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A Scenario for Development of an Autonomous Reconnaissance and Screening Capability and Areas Identified for Further Research and Development

by David Booth

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14. ABSTRACT
A proposed scenario is described for development of an autonomous force-on-force capability. In this scenario, Soldiers and robotic systems act as a team and perform the tasks of reconnaissance and screening. This scenario is the basis for further simulation and experimental research to be performed by ARL. This report emphasizes many of the challenges and capabilities that need to be developed for effective Soldier–robot teaming for a mission in such a scenario. The scenario depicts a much-scaled-down version of a typical cavalry unit mission of reconnaissance and screening. Key benefits identified for the use of robotic and autonomous system (RAS) include risk mitigation, enhanced situational awareness, improved operational tempo, accelerated command and control, and increased lethality and precision. Areas identified for further research and development include improving Soldier–robot trust, communication, shared understanding, and Soldier cognitive load. A structured three-phase approach is introduced for implementation of RAS into the mission scenario that includes details of the pre-mission preparation, mission execution, and post-mission activities to assist with further refinement of tactics, techniques, and procedures along with RAS technology.

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1. Introduction

This report describes a proposed scenario for developing an autonomous force-on-force capability. In this scenario, Soldiers and robotic systems act as a team and perform the reconnaissance and screening tasks of a cavalry mission. This scenario is the basis for further simulation and experimental research to be performed by the U.S. Army Combat Capabilities Development Command (DEVCOM) Army Research Laboratory (ARL). The tactical situation in the proposed scenario is defined by a Red Force (adversary) advance with the primary objective of capturing or destroying the Blue Force (friendly forces) base camp. A reconnaissance push mission is simultaneously performed by Blue Force autonomous reconnaissance units consisting of Soldier–robotic teams. The scenario depicts a much-scaled-down version of a typical cavalry unit mission of reconnaissance and screening.

Cavalry are the eyes and ears of the force commander, who act as reconnaissance and security assets.[1] Cavalry units conduct reconnaissance and security operations to develop situational understanding. This aids the parent unit's development of the common operational picture.

Reconnaissance operations provide commanders with information and facilitate decision making to conduct better-informed planning, help direct operations, and visualize the area of operations (AO). They help the commander identify gaps or weaknesses in the plan, identify opportunities to exploit, and make decisions and direct forces to achieve mission success.[1] Reconnaissance units must provide information rapidly and accurately. They help develop the situation rapidly and collect information on the threat's location, disposition, and composition. This affords reaction time and maneuver space to the brigade combat team (BCT),[2] which allows the BCT commander to shape the AO and accept or initiate contact at times and places of their choosing.[1,2]

Key benefits identified for the use of robotic and autonomous system (RAS) include risk mitigation, enhanced situational awareness (SA), improved operational tempo, accelerated command and control (C2), and increased lethality and precision. This report emphasizes many of the challenges and capabilities that need to be developed for effective Soldier–robot teaming for a mission in such a scenario. Modern reconnaissance will be a collaborative effort between well-trained Soldiers and their RAS partners, where technology is used to enhance human capability and dramatically reduce risk. Areas identified for further research and development include improving Soldier–robot trust, communication, shared understanding, and cognitive load.

Finally, a structured three-phase approach is introduced for implementation of RAS into the mission scenario that includes details of the pre-mission preparation, mission execution, and post-mission activities to assist with further refinement of tactics, techniques, and procedures (TTP) and RAS technology.

2. Situation

In this scenario, the tactical situation is defined by a Red Force advance with the primary objective of capturing or destroying the Blue Force base camp. Intelligence indicates that Red Force has several potential axes of advance passing through key terrain designated as Objective (OBJ) Lion, OBJ Snake, and OBJ Tiger.

In response, a reconnaissance push mission is executed by the Blue Force commander. Blue Force proactively positioned reconnaissance elements to monitor these likely advance routes. The reconnaissance units are dismounted to maximize stealth and due to the presence of restricted terrain. A zone reconnaissance mission is performed with a deliberate and stealthy tempo. Recent intelligence confirms that Red Force has committed its main effort and is initiating a deliberate attack through OBJ Tiger. Figure 1 shows an overall big-picture diagram of the scenario.

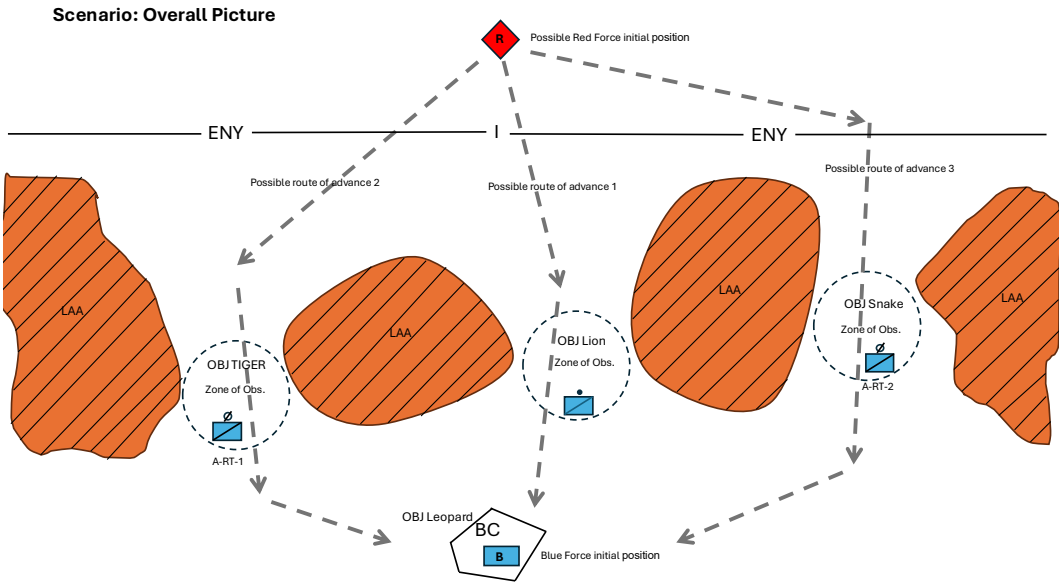

Figure 1. Overall operational view.

2.1 Enemy Forces

2.1.1 Composition and Strength

Intelligence indicates Red Force consists of at least two mechanized companies and one armored company with supporting reconnaissance, engineering, artillery, and air assets.

2.1.2 Disposition and Activity

Red Force is deployed at their approximate location in a disruption zone.

2.1.3 Capabilities and Intent

Red Force will attack to seize crossing sites to facilitate the battalion's decisive operation (DO), which is the advance of the battalion to seize OBJ Leopard.

2.2 Friendly Forces

2.2.1 Higher Headquarters (HQ) Mission

Blue Force has established a hasty defense focused on retaining key crossing sites to the north of their position. Their DO appears to be a strongpoint defense near OBJ Leopard.

2.2.2 Capabilities and Intent

Blue Force is capable of reinforced company-level counterattacks. They intend to use indirect fires to neutralize mounted forces and destroy dismounted infantry and engineers to prevent Red Force from amassing at the crossing sites. Their desired end state is to delay Red Force's advance for up to 48 h, allowing main defensive positions to be completed.

2.2.3 Adjacent Units

The main Blue Force task force is conducting a shaping operation to seize objectives further to the north, preventing the enemy from disrupting our southern advance.

3. Mission

Blue Force Autonomous Reconnaissance Team 1 (A-RT-1) is to conduct a reconnaissance and screening mission of OBJ Tiger. The team will confirm or deny the presence of enemy forward elements, gather detailed intelligence on Red Force composition and disposition, and, if ordered, execute delaying actions to disrupt the enemy's advance to facilitate the Blue Force task force's main attack. Figures 2 and 3 show top-down views of OBJ Tiger and the Military Operations on/in Urban/Urbanized Terrain (MOUT) site located there in this scenario.

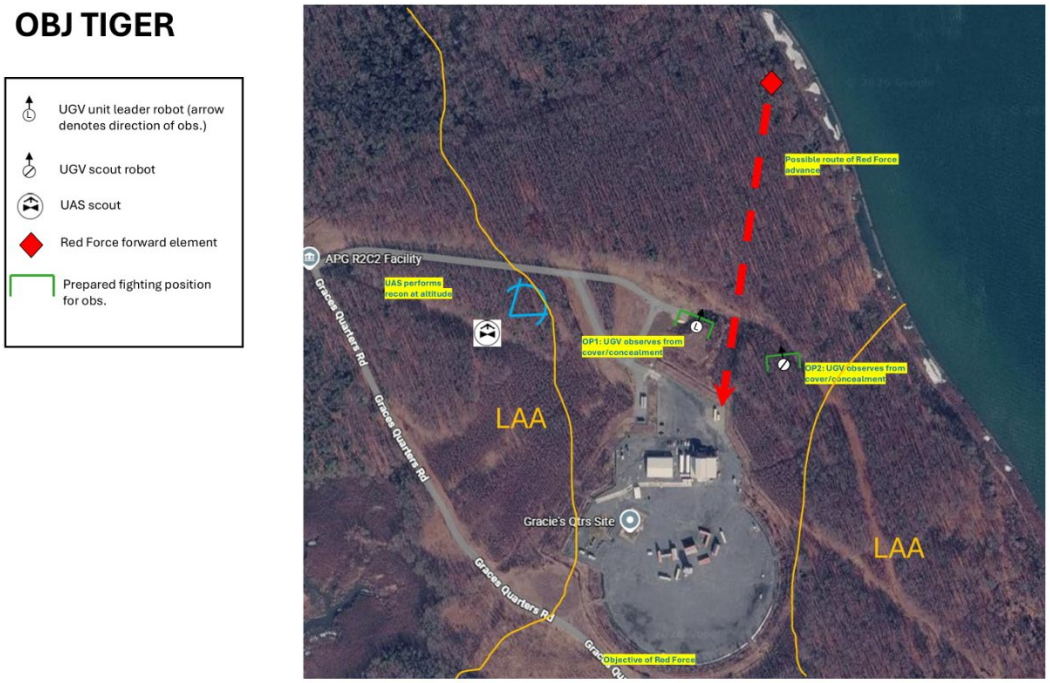

Figure 2. Scenario at OBJ Tiger.

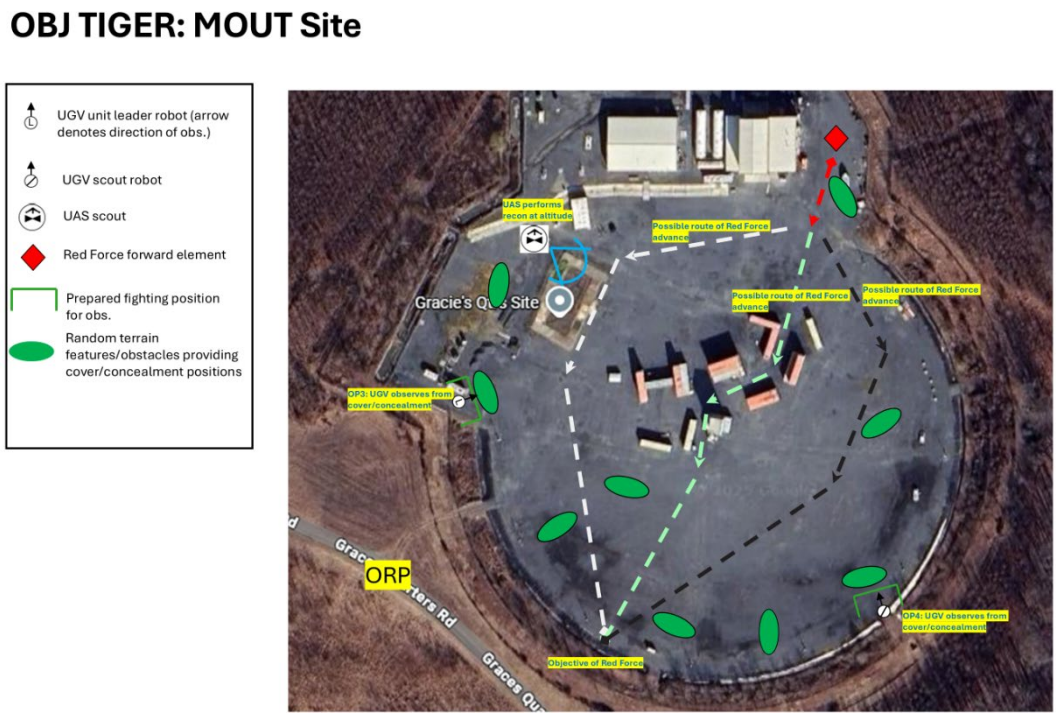

Figure 3. Scenario at OBJ Tiger: MOUT site.

Core Principles

The mission is fundamentally about information and time. The core purpose of the A-RT-1 mission is not to destroy the enemy, but to enable the main friendly force's success. It achieves this by:

Gaining Information: Using RAS to confirm the enemy's location, strength, and intentions without being detected.

Buying Time: If ordered, using precision fires and harassment to delay the enemy's advance, disrupting their plan and giving Blue Force commanders more time to react.

4. Execution

The following sections describe the details of the actions on the mission objective to be performed by A-RT-1 on the mission.

4.1 Commander's Intent

Purpose: The overarching purpose of this operation is to provide the Blue Force with timely and accurate intelligence to enable the seizure of crossing sites and ensure the unimpeded passage of the Blue Force's main effort.

Method: The Blue Force will achieve this purpose through a multilayered screen using aerial and ground-based autonomous systems in addition to human Soldiers to detect, identify, and track enemy elements. This allows the Blue Force to develop the situation and, if required, use integrated fires (artillery/aviation) to harass and delay the Red Force, shaping the battlefield for the decisive engagement.

End State: The desired end state is that Red Force's forward reconnaissance and screening elements are fixed or neutralized, their main body's composition and axis of advance are confirmed, and the Blue Force is postured to attack a weakened and disorganized enemy.

4.2 Concept of Operations

Phase 1: Movement to the Objective Rally Point (ORP): A-RT-1 will conduct a concealed movement from the vehicle dropoff via its assigned route, using stealth and terrain masking to avoid detection, to the designated ORP. All operational checks and final preparations for the reconnaissance will be completed at this location.

Phase 2: Leader's Reconnaissance: Upon arrival at the ORP, the team leader will initiate a detailed reconnaissance of OBJ Tiger. This will include the following:

- Confirming the objective's grid location and key terrain features.
- Performing initial aerial reconnaissance of the objective area using an unmanned aerial vehicle (UAS) to identify primary and alternate enemy avenues of approach.
- Identifying the specific entry point breaches being used by Red Force.
- Selecting optimal initial observation point (OP) sites to be occupied by unmanned ground vehicles (UGVs) to maximize observation of all possible routes of advance within the OBJ, while maintaining cover and concealment.
- Selecting a hide site for the Soldiers to operate from and placing Claymores.

Phase 3: Surveillance and Reporting

- UGVs will move to and occupy the designated OP locations.
- Continuous monitoring will be established. All Red Force activity will be reported immediately to higher HQ. The team will report using the SALUTE (Size, Activity, Location, Unit, Time, Equipment) report format (Use Boris intelligence report, Table 6-6).[3]
- OP locations will be adjusted as needed based on displacement criteria and UAS reports on the enemy's direction of advance to maintain contact.

- Early warning will be provided to HQ detailing the Red Force main force's location and composition. This is the team's Priority Intelligence Requirement.

Phase 4: Delay Enemy Advance

- This phase is triggered upon confirming the presence of enemy screening and reconnaissance elements.
- Based on engagement criteria, the team will harass enemy elements to disrupt their tempo, while avoiding decisive engagement.
- Submit Call for Fire (CFF) requests for fire support from available mortars and field artillery, or close air support from aviation attack assets on confirmed enemy positions (10-digit grid, description, etc.).[4]
- The team will displace in a coordinated manner along preplanned routes as necessary to new OPs, maintaining surveillance and continuing the screen and delay mission.

5. Sustainment (Administration and Logistics)

The following describes the details of the logistics, health service support, and enemy prisoners of war (EPWs) actions to be performed by A-RT-1 on the mission.

Logistics

- Resupply: The team will carry all required supplies for a 2-h mission. Emergency resupply will be conducted via UAS drop at predesignated cache points or at the hide location.
- Ammunition: Standard combat load.

Personnel

- Medical: In case of casualties, self-aid/buddy-aid will be the primary response for Soldiers. A casualty collection point will be designated at the ORP. Medevac requests will be made via the command net.
- EPWs: No EPWs are anticipated. If personnel are captured, they will be secured and moved to a designated location for exfiltration.

6. Command and Signal

The following describes the details of the command structure and communication procedures to be used by A-RT-1 on the mission.

Command

- Location of Commander: The Soldier team leader will be located at the command post hide located in the vicinity of the ORP. Succession of command will follow unit standard operating procedures (SOPs).
- Higher HQ Location: Blue Force command post is located at OBJ Leopard.

Signal

- Frequencies: Primary and alternate frequencies are listed in the Signal Operating Instructions (SOI).
- Call Signs: Unit call signs are in effect per the SOI.
- Challenge/Password: In effect.
- Emergency signals: Pyrotechnic signals for emergency exfiltration or immediate fire support are per unit SOP.

7. Integration of RAS

The effective use of RAS is central to this mission. These systems are not merely tools but are integrated as teammates to enhance capabilities, reduce risk to human Soldiers, and increase operational tempo.

7.1 Capabilities and Applications

The combination of aerial and ground platform robotic systems, with their capability differences, enhances the effectiveness of their use in this reconnaissance and screening mission.

7.1.1 Aerial Systems (UASs)

UASs provide a critical top-down view of the battlespace. Small quadcopters and fixed-wing drones are deployed for real-time video reconnaissance, target identification, and potentially as "loitering munitions" to harass enemy elements. A UAS can move at high speed and obtain superior visibility and SA of the objective surroundings due to their view from high altitude above terrain obstacles. However, they can only be used when weather conditions permit and have shorter endurance as their duration of operation is limited by their short battery life. Their payload is restricted by size, weight, and power constraints for the number of

sensors, compute capability, and weapons they can carry. The UAS can be cued at any time by the Soldier and/or UGV leader to gain better observation of threat disposition and composition. Advanced concepts like drone swarms represent future capabilities that can be incorporated into this scenario for saturating enemy defenses and providing overwhelming intelligence, surveillance, and reconnaissance (ISR).[5]

7.1.2 Ground Systems (UGVs)

UGVs, from small, legged robots (Vision 60 and Spot) to larger, wheeled platforms (Clearpath Warthogs), will be used for multiple tasks. These include initial reconnaissance of OBJ Tiger and establishing a persistent surveillance screen at established OPs. UGVs are a necessary complementary component of the robotic team and can be used with UAS to provide mixing and redundancy of assets to collect against the same intelligence requirement.[6] UGVs have the advantage over UASs in that they can hold terrain, carry heavier payloads, are easier to arm with weapons such as light machine guns, and are not as affected by weather conditions as UAS. Their ability to find cover and concealment for themselves by laying low and using terrain/obstacles allows their signature to be potentially lower than UAS, thus making them harder to detect. They can also carry a higher compute capacity than UAS, making it advantageous to have a UGV act as the leader of the robotic element of the team. Legged "mule"-type robots may also be used for logistical support in difficult terrain to perform sustainment tasks for the team.

7.1.3 Robotic Leadership

The leader of the team's robotic element should be a UGV due to its ability to carry the largest computing capability compared to smaller robotic systems such as the UAS. There will be a hierarchical chain of command structure for the robots that is generally based on the capability of each autonomous system. However, leadership should be flexible and can switch among robots during situations when the leader has poor SA or becomes damaged or disabled due to malfunction or enemy activity. The robotic leader should always be subordinate to the human Soldiers of the scout team and must obey their commands. The Soldiers will supervise the robots during actions such as reporting enemy activity and use of lethal force, such as CFFs, providing their approval decision for the robot to proceed.

7.2 RAS: The Key Enabler

This operation is not possible to execute as designed without RAS. The systems are not just support tools—they are central to the entire concept. The core benefits of RAS integration are as follows.

7.2.1 Risk Mitigation

In the context of the A-RT-1 mission, risk mitigation is the most immediate and important benefit. Robotic systems can operate and perform activities in areas of high risk to human safety.[7] The primary benefit is the ability to project force and gather intelligence without exposing human personnel to direct fire or hazardous environments like minefields. Before RAS, a human reconnaissance team would have to physically move into OBJ Tiger to confirm or deny the enemy's presence. This would expose them to potential ambushes, improvised explosive devices, or becoming pinned down by a superior force. RAS changes this by having A-RT-1 send a small UAS or a ground robot forward to perform the initial reconnaissance. If the drone is detected and destroyed, the team has only lost a piece of equipment, not a Soldier. The robotic system acts as an expendable forward sensor, taking the initial risk and allowing the human team to remain in a secure position until the situation is better understood. This allows the Soldier component of the team to stay safe while sending expendable robots to perform the most dangerous tasks.

7.2.2 Enhanced SA

A small human recon team has a limited field of view and can only be in one place at a time. Their ability to maintain 24/7 surveillance is limited by fatigue and the need for security.[3] RAS changes this by having A-RT-1 deploy multiple UGVs to different OPs while an aerial drone provides a wider view from above. This creates a multilayered sensor network that can monitor multiple enemy avenues of approach simultaneously. RAS provides continuous 24/7 surveillance of the battlefield that a human Soldier team could likely not achieve on its own, feeding real-time data to the Soldier team leader and improving the team's understanding of the battlefield situation. The robots do not get tired and can provide a continuous stream of thermal and electro-optical video back to the team leader. This gives the commander a comprehensive, real-time picture of the entire objective, allowing them to see the enemy's movements without being physically present.

7.2.3 Improved Operational Tempo

Observation improvements using RAS can dramatically improve operational tempo in the scenario at OBJ Tiger because multiple robots are deployed simultaneously, covering the entire area of OBJ Tiger in a shorter time than Soldiers could perform. Without RAS, human scouts move cautiously, taking significant time to cover terrain and report back what they see. In addition, robots can observe continuously, day or night, feeding a constant stream of data. The surveillance and reporting phase can be compressed in time substantially to near real-time.

Without RAS, a commander receives verbal reports from different scout teams and must manually piece them together on a map to understand the overall situation. This is slow and prone to errors. With RAS, artificial intelligence (AI) can play a critical role—improving this process by having data streams from the robots fed into a system with automatic target recognition. The AI can automatically identify and flag potential targets, for example, "T-72 tanks detected," and plot their locations on a digital map in real-time, filtering out irrelevant information. The commander is not just watching raw video—they are looking at a curated, live map of the enemy's disposition. The system can rapidly orient the commander to the situation.

7.2.4 Accelerated C2 Capabilities

Autonomous systems can process vast amounts of information and execute tasks faster than human counterparts, creating information advantages that can accelerate the decision-making cycle, and thus improve operational tempo so the commander can make decisions and act faster than the enemy. Information is a fundamental element of C2 and autonomous systems can dramatically accelerate C2 capabilities. The primary purpose of the C2 warfighting function is to assist commanders in integrating the other elements of combat power (movement and maneuver, intelligence, fires, sustainment, protection, information, and leadership) to achieve objectives and accomplish missions.[8,9]

The ability to process and report information faster can improve battle rhythm so information pertinent to decisions and the recommendations on decisions made to HQ are more timely and more effective to influence the decision making of the higher-echelon HQ.[10] This information advantage can be exploited to achieve objectives more effectively than the enemy can.[11]

Before RAS, a commander may have to make decisions based on an incomplete and possibly outdated picture of the battlefield. With RAS, a real-time understanding of the enemy's location, composition, and direction of travel can be determined with high confidence and relayed to the commander, allowing them to make much faster and better decisions.

7.2.5 Increased Lethality and Precision

By providing precise targeting data for indirect fires and having the potential for direct engagement, RAS enhances the team's ability to use force that is highly accurate and effective to suppress and neutralize threats while minimizing collateral damage. Phase 4 of the mission calls for A-RT-1 to delay the enemy, including CFF from artillery or aviation attack assets. Historically, this requires a forward observer to adjust fire, often while under direct threat. RAS changes this by having a robot

(either ground or air) that can stay on station and provide extremely accurate, real-time grid coordinates for enemy positions. It can use a laser designator to "paint" a target for precision-guided munitions. This ensures that when a CFF is made, the rounds are highly effective and the risk of fratricide (friendly fire) or collateral damage is significantly reduced. It is possible that A-RT-1 can deploy terminal effect drones or loitering munitions, which are essentially drones that are also the weapon.

Without RAS, a verbal command must be relayed by the Soldier, a fire mission calculated, and rounds fired, with a human observer providing slow corrections. With RAS, the decision to act can be executed in a brief amount of time. A command can be sent directly to a loitering munition to engage a target, or a fire mission can be automatically generated from robotic system targeting data and sent to the mortar platoon after approval from the Soldier scout. The time from decision to arrival of support fires is drastically reduced.

In summary, RAS allows A-RT-1 to find, understand, and react to the Red Force advance far more quickly, turning a reactive reconnaissance mission into a proactive one where the team can shape the battlefield to their advantage.

8. Developing Effective Soldier–Robot Teams and Future Development

For the scenario described in this report, there are several challenges that need to be overcome and capabilities that need to be developed for effective Soldier–robot teaming for a reconnaissance screening mission. Rather than viewing the robot as a tool, there needs to be a shift instead of regarding it as a teammate. Effective Soldier–robot teaming is achieved when the Soldier operator and the autonomous system work in a symbiotic relationship. The goal is to move beyond a simple remote-control model to one where the robot anticipates needs, provides decision support, and operates with a delegated level of autonomy. The human element remains critical. Technology alone is not enough; success is dependent on the Soldier–robot team. Significant challenges are not just technical, but human-centric. Soldiers must trust their robotic teammates in high-risk situations for the goals of the scout team to be successfully accomplished.[7]

The following areas, detailed in Sections 8.1–8.7, have been identified for further research and development.

8.1 Improving Soldier–Robot Trust

Soldier trust in their robotic systems is critical to successful Soldier–robot teaming. Soldier–robot teaming is fundamentally dependent on the Soldier's trust in the system's capabilities and reliability. The most significant challenge in developing effective Soldier–robot teams is establishing an appropriate level of trust. A robot's user must place neither too little nor too much trust in the system. Overtrust can lead to complacency, while a lack of trust leads to underutilization.[12] To build this trust, Soldiers must develop a "calibrated trust" in their robotic teammates, knowing exactly what they can and cannot do.[13] Calibrated trust refers to a user's confidence in the system matching its actual capabilities, avoiding both overtrust and distrust.[13] This requires systems that are explainable, reliable, and transparent in their operations. Trust can be built through consistent performance, transparent user interfaces, and comprehensive training that teaches Soldiers both the strengths and limitations of their robotic teammates.[14]

Robotic systems need to be transparent in their operation. The Soldier operator needs insight into the machine's reasoning, strengths, and weaknesses. This allows for the development of a shared mental model, which is critical for effective collaboration.[15] A key enabling technology for development is Explainable AI (XAI).[16] To build confidence, the AI must be able to provide clear, understandable reasons for its decisions and actions. To build trust, future systems must be able to explain their decision-making processes to Soldier operators, moving away from the black box nature of some current AI. Defense Advanced Research Projects Agency's (DARPA) XAI program specifically aims to create machine learning techniques that produce more explainable models.[16]

Reliability and predictability are other key aspects of this challenge. Trust is built on consistent and predictable behavior. Soldiers need to be confident that the autonomous system will perform as expected, especially in combat situations. This involves rigorous testing and validation to ensure the system's actions are accurate and repeatable.

8.2 Developing a Shared Understanding

Shared understanding is necessary for developing effective Soldier–robot teams.[15] The Soldiers and the robotic systems must have a shared sense of the mission and the environment. A shared understanding needs to be established for robots to be able to act like peers in Soldier–robot working relationships. For a Soldier and a robot to work as a team, they need a "shared mental model" or a common ground of understanding.[15,17] The machine must be able to infer human intent, and the human must understand the machine's state and reasoning. This is a significant

challenge because robots currently lack the social intelligence to intuitively grasp human intentions, goals, and emotions.[15,17]

8.3 Developing Effective Soldier–Robot Communication

Effective communication is vital. In addition to the robot understanding commands, it must also be able to communicate its own status, intentions, and uncertainties to the Soldier partner in an efficient way that does not cause cognitive overload. Creating systems where the robotic system can understand the Soldier's intent is an important aspect for further development. Developing the ability of AI to infer intent is a significant issue.[18] Humans are adept at inferring the mental states of their teammates from observed actions and context. Developing AI that can do the same, essentially creating a "Machine Theory of Mind,"[18] is a major focus of research programs like DARPA's Artificial Social Intelligence for Successful Teams (ASIST).[19] Research shows that AI's inability to process nonverbal cues, which humans rely on, is a challenge.[20] Further research is needed to overcome this as it may significantly hinder team performance, where hand signals and gestures play a major part in communication with a squad or team.

8.4 Advanced Interfaces and Secure Networking

Other key enabling technologies to address this challenge include the development of advanced interfaces like Android Tactical Assault Kit (ATAK) tablet controls[21] or Brain–Computer Interfaces (BCIs),[22] and secure, resilient networks. Advanced interface development needs to be focused on intuitive control systems that present information clearly and concisely, including tablet-based controls, and in the future, potentially BCIs, to allow for control without the involvement of peripheral muscles.[22] Secure and resilient networking will need to address the development of robust, nonjammable communication links, which are essential for maintaining control and receiving data from deployed assets.[23]

8.5 Human Factors and Cognitive Load

The autonomous systems must be designed to reduce the mental burden on the Soldier, not add to it. An effective Soldier–robot team must account for the Soldier operator's cognitive state. The interaction with an autonomous system should not place an undue mental burden on the human Soldier operator. Interfaces should help manage workload rather than adding to it and robotic behaviors that proactively anticipate Soldier needs can help reduce this load.[24,25] The Soldier must maintain a clear SA of the environment and the team's status. The AI can either enhance or degrade this awareness. Presenting too much or irrelevant information can lead to data overload, while failing to provide critical updates can create dangerous ommisions.[26]

8.6 Ethical and Legal Frameworks

The development of Soldier–robot teaming is complicated by ethical and legal questions. Accountability is a significant challenge in determining responsibility when an autonomous system makes an error. Establishing clear lines of accountability is crucial for deploying these systems, especially those capable of lethal action.[27] Integrating autonomous systems into military operations requires a reevaluation of the rules of engagement (ROE). Robotic systems must operate within the Law of War; however, clarification on the limitations of autonomous weapon use still needs to be made.[28] Established legal and ethical boundaries may be present, but the speed of AI-driven warfare may challenge traditional C2 structures.

8.7 Tactical ROE

From a tactical consideration, variable ROE should be developed and introduced into the robotic system decision-making processes that the senior commander can set to govern the behavior for the AI/robotic systems under his command. With this capability, engagement and disengagement criteria can be specified by the commander. With this variability of tactical ROE, robot behavior can be tuned with a settable range from aggressive to cautious action, depending on the requirements of the mission they are tasked with. This is for the tactical success of the mission as well as for abiding by overall ROE.

9. Phased Implementation of RAS

Implementation of RAS requires a disciplined process. Successfully using RAS in a real-world reconnaissance and screening mission requires a structured, three-phase approach.

9.1 Pre-Mission Preparation

Rigorous training, system configuration, and pre-combat checks are essential for success. An information collection plan needs to be developed.[29] Pre-mission preparation should include the following:

- **Mission and System Configuration:** Systems will be programmed with mission-specific data, including digital maps of the AO, initial waypoints, AI search parameters, and no-go zones.
- **Operator and Team Training:** The team will conduct rehearsals using the actual systems to build proficiency and solidify Soldier–robot teaming procedures under stress.

- **Pre-Combat Checks/Inspections:** Meticulous inspection of all hardware, software, batteries, communication links, and payloads will be performed to ensure mission readiness.[29]
- **Network and Communications Plan:** A detailed Primary, Alternate, Contingency, Emergency (PACE) plan will be established to ensure resilient data links against enemy jamming.[30]

9.2 Mission Execution

Commanders must task the robotic systems with information collection objectives, allowing them to use their autonomy, rather than simply remotely controlling them. Surveillance and screen reports must be rapidly transmitted to leadership. Mission execution should include the following:

- **Deployment and Infiltration:** RAS assets will be transported and deployed into the operational area to the designated ORPs.
- **Entry and Execution:** During entry, units are most vulnerable to enemy actions.[2] The commander will provide objectives (e.g., "Observe breach from cover/concealment location"), and the RAS will use its autonomy to achieve the goal.
- **Real-Time Data Management and Dissemination:** A Soldier operator or AI system will filter incoming data to identify and immediately disseminate key intelligence to relevant forces.
- **Transition:** The reconnaissance unit will receive reassignment based on any redefined adversary centers of gravity and the combatant commanders' decisions.[29]

9.3 Post-Mission Activities

Maintenance, data analysis, and After-Action Reviews (AARs) are critical for ensuring future success and improving tactics. Post-mission activities should include the following:

- **Recovery and Exfiltration:** Systems will be commanded to return to an ORP location or will be physically retrieved by the Soldier team.
- **Maintenance and Refurbishment:** After recovery, technicians will inspect, repair, recharge, and refurbish the systems to ensure they are ready for the next mission.
- **Data Analysis:** All video, system logs, and sensor data will be securely downloaded from the recovered robotic assets. All collected data will be analyzed to build a complete intelligence picture. This effort, led by intelligence and technical specialists, will focus on exploiting the collected

data. The analysis will be used to create finished intelligence products that inform future operations.[11,29,31]

- **AAR:** This is a structured debriefing with the A-RT-1 team to focus on performance, refining tactics, and improving the use of RAS.[3,31] Key topics will include:
  a) **Soldier–Robot Teaming Effectiveness:** Did the Soldier team trust the robotic system? Were the interfaces used effective under stress?
  b) **TTPs:** Were the methods for deployment, control, and recovery of the robotic systems effective? What new tactics were developed?
  c) **System Performance and Feedback:** Did the hardware (batteries, sensors, etc.) perform as expected? This feedback is critical for driving technical improvements.
  d) **Refinement of TTPs and RAS:** The findings from both the technical analysis and the tactical AAR will be combined to refine the TTPs, improve training, and provide clear, evidence-based feedback to drive the next generation of RAS technology.

10. Conclusion

This report focused on development of a scenario for an autonomous force-on-force capability involving reconnaissance and screening. This scenario will be used as a basis to support further autonomous systems' simulation and experimental research to be performed by ARL. The core purpose of the mission described is to gain information, using RAS teamed with Soldier scouts, to confirm the enemy's location, strength, and intentions without being detected, and buying time. The Soldier–robot team will have the capability to use supporting fires and harassment to delay the enemy's advance, disrupting their plan and giving Blue Force commanders more time to react.

Use of RAS in modern reconnaissance will be a collaborative effort between Soldiers and autonomous systems, where technology will enhance human capability and dramatically reduce risk. The key benefits identified include risk mitigation, enhanced SA, improved operational tempo, accelerated C2 capabilities, and increased lethality and precision. UGVs and UASs will operate in a supportive and complementary manner to provide mixing and redundancy of assets for a highly effective reconnaissance team. Successful use of RAS in a real-world mission will require a structured three-phase approach where pre-mission preparation, mission execution, and post-mission activities are performed that incorporate RAS technology into the entire process. Effective use of AARs will assist with further refinement of TTPs and RAS technology.

Success is dependent on the Soldier–robot team. Effective Soldier–robot teaming will be achieved when the Soldier operator and the autonomous system work in a symbiotic relationship. Soldiers must have calibrated trust in the autonomous systems, and these systems must be transparent, reliable, and predictable in their behavior. Soldiers and their robotic teammates need to have a shared understanding of the mission and the environment. Cognitive load must be successfully managed with robotic systems so that they effectively reduce the mental burden on the Soldiers.

Further areas of research and development were identified to improve the effectiveness of communication with robotic systems where the robotic system can go beyond just understanding commands but have the ability to understand the Soldier's intent and be able to process nonverbal cues. Key enabling technologies will include the further development of advanced interfaces and secure and resilient communication networks. Establishing clear lines of accountability of RAS also needs to be addressed, where the behavior of robotic systems follows established ROE. Developing an ability to vary the behavior of RAS based on the ROE set by the commander is an important area of research.

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List of Symbols, Abbreviations, and Acronyms

A-RT-1	Autonomous Reconnaissance Team 1
AAR	After-Action Review
AI	Artificial Intelligence
AO	Area of Operations
ARL	Army Research Laboratory
ASIST	Artificial Social Intelligence for Successful Teams
ATAK	Android Tactical Assault Kit
BCI	Brain–Computer Interface
BCT	Brigade Combat Team
C2	Command and Control
CFF	Call For Fire
DARPA	Defense Advanced Research Projects Agency
DEVCOM	U.S. Army Combat Capabilities Development Command
DO	Decisive Operation
EPW	Enemy Prisoner of War
HQ	Headquarters
ISR	Intelligence, Surveillance, and Reconnaissance
Medevac	Medical Evacuation
MOUT	Military Operations on/in Urban/Urbanized Terrain
OBJ	Objective
OP	Observation Point
ORP	Objective Rally Point
PACE	Primary, Alternate, Contingency, Emergency
RAS	Robotic and Autonomous System
ROE	Rules of Engagement
SA	Situational Awareness

SALUTE	Size, Activity, Location, Unit, Time, Equipment
SOI	Signal Operating Instructions
SOP	Standard Operating Procedure
TTP	Tactics, Techniques, and Procedures
UAS	Unmanned Aerial System
UGV	Unmanned Ground Vehicle
XAI	Explainable AI

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