads across S&T enterprise / Industry
- Autonomous behaviors are not platform specific enabling significant code reuse.

TARDEC’s autonomy investments focus on improving unmanned ground maneuver and integrating mission payloads on while continuously engaging the user in operational experiments / assessments

Better Buying Power Focus Areas:

- Achieve Affordable Programs
  Software code reuse from previous programs, increased capability w/o vendor lock
- Control Costs Throughout the Product Lifecycle
  Architecture enables reduced safety certification timeline reduced w/ M&S approach, mitigates obsolescence in rapidly evolving field
- Incentivize Productivity & Innovation in Industry/Academia/Gov’t
  Government managed software architecture enables industry to innovate around different RAS behaviors inviting broader industry participation.

- Eliminate Unproductive Processes and Bureaucracy
- Promote Effective Competition
  Competition ensures module level upgrades incorporate best of breed behaviors throughout the lifecycle
- Improve Tradecraft in Acquisition of Services
- Improve the Professionalism of the Total Acquisition Workforce

See FY17 NDAA – Section 805 on MOSA
Open Modular Ground Vehicle Autonomy

Autonomous Ground Vehicle Reference Architecture (AGVRA) - Set of guidelines to enable the robotics community to fulfill the Army’s Robotic and Autonomous System (RAS) commonality objectives by establishing an affordable means to deliver advanced capability to the Warfighter by utilizing architectural best practices and standards.

Interoperability Profile (IOP) defines software massaging & hardware interfaces between major subsystems of unmanned ground systems utilizing existing standards.

Autonomy Software Framework (ROS-M)

ROS 2.0 or ROS SE is an open source software framework for robotic development that provides the following features to allow for modular software development:

- Federation of repositories containing ROS software packages unique to military applications and requirements, including those that:
  - are requirement-developed
  - have been imported and modified from Open ROS
  - have been conversed/ported from existing, Government-owned RAS code bases

- ROS-M users can register Open ROS software modules and tools suitable for military RAS that meet certain ROS-M requirements

ROS-M is a modular, open source software framework for robotic development that provides:

- Autonomy Software Framework (ROS-M)
- Autonomous Ground Vehicle Reference Architecture (AGVRA)
- Set of guidelines to enable the robotics community to fulfill the Army’s Robotic and Autonomous System (RAS) commonality objectives by establishing an affordable means to deliver advanced capability to the Warfighter by utilizing architectural best practices and standards.

GVR Modular Software Approach (GMSA)

Success of this approach relies on strong government and industry collaboration developing interface standards at the appropriate level between applications.
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Future Manned / Unmanned Teaming Formations

Built on Open Autonomy Architecture (AGVRA)
On 10 FEB 17 at the L/F PoR AROC: relook and formulate a way to deliver the L/F technology in the hands of the Soldier faster and cheaper

Signed by LTG Murray on 4 May 2017

PLS A1

Defines purpose, requirements and roles & responsibilities to purchase up to 150 L/F PLS and conduct one year Operational Tech Demonstration

- Performance levels of TARDEC’s AGR Inc I solution to be evaluated Sep 2017.
- Coordinate with CIO/G6 and ARCYBER to tailor spectrum and cyber security requirements

Directed Requirement Schedule

<table>
<thead>
<tr>
<th>Year</th>
<th>2018</th>
<th>2019</th>
<th>2020</th>
<th>2021</th>
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<tbody>
<tr>
<td></td>
<td>Deliver 70 L/F PLS Trucks</td>
<td>Urgent Materiel Release</td>
<td>Operational Tech Demo</td>
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Army Acquisition Objective TBD at later date.

Operational Technology Demonstration (OTD)

- FORSCOM will identify high optempo Transportation Medium and Composite Truck Companies to field L/F PLS trucks
- TRADOC ICW ATEC, FORSCOM, G8 and AMC develops the analytical support and data collection plan to inform future CPD
## Expedient Leader Follower Schedule

<table>
<thead>
<tr>
<th>Increment I</th>
<th>Increment II</th>
<th>Increment III</th>
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<tbody>
<tr>
<td><strong>Baseline Architecture Design &amp; Build</strong></td>
<td><strong>Additional Autonomous Behaviors</strong></td>
<td><strong>Advanced Convoy Behaviors</strong></td>
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<td>✓ Modes (Leader Follower, Teleop) ✓ Assembly (Manual Line Up Vehicles) ✓ Formations (Column) ✓ Reverse (Teleoperation and Manned) ✓ GPS Denied (LOS to Leader) ✓ Turnaround (Vehicle K Turn) ✓ Obstacles (Static &amp; Large Dynamic) ✓ Dynamic Rerouting (None) ✓ AO (Primary &amp; Secondary Roads) ✓ Operations (Day and Night Driving) ✓ Weather (Light Rain/Snow/Fog) ✓ Safe Harbor (Stop)</td>
<td>✓ Modes (Augmented TeleOp, Waypoint) ✓ Assembly (Drive Past and Assemble) ✓ Formations (Inverted T) ✓ Trailers (Forward) ✓ Reverse (Retrotraverse) ✓ GPS Denied (Comms to Leader) ✓ Turnaround (U Turn) ✓ Obstacles (Negative) ✓ Dynamic Rerouting (Static Vehicle) ✓ AO (Open &amp; Rolling Terrain) ✓ Operations (Black Out) ✓ Weather (Moderate Rain/Snow/Fog) ✓ Safe Harbor (Pull Over)</td>
<td>✓ Modes (Augmented Waypoint) ✓ Assembly (Line Up in Depot) ✓ Formations (Staggered Column) ✓ Trailers (Forward &amp; Reverse) ✓ Reverse (Retrotraverse) ✓ GPS Denied (Know AO) ✓ Turnaround (U Turn with Obstacles) ✓ Obstacles (Small Dynamic) ✓ Dynamic Rerouting (Moving Vehicle) ✓ AO (Trails) ✓ Operations (PLS OMS/MP) ✓ Weather (Heavy Rain/Snow/Fog) ✓ Safe Harbor (Limited path)</td>
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Future Manned / Unmanned Teaming Formations

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NGCV RCV Top Line S&T Efforts

**Combat Vehicle Robotics (CoVeR)**
Develop/integrate technologies that enable scalable integration of multi-domain robotic and autonomous system maneuver capabilities teamed within Army formations supporting all combat warfighting functions.

**Artificial Intelligence & Machine Learning for NGCV**
AI and ML enabled advanced autonomous maneuver and teeming behaviors to enable unmanned NGCV with increasing autonomy, unburdening the Soldier operator, with a high degree of survivability and lethality in a highly contested environment.

**C4ISR Modular Autonomy**
Research and develop multifunction mission command, sensing, and communications technologies and approaches to enable the required C4ISR capabilities for autonomous and semi-autonomous platforms.

**Sensors for Autonomous Operations and Survivability**
Development of automated, advanced multi-function sensors and algorithms enabling man-unmanned combined arms maneuver in complex environments for next generation manned, optionally manned, and robotic platform applications.

**NGCV Robotic Combat Vehicle Prototypes**

- **Initial Capability Surrogate RCV**
  - 3GEN LRAS3
  - Automated Wide Area Search
  - Unmanned M113
  - CMI MCAS Remote Turret
  - 30mm XM813
  - Scenario Based Fire Control
  - PLWRWS Gimbal + Electric Driven 7.62 Cal weapon SBFC

- **Purpose Built RCV**
  Open competition to industry to develop purpose built unmanned platform with high inherent mobility and the ability to integrate multiple mission payloads (lethality, SA, engineering, etc.)
RCV Unmanned Experimental Prototype

- **Autonomy:**
  - Teleoperation
  - On-road Waypoint Navigation
  - Leader-Follower
  - Integrated 360 Situational Awareness
  - Pre-shot detection, Hostile Fire Detection & Localization
  - Autonomous Search and Target Acquisition (AiTD/R)
  - Range of Control: 1km line of sight
  - Loss of Control: Vehicle returns to last point of communication
- **Sensors:**
  - x2 UAS; potentially x2 tethered UAS
  - HD Uncooled Local Situational Awareness Cameras
  - Digital Video Architecture
  - Degraded visual environment capable
  - x2 long range target acquisition systems (Stabilized) (2G FLIR or 3G FLIR LRAS3)
- **Lethality:**
  - x1 XM813 30mm remote weapon station (RWS) with ammunition handling system (AHS) and Scenario Based Fire Control System
  - x2 purpose built electric drive 7.62 machine gun remote weapon station (RWS)
  - x1 Automatic turreted mortar (81mm)
- **Mobility:**
  - Maneuver with manned vehicles with augmented teleoperation
  - Basic obstacle detection and avoidance at < 20 MPH on road and < 10 MPH off-road speeds
  - Limited teaming and basic tactical behaviors for on-road operations
  - Terrain: Roads/Trails/Open and urban Terrain/Static Obstacles
  - Weather & Environment: Light Dust/Rain/Snow
- **Span of Control (Human in the Loop):**
  - x1 MFV for x2 RCVs
  - No crew members
  - 2 operators per RCV led by 1 section sergeant (5 total RCV crew members)
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**Future Manned / Unmanned Teaming Formations**

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Built on Open Autonomy Architecture (AGVRA)
Robotics for Complex Missions

Remote Reconnaissance Vehicle (R2V)

R2V provides real-time organic EW capability enabling Brigade and Battalion Shaping operations

Coalition Assured Autonomous Resupply (CAAR)

CAAR 2019 Grayling, MI Demo will highlight Autonomy and Weaponization on SMET-Class Surrogates

*Representative system, shown with GDLS permission

Autonomous Tunnel Exploitation

Yearly coalition demonstrations at tunnel facilities in Korea
Logistics Resupply and Combat Robotics Safety

AGR and Expedited Leader Follower

- AGR has collaborated with ATEC in order to build safety into the design for unmanned operations.
- Building a robust safety strategy requires:
  - Identifying the potential mishaps
  - Building mitigations into the design
  - Providing evidence the mitigations work and are reliable

There are two key aspects of the safety strategy:

- **Isolate** safety criticality to the minimal set of software components.
- Required because autonomous systems will continue to evolve and increase capability.
  - **Redundancy** built into design so the system can be its own backup
  - Reduces the required reliability and level of rigor required
  - Allows for mission completion in the event something does fail.

Combat Vehicle Robotics

- Holistic approach to the development of Robotic and Autonomy System (RAS) robotic systems.
  - Establishment of RAS Safety Office
  - Development of RAS Safety Standards
  - Development of RAS Virtual Testing Procedures
  - Research in Safety Based Design Methodology for Robotic Systems

Methodology for Development of Fieldable Robots

- **RAS-Safety Design & Research**
  - Robotic Systems Designed for Safe Operations

- **RAS - Safety Verification**
  - RAS Safety Standards & Virtual Safety Testing

- **End Result**
  - Fieldable Robots that have obtained Safety Confirmations
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 assessing options for upgrading vulnerable components.

MILESTONES & OBJECTIVES

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<th>Trial 1: Baseline long-distance, intercontinental control in austere environment</th>
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- US-AUS Project Arrangement (PA)
- Refine autonomous control methods to mitigate latency over long distance (SATCOM)

Trial 2: Assess vulnerabilities via AUS EW attacks

- Develop EW-resiliency and novel autonomous behaviors to counter passive (e.g., GPS- and COMS-denial) and active EW threats
- Upgrade component hardware to overcome and mitigate EW threats

Trial 3: Assess protection vs AUS EW attacks

- Write technical reports

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.
Opportunities for Industry to Participate

Join consortium working to develop Army autonomy framework and gain access to free autonomy software.

Contact Us: ROSMINFO@NAMConsoritum.org

Opportunities are coming soon through Defense Mobility Enterprise for recently funded accelerations in Combat Vehicle Robotics. Join for access and respond.

- Advanced Autonomy Behaviors
- Unmanned Combat Platforms
- Human Machine Interface
- Platform Sensors and Computing
- Autonomous System Testing / Safety
- By-wire Actuation of Platforms

Join TARDEC INDUSTRY DAYS on 25-26 April in Warren, MI for ROS-M software modularity demonstration and detailed information on new opportunities for TARDEC’s S&T Investments and for NGCV Manned and Unmanned Prototypes
BACKUP
Autonomous system development is an interdisciplinary practice underpinned by continuous virtual and physical testing.
## Next Generation Combat Vehicle Cross Functional Team

**S&T Incremental Growth for NGCV Unmanned**

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**Foundational Software, Behaviors, Algorithms, Code, Machine Learning – Continuous Updates Incorporated with Experimental Prototypes**

### RCV Surrogate Build

**Phase 1**

### Purpose-Built RCV Experimental Prototype

**Phase 2**

### Purpose-Built RCV Experimental Prototype

**Phase 3**

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### Combined Efforts

**ICD**

- Maneuver with manned vehicles with augmented teleoperation, or operate in a scout-like role with constant user control required
- Basic obstacle detection and avoidance at < 20 MPH on road and < 10 MPH off-road speeds
- Limited teaming and basic tactical behaviors for on-road operations
- Resupply of maneuver formations with unmanned ground vehicles
- Remoted lethality on med cannon / small arms
- Universal processing box for basic autonomous target acquisition (AiTR), target tracking (human and vehicle targets in open environments)
- Pre-Shot detection of threat optics for threat detection in complex environments
- 3GEN LRAS for long range target acquisition with automated wide area search auto-scanning capability 360 all-weather SA with Electro-Optic and Thermal Cameras (EO/IR) and integrated HFD and localization handoff for anti-armor threats

**MET-D**

**MBL**

**MUM-T SIM**

**ATEC Testing**

**Operational Unit Evaluation**

### 2019

- Purpose build platform with high level of inherent mobility at reduced overall platform weight.
- Platform designed for modular mission payloads to support multiple RCV mission roles
- Improved semi-autonomous maneuver capability with basic obstacle detection / obstacle avoidance (ODOA).
- Increase operational speed both on and off road.
- Initial teaming for basic on and off-road tactical behaviors (formations, firing positions)
- Universal processing box with improved aided target recognition, target tracking against expanded threat sets and standard AiTR architecture
- Integrated 3GEN FLIR for long range target acquisition and engagement
- 360 all-weather Situational Awareness with EO/IR cameras and integrated Hostile Fire Threat Detection with optimized processing

### 2021

- Purpose build platform with high level of inherent mobility at reduced overall platform weight.
- Platform designed for modular mission payloads to support multiple RCV mission roles
- Improved semi-autonomous maneuver capability with basic obstacle detection / obstacle avoidance (ODOA).
- Increase operational speed both on and off road.
- Initial teaming for basic on and off-road tactical behaviors (formations, firing positions)
- Universal processing box with improved aided target recognition, target tracking against expanded threat sets and standard AiTR architecture
- Integrated 3GEN FLIR for long range target acquisition and engagement
- 360 all-weather Situational Awareness with EO/IR cameras and integrated Hostile Fire Threat Detection with optimized processing

### 2023

- Maneuver with manned vehicles using limited semiautonomous behaviors as unmanned wingman, or operate in a scout-like role with reduced user attention
- Obstacle detection and avoidance at relevant speeds (limited negative obstacle detection)
- Additional teaming for basic on and off-road tactical behaviors (additional formations, bounding, over watch)
- Resupply of maneuver formations with unmanned air and ground vehicles
- Improved Hostile Fire Threat Detection for expanded threat fire and improved speed
- Universal processing box with target tracking and an initial demonstration of improved AiTR through shared ground and UAS target acquisition data

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**Platform Delivery**

**6x MFVs (2x 3 Designs)**

**4x RCVs**

**Company Set (7/14)**

(MFV/RCV)

**Operational Unit Evaluation**

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**Company Set**

(7/14)

(MFV/RCV)