U.S.ARMY

THE US ARMY

ROBOTIC AND AUTONOMOUS SYSTEMS STRATEGY

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Foreword

From the Vice Chief of Staff of the Army

Winning wars today and in the future will depend on adaptive leaders, skilled Soldiers, and well-trained teams empowered with advanced technologies. The Army Robotic and Autonomous Systems (RAS) Strategy describes how the Army will integrate new technologies into future organizations to help ensure overmatch against increasingly capable enemies. Consistent with the 2015 National Military Strategy, the RAS Strategy describes how the Army will use human-machine collaboration to meet the JCS Chairman's goal of increasing operational options for Joint Force commanders. The integration of RAS will help future Army forces, operating as part of Joint teams, defeat enemy organizations, control terrain, secure populations, and consolidate gains. RAS capabilities allow future Army forces to conduct operations consistent with the concept of multi-domain battle, projecting power outward from land, into the air, maritime, space and cyberspace domains to preserve Joint Force freedom of movement and action. Executing this strategy requires Army leaders to think clearly about how to integrate RAS into operations; learn through rigorous experimentation; analyze what we learn to focus and prioritize efforts; and implement RAS-enabled concepts across doctrine, organization, training, materiel, leadership and education, personnel, facilities and policy.

Because enemies will attempt to avoid our strengths, disrupt advanced capabilities, emulate technological advantages, and expand efforts beyond physical battlegrounds, the Army must continuously assess RAS efforts and adapt. The Army will prioritize investments based on how RAS capabilities contribute to interim solutions to the Army Warfighting Challenges. (http://www.arcic.army.mil/initiatives/armywarfightingchallenges). Pursuing RAS allows Army Soldiers and teams to defeat capable enemies and maintain overmatch across five capability objectives: increase situational awareness; lighten the warfighters' physical and cognitive workloads; sustain the force with increased distribution, throughput, and efficiency; facilitate movement and maneuver; and increase force protection.

Success depends on Army leaders sharing a common vision and collaborating to determine how best to integrate RAS into joint operations. Delivering RAS capabilities will not be easy. And because RAS is a relatively new range of capabilities, execution will require Army leaders to be open to new ideas and encourage bottom-up learning from Soldiers and units in experimentation and the Army's warfighting assessments.

Daniel B. Allyn
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Section I

Why the Army Pursues Robotic and Autonomous Systems (RAS)

The Army RAS Strategy directs actions necessary to achieve unity of effort in the integration of ground and aerial RAS capabilities into Army organizations. Effective integration of RAS improves U.S. forces' ability to maintain overmatch and renders an enemy unable to respond effectively. The Army must pursue RAS capabilities with urgency because adversaries are developing and employing a broad range of advanced RAS technologies as well as employing new tactics to disrupt U.S. military strengths and exploit perceived weaknesses. RAS are increasingly important to ensuring freedom of maneuver and mission accomplishment with the least possible risk to Soldiers.

Pursuing RAS allows the Army to improve the combat effectiveness of the future force. Development of RAS solutions within Army formations emphasizes human-machine collaboration. Integrated human-machine teams will allow forces to learn, adapt, fight and win under uncertain situations. RAS-enabled teams give leaders time and space to make decisions that achieve tactical and operational gains.

Today's investment in RAS will help ensure that the Army can address three compelling challenges: 1) increased speed of adversary actions, including greater standoff distances; 2) increased use of RAS by adversaries; and 3) increased congestion in dense urban environments where communications will be stretched to the breaking point.

To advance RAS development and address these challenges, five capability objectives guide technology development and employment of Unmanned Ground Systems (UGS) and Unmanned Aircraft Systems (UAS):

a. **Increase situational awareness.** Complex terrain and enemy countermeasures limit Soldiers' abilities to see and fight at the battalion level and below. Advancements in RAS allow for persistent surveillance and reconnaissance over wide areas, often going where manned systems cannot, thereby increasing standoff distances, survivability and reaction time for commanders.

b. **Lighten the Soldiers' physical and cognitive workloads.** Excessive equipment requirements reduce stamina and endurance. Autonomous systems lighten equipment loads and increase Soldier speed, mobility, stamina and effectiveness. Vast amounts of information overload leaders' ability to make decisions. RAS facilitate mission command by collecting, organizing, and prioritizing data to facilitate decision-making as well as improving tactical mobility while reducing cyber, electronic, and physical signatures.

c. **Sustain the force with increased distribution, throughput and efficiency.** Logistics distribution is resource intensive. Soldiers and teams become vulnerable at the end of extended supply lines. Air and ground unmanned systems and autonomy-based capabilities enhance logistics at every stage of supply movement to the most forward tactical resupply points. RAS move materiel to the most urgent points of need and provide options for Army logistics distribution to the warfighter.

d. **Facilitate movement and maneuver.** Joint Combined Arms Maneuver in the 21st Century requires ready ground combat forces capable of outmaneuvering adversaries physically and cognitively in all domains. Through credible forward presence and resilient battle formations, future ground forces integrate and synchronize joint, interorganizational, and multinational capabilities to create temporary windows of superiority across multiple domains; seize, retain, and exploit the initiative; and achieve military objectives. Investments in Anti-Access/Area Denial (A2AD) capabilities allows future enemies to engage Army forces earlier and at greater distances. In addition, adversaries will look to emplace obstacles to threaten movement maneuver across extended avenues of advance. As a counter, Army forces employ RAS to extend the depth of the area of operations and to provide responses to enemy action. RAS expand the time and space at which Army forces can operate and improve the ability to overcome obstacles.

e. **Protect the force.** The congested and contested future operational environment (OE) increases Soldiers' exposure to hazardous situations. RAS technologies will enhance Soldiers' survivability by providing greater standoff distance from enemy formations and rockets, artillery, and mortars as well as placing less Soldiers at risk during convoy operations.

Of the five capability objectives, the priority in the near-term is to increase situational awareness and lighten the Soldier's physical load, which will improve combat effectiveness of dismounted units. In the mid-term, the priority is to improve sustainment and soldier protection with automated convoy operations. The autonomous technology within automated convoy operations will transfer to many other future initiatives such as unmanned combat vehicles. In the far-term, the priority is to facilitate maneuver with unmanned combat vehicles, which will increase capabilities within brigade combat teams.

RAS contributions to DoD:

1. Reducing the number of warfighters in harm's way
2. Increasing decision speed in time-critical operations
3. Performing missions impossible for humans

Defense Science Board
Summer Study on Autonomy
August 2016

Achieving the five capability objectives and integrating RAS into existing formations will take time and calls for an evolutionary approach. The Army invests now to seize technological opportunities, such as soldier-borne sensors and tethered or tele-operated systems connected to combat vehicles and aircraft to provide these capabilities and while also learning from the integration of RAS and refining concepts and requirements to improve combat effectiveness.

Section II

RAS Priorities in the Near-, Mid-, and Far-Term Horizons

The Army expresses its vision for RAS by outlining realistic objectives in the near-term (2016-2020), feasible objectives in the mid-term (2021-2030), and visionary objectives for the far-term (2031-2040). Near-term objectives are partially funded in current budgets. Mid-term priorities have research and procurement funding lines submitted for the budget under consideration. Visionary objectives have limited research and development funding programmed in the budget.

Over the next twenty five years, three technology advancements are essential to allow the fastest, and cost effective achievement of the RAS capability objectives: autonomy, artificial intelligence, and common control.

Autonomy is the level of independence that humans grant a system to execute a given task in a stated environment. It is based on a combination of sensors and advanced computing to navigate this environment and the software sophistication necessary for machine decision-making. Enhanced autonomy capabilities will mean fewer Soldiers are required for robot control as RAS perform dull, dirty and dangerous tasks on their own. Higher levels of autonomy will permit RAS to perform higher risk missions for longer duration, expand operational depth and standoff distance and allow Soldiers to focus on those missions humans do best.

The process to improve RAS autonomy takes a progressive approach that begins with tethered systems, followed by wireless remote control teleoperation, semi-autonomous functions, and then fully autonomous systems. In 2016, most UGS and UAS operate between teleoperation and semi-autonomy. Because some autonomous capabilities advance and others lag behind due to technological constraints, the Army must consider optionally-manned systems that can use human operators for specific, complex, mission-critical tasks until autonomy matures. The Army seeks to maintain human control over all autonomous systems. It will achieve this goal by keeping humans "in-the-loop or on-the-loop" of current and future RAS. Humans in-the-loop will allow final decisions to be determined by a human operator on whether to proceed further in an activity; one example is lethal systems. Humans on-the-loop will allow humans to intervene in RAS systems such as automated vehicles. In both cases, the Army's aim is to have human judgement making critical decisions when employing autonomous systems.

Artificial intelligence (AI) is the capability of computer systems to perform tasks that normally require human intelligence such as perception, conversation, and decision-making. Advances in AI are making it possible to cede to machines many tasks long regarded as impossible for machines to perform. AI will play a key role in RAS development as reasoning and learning in computers evolves. AI will improve the ability for RAS to operate independently in tasks such as off-road driving and analyzing and managing mass amounts of data for simplified human decision-making. Increasingly, AI will account for operational factors such as mission parameters, rules of engagement, and detailed terrain analysis. As human-machine collaboration matures, AI will contribute to faster and improved decision-making in five areas: identifying strategic indications and warnings; advancing narratives and countering adversarial propaganda; supporting operational/campaign-level decision-making; enabling leaders to employ "mixed" manned/unmanned formations; and enhancing the conduct of specific defensive missions in which functions of speed, amount of information, and synchronization might overwhelm human decision-making.

Common control is the ability for one common software package to control an array of ground and air systems, and is critical for maximizing management of multiple and varied RAS. Common control will allow one Soldier to control multiple robots with one controller, reducing physical and cognitive burdens on Soldiers operating the system. Common control also overcomes operational limitations (data sharing / encryption / range /transferring control of platforms and payloads), while realizing cost savings and simplifying sustainment through compatible display units, batteries, and radios.

The Army's prioritization of the Common Operating Environment (COE) will facilitate common control through common standards and technologies that facilitate mission command and simplify the network. The COE is not a system or an acquisition program of record. Rather, it operates as a playbook for how Army IT products are built and deployed. The COE provides standards to unite existing programs and new technologies on a common software foundation, simplifying development, integration, training and sustainment. To support flexible employment of RAS, and gain maximum benefit from the information they provide, the Army will emphasize compatibility in the mobile, mounted, command post, and sensor components of COE.

In addition to advancements of autonomy, AI and common control, the Army requires government-owned architecture, interoperability, common platforms, and modular payloads as necessary additional software and hardware to realize the following benefits:

-Cost-savings with common RAS platforms means more funds to purchase more robots

-Faster upgrades to support innovation and accelerated capability development

-Component/payload modularity to facilitate RAS integration in different mission sets. For example, in one mission a medium UGS can be used to carry extra supplies, and in the next mission employ a chemical, biological, radiological and nuclear (CBRN) sensor payload, while in a third mission, it may emplace a surveillance asset.

Finally, cyber protection and mission assurance are critical for effective RAS development and employment. Mission assurance, the actions taken to achieve mission resiliency and ensure the continuation of mission essential functions and assets allowed under all conditions and across the spectrum of threats and hazards, allows units to connect to a defended network, resulting in a much higher probability of mission success. The Army must improve cyber protection and mission assurance; future RAS will rely on cyber capabilities and data links across cyberspace and the elector-magnetic spectrum.

To accomplish the capability objectives in this strategy and the critical underlying technologies, the Army must invest now and adjust transformation priorities to achieve specific goals over the next 25 years. The following sections identify the priorities in three broad time horizons.

Near-term (2016-2020)

Through 2020, the Army matures concepts and initiates or continues programs to increase **situational awareness, lighten the Soldier load, improve sustainment, facilitate movement, and protect the force**.

To **increase situational awareness** for dismounted forces in the near term, the Army procures more man portable RAS at lower echelons, capitalizing on increased endurance, sensory-obstacle avoidance, autonomy and miniaturization for small UGS and UAS that enable tactical forces to make contact with threats on their own terms. To increase situational awareness for mounted forces, the Army invests in tethered and untethered UAS that feed autonomous navigational systems and send video streams to leaders. While stationary, these UAS support local security operations.

To **reduce the amount of equipment carried** by dismounted formations, the Army pursues ground RAS platforms of varied scalable sizes and mission configurations. Soldiers operating dismounted for long periods will shift physical burdens to RAS platforms that provide a mobile power source and carry equipment, weapons, ammunition, water, food, and other supplies. RAS will increase small dismounted unit endurance and reach. To continue to lighten the Soldier load in the future, the Army invests in exoskeleton technology. Research in autonomy, AI, and common control will improve future increments of medium UGS to lighten the Soldier load.

Near-Term Priorities

- Increase situational awareness for dismounted forces at lower echelons
- Lighten the physical load for dismounted forces
- Improve sustainment with automated ground resupply
- Facilitate movement with improved route clearance
- Protect the Force with EOD RAS platform and payload improvements

To **lighten the cognitive load**, the Army continues advancements in computing/AI, clearing fires and intelligence analysis. RAS will enable the Mission Command Network in terms of 'maneuvering' the network, extending the network by providing connectivity in dangerous situations, improving the agility and tactical mobility of command posts, and reducing the signature of command post nodes by dispersing the emitters normally associated with them. At the same time, the increasing use of RAS will require changes to the Mission Command System, particularly in terms of knowledge management and the Mission Command Network.

To **sustain high tempo operations** at the end of extended and contested lines of communication, the Army invests in automated ground resupply convoys for increased throughput and self-guided resupply parachutes for improved resupply across wide areas. Vehicle sensors, computers, and decision support tools will manage vehicle attributes including speed, interval, obstacle avoidance, limited visibility operations, thus increasing threat mitigation. Tactical wheeled vehicles, equipped with active safety and semi-autonomous leader-follower technology, conduct semi-autonomous convoy operations that provides logistics formations the ability to rest drivers for critical tasks only humans can perform. Science and technology investments in the near-term improve autonomy to make automated ground resupply and UAS resupply feasible in the mid-term.

To **ensure freedom of maneuver** on the battlefield, the Army invests in capabilities for route clearance, breaching, and C-IED. Science and technology investments in the near-term improve off-road ground vehicle autonomy, the greatest technological challenge for employment of unmanned combat vehicles. Research emphasizes cognitive aids to "optimally pilot" the Army's Future Vertical Lift, and similar technology investments in airframe and propulsion to ensure UAS possess the reach, protection and lethality required for manned/unmanned combined arms maneuver.

To **protect the force**, the Army continues investment in RAS for Explosive Ordnance Disposal

(EOD) operations including advanced EOD technologies (e.g., route clearance payloads and increased autonomy for small robots to clear routes and obstacles faster.) Other RAS efforts protect the force, particularly by increasing situational awareness through such systems like soldier borne sensors.

Ultimately, the primary near-term investments are in pursuit of autonomous technology development, which will begin to change how the Army operates by steadily integrating autonomous systems into combined arms maneuver. Acquiring these capabilities will allow the Army to increase force protection, lighten the physical load of dismounted forces, and increase situational awareness.

Vignette: Urban Operations (2025)

Squads and platoons equipped with small RAS in urban terrain make contact on their own terms, thus reducing the need for formations to maintain the traditional 6:1 attacker-to-defender ratio commonly associated with conventional urban combat operations. Squad Multipurpose Equipment Transports carry supplies and small unit enablers, such as additional weapons, power generation, and other ground robots. These capabilities enable Soldiers and tactical units to avoid threats, maneuver and clear objectives efficiently, and initiate contact under favorable conditions. Platoons and squads will use these systems to aid in reconnaissance missions across three dimensions (surface, supersurface, and subsurface) and to protect Soldiers. UAS sensors loitering overhead work with UGS platforms on the ground to provide enhanced situational awareness to human teammates in order to create better tactical options for small unit leaders.

Mid-term (2021-2030)

From 2021-2030, the primary focus is improvements in **situational awareness, Soldier load reduction, sustainment and maneuver**. The Army improves the ability to develop and sustain understanding through human-machine collaboration, advanced RAS, and swarming capabilities. The Army invests in new programs to pursue exoskeleton to reduce Soldiers' physical load and an unmanned combat vehicle to deliver advanced capabilities to maneuver units. Improvements to automated convoy operations achieve full autonomy removing Soldiers from the lead vehicle under the Leader-Follower program.

Mid-Term Priorities

- Increase situational awareness with advanced, smaller RAS and swarming
- Lighten the load with exoskeleton capabilities
- Improve sustainment with fully automated convoy operations
- Improve maneuver with unmanned combat vehicles and advanced payloads

RAS capabilities support Army formations by providing **advanced situational awareness** tools and improve maneuver and lethality of air-ground teams configured with manned and unmanned combat systems. RAS technologies executing "persistent stare" missions will free Soldiers from the cognitive and physical burdens of surveillance and reconnaissance missions. In addition, the increasing occurrence of manned/unmanned formations will further impact information flows, requiring new knowledge management tactics, techniques and procedures (TTP) and further revisions to the Mission Command Network. The Army builds upon existing capabilities for situational awareness with swarming capabilities to increase the coverage, persistence, and duration of intelligence, surveillance and reconnaissance (ISR) missions at all echelons. More increments of small UAS and UGS improve size, weight, power, and cooling. Small UGS with increased autonomy serve as static and mobile sensors on the battlefield, capable of providing redundant communications and navigation assistance in degraded environments. Swarming robots provide a collaborative, multi-robot system consisting of large numbers of mostly simple physical robots that interact with each other and the environment. Using artificial intelligence, these networked robots provide a desired collective behavior by covering larger areas while sharing information.

To continue **transferring the Soldier load** onto RAS platforms, the Army increases autonomy in medium-sized and larger UGS for increased resupply throughput and movement of squad enablers between dismounted echelons. Medium-sized and larger UGS platforms will make one of the biggest leaps in capability when the Army adds Modular Mission Payloads (MMPs), such as CBRN and ISR sensors, lethal capabilities, communications packages and medium UAS platforms. The Army introduces exoskeleton technologies that lighten the Soldier load and allow for increased Soldier protection (armor) during close combat, and enable Soldiers to carry more innovative and capable firepower solutions at the individual Soldier level.

The Army **improves automated sustainment** by adding advanced appliqué robotic systems to new vehicle fleets. Where in the near-term, automated resupply only followed manned lead vehicles, in the mid-term, vehicles will move autonomously among security elements. To improve sustainment throughput capabilities, the Army begins programs for medium and large cargo UAS to reduce reliance on manned rotary wing support. Similarly, casualty evacuation (CASEVAC) requires greater efficiency as units operate dispersed. Future unmanned systems assist in enabling CASEVAC, as autonomous systems operate in all conditions and stage forward with support units, shortening the transition time from initial injury to casualty collection points or treatment facilities centers.

To **facilitate movement and maneuver**, the Army will introduce unmanned combat vehicles designed to function and maneuver across variable and rough terrain under combat conditions. Capitalizing on earlier successes achieved in wheeled logistics autonomy prototypes, the first increments of RAS enabled combat platforms will have optionally-manned, teleoperated or semi-autonomous technology. As autonomous off-road technology fully matures, the Army will not wait for perfection in off-road navigation and tactical, inferential decision-making software before fielding autonomous prototypes for testing. Instead the Army will seek to provide opportunities to field what technologies exist today in an expectation of rapid innovation and evolution over the next ten years. In addition, to support formations in moving and maneuvering against the enemy, TTPs will be developed for tactical deception operations. Lastly, to improve maneuver, the Army modernizes its UAS fleet with a future family of UAS, starting with scalable control interfaces and a runway-independent, expeditionary tactical UAS. Reduced signatures and small, guided munitions capability will improve UAS survivability and lethality.

From 2021-2030, the Army continues research in autonomy, machine learning, AI, power management, and common control to achieve more capable UGS and UAS. While full autonomy is not achieved in the mid-term, the Army will be in position for success in the far-term.

Vignette: Setting the Theater in Future Crises

"There is nothing more common than to find considerations of supply affecting the strategic lines of a campaign and a war." - Carl von Clausewitz

In April 2025, an enemy invades an ally's capital with heavy forces to occupy and annex resource-rich national territory. In support of its ally, the U.S. deploys an ABCT that links up with armored assets from prepositioned stocks.

Based on the immediacy of the need and limited logistical support, the Army uses Leader-Follower unmanned ground transport convoys to line-haul fuel, ammunition, and repair parts from storehouses to support the ABCT in the ally's country.

The Leader-Follower capability successfully supports the forward deployed BCT, utilizing a mix of manned and unmanned vehicles to conduct convoy operations. Convoys employ dedicated short-range radios and computerized, behavioral algorithms to allow multiple unmanned trucks to follow the leading manned truck.

In this scenario, the automated Leader-Follower capability allows minimal logistics personnel to oversee wheeled convoys on a 700-mile trek in support of a U.S. ally in its preparation for possible combat operations. Using the automated technology frees up more slots for combat arms Soldiers to flow earlier into theater. RAS capabilities also enable the swift and organized movement of tons of supplies on short notice without the need for large numbers of logisticians to be present on the ground ahead of operational combat units.

Far-term (2030-2040)

From 2031-2040, the Army displaces its antiquated autonomous systems and fields new autonomous UGS and UAS developed through commercial research and science and technology investments made in the near- and mid-terms. Studies and lessons learned from near- and mid-term initiatives inform new organizational designs that fully incorporate autonomous systems. The Army uses these technologies to maintain advantage of situational understanding from home station to initial entry, enabling rapid transition to other operational phases.

Autonomous systems, fully integrated into the force, allow Soldiers and leaders to focus on the execution of the mission rather than the manipulation and direct task control of robots. Next generation unmanned combat vehicles and aircraft enable Army forces to create multiple options for commanders, and to rapidly task organize and fight differently based on shifting mission variables.

Human-machine teams adapt continuously and conduct persistent reconnaissance and security missions for extended durations. The Army adds computerized technology to the Soldier exoskeleton to create a complete "warrior suit" with integrated displays that aggregates a common operating picture, provides intelligence updates, and integrates indirect and direct fire weapons systems.

Far-Term Priorities

- Increase situational awareness with persistent reconnaissance from swarming systems
- Improve sustainment with autonomous aerial cargo delivery
- Facilitate maneuver with advancements to unmanned combat vehicles

To increase **situational awareness**, the Army delivers swarms of multiple small robots to an area of operations in advance of close combat maneuver forces. Delivery options range from using a simple shipping container to a special-purpose platform from which smaller craft or robotic systems are launched or maintained. Swarm robots will be fully powered, self-unpacking, and ready for immediate service.

Autonomous systems and swarm robots enable a maneuverable network, greatly improving the tactical mobility and signature management of command posts. As before, the existence of manned/unmanned formations requires new knowledge management and adjustments to the Mission Command Network. Entire logistics efforts are automated, allowing Soldiers to focus on combat activities and direct missions where human decisions and actions are required.

The Army **improves sustainment** capability with autonomous cargo delivery. On the ground, the focus is on fully automating tactical wheeled vehicles. Autonomous aerial systems provide increased resupply capabilities to move containerized and packaged loads between distribution nodes and forward areas with reduced reliance on manned rotary wing support.

To **facilitate maneuver**, formations benefit from armed ground and aircraft robotic platforms with smaller signatures and longer endurance, working alone or in pairs, to destroy high-value targets deep in enemy territory. Unmanned combat vehicles will have the capability to move and maneuver autonomously, extending the effects of the manned-unmanned team. Technologies enable manned and unmanned teaming in both air and ground maneuver through investments in scalable sensors, teaming, AI, and Soldier-robot communication.

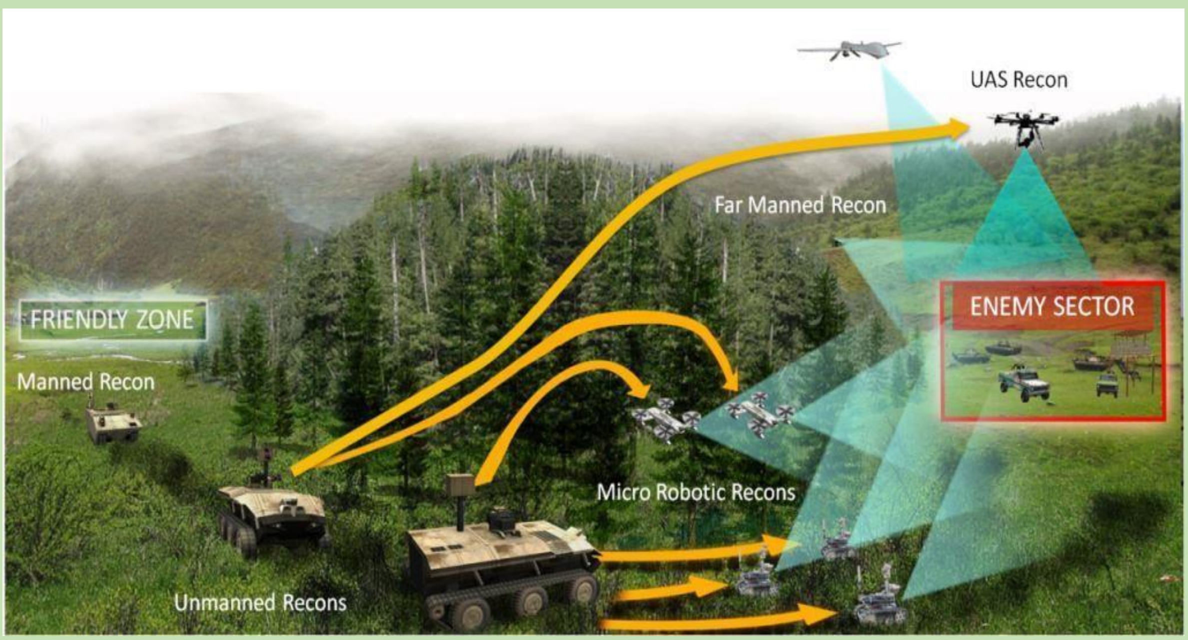
In the far-term, RAS allow commanders to retain the initiative during high-tempo, decentralized operations. Rapidly deployable RAS capable of connecting mission command systems will allow for mission command on-the-move and the rapid transition to offensive operations after initial entry. RAS also increase situational understanding in urban environments through reconnaissance and mapping of subterranean systems. Expendable RAS platforms will provide commanders the ability to take operational risks previously unimaginable with solely manned formations. Machines will take the place of humans maneuvering through the most dangerous avenues of approach and will make contact with likely threats without costing commanders valuable Soldiers. With less human exposure to hazards, the risks inherent with deception operations, penetrations behind enemy defenses, and exploitation and pursuit operations become less costly, giving commanders greater options and more reliable freedom of maneuver.

Vignette: Reconnaissance and Security Operations

Mounted combat in the far-term includes small UGS working alongside Soldiers with robotic integration across all formations and mission templates. For reconnaissance and security missions, mounted scouts, augmented with vehicle-launched semi-autonomous UAS, detect threats along the axis of advance before main body forces are surprised or engaged with enemy long-range systems.

Dismounted scouts, augmented with small ground robots, use reconnaissance and security platforms to relay data to higher echelons. RAS will swarm enemy sectors to feed real-time data to mounted and dismounted scouts. Army intelligence will allow for the effective and efficient operational employment of RAS sensors, providing higher degrees of situational awareness. RAS increase capabilities at all echelons from the squad to the BCT, to create opportunities for BCT commanders to fight more effectively with greater understanding of the enemy's disposition and strengths.

With increased RAS on the battlefield, the enemy will employ countermeasures to affect RAS, and communication/data links. To ensure mission assurance, future RAS will have redundant communications and the ability to operate in GPS-denied environments.



Section III

Aligning Ends, Ways, and Means

Ends

Army formations use RAS to increase combat effectiveness and to maintain overmatch in combined arms operations against capable enemies.

Ways

The Army accomplishes the capability objectives in this strategy through prioritization of RAS capabilities and innovation through continuous leaning improvisation and adaption.

Prioritization

To achieve the five capability objectives in this strategy, the Army prioritizes autonomy, AI, and common control as key efforts. These technology advancements are pervasive throughout this strategy. Foremost is autonomy for ground vehicles because, as a land force, the Army relies on ground combat vehicles and off-road mobility. It is the most challenging, military-specific requirement. Automated capability for tactical wheeled vehicles on primary and secondary roads will also be a priority. Autonomy is a gateway technology that, once obtained, will be integrated into all ground vehicles, combat or otherwise. Its impact will influence all warfighting functions.

Ground vehicle autonomy increases force protection by have RAS conduct dirty and dangerous tasks. Immediate investment of semi-autonomous capability, such as automated convoy resupply, will reduce the number of Soldiers required to operate vehicles during convoy operations, thereby reducing the number exposed to risk. Transferring autonomous technology to current Army systems will reduce the costs of new start programs and avoid carrying integration costs and training costs.

In the mid- to far-term time horizons, autonomous RAS with advanced payloads will deploy in depth at the squad through brigade level to expand terrain coverage, create tactical options, and increase force protection.

Innovation

The Army Operating Concept defines innovation as the result of critical and creative thinking and the conversion of new ideas into valued outcomes. The RAS strategy encourages innovation via new or significantly improved products, processes, organizational methods, marketing methods, and internal practices. Innovation does not come from technology alone, it emerges from evolutionary problem-solving directed at specific operational and tactical issues. It requires coherent frameworks of doctrine and concepts. The innovation process generates new ideas for the Army to advance RAS design, development, and employment.

The Army's laboratories within the Research, Development, and Engineering Command (RDECOM) develops new technologies, and the Centers of Excellence innovate and experiment to develop ideas, insights, and requirements, using Science and Technology objectives, to decide whether to invest in a concept, discard it, or experiment further.

Means

The means of the RAS Strategy are the resources used to accomplish the objectives. To achieve overmatch, the Army must analyze and apply emerging technologies and new organizational concepts now, identify and take advantage of existing material solutions, and support new Research and Development initiatives. Additional resources must follow new or adjusted priorities. The RAS strategy outlines this through time, funding and organizations.

Time: The Army acquisition process requires many time-consuming tasks and processes, which is why the RAS progressions are time-phased. By working together, the four primary Army organizations in the robotic community (Army Materiel Command, Training and Doctrine Command, Army Staff, and the Assistant Secretary of the Army for Acquisition, Logistics and Technology) can expedite how quickly warfighters receive RAS. Organizations like the Rapid Capability Office will also streamline innovation opportunities and permit RAS to exploit technology breakthroughs.

Funding: Funding is critical for the development and procurement of RAS and the technology required to make RAS effective. The current Strategic Portfolio Analysis Review (SPAR) is well postured to align priorities and resources to achieve the objectives within the RAS Strategy.

Organizations: Organizations within the RAS community offer the capabilities, resources, and expertise to pursue and achieve RAS capabilities. Those critical to accomplishing the RAS end state are: RDECOM, TRADOC, Army and DoD labs, academia, and commercial robotic vendors in the U.S. industrial base. The Army leverages commercial research whenever possible to reduce costs and increase capabilities. Collaborative innovation venues and processes will continue to evolve providing routine and frequent opportunities for the Army and industry to work together to develop RAS capabilities. The Army facilitates adjustments in the Army Science and Technology community to keep pace with rapid evolution of RAS, computer processing power, and software. Lastly, the Army collaborates with the other military Services with the Joint Concept for Robotic and Autonomous. The Army benefits when working with the other Services on common programs and capabilities. Two examples with the Marine Corps are the universal robotic controller and the Joint Automated Aerial Resupply (JAAR, a medium UAS with initial objectives to carry 200-300 pounds 1-75 miles). One example of collaboration with the Navy is the common architecture and software created for the universal robotic controller.

The SIDRA Development Process

To link the strategy's ways and means, the Army uses a five-step development process as a bridge to modernize the technologies. This process includes the following steps:

Sustain current systems.
- Maintain current fleet of tele-operated UGSs and remotely piloted UAS
- Recapitalize older robots

Improve existing systems.
- Field a universal controller for legacy and new programs
- Field autonomous technologies within UGS and UAS where possible
- Refine automated ground resupply operations as the Army's first semi-autonomous vehicle

Develop new capabilities.
- Develop off-road autonomy for unmanned combat vehicles
- Develop swarming for advanced reconnaissance
- Develop artificially intelligent augmented networks and systems

Replace obsolete systems.
- Replace non-standard equipment systems with new programs of record
- Replace manned systems with unmanned systems to allow Soldiers to perform other tasks

Assess new technologies and systems.
- Continue assessments on the state of UGS and UAS autonomy to ensure systems progress with available technology
- Determine where technologies can serve cross-domain solutions, especially with new payloads

Section IV

RAS and Interim Solutions to the Army Warfighting Challenges

Given the current level of development and future technology, RAS capabilities assist leaders and Soldiers to address many of the Army Warfighting Challenges (AWfCs) that describe enduring operational problems listed in the Army Operating Concept. The AWfCs represent first-order questions to frame learning and collaboration that improves combat effectiveness of the current and future force. AWfCs focus on concept and capability development, and because they are enduring, they allow the Army to integrate near-term, mid-term and long-term efforts to deliver the future force.

The AWfCs listed below are directly impacted by RAS capabilities sought in the near- and mid-terms.

AWfC 1 - Develop Situational Understanding: *How to develop and sustain a high degree of situational understanding while operating in complex environments against determined, adaptive enemy organizations.*

RAS improve reconnaissance and security operations by focusing on terrain and enemy forces, by developing the situation, and by protecting the force through early and accurate warning. RAS also increase situational awareness in complex environments through reconnaissance and mapping of sub- and supersurface environments. RAS collects and processes raw data (e.g., full motion video) to produce intelligence such as visualization of a potential adversary with a location identifier. Such information helps shape and identify hazards, providing leaders with better situational awareness and improved understanding.

AWfC 7 - Conduct Space and Cyber Electromagnetic Operations and Maintain Communications: *How to assure uninterrupted access to critical communications and information links (satellite communications, positioning, navigation, and timing, and intelligence, surveillance, and reconnaissance) across a multi-domain architecture when operating in a contested, congested, and competitive operating environment.*

RAS will provide unmanned air and ground communications relays and support uninterrupted access to critical data links. Potential enemies are developing cyber-electromagnetic and space capabilities (such as disruptive and destructive malware, and electronic warfare systems and anti-satellite weapons) to disrupt, jam, spoof, and hack communications and precision navigation and timing systems.

AWfC 11 - Conduct Air-Ground Reconnaissance and Security Operations: *How to conduct effective air-ground combined arms reconnaissance and security operations to develop the situation rapidly in close contact with the enemy and civilian populations.*

RAS provide persistent surveillance and reconnaissance with unmanned systems allowing units to conduct security operations across a wider area for longer durations while enabling Soldiers to focus on other missions. Future systems employ advanced technologies to extend endurance and standoff.

AWfC 12 - Conduct Joint Expeditionary Maneuver and Entry Operations: *How to project forces, conduct forcible and early entry, and transition rapidly to offensive operations to ensure access and seize the initiative.*

UGS and UAS equipped with mission payloads and armaments will conduct reconnaissance based on tasks given by the operator. High definition sensors will integrate threat detection, queuing, and imagery over an integrated network in degraded visual environments for extended duration in areas inaccessible by Soldiers.

Use of unmanned systems in mounted and dismounted maneuver formations leads to smaller platforms that are more mobile and transportable, enabling greater expeditionary maneuver capability.

AWfC 13 - Conduct Wide Area Security: *How to establish and maintain security across wide areas to protect forces, populations, infrastructure, and activities necessary to shape security environments, consolidate gains, and set conditions for achieving policy goals.*

AWfC 15 - Conduct Joint Combined Arms Maneuver: *How to conduct combined arms air-ground maneuver to defeat enemy organizations and accomplish missions in complex operational* *environments.*

RAS contribute to AWfCs 13 and 15 by conducting persistent surveillance of enemy avenues of approach, terrain denial with anti-armor robotic platforms, and targeting data collection to support indirect and direct fires. RAS provide units and teams with protection and standoff from IEDs and other explosives through detection, diagnostics, identification, neutralization, and render-safe capabilities. RAS support operations to enhance friendly force freedom of action, shape terrain, and control enemy movement.

AWfC 16 - Set the Theater, Sustain Operations and Maintain Freedom of Movement: *How to set the theater, provide strategic agility to the Joint Force, and maintain freedom of movement and action during sustained and high-tempo operations at the end of extended lines of communication in austere environments***.**

RAS augment sustainment operations with autonomous ground and aircraft systems. Associated sensors, computers and decision support tools aid navigation, route selection, vehicle control, and vehicle management such as speed, intervals, and obstacle avoidance. They also conduct triage and evacuate casualties under fire. Autonomous aircraft systems provide increased resupply capabilities while reducing manning requirements.

AWfC 17 – Integrate Fires: *How to coordinate and integrate Army and JIM fires, and conduct targeting across all domains to defeat the enemy and preserve freedom of maneuver and action across the range of military operations.*

AWfC 18 - Deliver Fires: How to deliver fires to defeat the enemy and preserve freedom of action across the range of military operations.

RAS contribute to both AWfCs 17 and 18. UAS have demonstrated the potential to generate accurate targeting locations for precision fires and the ability to report battle damage assessments. By employing next generation sensors and shooters, RAS achieve real-time integration and optimization of targeting data for a range of fires applications. RAS fuse data from all joint, national, and multinational sensors from space to subterranean to achieve real time integration and optimization of targeting data. RAS enable forces to move accurately and quickly track and defeat targets, match targets with effects, and coordinate capabilities.

AWfC 19 - Execute Mission Command: *How to understand, visualize, describe, and direct operations consistent with the philosophy of mission command to seize the initiative over the enemy and accomplish the mission across the range of military operations.*

RAS will facilitate mission command by collecting, organizing, and prioritizing immense amounts of data to aid decisions making. RAS will also improve command post tactical mobility while reducing the cyber, electronic, and physical signature.

Section V

Conclusion

The Army RAS Strategy is a call to commit time, talent, and resources now to position the Army for victory in future conflicts. In pursuing RAS technologies, the Army addresses three challenges in the future OE: accelerated speed of action on the battlefield, increased use of RAS by adversaries, and amplified complexity of contested environments. To overcome these challenges, the Army must seize technological opportunities for RAS development.

The RAS Strategy will evolve over time but, as it does, it will continue to remain focused on the fundamental objective of maintaining overmatch and pursuing new technologies to protect Soldiers. Integrating RAS into the Army will not be easy. Capabilities like medium- and large-autonomous ground vehicles will take time to integrate because of the great technological and environmental challenges involved. This strategy outlines the essential activities necessary to foster unity of effort and identifies opportunities to accelerate ground and aerial RAS capabilities in a resource-constrained environment. Following publication of this Strategy, the Army's RAS execution order to implement the Strategy and its subsequent RAS Concepts of Operation and Concepts of Employment will provide more detailed guidance for the integration of RAS capabilities.

This evolutionary process will achieve the five capability objectives: increase situational awareness; lighten the warfighters' physical and cognitive workloads; sustain the force with increased distribution, throughput and efficiency; facilitate movement and maneuver; and increase force protection. RAS will lead the Army to accomplish its technology advancements: autonomy, artificial intelligence, common control, government-owned architecture, interoperability, common platforms, and modular payloads.

To win in a complex world, the Army uses RAS to provide the Joint Force with multiple options to operate across multiple domains, to present enemies and adversaries with multiple dilemmas, and to defeat enemies. By directing a clear vision of how the Army intends to exploit breakthroughs in RAS technology and innovation, the RAS Strategy helps reshape the vision for how the Army fights in the future.

Appendix A. Acronyms and Terms

Acronyms

A2AD	Anti-access/Area Denial
ACO	Automated Convoy Operations
ACE	Army Capability Enablers
AEWE	Army Expeditionary Warrior Experiment
AFRL	Air Force Research Laboratory
AI	Artificial Intelligence
AOC	Army Operating Concept
AMRDEC	Aviation and Missile Research, Development and Engineering Center
ARDEC	Armament Research, Development and Engineering Command
ARL	Army Research Laboratory
ARO	Army Research Office
AWA	Army Warfighting Assessments
AWFC	Army Warfighting Challenges
BCT	Brigade Combat Team
C4ISR	Command, Control, Communications, Computers, Intelligence, Surveillance, and Reconnaissance
CASEVAC	Casualty Evacuation
CBRN	Chemical, Biological, Radiological, and Nuclear
CERDEC	Communications-Electronics Research, Development and Engineering Center
C-IED	Counter Improvised Explosive Device
CONOPS	Concept of Operations
CoP	Community of Practice
COP	Common Operating Picture
COTS	Commercial Off the Shelf
DARPA	Defense Advanced Research Projects Agency
DoD	Department of Defense
DOTMLPF-P	Doctrine, Organization, Training, Materiel, Leadership and Education, Personnel, Facilities, and Policy
ECBC	Edgewood Chemical Biological Center

ECP	Engineering Change Proposal
EOD	Explosive Ordnance Disposal
ERDC	Engineering Research and Development Center
FMV	Full Motion Video
GCS	Ground Control Station
GPS	Global Positioning System
IED	Improvised Explosive Device
IEEE	Institute of Electrical and Electronics Engineers
IPT	Integrated Product Team
ISR	Intelligence, Surveillance, and Reconnaissance
JLOTS	Joint Logistics Over-the-Shore
LF	Leader-Follower
LIRA	Long-Range Investment Analysis
LRRDPP	Long-Range Research and Development Plan
MMP	Modular mission payload
MOCU	Multi-Robot Operator Control Unit
MOSA	Modular Open-Systems Approach
MP	Military Police
MRAP	Mine Resistant Ambush Protected
MUM-T	Manned-Unmanned Teaming
NIE	Network Integration Evaluations
NSRDEC	Natick Soldier Research, Development and Engineering Center
OCU	Operator Control Unit
OE	Operational Environment
ONR	Office of Naval Research
OSD	Office of the Secretary of Defense
PEO	Program Executive Office
PM	Program Manager
PNT	Positioning, Navigation and Timing
POR	Program of Record
RAS	Robotic and Autonomous Systems

RD&E	Research, Development and Engineering
RDEC	Research, Development and Engineering Center
RDECOM	Army Research, Development and Engineering Command
RDT&E	Research, Development, Test and Evaluation
RSTA	Reconnaissance, Surveillance and Target Acquisition
S&T	Science and Technology
SPAR	Strategic Portfolio Analysis Review
STO	Science and Technology Objectives
STO-D	Science and Technology – Development
S&T	Science and Technology
TARDEC	Tank Automotive Research Development and Engineering Center
TARDEC	Tank Automotive Research Development and Engineering Center
TEV&V	Test, Evaluation, Validation & Verification
TRADOC	Training and Doctrine Command
TTP	Tactics, Techniques and Procedures
UAS	Unmanned Aerial System
UAV	Unmanned Aerial Vehicle
UGS	Unmanned Ground System
UGV	Unmanned Ground Vehicle
UMV	Unmanned Maritime Vehicle
USV	Unmanned Surface Vehicle
UUV	Unmanned Undersea Vehicle
WMD	Weapons of Mass Destruction

Terms

Appliqué kit - Add on kit that enables manned platforms to be operated with unmanned capabilities at the commander's discretion.

Army Warfighting Challenge - Enduring operational problems listed in the Army Operating Concept. The AWfCs represent first-order questions to frame learning and collaboration to improve the combat effectiveness of the current and future force.

Artificial intelligence - Capability of computer systems to perform tasks that normally require human intelligence such as perception, conversation, and decision-making. Advances in AI are making it possible to cede to machines many tasks long regarded as impossible

Automated Convoy: A convoy in which all task vehicles/cargo carrying platforms that make up the convoy are automated (C2, security vehicles, and maintenance/Recovery vehicles are always manned).

Automation - The level of human intervention required by a system to execute a given task(s) in a given environment. The highest level of automation (full) is having no immediate human intervention, and can be considered unmanned. The remnant of human intervention at this highest automated level is left to command/control oversight (i.e. planning/task identification).

Autonomy - the level of independence that humans grant a system to execute a given task in a given environment. The condition or quality of being self-governing to achieve an assigned mission based on the system's own situational awareness (integrated sensing, perceiving, analyzing) planning and decision-making. This independence is a point on a spectrum that can be tailored to the specific mission, level of acceptable risk, and degree of human-machine teaming.

Combat information - Unevaluated data, gathered by or provided directly to the tactical commander which, due to its highly perishable nature or the criticality of the situation, cannot be processed into tactical intelligence in time to satisfy the user's tactical intelligence requirements.

Intelligence - 1. The product resulting from the collection, processing, integration, evaluation, analysis, and interpretation of available information concerning foreign nations, hostile or potentially hostile forces or elements, or areas of actual or potential operations. 2. The activities that result in the product. 3. The organizations engaged in such activities. (JP 2-0)

Intelligence Analysis - The process by which collected information is evaluated and integrated with existing information to facilitate intelligence production. (ADRP 2-0)

Intelligence, surveillance, and reconnaissance - An activity that synchronizes and integrates the planning and operation of sensors, assets, and processing, exploitation, and dissemination systems in direct support of current and future operations. (JP 2-01)

Interoperability - Ability of a system to work with or use the parts or equipment of another system.

Leader-Follower function - An appliqué kit that provides a limited robotic-like capability to transportation and distribution units. A manned Leader vehicle leads three to seven unmanned Follower vehicles.

Machine intelligence, perception, and reasoning - The capability of an RAS to sense and perceive its environment, process inputs, render conclusions about the data that provides the machine with the ability to act appropriately in an uncertain environment using sophisticated inferential cognitive mechanisms such as learning and reasoning.

Manned-unmanned Teaming – Manned-unmanned Teaming is the synchronized employment of Soldiers, manned and unmanned air and ground vehicles, robotics, and sensors to achieve enhanced situational understanding, greater lethality, and improved survivability. The concept of MUMT is to combine the inherent strengths of manned and unmanned platforms to produce synergy and overmatch with asymmetric advantages.

Optionally-Manned Platform - A RAS system that is capable of offering operational employment either as a robotic platform or a traditional manned vehicle or system.

Processing and Exploitation – In intelligence usage, is the conversion of collected information into forms suitable to the production of intelligence. (JP 2-01)

Remotely Piloted/Controlled - A mode of operation wherein the human operator, without benefit of video or other sensory feedback, directly controls the actuators of a UMS on a continuous basis, from off the vehicle and via a tethered or radio linked control device using visual line of sight cues. In this mode, the UMS takes no initiative and relies on continuous or nearly continuous input from the user.

Robot - a powered machine capable of executing a set of actions by direct human control, computer control, or a combination of both. It is comprised of a platform system, software, and a power source.

Robotics - The science or study of the technology that is used to design, build, and operate robots.

Robotic and Autonomous Systems (RAS) - is an accepted term within academia and the science and technology (S&T) community and highlights the physical (robotic) and cognitive (autonomous) aspects of these systems. For the purposes of this concept, RAS is a framework to describe systems that have a robotic element, an autonomous element, or more commonly, both. As technology advances, there are more robotics systems with autonomous capabilities.

Robotized - Transitioned from a non-robotic to a robotic state.

Robotic Wingman - A tactical RAS platform that augments manned, tactical, ground combat platforms. A robotic wingman may acquire and transmit data and combat information, lead columns of manned vehicles, augment manned platform movement and maneuver, or operate independently out of close proximity to manned systems. A robotic wingman will use variable degrees of direct human control, robotic/A.I. command and control technology. These RAS will create options for human commanders by creating standoff between humans and threat contact. Commanders will be able to communicate desired routes, objectives and to use variable amounts of direct control or autonomy for these RAS depending on risk, complexity of task, and the need for human control of weapons engagement. Robotic Wingmen will operate at a level of performance, when employed, which will be comparable to a manned vehicle.

Sensor - A devise intended to detect and provide perceivable, measurable data. For the purpose of this strategy, sensor definitions for unmanned systems are wrapped into the RAS discussion as reconnaissance remains tied to one of the primary robotic mission. Sensors are critical enablers to this capability. Sensors may refer to the robots themselves or their specific mission payloads.

Swarm - Swarming is a method of operations where large numbers of autonomous systems actively coordinate their actions to achieve operational outcomes. Swarming overwhelms targets by using mass and attrition in combination with decentralized maneuvers or combined fires from multiple directions.

Tele-Operated - A mode of operation wherein the human operator, using video feedback and/or other sensory feedback, either directly controls the actuators or assigns incremental goals, waypoints in mobility situations, on a continuous basis, from off the vehicle and via a tethered or radio linked control device. In this mode, the RAS may take limited initiative in reaching the assigned incremental goals.

Unmanned Ground Vehicle (UGV) - An electro-mechanical unmanned ground platform. Can be operated via remote control, tele-operation, or may be equipped with some degree of autonomous behavior. Such a platform may also retain the ability to optionally-manned, where robotic capability is not necessary or desired.

Unmanned system - An air, land, surface, subsurface, or space platform that does not have the human operator physically onboard the platform.

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