RECORD VERSION

STATEMENT BY

DR. JONATHAN BORNSTEIN
CHIEF, AUTONOMOUS SYSTEMS DIVISION
VEHICLE TECHNOLOGY DIRECTORATE
ARMY RESEARCH LAB

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Chairman Wilson, Ranking Member Langevin, and other distinguished members of the subcommittee, thank you for the opportunity to speak with you about the research and development work being pursued by the Army to improve the autonomy capabilities of future military systems, including the capability for collaboration and teaming between both autonomous and manned systems.

The Army Operating Concept – 2020-2040, recently published by the U.S. Army Training and Doctrine Command (TRADOC) Army Capabilities Integration Center (ARCIC), notes that

> "The application of emerging technology creates the potential for affordable, interoperable, autonomous, and semi-autonomous systems that improve the effectiveness of Soldiers and units. Autonomy-enabled systems will deploy as force multipliers at all echelons from the squad to the brigade combat teams. Future robotic technologies and unmanned ground systems (UGS) will augment Soldiers and increase unit capabilities, situational awareness, mobility, and speed of action. Artificial intelligence will enable the deployment of autonomous and semi-autonomous systems with the ability to learn. Decision aids will reduce the cognitive burden and help leaders make rapid decisions. Artificial intelligence may allow robots and automated systems to act with increased autonomy. Robotics will enable the future force by making forces more effective across wider areas, contributing to force protection, and providing increased capabilities to maintain overmatch.[1]"

The document provides the vision that "autonomous and semi-autonomous operational capabilities may increase lethality, improve protection and extend Soldiers' and units' reach." It also advises that "because technologies change rapidly and transfer easily, the U.S. military will have to accelerate new technologies into the force to maintain its ability to overmatch enemies." ARCIC, together with the Army's Science & Technology (S&T), Acquisition, Test and Evaluation, and Training and Doctrine communities, is developing the Robotics and Autonomous Systems strategy to

[1] Army Operating Concept, TRADOC PAM 525-3-1, October 2014

implement this vision, creating a roadmap for autonomy technology development, materiel acquisition, and training for the next 30 years. The materiel strategies and principles developed across the Army S&T enterprise[2] will contribute to this strategy.

In his recent presentation at the Reagan Presidential Library, the Deputy Secretary of Defense noted that a study by the Defense Science Board stated that autonomy technology has reached an "inflection point." The technology now is being pursued widely. It is being pursued globally and by the commercial sector. Almost daily we hear about its application by Amazon, Tesla, Uber and others. We see elements of the technology in many of the cars we drive. There are differences, however, between the commercial and the military application of the technology. Commercial usage generally focuses on benign, permissive, and structured environments. The military must design for adversarial, highly dynamic, and unstructured environments. The requirement for reliability and predictability of response in commercial applications reduces the requirement for learning, while unknown and dynamic conditions of tactical environments requires the system to learn and alter its behavior based upon experience.

The Army community has undertaken efforts for mid-term and more advanced far-term capabilities, in support of the Army's strategy, while also providing support for nearer-term efforts that will permit the Army to gain experience in complex software systems. TRADOC Centers of Excellence have used the ongoing Network Integration Evaluation (NIE) and beginning this fiscal year the Robotics Enhancement Program (REP) to place surrogate experimental autonomous systems in the hands of soldiers. Such experimentation will inform and aid development of future requirements, doctrine, tactics, techniques and procedures required to effectively employ this new capability, and is critical to gaining trust in this technology.

The Army recently concluded the Autonomous Mobility Applique System (AMAS) Joint Capability Technology Demonstration (JCTD) to provide possible initial solutions

[2]Comprised of the Army Materiel Command (AMC) Research, Development and Engineering Command (RDECOM), the U.S. Army Corps of Engineers (USACE) Engineering Research Development Center (ERDC), the Space and Missile Defense Command/Army Forces Strategic Command (SMDC/ARSTRAT) Technical Center, the Medical Command (MEDCOM) Medical Research and Materiel Command (MRMC), and the Army G1, Army Research Institute for Behavioral and Social Sciences (ARI)

that the Army could use to adopt emerging autonomy technology aboard current platforms. The demonstration showed that tactical wheeled vehicles could navigate on roads at operational speeds as optionally manned vehicles, enabling the crew to spend time to improve situational awareness and survivability, while retaining the ability to assume vehicle control when required.

The technology architecture that was used in the demonstration separated the vehicle specific “drive-by-wire,” low level sensing and actuation from the true autonomous sensing and decision making for vehicle mobility. This paralleled the construct recommended by the 2012 Defense Science Board (DSB) Task Force on Autonomy in DOD Systems. The AMAS JCTD was a significant step for the introduction of autonomy technology for convoy operations. It provided a limited capability that is valuable both operationally and for providing feedback to shape future technology development. The Army will continue to build upon this initial capability to develop the technology that will expand the ability of vehicles to autonomously maneuver in all environments and appropriately react to unexpected events. Follow on efforts are underway in applied research and advanced technology development to increase the capabilities demonstrated in the JCTD and address technology gaps to move to a more autonomous convoy for resupply.

The S&T enterprise’s efforts are focused on seven main thrusts. It is focused on the maturation and demonstration of advanced manned/unmanned teaming for both air vehicles and ground vehicles that will permit unmanned assets to serve as “wingmen” to manned elements of the Force. The enterprise is also exploring effective teaming of unmanned air and ground vehicles. It is developing robotic technologies and capabilities that will enable unit resupply and sustainment operations using optionally-manned and unmanned vehicles and it is developing cognitive decision tools for effectively commanding teams of advanced Unmanned Air Systems (UAS). For the longer term it is conducting research focused on creating the technology that will seamlessly integrate unmanned elements, both ground and air, into small unit teams and research that will enable development of swarms of unmanned systems capable of effectively conducting military missions at range. Taken as a whole, these efforts will provide the underpinnings for autonomous systems that can operate side-by-side with

our Soldiers on the battlefield in applications ranging from unit resupply to reconnaissance and similar tactical operations.

Although the autonomy technologies available today work well for the sets of conditions for which they were designed and tested, they lack the flexibility and adaptability that would enable them to work well for other situations. Systems using today's technologies must be teamed with humans to supply the cognitive capability required for complex missions, while the unmanned element performs repetitive or persistent tasks. For example, even seemingly simple tasks such as exiting from a vehicle proved difficult for the robot competitors at the recent DARPA Robotics Challenge. Significantly advancing autonomy technology - taking machines from tool to teammate -will require technology advancement beyond what we have today. It will require that the soldier and the machine have common, though not necessarily identical, models of the world. It will require machines to reason more successfully, and to have an ability to learn from limited amounts of data. And it will require machines to infer desired actions based upon contextual knowledge or commander's intent. Humans excel at these cognitive skills, but machines currently do not. Army Basic Research efforts are directed towards these challenges, and we are making progress. For example, in the realm of machine teaming, researchers taking part in the Army Research Laboratory's (ARL) MicroAutonomous Systems and Technology (MAST) Cooperative Technology Agreement (CTA) have recently demonstrated micro-air vehicles with the ability to swarm, as well as maintain local reference without reliance upon GPS.

Perhaps the most critical roadblock to adopting autonomous technologies is ensuring that operators trust a system will do what it is supposed to on the battlefield. They will only gain this trust if we can demonstrate that these systems perform as advertised in complex, highly dangerous situations. Testing these complex systems will require methodologies very different from those utilized today. The introduction of learning, permitting software to modify its behavior with experience, will greatly complicate the testing process. The Army together with the other services is examining alternative paradigms for test and evaluation, exploring the use of licensure vice certification and continual evaluation, much as governments license drivers today.

We are also cognizant that autonomous systems, being complex computer systems on networks and potentially separated from the manned force, will be subject to cyber threats. To combat potential threats, the Army has been developing techniques for predicting how networks of systems reorganize to enable early detection of anomalous behavior. We are conducting research directed at learning for detection of cyber compromises and research on autonomous self-patching of cyber vulnerabilities as they are uncovered, among other areas. The goal is early detection and mitigation of cyber threats.

In conclusion, once again I would like to thank Chairman Wilson, Ranking Member Langevin, and other distinguished members of the committee for the opportunity to discuss the Army's role pursuing autonomy capabilities for future military systems. The Army is committed to developing autonomous systems that can work side by side with our Soldiers. I look forward to your questions.