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

Shaping the Future: Army Robotics and Autonomous Systems

March 2016

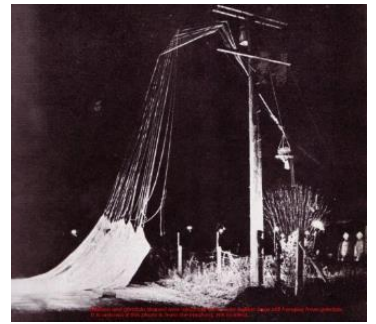
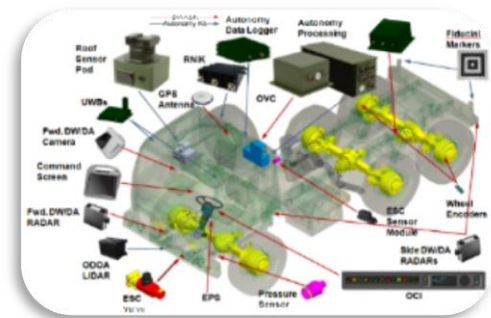
Dr. Bob Sadowski
Army Chief Roboticist
TARDEC Ground Vehicle Robotics



Perspective



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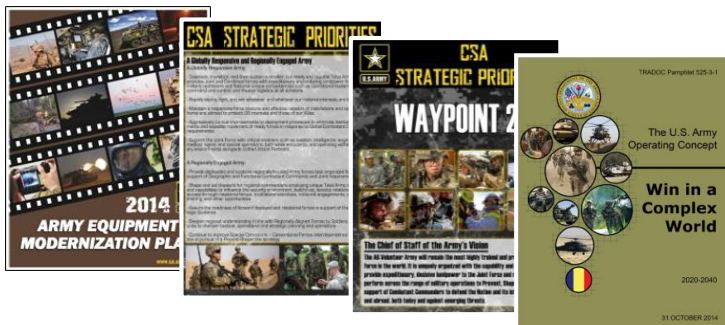


- WWII Photos From Wikipedia

Shaping the Future



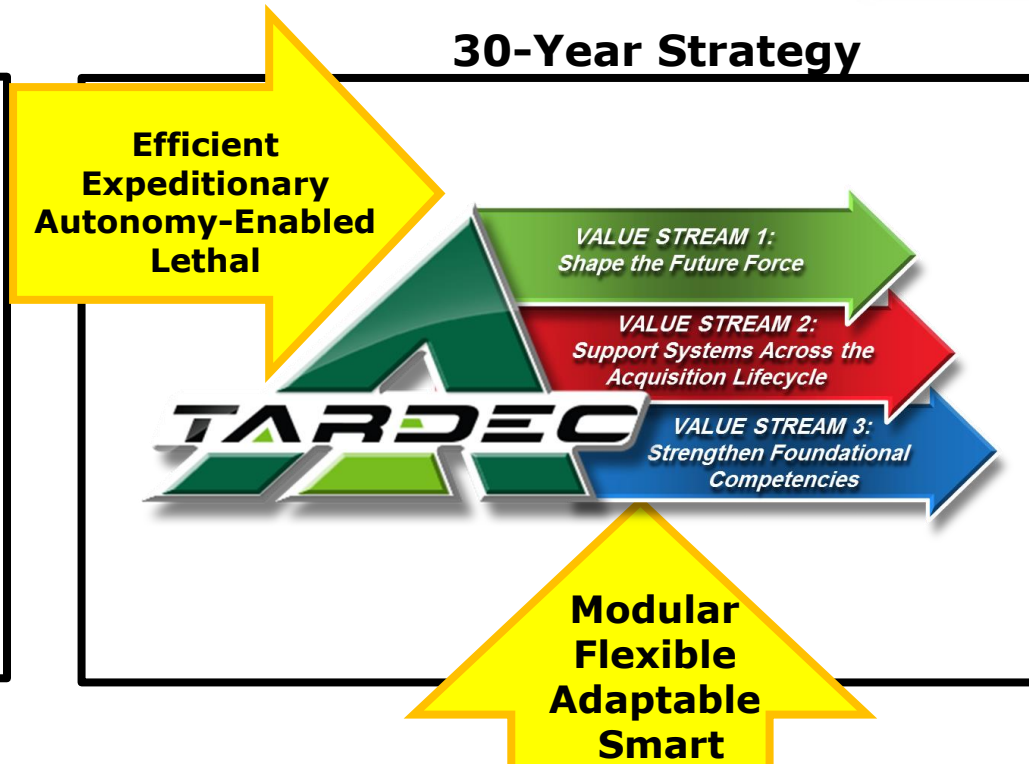
Strategic References



The future will be characterized by:

- **Complex operational environments**
- **Broad range of engagements**
- **Proliferation of advanced technologies**
- **Fiscal austerity**

30-Year Strategy



Art of the Possible

Survivability	Power and Energy	Electronic Architecture	Autonomy	Software	Human Interface	Force Projection
Modeling and Simulation				Advanced Concepts		



Driving the Army's Future

Key Themes of both TARDEC's Strategy and AOC

- *Modular Adaptable, & Flexible Platforms*
- *Capability, not Equipment Focused*
- *Expeditionary Force*

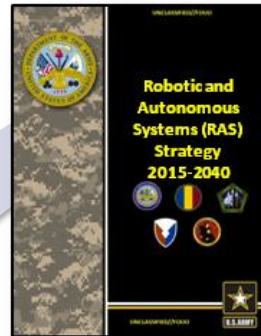
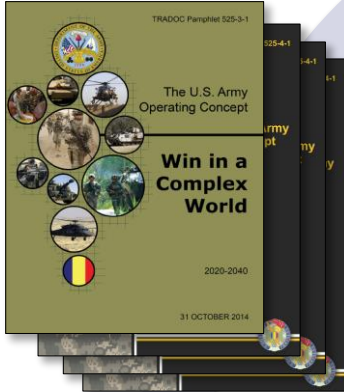


Air Deployable, Modular Platforms



TARDEC authored S&T portion of the RAS

- *Prioritizes robotics and autonomous systems (RAS) requirements across all formations*
- *Integrates RAS as an a key to the Army's differential advantage over adversaries*



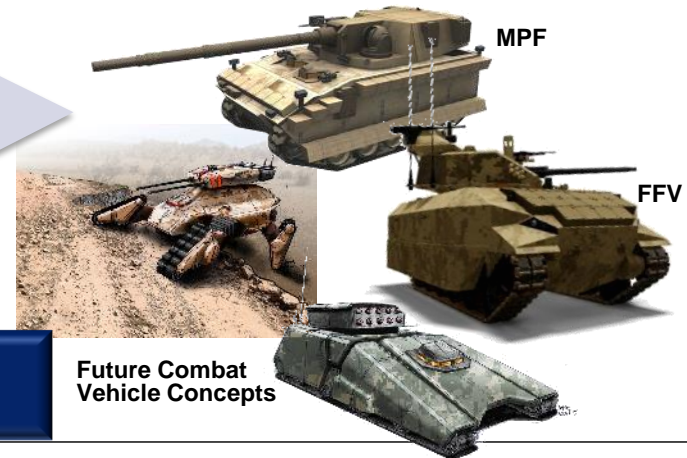
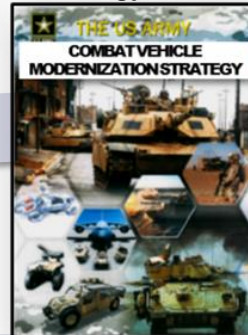
Unmanned Convoys



Unmanned Main Battle Tank Concepts

TARDEC authored the follow sections of CVMS:

- *Combat Vehicle 101*
- *Science & Technology Prioritization and Insertion Criteria*
- *Integrating Robotic and Autonomous Systems Technology in Combat Vehicle Modernization.*



Future Combat Vehicle Concepts

AOC = Army Operating Concept
 RAS = Robotic and Autonomous Strategy
 CVMS = Combat Vehicle Modernization Strategy
 MPF = Mobile Protected Firepower
 FFV = Future Fighting Vehicle

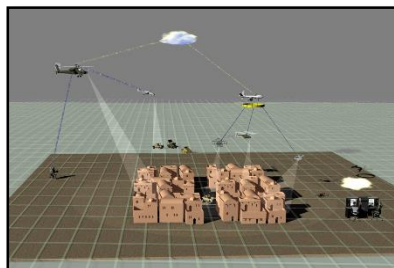


TARDEC's Strategy has direct influence on the Army's Future Operational and Material Strategies

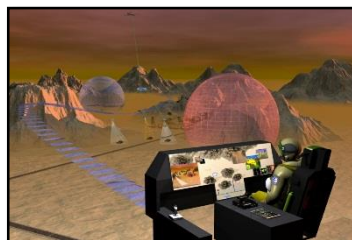
Autonomous Systems Strategic Capability Progression



Unmanned Air Systems Autonomy (2020)



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

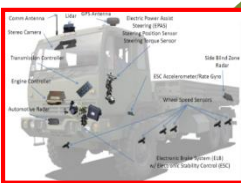


Dynamic Force & Mission Autonomy (2030-2040+)



2035

Combined Arms Maneuver (2030-2035)



2015



Active Safety Driver Assist Appliqué Kits (2015)

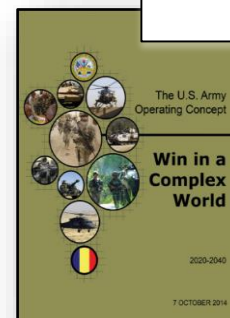


Extend the Reach of the Warfighter (2020)



Autonomous Convoy Operations (2020-2025)

“Adapt, Evolve, and Innovate”



Near Term Capabilities:

- Leader Follower Convoy Technology Employment
- Autonomous Mobility Applique System (AMAS)
- Lighten the Soldier load
- Enhance stand-off from threats and improve situational awareness

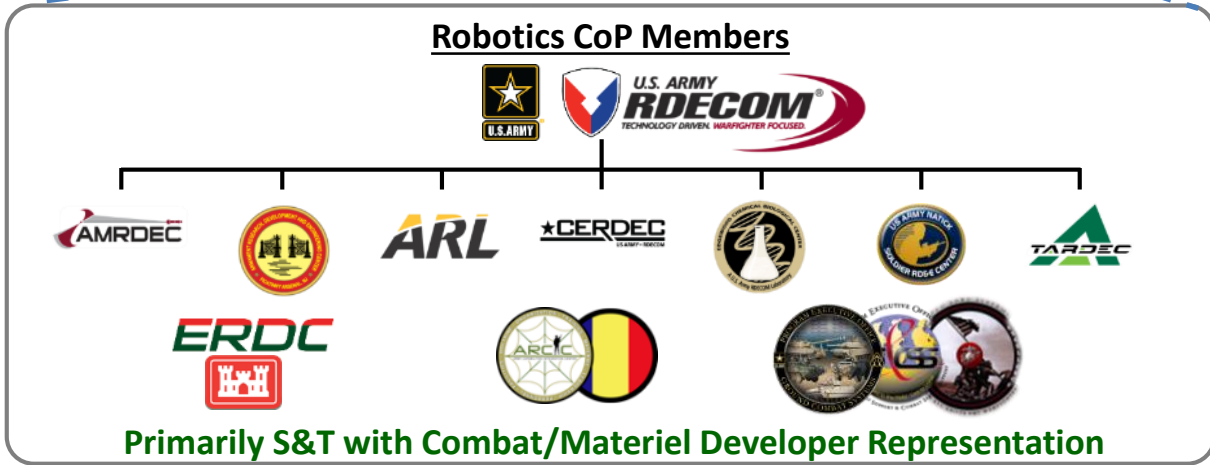
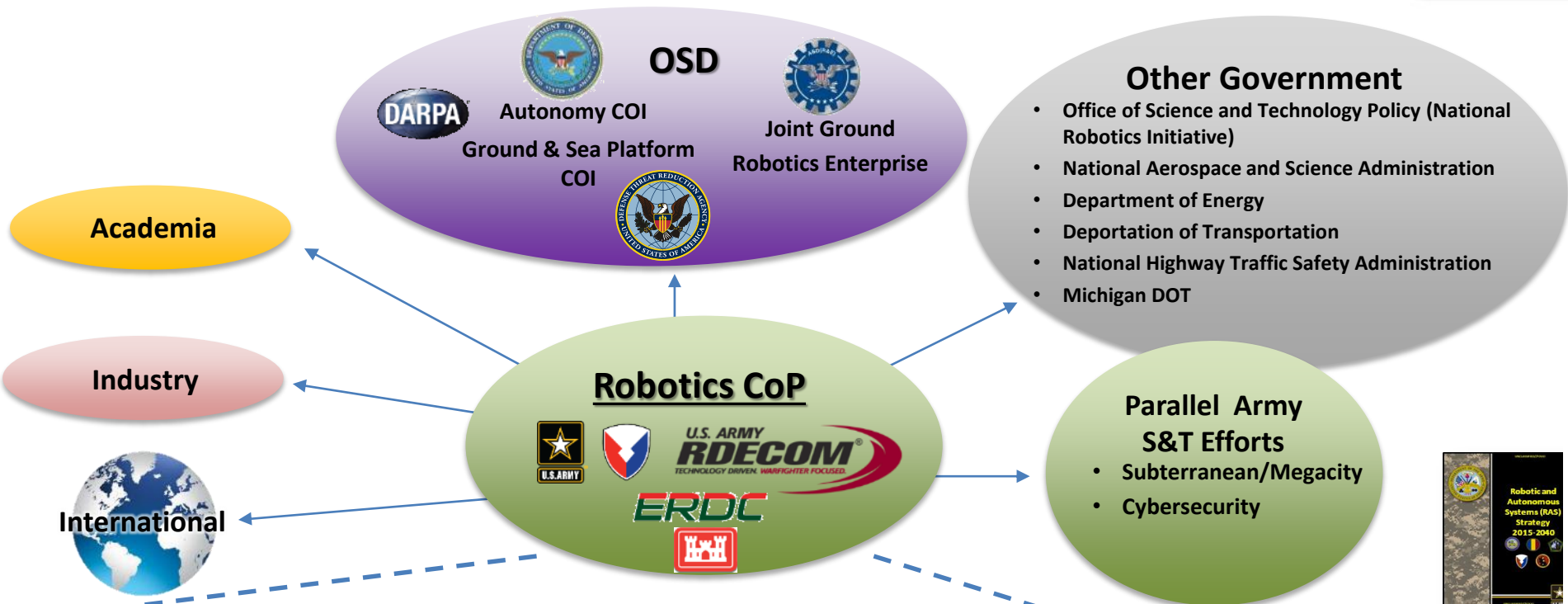
Mid Term Capabilities:

- Improve the autonomy of unmanned systems
- Enable unmanned cargo delivery
- Act as a “teammates” rather than tools
- Micro autonomous air/ground systems will enhance Platoon, Squad, and Soldier situational awareness.

Far Term Capabilities:

- Enable manned and unmanned teaming in both air and ground maneuver through scalable sensors, scalable teaming, Soldier-robot communication, and shared understanding through advancements in machine learning.

Robotics Community of Practice (CoP)

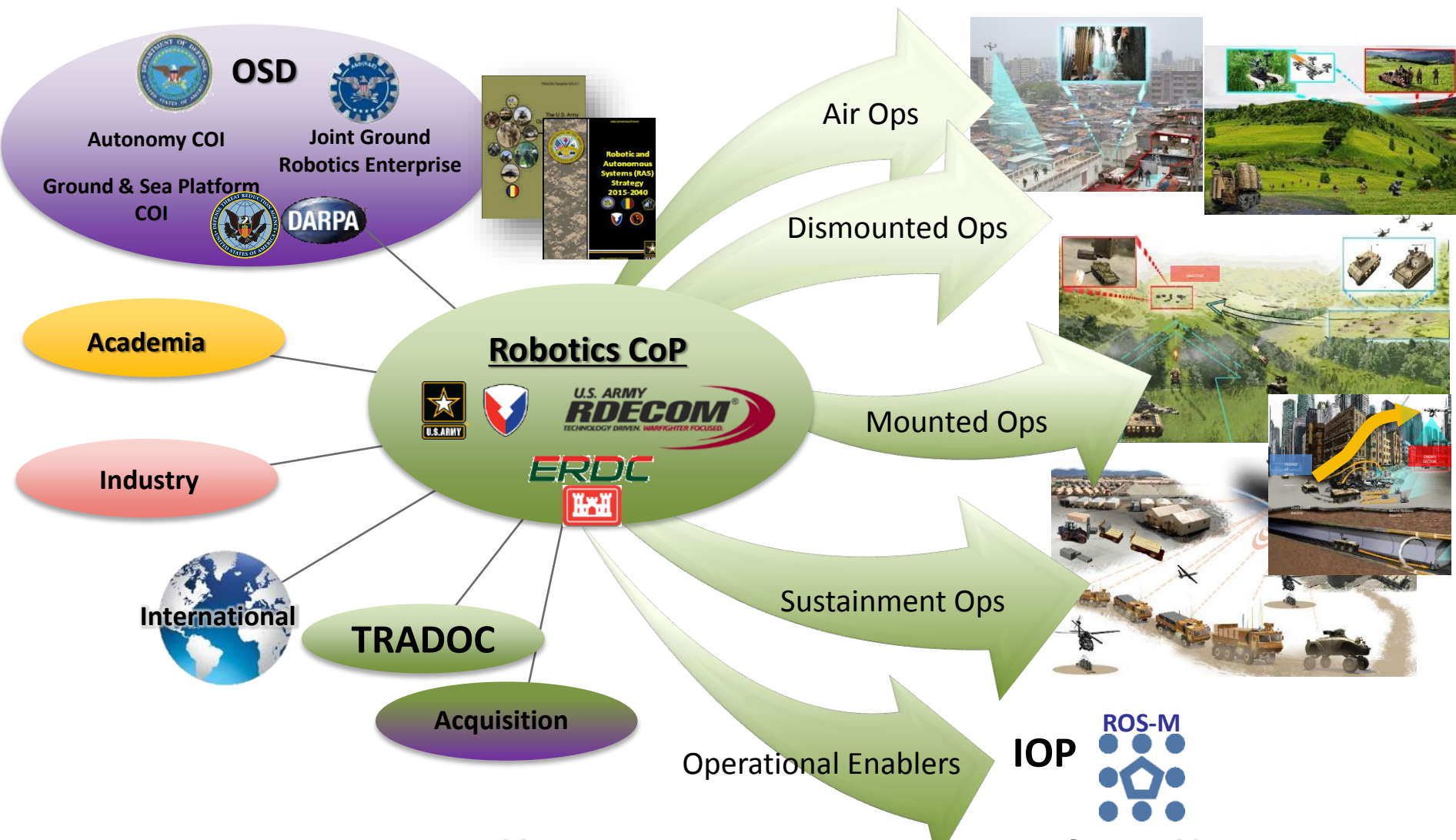


Robotics CoP is responsible for managing implementation of the Army RAS S&T Annex.

- Tasked to have:**
- Visibility of Ongoing RAS Efforts
 - Develop/Refine Roadmaps
 - Keep RAS Demonstration & Experimentation Schedule
 - Develop Transition Plans
 - Establish & Maintain Linkages



Achieving Army RAS Capability



Develop, demonstrate, and transition tactically and operationally relevant **RAS capability** across Army formations supporting the warfighting functions and **informing future requirements** by leveraging **Govt, academic, international, and industrial partners** enabling the strategic effects elicited in the AOC.

OSD Accelerated Autonomous Convoy Technologies



2006-2012

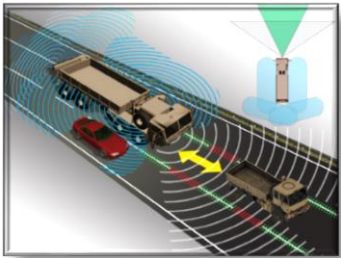
Army S&T Convoy Active Safety Technologies



Tech Development / System Concepts



2008-2012
USMC S&T Cargo UGV



2012-2014

AMAS: Autonomous Mobility Applique System
Joint Capability Technology Demonstrator

Driver Warning / Driver Assist



Technology Demo
2013

Teleoperation WayPoint Leader/Follower



Technology Demo
2014

Driver Warning / Driver Assist & Leader/Follower



Operational Demo
2014

Leader/Follower



Extended Warfighter Experiment
2016

2015 - 2021

Army S&T Autonomous Ground Resupply

Manned Leader / Unmanned Follower



Operational Evaluation
2017

Autonomous Convoy



Operational Evaluation
2019

Operational Evaluation
2021

System Design / Fabrication / System Test and Evaluations

Ongoing - Future

Potential Future Programs: Leader/Follower and Autonomous Convoy Operations



Inform feasible and achievable Requirements development for future capabilities
Informs performance specifications for Future Programs of Record (PoR)



MTRV
• Primary mover for Marines



M915
• Used in commercial trucking



MTV
• Well understood dynamics
• Workhorse for short missions



PLS
• Multiple steering axes
• Primary mover for retrograde



LMTV
• Well understood dynamics
• Workhorse for short missions



HET
• Significantly larger with different dynamics profile
• Trailer



RG-31
• Additional controls for the mine roller unit

Beginning with the DARPA Grand Challenges and AMAS JCTD

Achieving RAS capability: Extending Warfighter Reach



Demonstrate the capability of unmanned systems to execute long-duration missions over extended distances without support from operators on the ground.

Camp Grayling Challenge
2012 – Grayling, MI

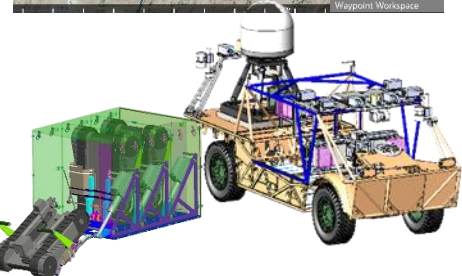
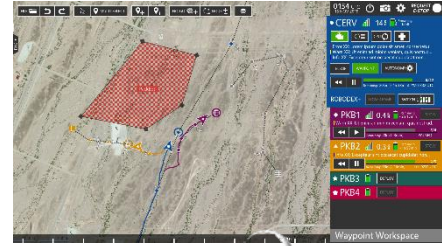
ERWR Tactical Resupply
2014 – Ft Benning, GA

ERWR CBRN
2015 – West Palm Beach, FL

ERWR Long Duration
2016 – Pittsburgh, PA

Multi-UGV Extended Range
2016 – Grayling, MI

ERWR CBRN Soldier Assessment
TBD



Benefits:

- Execute high-risk missions without putting soldiers at risk.
- Extend warfighter reach (distance and width of area covered).
- Rapid response to critical resupply missions with no risk to operator.

Achieving RAS capability: Partnering with Industry



Autonomous aerial delivery of an autonomous ground robot to explore/map threats within a potential chemical, biological or radiologically contaminated area



- Combined effort between ECBC/DTRA, TARDEC, AMRDEC/AATD, NREC, and Sikorsky
- Integration of standard handheld CBRN sensors onto the ground platform

Achieving RAS capability: Experimentation



Remote Weapons Station SMET

Oct 2105: Robotic Enhanced Company



ADIM



SMET surrogates demonstrated reduced Soldier load, enhanced lethality, commo network extension, lane clearing, non-standard casualty evacuation,, and battery charging capabilities



Utility SMET



CASEVAC/ AP Lane Clearing SMET



Alaska - Arctic

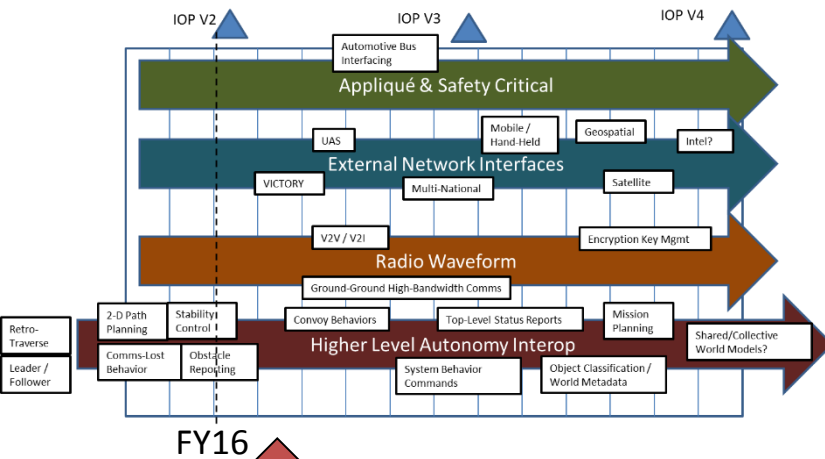


Hawaii - Jungle

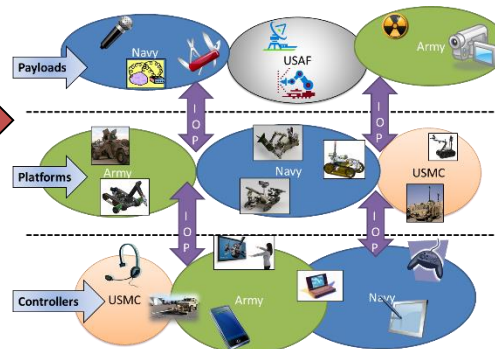
- Experimentation with the user community is a key component
- Recent warfighter experiments have mixed both industry and S&T platforms across a variety of environments
- Informs industry, S&T, combat and material developer communities



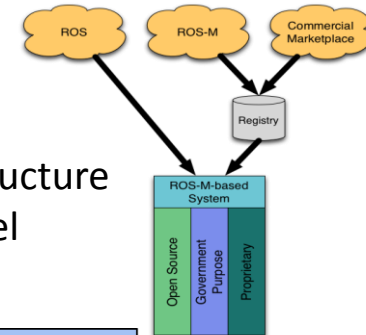
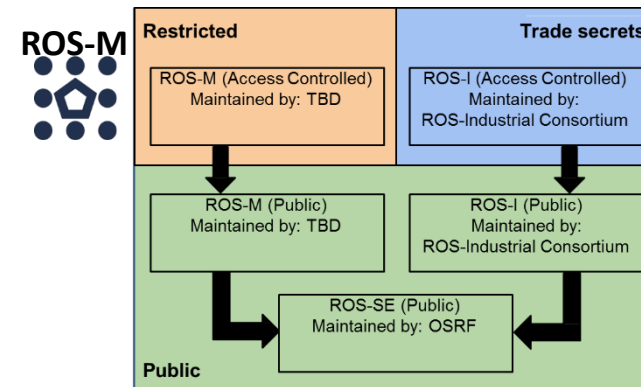
Achieving RAS capability: Open, Modular Architectures/Interfaces



IOP Development Path and Simplified model



Proposed ROS-M management structure parallels ROS-I Industry model



- ROS-SE: Security-Enhanced:
 - Keep common functionality open
 - Control access to components where needed

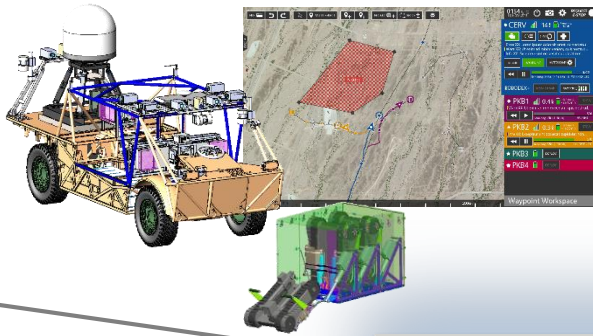
- Interoperability Profiles (IOP) v1 is the path to modular payloads, components, etc. Defines software messaging & hardware interfaces between major subsystems of unmanned ground systems
- ROS-M or Military version of the Robotics Operating System leverages the success of ROS within Academia, DARPA Grand Robotics Challenge and ROS Industrial efforts.
- By design, furthers innovation and reduces development timelines by promoting code re-use at the module level, certification to reduce testing risk/cost, and a marketplace for ideas/collaboration

Ongoing RAS Capability Demonstrations



Multi-UGV Extended Range

2016 Grayling, MI

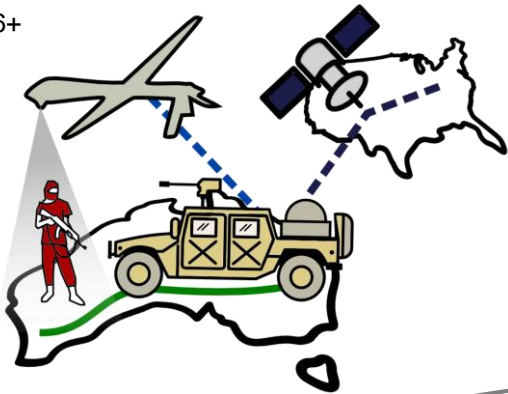


Autonomous Ground Resupply

2015+

TORVICE

2016+



Automated Robotics for Installation & Base Operations

2016+ Ft Bragg, NC | 2016+ Ft Leonard Wood, MO



Michigan DOT Collaboration

2016+ I-69 Corridor, MI



Future Capability Demonstrations

- Route Clearance
- Perimeter Security
- Pathfinder
- Reconnaissance Surveillance & Target Acquisition
- Call for Fire
- Long-duration Overwatch

Demonstrating Capability of Unmanned Systems to Execute Operationally Relevant Scenarios for the Warfighter

External Business Office (EBO)



The EBO is Your Connection for New Opportunities

Industry Days - April 2016

Visit TARDEC's Web Site www.army.mil/TARDEC for detail.

- **TARDEC Capabilities**
- **30-Year Strategy**
- **New Opportunities**

The screenshot shows the TARDEC website homepage. At the top, it displays the U.S. Army logo and the text 'WWW.ARMY.MIL/TARDEC U.S. Army Tank Automotive Research Development and Engineering Center'. Below this is a navigation bar with 'Social Media' links (Facebook, Twitter, YouTube, LinkedIn) and a search bar. The main content area is divided into several sections: 'TARDEC Links' (About TARDEC, Home, Event Calendar, Our Enterprise Partners, Awards, Engage TARDEC, Collaborate, Our Capabilities, TARDEC 30-Year Strategy, Opportunities, National Automotive Center (NAC)), 'TARDEC STORIES' (Michigan Gov. Snyder Visits Army Facilities at Detroit Arsenal, TARDEC Associate Finalist for Army Civilian Innovation of the Year, Collaboration with academia drives Soldier Innovation at TARDEC), 'SAVE THE DATE: Ground Vehicle Systems Engineering & Technology Symposium', and 'MISSION' (Develop, integrate and sustain the right technology solutions for all manned and unmanned Department of Defense (DoD) ground systems and combat support systems to improve Current Force effectiveness and provide superior capabilities for the Future Force). A red circle highlights the 'TARDEC STORIES' section, and a red arrow points from the 'New Opportunities' bullet point in the text above to this section.

Connect with us through our Ground Vehicle Gateway (online) to submit:

- **New Proposals**
- **Technology Plans**

We Need Your Help to Shape the Future of the Army and Deliver Advanced Capabilities to the Warfighter